MACROINVERTEBRATE COLONIZATION AND ASSEMBLAGES ASSOCIATED WITH AQUATIC MACROPHYTES IN A NEWLY CREATED URBAN FLOODWAY ECOSYSTEM, DALLAS, TX

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A study of macroinvertebrate colonization and assemblages, including secondary productivity of the familiar bluet damselfly or *Enallagma civile* Hagen (Odonata: Coenagrionidae), associated with the aquatic macrophytes *Heteranthera dubia* (Jacq.) MacMill. (water stargrass) and *Potamogeton nodosus* Poir. (American pondweed) was conducted at the Dallas Floodway Extension Trinity River Project (DFE) Lower Chain of Wetlands (LCOW), Dallas, TX, from September 2010 through November 2011. Macroinvertebrate abundance, taxa richness, Simpson's index of diversity, and Simpson's evenness from the two macrophytes and from three different wetland cells of varying construction completion dates, water sources, and native aquatic vegetation establishment were analyzed along with basic water quality metrics (temperature °C, pH, dissolved oxygen mg/L, and conductivity µs/cm). *E. civile* nymphs were separated into five developmental classes for secondary productivity estimations between macrophytes and wetland cell types. Mean annual secondary productivity in the DFE LCOW among two macrophytes of *E.* civile was 1392.90 ash-free dry weight mg/m^2/yr, standing stock biomass was 136.77 AFDW mg/m^2/yr, cohort production / biomass (P/B) ratio was calculated to be 4.30 / yr and the annual production / biomass (P/B) ratio was 10.18 /yr.

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CHAPTER 1

INTRODUCTION

Created Wetlands

Man-made wetlands are created for a variety of reasons, including environmental mitigation, recreation, flood water purposes, wastewater effluent polishing, wildlife management, as well as agricultural and livestock uses. No matter what their purpose, created lentic habitats such as wetlands are currently part of most urban landscapes. While constructed wetlands are common, research regarding their development and floral and faunal community establishment and expansion in terms of ecological function is not. Assessing this functional progress, in newly created systems, such as aquatic plant and animal relationships can provide valuable information to aquatic systems management and conservation biology in terms of productivity development and energy flow.

Epiphytic Macroinvertebrates

Epiphytic macroinvertebrates or "phytomacrofauna" are an important link in the transfer of organic material and energy between trophic levels in aquatic ecosystems and represent a primary food source for many aquatic, terrestrial, and avian fauna (Gerking 1962, Krull 1970, Keast 1984, Engel 1988). Numerous studies have assessed and revealed the obliging relationship between macroinvertebrate community structure in aquatic systems with the abundance and morphology of submersed aquatic vegetation or "macrophytes" (Downing et al. 1985, Beckett et al. 1992, Collier et al. 1999). For example, macrophyte stands have been shown to support higher macroinvertebrate density and diversity than contiguous open habitat in aquatic systems (Engel 1988, Thorp et al. 1997). Additionally, it is has been revealed that plant morphology and architecture is one of the most considerable defining factors in terms of the colonization of epiphytic macroinvertebrates (Brown 1988, Beckett, 1991, Thorp et al. 1997). For example, macroinvertebrate colonization and concentrations are frequently higher on more dissected-leaved versus non-dissected macrophytes (Brown 1988, Cheruvelil et al. 2002). Many reasons can contribute to this, including a higher vegetation surface area, more substrate for the attachment of reproductive forms, protection from predation, as well as a greater density of food resources.

Although general community parameters of epiphytic macroinvertebrate have been studied expansively, practical and quantitative ecological studies have only been briefly considered (Raburu et al. 2002, Balci & Kennedy 2003, Jeong et al. 2009). In particular, macroinvertebrate secondary productivity associated with different macrophyte species, in addition to structural parameters, is lacking in the literature.

Secondary production, defined as the amount of biomass produced by a faunal group per unit area over time, combines individual development and survival into a single number (Hynes 1961, Benke 1979, Rigler and Downing 1984). It is principally useful because it quantifies the role of individual species within an ecosystem in terms of population and trophic dynamics. In turn, through ecological relationships, other species as well as functional groups can be assessed for their biological role.

Assessing the functional relationship between macrophytes and macroinvertebrates in a newly created wetland ecosystem will provide valuable information to fields such as aquatic restoration and conservation biology by gaining insight into the quality of faunal habitat provided by a particular plant species. Researchers and restoration ecologists can use this information to assess and quantify wetland development and community establishments over time, including energy flow and cycling of nutrients.

Research Objectives

The intentions of this study were to investigate macroinvertebrate colonization, taxa richness, abundance, and community composition associated with two native aquatic macrophytes *Heteranthera dubia* (Jacq.) MacMill. (water stargrass) and *Potamogeton nodosus* Poir. (American pondweed) in a unique constructed wetland ecosystem undergoing native aquatic vegetation community establishment. Comparisons of the above parameters were made between different wetland cells of varying construction completion dates, water sources, and native aquatic vegetation establishment.

In addition, secondary productivity of the familiar bluet *Enallagma civile* Hagen (Odonata: Coenagrionidae) was examined along with its associations between species of macrophytes and various wetland cells. *E. civile* was chosen for the species-specific functional productivity study because of its common and abundant nature in littoral zones of newly established lentic systems (Benke 1975) as well as its importance in ecosystem function as a transitional trophic link as both predator and prey (Corbet 1980). The goal was to establish a baseline for secondary productivity of this epiphytic macroinvertebrate in a dynamic wetland ecosystem. In turn, this will function to quantify and evaluate effects of aquatic conservation and management practices.

Hypotheses

- H_a: Macrophyte type has significant effect on macroinvertebrate community structure.

- H_a: Wetland type has significant effect on macroinvertebrate community structure.
- H_a: Interaction of macrophyte and wetland has significant effect on macroinvertebrate community structure.
- H_a: Macroinvertebrate communities are significantly different between wetland cells or among sampling sites.
- H_a: Sampling date has significant effect on macroinvertebrate community structure, along with its interaction with wetland and plant type.
- H_a: Site characteristics, such as vegetation establishment and shoreline distance have significant effects on macroinvertebrate community structure.
- H_a: Overbanking or flood events have significant effects on macroinvertebrate community structure.
- H_a: Water quality (temperature ºC, pH, dissolved oxygen mg/l, conductivity µs/cm) is significantly different between wetlands or among sampling sites.
- H_a: Significant correlation between macroinvertebrate community structure and water quality (temperature ºC, pH, dissolved oxygen mg/l, conductivity µs/cm).

Study Macrophytes

Heteranthera dubia and *Potamogeton nodosus* were chosen as macrophytes of interest to assess aquatic plant and animal relationships because of their varying architecture, availability, applicability to vegetative community establishment efforts, and growth success in the study area. Water stargrass and American pondweed are both perennial flowering submersed aquatic plants native to the United States (Muenscher 1944, Stuzenbaker 1999). *H. dubia* is a submersed, grass-like herb with slender branching stems which often roots at the nodes. It has yellow flowers which rise above the water surface from leaf axils (Figures 1.1 and 1.2). *H. dubia* leaf morphology is linear or ribbon-like, thin, sessile, finely parallel-veined and without and distinct mid-vein. The plant often forms dense colonies (Stuzenbaker 1999).

Figure 1.1. *Heteranthera dubia* (Jacq.) MacMill foliage

Figure 1.2. *Heteranthera dubia* (Jacq.) MacMill) flower

P. nodosus has both thin submersed and floating thick elliptical leaves with an emergent fruiting spike. *P. nodosus* morphology has less branching and its above ground structures (leaves and stems) are larger and less abundant than *H. dubia*, making it the less dissected or lower surface area plant of the pair in most cases (Figures 1.3 and 1.4). Both species are considered high in wildlife value for aquatic fauna as well as ducks and wading birds (Stuzenbaker 1999). Previous studies assessing macroinvertebrate associations with *H. dubia* or *P. nodosus* include general colonization (Berg 1949), abundances (Beckett 1991), taxa richness and *Chironomidae spp.* annual secondary productivity (Balci and Kennedy 2003), herbivory (Nachtrieb et al. 2007, Nachtrieb 2008), and plant / animal biogeographic variations (Harms 2011).

Figure 1.3. *Potamogeton nodosus* Poir. floating and submersed leaves

Figure 1.4. *Potamogeton nodosus* Poir. floating leaves

Study Area and Site Description

This study was conducted in a series of newly created urban wetlands that are components of The Dallas Floodway Extension Trinity River Project (DFE), Dallas, TX (Figure 1.5). The DFE was constructed by the U.S. Army Corps of Engineers Fort Worth District (SWF) along with the City of Dallas, Texas (COD). Its main component, and study area, consists of a chain of six unique wetlands termed the lower chain of wetlands (LCOW). Wetland cells are individually named cells D, E, E-West, F, F-North, & G (Figures 1.6 and 1.7). Cell F is further subdivided by culverts to form Cell F(West) and F(East). The LCOW's primary function is to provide overflow for floodwaters along the western side of the Trinity River in Dallas, TX. During low or normal Trinity River flow periods, the LCOW is hydraulically fed and water levels are maintained with discharge from the Dallas Central Wastewater Treatment Plant

(CWTP) outflow to the river. The LCOW is located in south Dallas' southern Trinity River Corridor from IH-45 and Cedar Creek to loop 12, which is approximately 6.5 kilometers long.

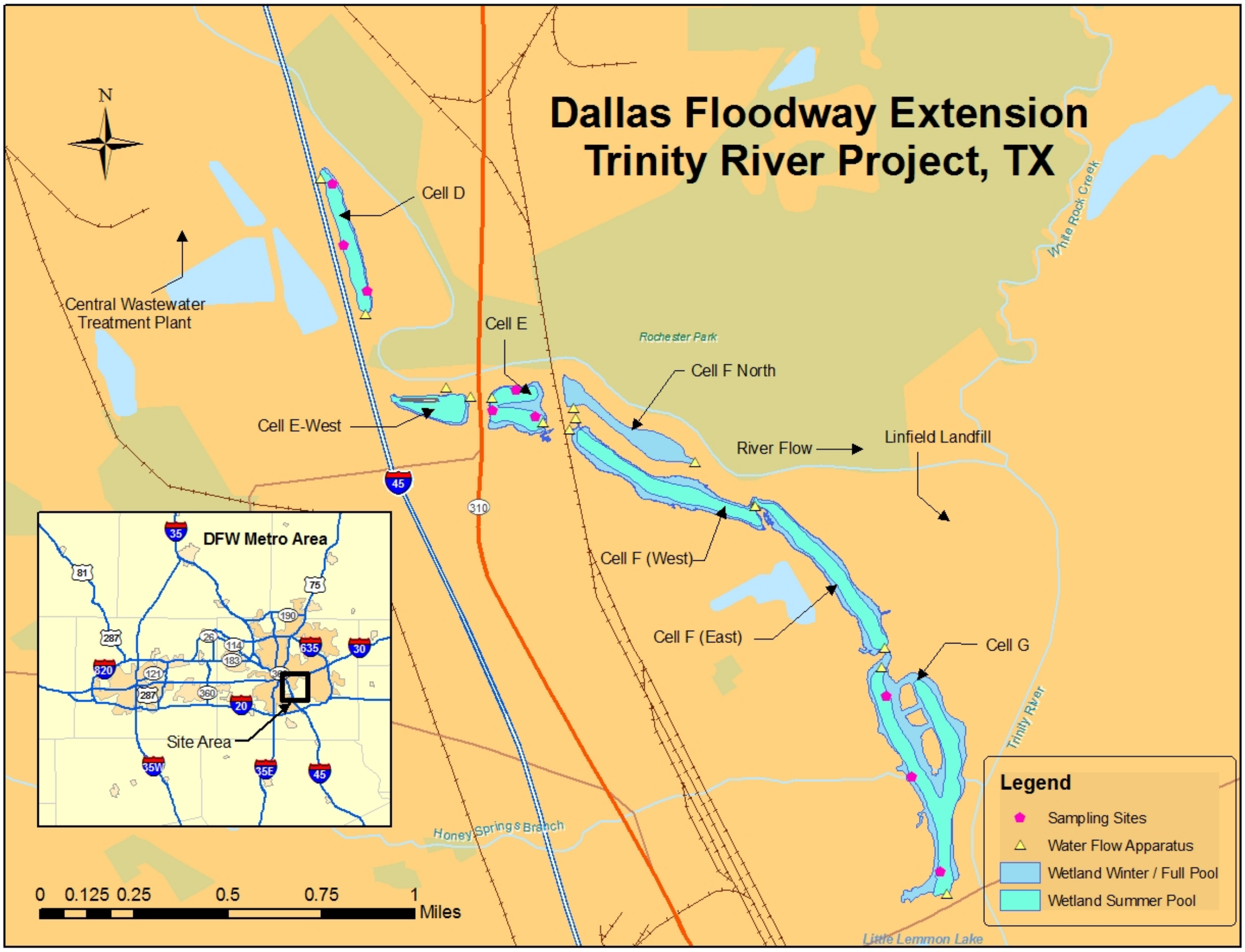

Figure 1.5. The Dallas Floodway Extension (DFE) Trinity River Project, Dallas, TX wetlands project site map

Figure 1.6. Aerial view of Trinity River and DFE LCOW wetland cells E-West, E, F and F-North facing southeast from Dallas, TX.

Figure 1.7. Aerial view of Trinity River and DFE LCOW wetland cells F and G facing northwest to downtown Dallas, TX.

The secondary goal of the DFE is to develop quality aquatic and terrestrial habitat for waterfowl and other wildlife in a floodwater passage by planting and establishing native aquatic vegetation and continually practicing ecosystem management. A significant component of the linkage between aquatic vegetation establishment and creating a productive urban wetland system for wildlife that utilize the system as upper trophic-level consumers are secondary producer populations that colonize the wetlands, including aquatic epiphytic macroinvertebrates. This is why it is important to gain more knowledge of how plant-epiphytic macroinvertebrate relationships develop in these systems and which associations are most productive. This information can be used to advance aquatic urban conservation and management practices.

Aquatic vegetation community establishment at the DFE LCOW has been conducted by the US Army Corps of Engineer Lewisville Aquatic Ecosystem Research Facility (LAERF), Lewisville, TX. The LAERF's role included planning and establishment of native aquatic plant communities and long-term monitoring and management of the system to maintain ecosystem functioning (Dick et al. 2010). The potential final ecosystem restoration, after construction and hydraulic testing, will result in an estimated 110 hectares of habitat development, including 50 hectares of emergent wetlands, 18 hectares of open water, and 42 hectares of grasslands (Dick et al. 2010).

Construction of the LCOW portion of the DFE ecosystem restoration project is complete and there are currently two different types of wetlands defined by the construction completion date, native aquatic vegetation establishment, and water source (direct wastewater effluent versus wetland-channeled effluent). The first wetland type is represented by wetland Cell D, which for the purpose of this study served as the "reference" wetland (Figures 1.8-1.10). It receives direct effluent, was completed in 2005, and has had plant establishment and ecosystem management thereafter. The second type of wetland is referred to as “developing” wetlands, which includes wetland cells E, E-West, F, F-North, and G (Figures 1.11 and 1.12). Construction of these wetlands was completed in 2009 and plant establishment and ecosystem management initiated thereafter. Wastewater effluent directly enters Cell E (developing direct effluent wetland) and cascades through weir gates to Cell F, then Cell G (developing channeled effluent wetland). Cell E-West is filled directly from the CWTP, while F-North is filled by overflow from Cell F.

Figure 1.8. Aquatic vegetation established in the DFE LCOW's reference wetland cell D

Figure 1.9. Aquatic vegetation established in the DFE LCOW's reference wetland cell D

Figure 1.10. Aquatic vegetation established in the DFE LCOW's reference wetland cell D

Figure 1.11. Aquatic vegetation establishment in the DFE LCOW's developing wetland cell E-West

Figure 1.12. Aquatic vegetation establishment in the DFE LCOW's developing wetland cell E

The nature of this study was influenced by the dynamics of this unique created wetland ecosystem that functions as a floodway extension for the Trinity River in a major U.S. city (Dallas, TX). The individual wetlands are continually evolving variably, due to different completion dates, various vegetation development, and different flooding intensities. Periodic flooding simulated natural or "native" wetlands and in some cases "reset" the ecosystem. For example, floods or overbanking events may have influenced the floral communities, thus effecting epiphytic macroinvertebrate colonization and community composition. All pertinent factors (environmental, flooding, restoration, etc.) that affected the outcome or results of this study were carefully examined and noted.

In addition to plant establishment and monitoring, other preliminary observations in the LCOW have included water quality, sedimentation (depth transects), and informal biological monitoring (macroinvertebrates, fish, reptiles, amphibians, mammals, and birds). Water quality was monitored for the duration of the project due to high nutrient loads from the wastewater source to promote the best conditions and locations for plant establishment.

CHAPTER 2

MATERIALS AND METHODS

Site Selection and Vegetation Establishment

Successful vegetation community establishment practices that were developed during the planting and management of the reference wetland cell D since its construction in 2005 were applied to all of the other wetlands following their construction. These include, planting a variety of macrophyte species (Table 2.1) with different growth forms (submersed, floating-leaved, and emergent) at specific planting depths and zones using protective exclosure devices to prevent herbivory on newly planted submersed and floating-leaved macrophytes (Figures 2.1-2.3). *Heteranthera dubia* (Jacq.) MacMill and *Potamogeton nodosus* Poir. were chosen as the study macrophytes to assess macroinvertebrate assemblages because of their contrasting morphology as well as their previous success of establishment in the DFE LCOW.

Table 2.1. Twenty-six species of native aquatic plants representing three growth forms have been installed in the Dallas Floodway Extension Trinity River Project's Lower Chain of Wetlands since 2005. Most of these established successfully.

Common Name	Scientific name	Growth form
Wild celery	*Vallisneria americana*	submersed
Illinois pondweed	*Potamogeton illinoensis*	submersed
American pondweed	*Potamogeton nodosus*	submersed
Slender pondweed	*Potamogeton pusillus*	submersed
Water stargrass	*Heteranthera dubia*	submersed
Horned pondweed	*Zannichellia palustris*	submersed
Southern naiad	*Najas guadalupensis*	submersed
Muskgrass	*Chara vulgaris*	submersed
Coontail	*Ceratophyllum demersum*	submersed
Fragrant water lily	*Nymphaea odorata*	floating-leaved
Mexican water lily	*Nymphaea mexicana*	floating-leaved
Bulltongue	*Sagittaria graminea*	emergent
Arrowhead	*Sagittaria latifolia*	emergent
American bulrush	*Schoenoplectus americanus*	emergent
Softstem bulrush	*Schoenoplectus tabermontani.*	emergent
Squarestem spikerush	*Eleocharis quadrangulata*	emergent
Flatstem spikerush	*Eleocharis macrostachya*	emergent
Slender spikerush	*Eleocharis acicularis*	emergent

Common Name	Scientific name	Growth form
Soft rush	*Juncus effusus*	emergent
Cherokee sedge	*Carex cherokeensis*	emergent
Pickerelweed	*Pontederia cordata*	emergent
Arrow arum	*Peltandra virginica*	emergent
Creeping burhead	*Echinodorus cordifolius*	emergent
Tall burhead	*Echinodorus berteroi*	emergent
Water hyssop	*Bacopa monnieri*	emergent
Water smartweed	*Polygonum aquaticum*	emergent

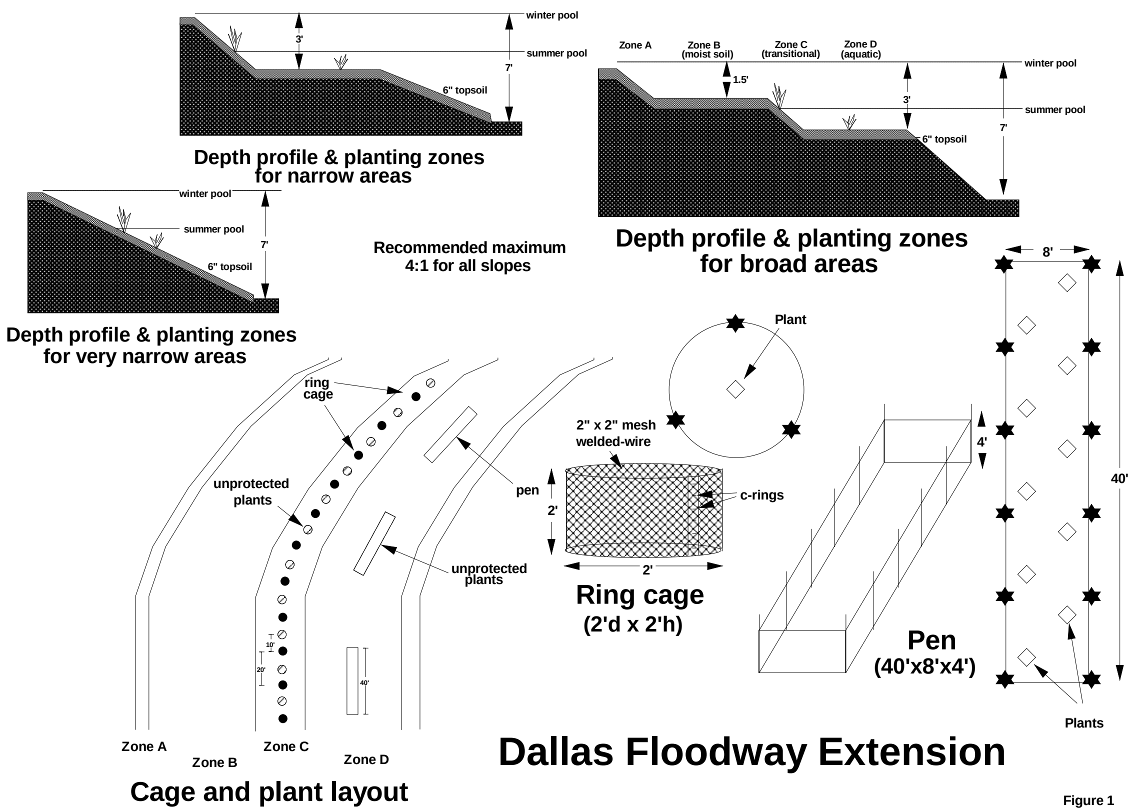

Figure 2.1. Example of herbivore exclosures, plant layouts, and depth profile and planting zones (Zone A: upland to wetland, Zone B: moist soil wetland, Zone C: emergent wetland, Zone D: aquatic plant zone).

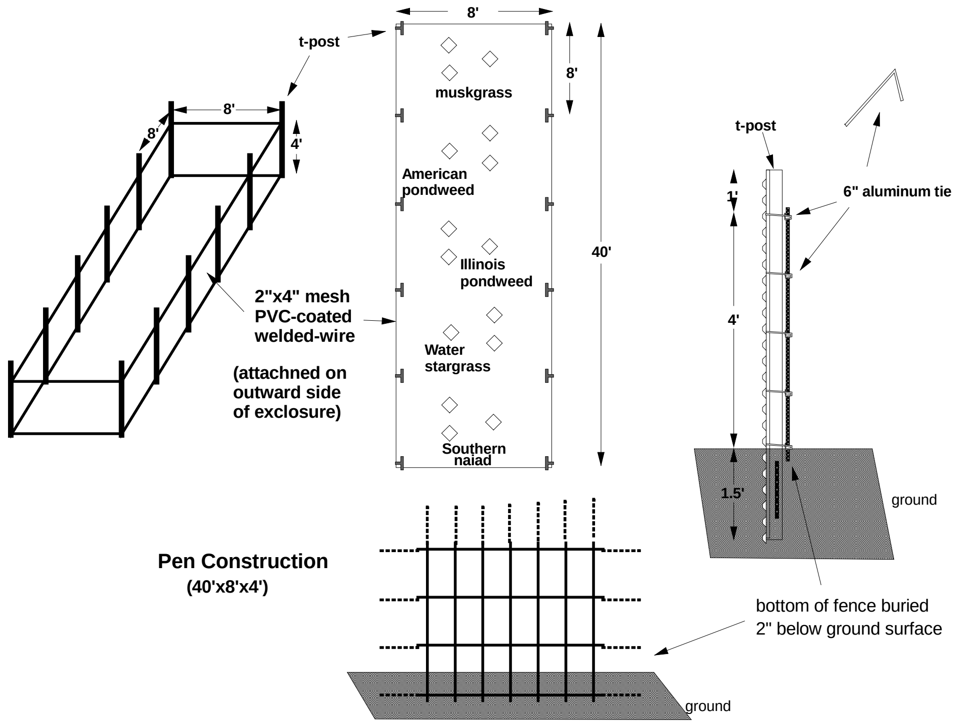

Figure 2.2. Detailed schematic of a “pen” herbivore exclosure

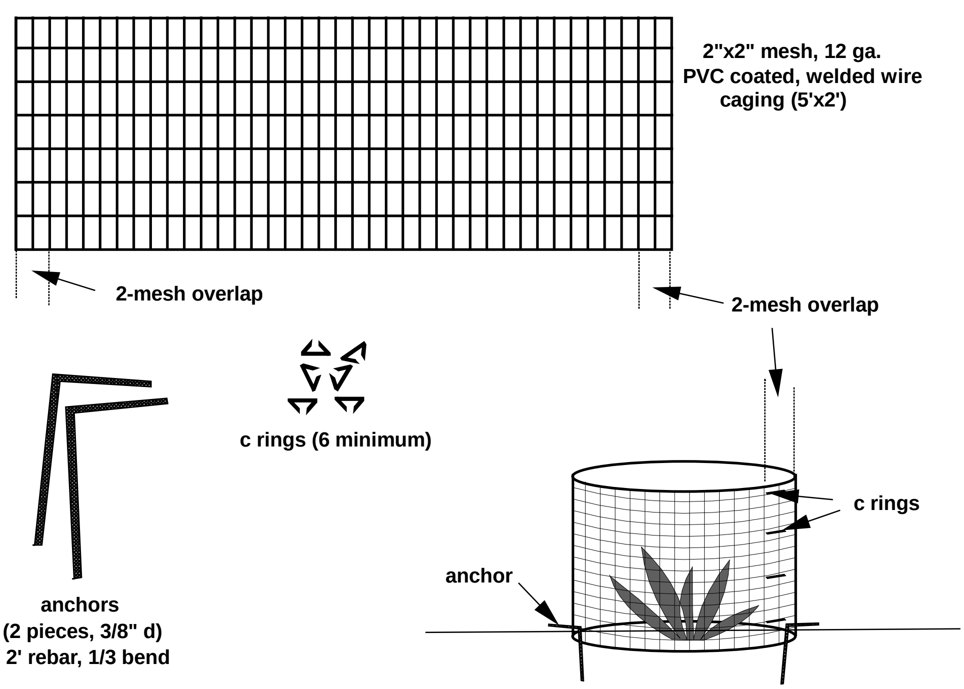

Figure 2.3. Detailed schematic of a “ring cage” herbivore exclosure

As previously stated, this study was conducted in a series of wetlands (LCOW) that are a component of the DFE, in which water levels are maintained by wastewater effluent from the Dallas Central Wastewater Treatment Plant. The design of this study includes three specific wetland types in the LCOW as wetlands of interest to compare epiphytic macroinvertebrate community development : (1 – Cell D) reference wetland receiving direct effluent constructed in 2005 (2 – Cell E) developing wetland constructed in 2009 receiving direct effluent and (3 – Cell G) developing wetland constructed in 2009 receiving wetland-channeled effluent. All wetlands received ongoing native aquatic vegetation community establishment in the same year of their construction completion dates and hydraulic testing

During the course of this study, the LCOW lacked substantial submersed macrophyte beds because of herbivory among other reasons, even in the established reference wetland (Figure 2.4).

Figure 2.4. Herbivorous turtles trapped at the reference wetland cell D, an example of animals whom make submersed aquatic vegetation establishment difficult in the DFE LCOW lentic system.

This made it difficult to find the macrophytes of interest to sample. For this reason, the most favorable option was to set up a controlled environment of vegetation "founder colonies" within each of the wetlands of interest. Individual plants were installed with protective exclosures during their vulnerable establishment phase in groups or founder colonies. The goal of founder colonies is that plants will eventually exceed a threshold of propagule production versus herbivorous and environmental pressures allowing for plant establishment throughout the particular aquatic system (Smart et al. 1996 and 1998, Smart and Dick 1999 and 2005).

Three sites (n=3) per wetland (n=3) were constructed to assure the possibility of macrophytes to sample as well as provide field replicates in each wetland. Each site consisted of four 0.9m tall, 0.9m diameter, 3.8cm x 3.8cm mesh PVC coated welded wire ring cages as protective exclosures for each plant species (eight total per site). Lids were eventually added to the exclosures to prevent herbivory from waterbirds. The multitude of plant / exclosure installations per site allowed for adequate destructive sampling as well as prevented herbivory for vegetation establishment. The exclosure mesh size was large enough to simulate a natural environment by allowing access to small predatory fauna while preventing that of large herbivores such as basking turtles that would have been detrimental for plant establishment (Figure 2.4). Each plant and associated exclosure was installed at a 0.45m water depth. Vegetation was planted in spring 2010 and was not fully established for sampling until fall 2010. Figures 2.5 - 2.11 illustrates site construction for vegetation establishment.

Figure 2.5. *Heteranthera dubia* and *Potamogeton nodosus* founder colony in developing wetland cell E set up for epiphytic macroinvertebrate sampling

Figure 2.6. *Heteranthera dubia* and *Potamogeton nodosus* founder colony in developing wetland cell E set up for epiphytic macroinvertebrate sampling

Figure 2.7. *Heteranthera dubia* and *Potamogeton nodosus* founder colony in developing wetland cell E set up for epiphytic macroinvertebrate sampling

Figure 2.8. *Heteranthera dubia* (four cages on left) and *Potamogeton nodosus* (four cages on right) founder colony in developing wetland cell G set up for macroinvertebrate sampling

Figure 2.9. *Heteranthera dubia* and *Potamogeton nodosus* founder colony in developing wetland cell E with protective lids.

Figure 2.10. *Heteranthera dubia* (right) and *Potamogeton nodosus* (left) successful establishment for macroinvertebrate sampling in protective herbivory exclosures

Figure 2.11. *Heteranthera dubia* and *Potamogeton nodosus* founder colony in developing wetland cell G fully developed and spreading throughout wetland from propagules

Data Collection

After vegetation was established in September 2010, sampling of macrophytes and associated fauna from wetlands began. Collections were made every two weeks for the duration of one year except during periods of plant senescence (December 2010 – March 2011) and flooding events. Each of 14 sampling dates from September 2010 - November 2011 yielded a total of 18 unique samples each trip by sampling two types of macrophytes in three sites per each of three wetlands. Plants and associated faunal colonies were collected from one individual exclosure per site by placing a polyester mesh bag (250 μm) sampling device over the plant carefully to minimize macroinvertebrate disruption (Figure 2.12). These sampling devices with mesh sizes ranging from 75 to 1500 μm were purchased from Pentair Aquatic Eco-Systems (Apopka, FL) and are sold as water or pond pre-filters and zooplankton collectors. After placement of the bag a 20-50 cm plant segment was cut at its base. The bag opening was then "squeezed" shut and inverted while removing the sample carefully from the water (Figure 2.13).

Figure 2.12. Epiphytic macroinvertebrate nylon net (250 μm) sampling device

Figure 2.13. Epiphytic macroinvertebrate nylon net (250 μm) sampling device with American pondweed sample and associated fauna

In addition to animal and plant collections, general water quality (dissolved oxygen mg/L, pH, temperature ºC, and conductivity µs/cm) was taken at each sampling site during each sampling trip with a Hydrolab Quanta Multiparameter Sonde (Hach Hydromet Loveland, CO). This helped assess epiphytic macroinvertebrate community structure at the DFE LCOW along with environmental variables.

Sample Processing

In the laboratory, vegetation samples were rinsed and macroinvertebrates were retained using a 250 µm sieve. Plants were inspected under a Nikon SMZ 1000 dissecting microscope (Nikon, Melville, NY) to remove macroinvertebrates not dislodged by the washing process. Macroinvertebrates were picked from debris retained by the sieve, sorted by taxon and counted. Animals were indentified to genus where applicable (McCafferty 1983, Merritt et al 2008, and Thorp and Covich 2010). The macroinvertebrate of interest for secondary productivity analysis (*Enallagma civile*) was removed for developmental size class determination and biomass estimation. After all animals were removed from plant material, plants were dried at 105 C for 24 hours to obtain a plant dry weight for insect density estimations.

Macroinvertebrate counts were expressed in relation to estimated surface areas of macrophytes to more accurately reflect macroinvertebrate colonization and density. Plant surface area measurement methods for quantitative studies of epiphytic organisms such as planimetric techniques (Cattaneo and Kalff 1980, Peets et al. 1994), weighed-images measurements (Biochino and Biochino 1979, Gregg and Rose 1982), colorimetry (Cattaneo and Carignan, 1983; Watala and Watala, 1994), image analysis (Gerber et al., 1994), and physical measurements (Spence et al., 1973; Brown and Manny, 1985) are laborious in large studies such as this one. For this reason, relationships between plant surface area and dry biomass were used to determine epiphytic macroinvertebrate colonization densities in this study.

Methods described by Balci and Kennedy (2003) were used to estimate surface area of the more finely dissected macrophyte *H. dubia* where (n = 20, r^2= 0.82) of dry weight (mg) = 19.62 + 0.0128 (plant surface area cm^2) and 1 mg of plant dry weight developed 0.678 cm^2 of plant surface area. Similar to Beckett and Aartila (1991), leaf surface area of *P. nodosus* was estimated by considering leaves ellipses and then multiplying by two to account for both sides of the leaves. The formula for a cylinder was used to estimate both petiole and stem surface area for this species. Leaf, stem, and petiole surface areas were summed to obtain a total surface area. Regression analysis and methods described by Sher-Kaul et al. (1995), Armstrong et al. (2002), and Feldmann and Noges (2009), were used to relate plant surface area to dry biomass measurements taken from *P. nodosus*. All stem (n= 20), petiole (n=20) and leaf (n=80) measurements were made using a digital caliper (Traceable®, Friendswood, TX).

Secondary Production

Annual secondary production for *Enallagma civile* was estimated using the size frequency method described by Hynes (1961) and Hynes and Coleman (1968), as modified by Hamilton (1969) and Benke (1979). Guidelines for calculations were garnered from (Benke and Huryn 2006). To use this method, damselfly nymph development was studied by frequency analysis of development classes based on morphological features such as wing pad and caudal gill development. This method was described by Cianciara (1980) on the interpretation of life cycles of mayflies and later used in similar life history studies (Taylor and Kennedy 2006). Standing stock biomass, uncorrected and corrected annual secondary production, and cohort and annual production to biomass (P/B) ratios were calculated for plants (n=2), wetlands (n=3) and for the yearlong sampling period.

Production estimates were corrected with the cohort production interval or CPI. CPI is the amount of time during one year that individuals of the target species are aquatically productive, the nymphal stage in *E. civile* (Benke, 1979). The CPI of *E. civile* was calculated by information available in the literature on days spent in nonproducing stages from the total life span. Braccia (2007) used a cohort production interval or CPI of 154 d for *E. civile*, with a "6-month total life span and subtracting 21.5 d as eggs (Brigham et al. 1982) and 7 d as adults (Bick & Bick 1963) from 182.5 d." Annual secondary production was reported as ash-free dry weight (AFDW) mg/m^2/yr separately for each wetland type as well as macrophyte.

E. civile nymphs were divided into five developmental classes based on morphological features for the purposes of the size-frequency method for an annual secondary productivity assessment. Developmental class I is represented by first or second instar nymphs with no wingpads, minimal antennae, gill, prementum, and labrum development, as well as their hind legs extending beyond the posterior margin of their abdomen (Figure 2.14). Developmental class II has no wingpads, segmented antennae, underdeveloped gills, and a developed prementum with both setae and papal lobes present (Figure 2.15). Developmental class III shows the first sign of wing pad development (not surpassing posterior margin of abdominal segment I) and mature gills (Figures 2.16). Class IV is represented by nymphs with maturing gills surpassing abdominal segment I (Figure 2.17). Class V have fully developed wingpads and gills and are represented by the final two nymphal instars (Figure 2.18).

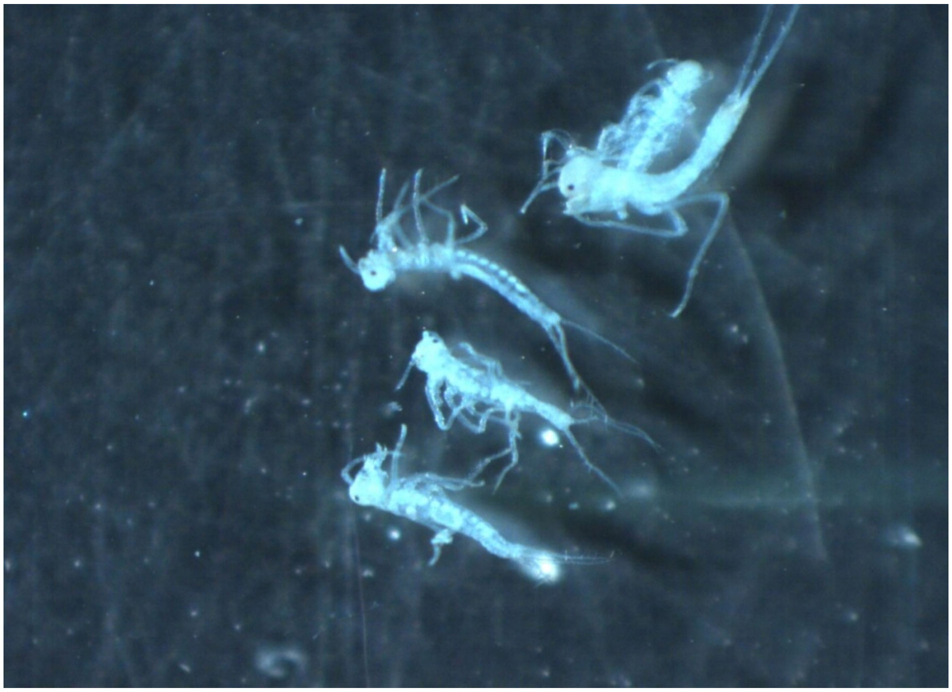

Figure 2.14. *Enallagma civile* nymphs developmental class I

Figure 2.15. *Enallagma civile* nymphs developmental class II

Figure 2.16. *Enallagma civile* nymphs developmental class III

Figure 2.17. *Enallagma civile* nymph developmental class IV

Figure 2.18. *Enallagma civile* nymph developmental class V

Estimation on dry mass of *E. civile* was done by collecting live nymphs from the study area. Nymphs were divided into the five developmental classes and placed separately in a drying oven at 35 ºC, to avoid volatilization of lipids, for 24 hours and dried to a constant weight. Samples were placed in a desiccator with Drierite (TM, Xenia, OH) and cooled for 3-4 hours, then weighed. Ash content of dried nymphs was measured by then placing samples into a Thermolyne 30400 muffle furnace (Thermo Fisher Scientific Inc.) at 550 C for 1 hour then cooled to room temperature and weighed on a Mettler AJ100 microbalance (Mettler Instrument Corps, Highstown, NJ). The ash-free dry weight (AFDW) used for secondary production dry mass estimations were calculated by subtracting the dry ash-weight from the original nymph developmental class dry weights. This provided a measure of organic content weight of the nymphs free of any inorganic matter that might be in the gut or adhering to the surface of the specimens. The purpose of this method is to get the nymph samples free of any inorganic matter that the nymphs may have ingested during eating prior to collection.

Data Analysis

Epiphytic macroinvertebrate community structure was determined and compared for each macrophyte type (n=2), each wetland type (n=3), and each sampling date (n=14). Metrics used to determine and compare community structure were macroinvertebrate abundance per m^2 surface area of vegetation (no./m^2), taxa richness, Simpson's index of diversity, and Simpson's evenness (Simpson 1949, Hill 1973). Data was analyzed using statistical software SigmaPlot Version 11.0 (Systat Software Inc., San Jose, CA).

Data was Log_{10} transformed in certain cases to meet analysis of variance's (ANOVA's) statistical assumption of normality (Shapiro-Wilk's W test). If data did not meet normality with or without transformation, original data was used in statistical testing. Power analysis was evaluated for each ANOVA using SigmaPlot version 11.0, which evaluates the sample size necessary to achieve a statistically significant result using original statistics standard deviations and means. Non-transformed data is presented in the results and discussion. All statements of significance refer to an alpha level of 0.05. The previously stated hypotheses are given with their corresponding test used to determine biostatistical significance ($\alpha = 0.05$):

Two-way analysis of variance and Holm-Sidak multiple pair wise comparison tests were performed. If no significant interaction was present between independent variables tested, but significant differences were observed between individual variables, then a t-test or one-way analysis of variance along with a pair-wise comparison test was conducted:

- H_a: Macrophyte type has significant effect on macroinvertebrate community structure.

- H_a: Wetland type has significant effect on macroinvertebrate community structure.

- H_a: Interaction of macrophyte and wetland has significant effect on macroinvertebrate community structure.

- Ha: Sampling date has significant effect on macroinvertebrate community structure, along with its interaction with wetland and plant type.

- H_a: Macroinvertebrate communities are significantly different between wetland cells or among sampling sites.

- H_a: Water quality is significantly different between wetlands or among sampling sites.

- H_a: Site characteristics, such as vegetation establishment and shoreline distance have significant effects on macroinvertebrate community structure

- H_a: Overbanking or flood events have significant effect on macroinvertebrate community structure.

Multiple linear regression and simple linear regression:

- H_a: Significant correlation between macroinvertebrate community structure and water quality (temperature, pH, dissolved oxygen, conductivity).

- Assess a relationship between dry biomass (g) and surface area (m^2) of *Potamogeton nodosus.*

Secondary production estimation of *E. civile* (AFDW mg/m^2/yr) was also conducted assessing differences between macrophytes and wetland cell types.

CHAPTER 3

RESULTS

Relationship of *Potamogeton nodosus* Poir. Plant Surface Area to Dry Biomass

Morphological characteristics and surface area estimates for *Potamogeton nodosus* Poir. are give in Table 3.1. The relationship between plant dry biomass and surface area was established using the equation (n=17, r^2=0.251) cm^2 plant surface area = 79.298 + (109.357 * g plant dry biomass) (Figure 3.1). Using the method, on average 1 g of dry plant biomass = 188.66 cm^2 of plant surface area

Table 3.1. Morphological characteristics of *Potamogeton nodosus* used to determine a dry biomass to surface area relationship. Values are given as means ± SD.

Number of plants	17
Stem length (mm)	193.6 ± 48.9
Number of leaves per plant	4 ± 1
Leaf major axis length (mm)	90.9 ± 30.7
Leaf minor axis length (mm)	14.6 ± 4.5
Petiole length (mm)	60.2 ± 29.9
Plant surface area (cm^2)	103.0 ± 21.9
Plant dry weight (g)	0.217 ± 0.101

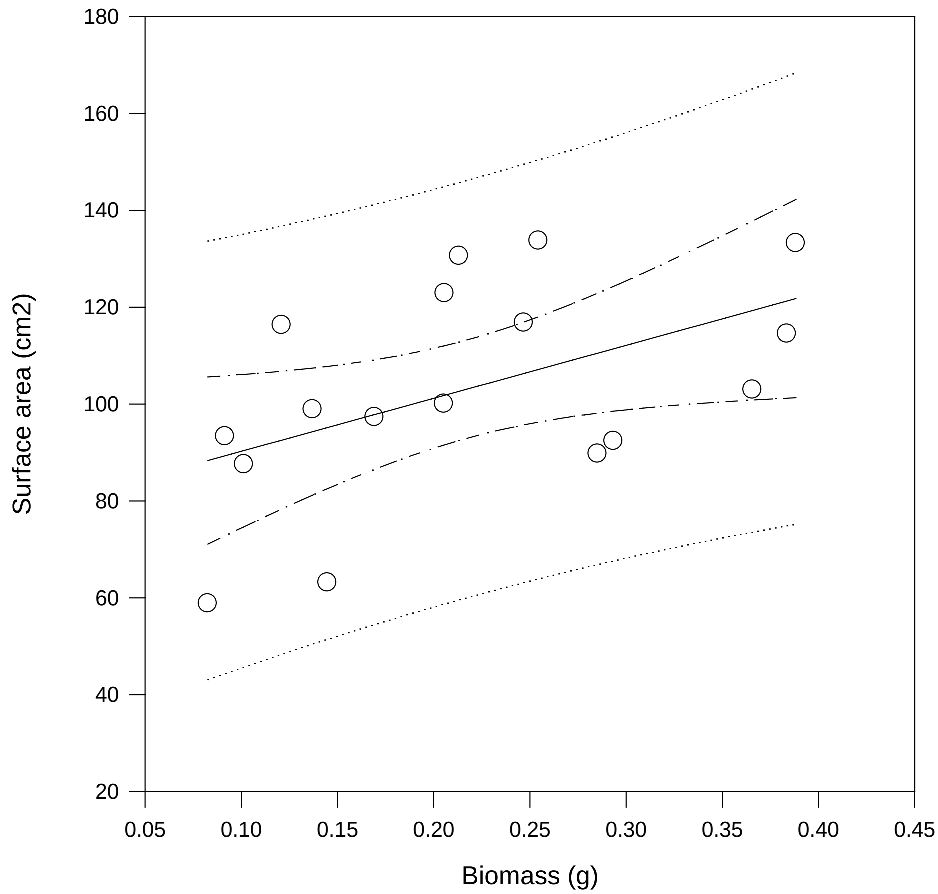

Figure 3.1. Relationship of biomass to surface area of *P. nodosus* (n=17, r^2=0.251). Raw data, 95% population confidence interval, 95% regression confidence interval, and regression line given.

Macroinvertebrate Assemblages

Epiphytic macroinvertebrate taxa collected from *P. nodosus* and *Heteranthera dubia* (Jacq.) MacMill. in the Dallas Floodway Extension Lower Chain of Wetlands (DFE LCOW) are given in Table 3.2. Thirty-five unique arthropods, 1 annelid, and 7 mollusks taxa were collected from September 2010 to November 2011 in a total of 244 samples. Included in the table are different wetland cells and plants from which animals were observed, as well as taxa resolution used.

Table 3.2. Epiphytic macroinvertebrate taxa collected from *P. nodosus* (P) and *H .dubia* (H) from the Dallas Floodway Extension Lower Chain of Wetlands between September 2010 and November 2011. Wetlands are denoted as reference wetland (Ref., Cell D), developing direct effluent wetland (D.D., Cell E), and developing channeled effluent wetland (D.C., Cell G).

Class	Order	Family	Genus	Ref. P.	Ref. H.	D.D. P.	D.D. H	D.C. P.	D.C. H
			Annelida						
Clitellata	Oligochaeta (SC)	Naididae		X	X	X	X	X	X
			Arthropoda						
Arachnida	Acrifromes	Hydrachnida		X	X	X	X	X	X
Crustacea (SP)	Amphipoda	Dogielinotidae	*Hyalella*	X	X	X	X	X	X
Crustacea (SP)	Decapoda	Paleamonidae	*Paleamontes*	X	X	X	X	X	X
Entognatha	Collembola	Sminthuridae	*Sminthurides*	X					
Insecta	Coleoptera	Elmidae	*Stenelmis*	X		X	X		X
Insecta	Coleoptera	Haliplidae	*Peltodytes*	X	X	X		X	X
Insecta	Coleoptera	Hydrophilidae	*Berosus*	X	X	X	X	X	X
Insecta	Coleoptera	Hydrophilidae	*Enochrus*	X	X	X	X		X
Insecta	Diptera	Ceratapogonidae	*Bezzia*	X	X	X	X	X	X
Insecta	Diptera	Ceratapogonidae	*Culicoides*	X	X	X	X	X	X
Insecta	Diptera	Chironomidae	Chironominae (SF)	X	X	X	X	X	X
Insecta	Diptera	Chironomidae	Orthocladiinae (SF)	X	X	X	X	X	X
Insecta	Diptera	Chironomidae	Tanypodinae (SF)	X	X	X	X	X	X
Insecta	Diptera	Culicidae	*Culiseta*	X				X	
Insecta	Diptera	Ephydridae		X		X	X	X	
Insecta	Diptera	Stratiomyidae	*Stratiomys*	X	X				
Insecta	Ephemeroptera	Baetidae	*Baetis*		X		X	X	X
Insecta	Ephemeroptera	Baetidae	*Callibaetis*	X			X	X	X
Insecta	Ephemeroptera	Caenidae	*Caenis*	X	X	X	X	X	X
Insecta	Hemiptera	Belostomatidae	*Belostoma*	X	X	X	X	X	X
Insecta	Hemiptera	Corixidae	*Hesperocorixa*	X		X	X	X	
Insecta	Hemiptera	Hebridae	*Hebrus*	X		X		X	X
Insecta	Hemiptera	Gerridae	*Metrobates*		X		X		

Class	Order	Family	Genus	Ref. P.	Ref. H.	D.D. P.	D.D. H	D.C. P.	D.C. H
Insecta	Hemiptera	Mesoveliidae	*Mesovelia*	X	X	X	X	X	X
Insecta	Hemiptera	Naucoridae	*Pelocaris*		X				
Insecta	Hemiptera	Nepidae	*Ranatra*			X			
Insecta	Hemiptera	Pleidae	*Neoplea*	X		X		X	X
Insecta	Hymenoptera							X	X
Insecta	Lepidoptera	Crambidae	*Synclita*	X	X	X	X	X	X
Insecta	Odonata	Aeshnidae	*Anax*				X	X	X
Insecta	Odonata	Coenagrionidae	*Enallagma*	X	X	X	X	X	X
Insecta	Odonata	Libellulidae	*Erythemis*	X	X	X	X	X	X
Insecta	Trichoptera	Brachycentridae	*Brachycentrus*	X	X	X	X	X	X
Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*					X	
Insecta	Trichoptera	Hydroptilidae	*Orthotrichia*	X	X	X	X	X	X
			Mollusca						
Bivalvia	Veneroida	Corbiculidae	*Corbicula*			X	X	X	
Gastropoda	Basommatophora	Lymnaidae	*Fossaria*			X	X		
Gastropoda	Basommatophora	Physidae	*Physa*	X	X	X	X	X	X
Gastropoda	Basommatophora	Planorbidae	*Helisoma*	X	X	X	X		X
Gastropoda	Heterostropha	Valvatidae	*Valvata*				X		
Gastropoda	Pulmonata (sc)	Ancylidae	*Ferrissia*	X		X		X	X
Gastropoda	Rissooidea	Pomatiopsidae	*Pomatiopsis*	X		X	X		
			TOTALS	33	26	32	32	32	30

(SC), subclass; (SP) subphylum; (SF), subfamily

Community structure metrics used to compare faunal taxa differences between wetlands (n=3), sites (n=3) plants (n=2), and dates (n=14) were abundance (number individuals per m^2 plant surface area), taxa richness, Simpson's index of diversity, and Simpson's evenness. Tables 3.3 give descriptions of these community parameters in terms of plant type and wetland cell type over the duration of sampling.

Table 3.3. Description (mean ± SD) of macroinvertebrate community structure metrics in the DFE LCOW from two macrophytes (*P. nodosus* and *H. dubia*) and three wetland types (reference, developing direct effluent, and developing channeled effluent).

	P. nodosus	*H. dubia*	Reference	Dev. direct	Dev. channeled
Abundance	8693 ± 6607	3928 ± 2954	5759 ± 5745	7825 ± 6559	5438 ± 4186
Richness	10.189 ± 4.011	9.934 ± 3.551	10.217 ± 3.973	9.103 ± 3.652	10.807 ± 3.553
Diversity	0.529 ± 0.209	0.537 ± 0.203	0.622 ± 0.169	0.452 ± 0.188	0.521 ± 0.221
Evenness	0.284 ± 0.147	0.281 ± 0.118	0.339 ± 0.152	0.254 ± 0.115	0.253 ± 0.110

Several significant differences were revealed during general statistical testing between macroinvertebrate structural dependent variables and independent variables plant type, wetland type, and sampling date. All community structure variables were found to be significantly different between wetland types and sampling dates. Taxa richness, Simpson's index of diversity, and Simpson's evenness all demonstrated a significant difference with the interaction between wetland type and sampling date. In addition, macroinvertebrate abundances (no/m^2) were significantly different between plant types. There was no significant differences in macroinvertebrate community structure in terms of sites or field replicates (n=3 per wetland) in different wetlands or among plant types. Tables 3.4 - 3.12 provides summaries and results of statistical tests used to reveal these relationships as well as multiple range comparison tests to show differences among "treatments". Figures 3.2 - 3.13 illustrate these differences in macroinvertebrate community structure dependent on sampling date, wetland type and macrophyte.

Abundance

A one-way analysis of variance of $\log_{10}$ transformed macroinvertebrate abundance data resulted in a significant difference between wetlands. However, a Holm-Sidak multiple range comparison test yielded no significant differences among individual comparisons because of the scarcely significant result of p = 0.033.

Table 3.4. Summary table of a one-way analysis of variance (ANOVA) comparing $\log_{10}$ transformed macroinvertebrate abundance (no./m^2) with wetland cell type (reference, developing direct effluent, and developing channeled effluent). Power of performed test with $\alpha = 0.05$: 0.482

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Wetlands	2	0.902	0.451	3.463	0.033
Residual	241	31.382	0.130		
Total	243	32.284			

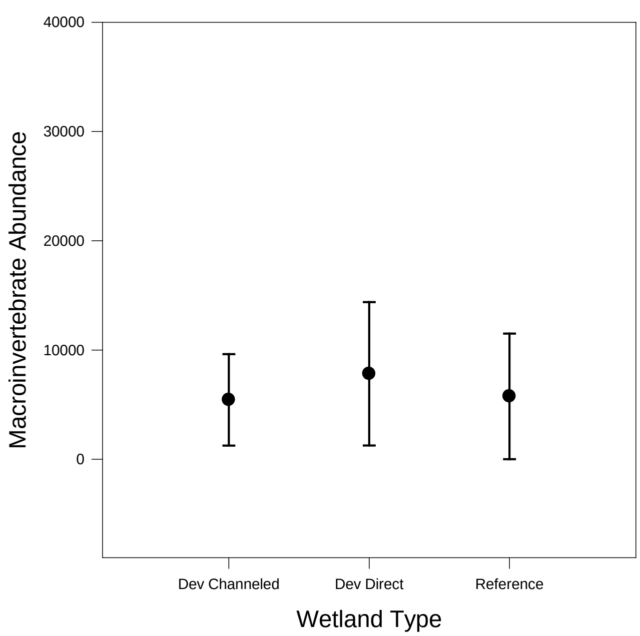

Figure 3.2. Macroinvertebrate abundance (no./m^2) mean ± SD between wetland type at the DFE LCOW.

Table 3.5. Summary table of a t-test comparing $\log_{10}$ transformed macroinvertebrate abundance (no./m^2) with plant type (*P. nodosus* and *H. dubia*). t = -8.423 with 242 degrees of freedom. (P = <0.001). Power of performed test with α = 0.050: 1.000

Group	**N**	**Mean**	**Std Dev**	**SEM**
HET	122	3.481	0.326	0.0295
PNOD	122	3.828	0.316	0.0286

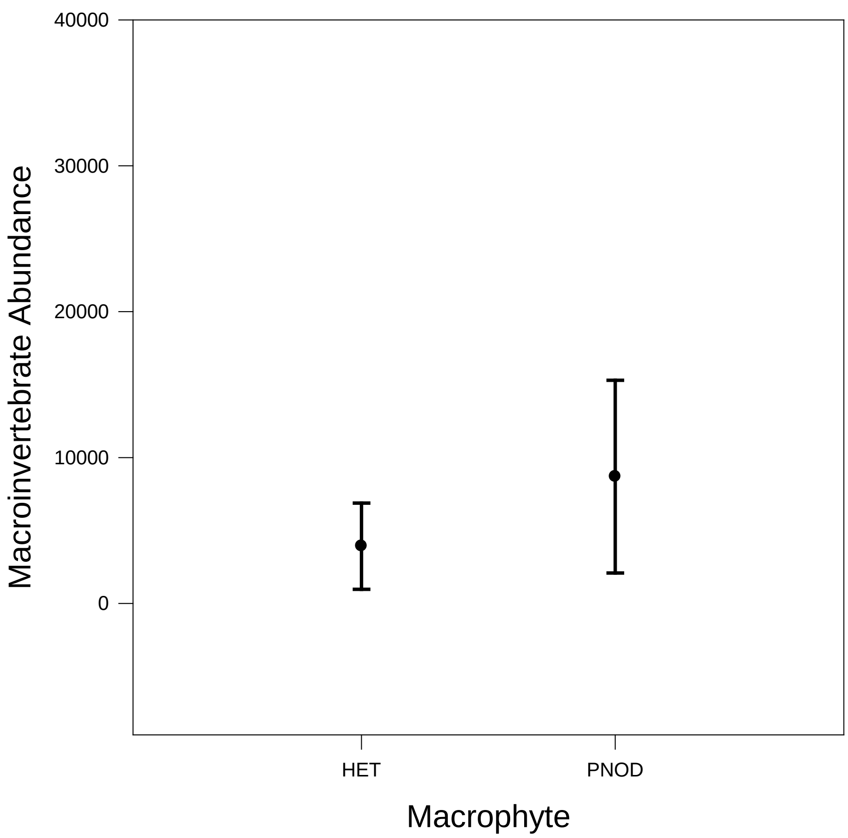

Figure 3.3. Macroinvertebrate abundance (no./m^2) mean ± SD between macrophyte type (HET = *H. dubia* and PNOD= *P. nodosus*) at the DFE LCOW.

Table 3.6. Summary table of a one-way analysis of variance (ANOVA) comparing $\log_{10}$ transformed macroinvertebrate abundance with sampling date (n=14). Power of performed test with α = 0.05: 0.999

Source of Variation	DF	SS	MS	F	P
Dates	13	6.593	0.507	4.540	<0.001
Residual	230	25.691	0.112		
Total	243	32.284			

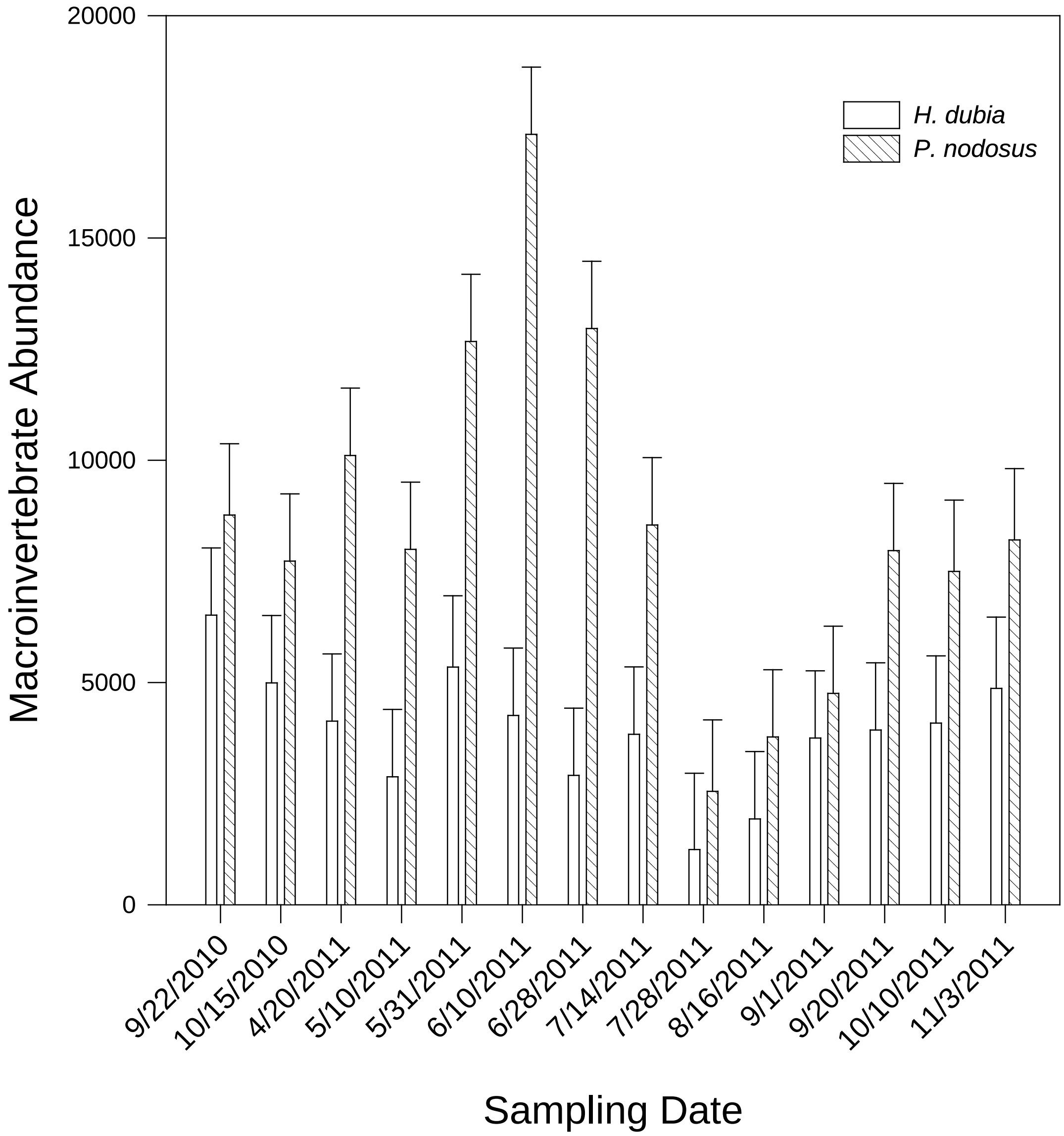

Figure 3.4. Macroinvertebrate abundance (no./m^2) mean + one SD between macrophytes and sampling dates at the DFE LCOW.

Richness

Table 3.7. Summary table of a two-way analysis of variance (ANOVA) comparing macroinvertebrate taxa richness with wetland type (n=3) and sampling date (n=14).

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Wetland	2	127.631	63.816	8.142	<0.001
Date	13	1324.258	101.866	12.997	<0.001
Wetland x Date	26	433.235	16.663	2.126	0.002
Residual	202	1583.167	7.837		
Total	243	3476.078	14.305		

Power of performed test with $\alpha = 0.05$: for Wetland : 0.943

Power of performed test with $\alpha = 0.05$: for Date : 1.000

Power of performed test with $\alpha = 0.05$: for Wetland x Date : 0.870

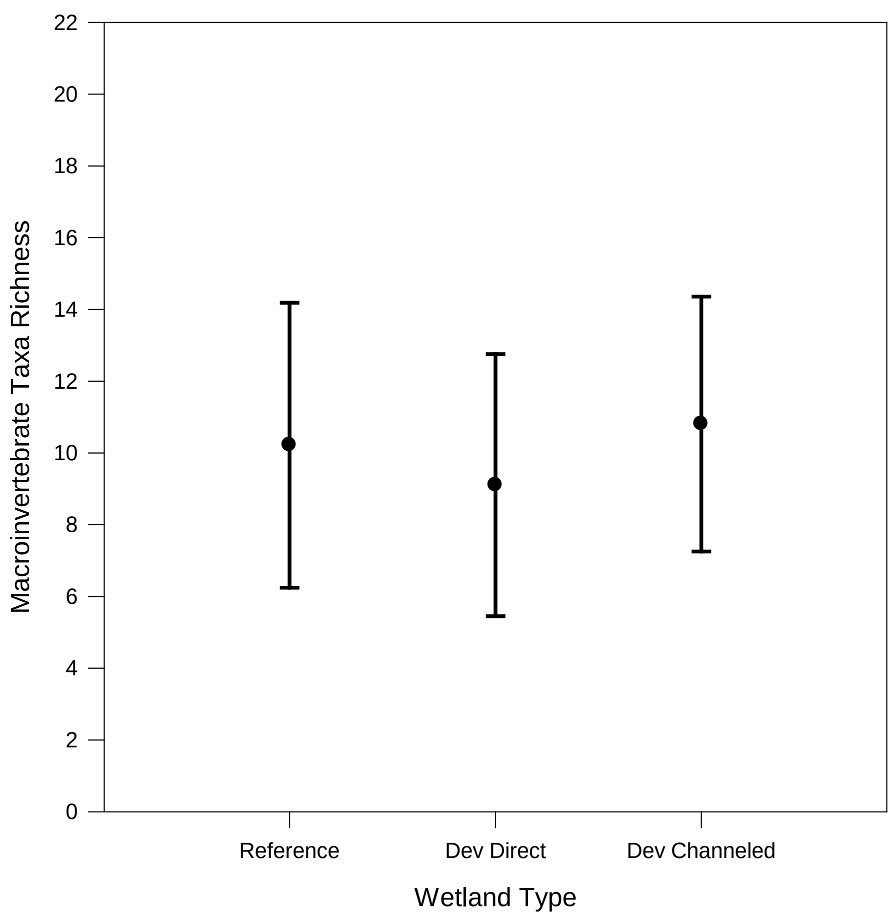

Figure 3.5. Macroinvertebrate taxa richness (mean ± SD) scatter-plot between wetland types at the DFE LCOW.

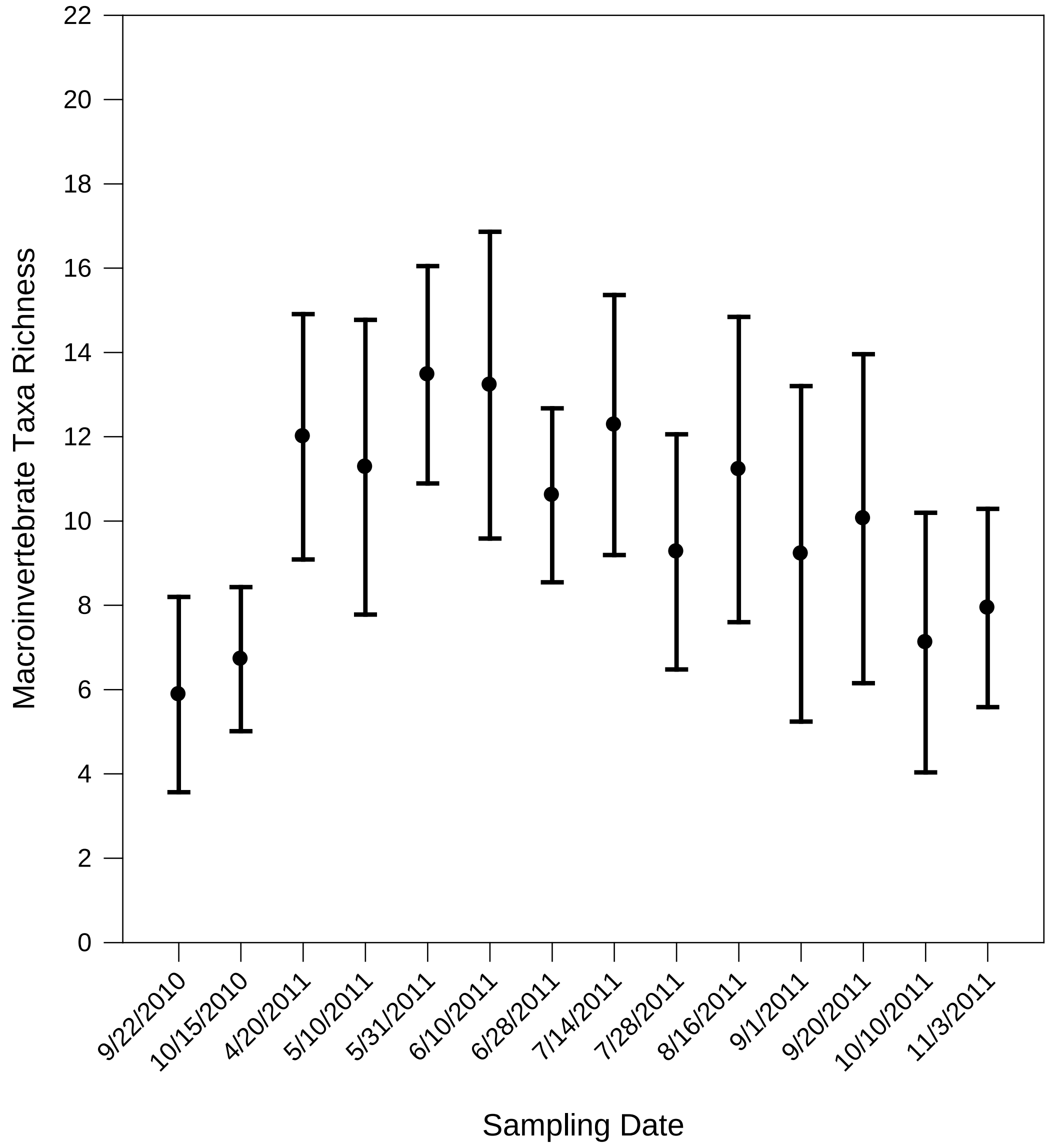

Figure 3.6. Macroinvertebrate taxa richness (mean ± SD) scatter-plot between sampling dates at the DFE LCOW.

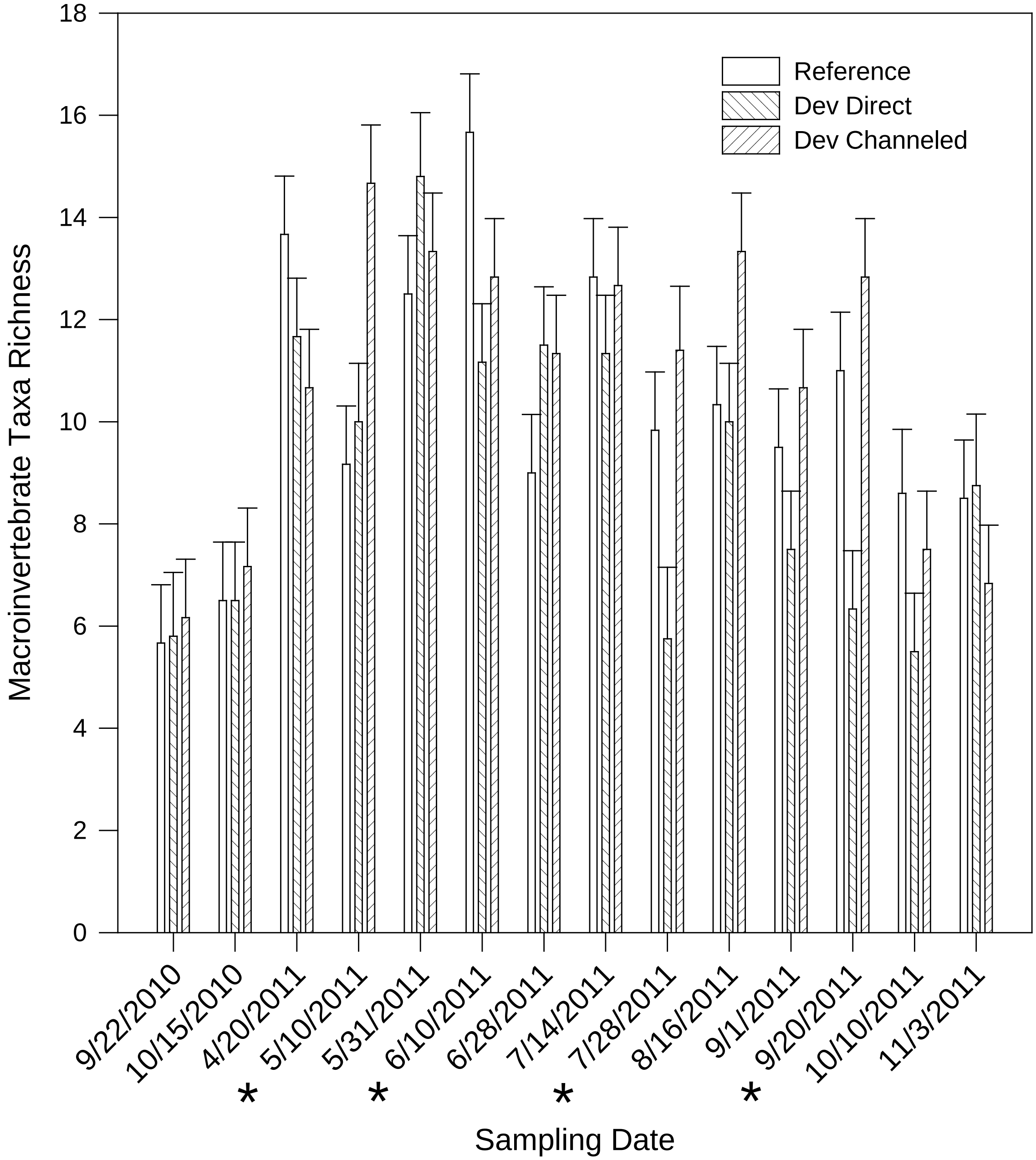

Figure 3.7. Macroinvertebrate taxa richness (mean + one SD) between sampling dates and wetland types at the DFE LCOW. Asterisks indicate dates with significant taxa richness / wetland type differences (Holm-Sidak pair-wise comparison, α = 0.05).

Table 3.8. Pair-wise multiple comparison procedures (Holm-Sidak method) for sampling dates where a significant (two-way ANOVA) taxa richness / wetland comparison was observed. Wetland types: reference wetland = R, developing direct effluent wetland = DD, and developing channeled effluent = DC. Sampling date, wetland comparison, difference of means, t level, unadjusted P, critical level and significance at α = 0.05 given.

Date	Comparison	Dif. means	t	Unadj. P	Crit. level	Significant
5/10/2011	DC vs. DD	4.667	2.887	0.004	0.025	Yes
	R vs. DD	0.833	0.516	0.607	0.050	No
	DC vs. R	5.500	3.403	<0.001	0.017	Yes
6/10/2011	DC vs. DD	1.667	1.031	0.304	0.050	No
	R vs. DD	4.500	2.784	0.006	0.017	Yes
	DC vs. R	2.833	1.753	0.081	0.025	No
7/28/2011	DC vs. DD	5.650	3.009	0.003	0.017	Yes
	R vs. DD	4.083	2.260	0.025	0.025	Yes
	DC vs. R	1.567	0.924	0.356	0.050	No
9/20/2011	DC vs. DD	6.500	4.021	<0.001	0.017	Yes
	R vs. DD	4.667	2.887	0.004	0.025	Yes
	DC vs. R	1.833	1.134	0.258	0.050	No

Diversity

Table 3.9. Summary table of a two-way analysis of variance (ANOVA) comparing macroinvertebrate Simpson's index of diversity with wetland type (n=3) and sampling date (n=14).

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Wetland	2	1.180	0.590	29.952	<0.001
Date	13	3.215	0.247	12.556	<0.001
Wetland x Date	26	1.794	0.0690	3.503	<0.001
Residual	202	3.978	0.0197		
Total	243	10.280	0.0423		

Power of performed test with α = 0.05: for Wetland : 1.000

Power of performed test with α = 0.05: for Date : 1.000

Power of performed test with α = 0.05: for Wetland x Date : 1.000

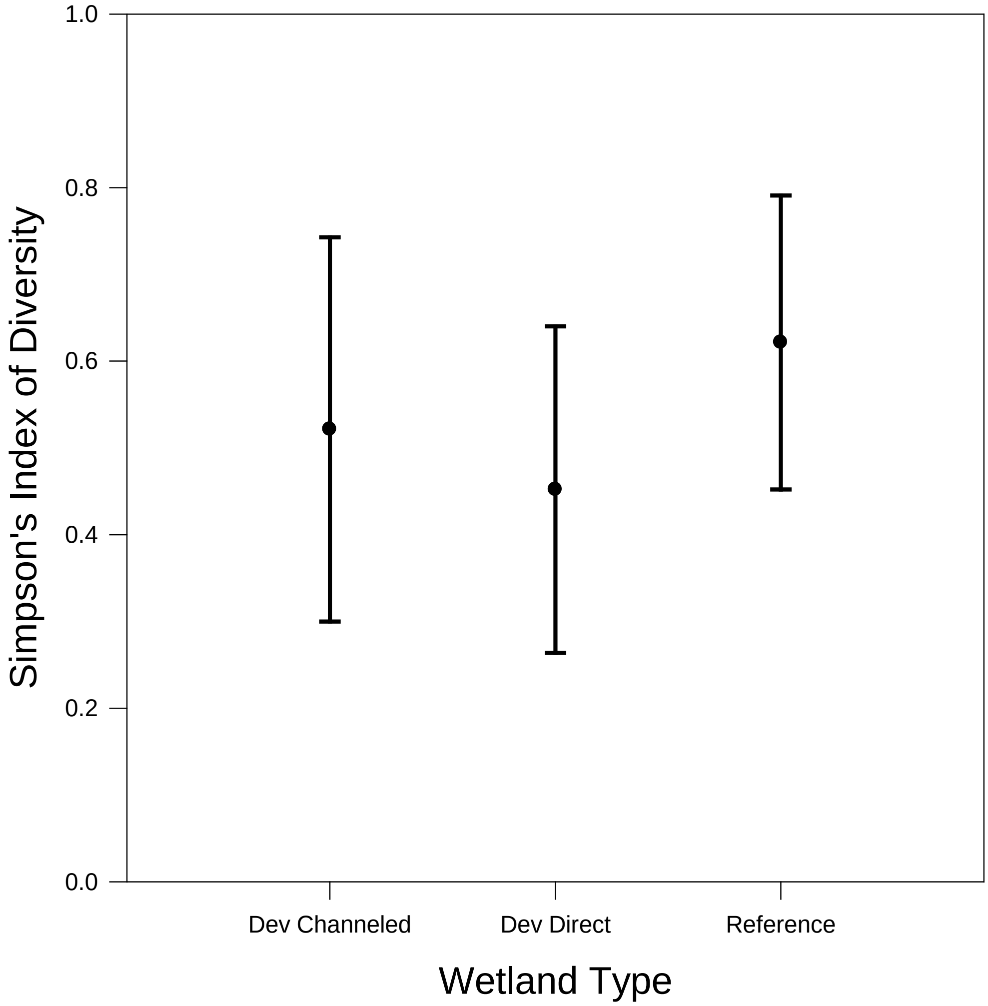

Figure 3.8. Macroinvertebrate Simpson's index of diversity (mean ± one SD) between wetland types at the DFE LCOW.

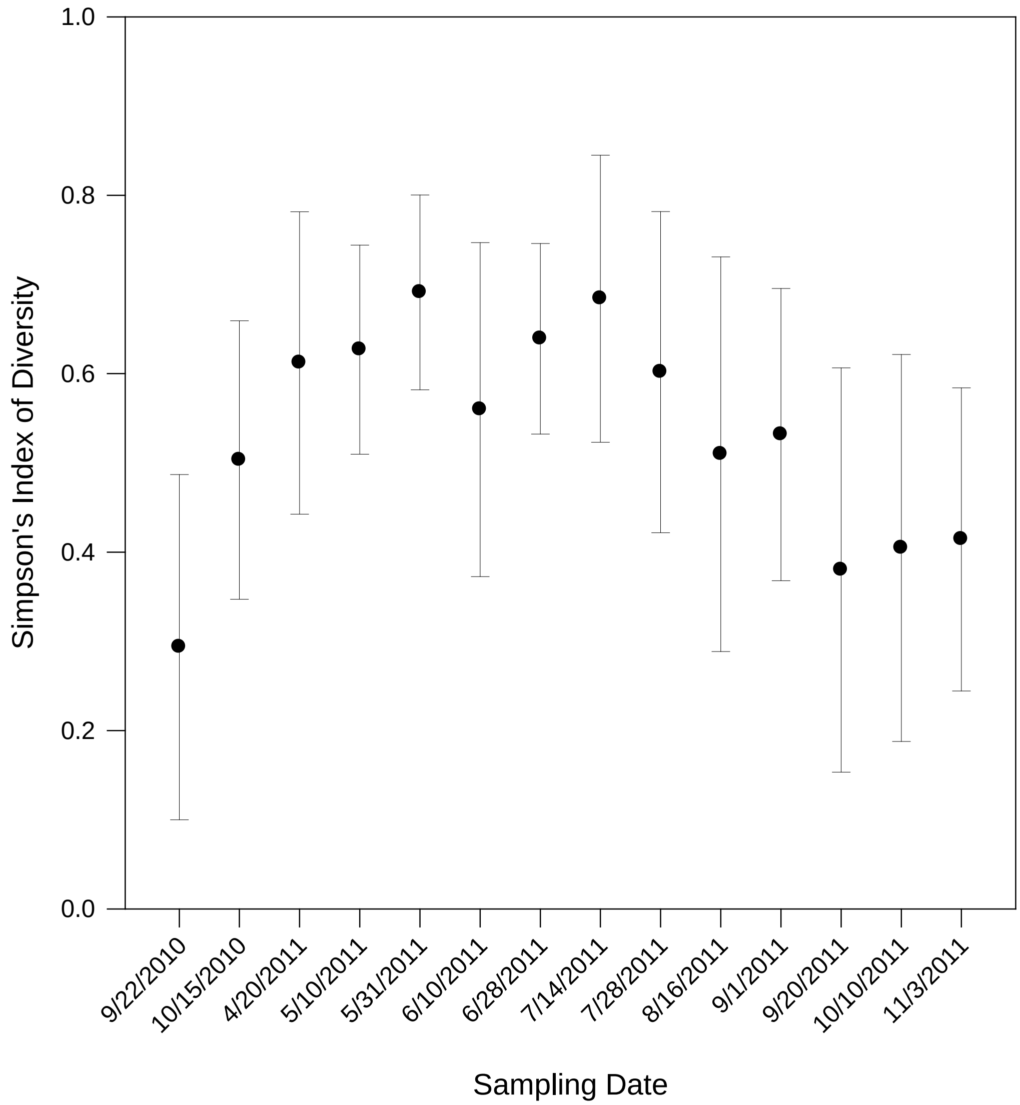

Figure 3.9. Macroinvertebrate Simpson's index of diversity (mean ± one SD) between sampling dates at the DFE LCOW.

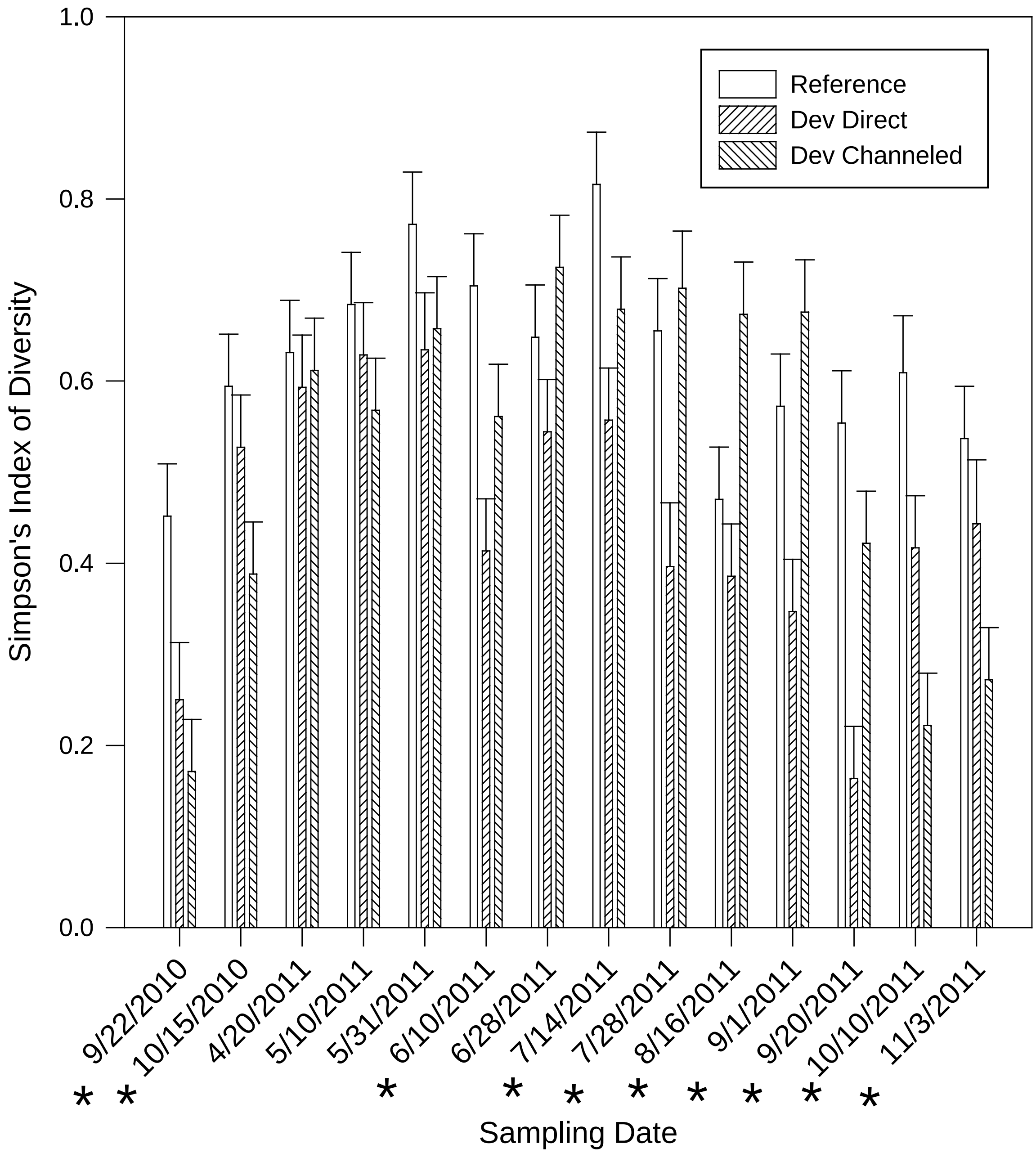

Figure 3.10. Macroinvertebrate Simpson's index of diversity (mean + one SD) between sampling dates and wetland types at the DFE LCOW. Asterisks indicate dates with significant diversity / wetland type differences (Holm-Sidak pair-wise comparison, $\alpha = 0.05$).

Table 3.10. Pair-wise multiple comparison procedures (Holm-Sidak method) for sampling dates where a significant (two-way ANOVA) Simpson's Index of Diversity / wetland comparison was observed. Sampling date, wetland comparison, difference of means, t level, unadjusted P, critical level and significance at $\alpha = 0.05$ given

Date	Comparison	Dif. means	t	Unadj. P	Crit. level	Significant
9/22/2010	Reference vs. Dev Channeled	0.280	3.462	<0.001	0.017	Yes
	Reference vs. Dev Direct	0.202	2.373	0.019	0.025	Yes
	Dev Direct vs. Dev Channeled	0.0789	0.928	0.354	0.050	No
10/15/2010	Reference vs. Dev Channeled	0.206	2.545	0.012	0.017	Yes
	Dev Direct vs. Dev Channeled	0.139	1.719	0.087	0.025	No
	Reference vs. Dev Direct	0.0669	0.826	0.410	0.050	No
6/10/2011	Reference vs. Dev Direct	0.291	3.591	<0.001	0.017	Yes
	Dev Channeled vs. Dev Direct	0.148	1.823	0.070	0.025	No
	Reference vs. Dev Channeled	0.143	1.768	0.079	0.050	No
7/14/2011	Reference vs. Dev Direct	0.259	3.196	0.002	0.017	Yes
	Reference vs. Dev Channeled	0.137	1.691	0.092	0.025	No
	Dev Channeled vs. Dev Direct	0.122	1.505	0.134	0.050	No
7/28/2011	Dev Channeled vs. Dev Direct	0.306	3.248	0.001	0.017	Yes
	Reference vs. Dev Direct	0.259	2.859	0.005	0.025	Yes
	Dev Channeled vs. Reference	0.0468	0.550	0.583	0.050	No
8/16/2011	Dev Channeled vs. Dev Direct	0.288	3.550	<0.001	0.017	Yes
	Dev Channeled vs. Reference	0.203	2.508	0.013	0.025	Yes
	Reference vs. Dev Direct	0.0844	1.042	0.299	0.050	No
9/1/2011	Dev	0.329	4.058	<0.001	0.017	Yes

Date	Comparison	Dif. means	t	Unadj. P	Crit. level	Significant
	Channeled vs. Dev Direct					
	Reference vs. Dev Direct	0.225	2.781	0.006	0.025	Yes
	Dev Channeled vs. Reference	0.103	1.277	0.203	0.050	No
9/20/2011	Reference vs. Dev Direct	0.390	4.818	<0.001	0.017	Yes
	Dev Channeled vs. Dev Direct	0.258	3.187	0.002	0.025	Yes
	Reference vs. Dev Channeled	0.132	1.630	0.105	0.050	No
10/10/2011	Reference vs. Dev Channeled	0.387	4.555	<0.001	0.017	Yes
	Dev Direct vs. Dev Channeled	0.195	2.405	0.017	0.025	Yes
	Reference vs. Dev Direct	0.192	2.262	0.025	0.050	Yes
11/3/2011	Reference vs. Dev Channeled	0.265	3.269	0.001	0.017	Yes
	Dev Direct vs. Dev Channeled	0.171	1.891	0.060	0.025	No
	Reference vs. Dev Direct	0.0936	1.033	0.303	0.050	No

Evenness

Table 3.11. Summary table of a two-way analysis of variance (ANOVA) comparing macroinvertebrate evenness with wetland type (n=3) and sampling date (n=14).

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Wetland	2	0.388	0.194	14.274	<0.001
Date	13	0.463	0.0356	2.622	0.002
Wetland x Date	26	0.704	0.0271	1.993	0.004
Residual	202	2.743	0.0136		
Total	243	4.306	0.0177		

Power of performed test with α = 0.05: for Wetland : 0.999

Power of performed test with α = 0.05: for Date : 0.856

Power of performed test with α = 0.05: for Wetland x Date : 0.808

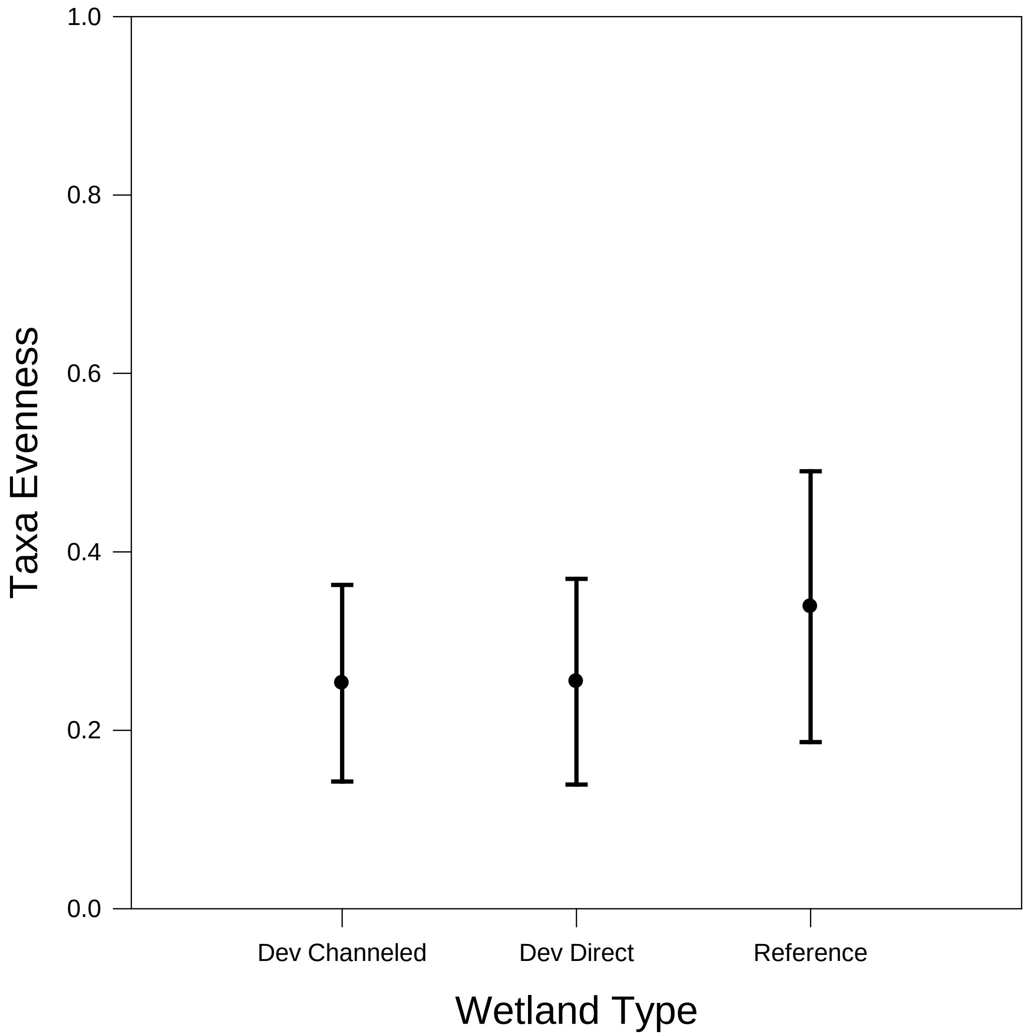

Figure 3.11. Macroinvertebrate evenness (mean ± one SD) between wetland types at the DFE LCOW.

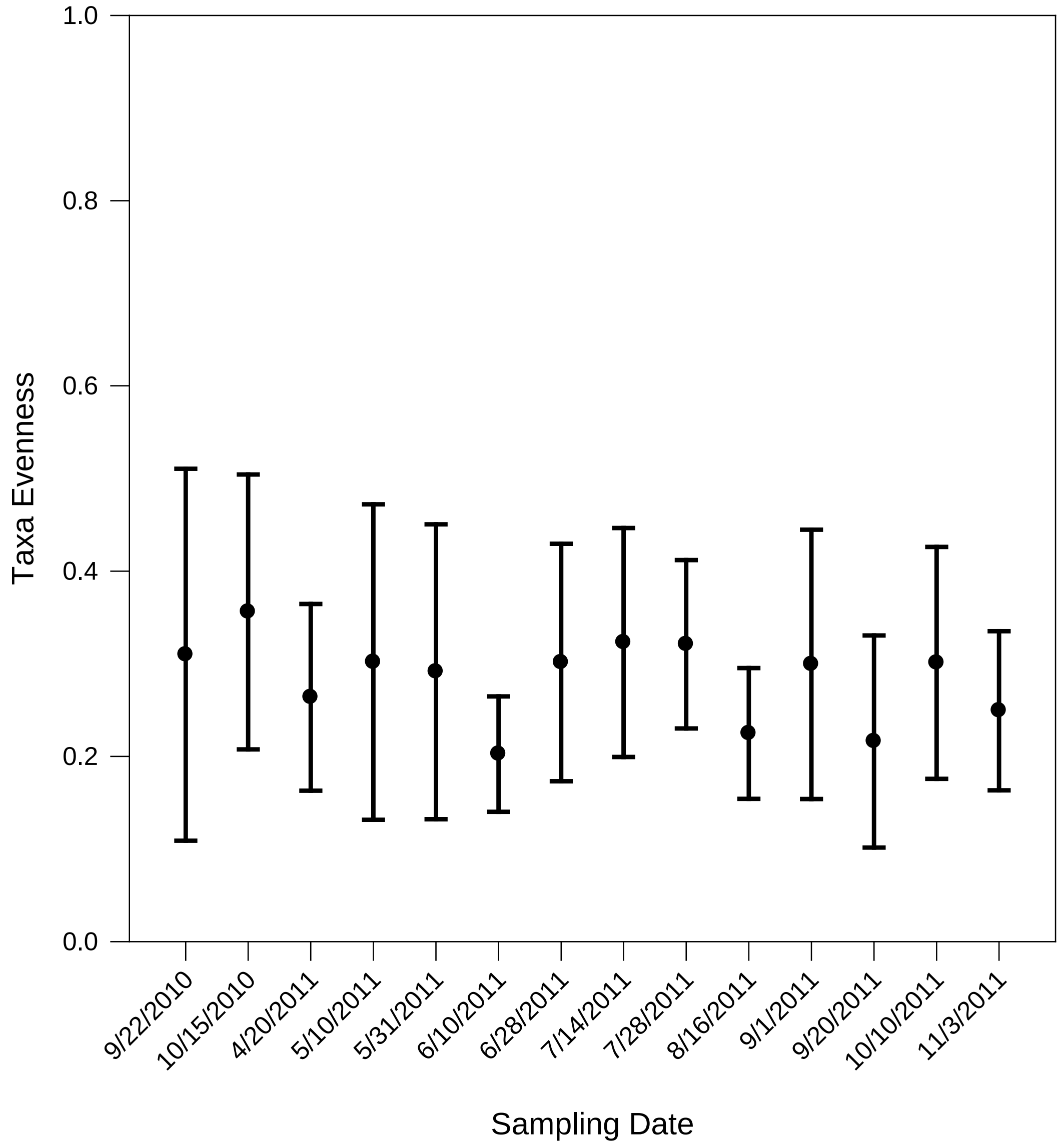

Figure 3.12. Macroinvertebrate evenness (mean ± one SD) between sampling dates at the DFE LCOW.

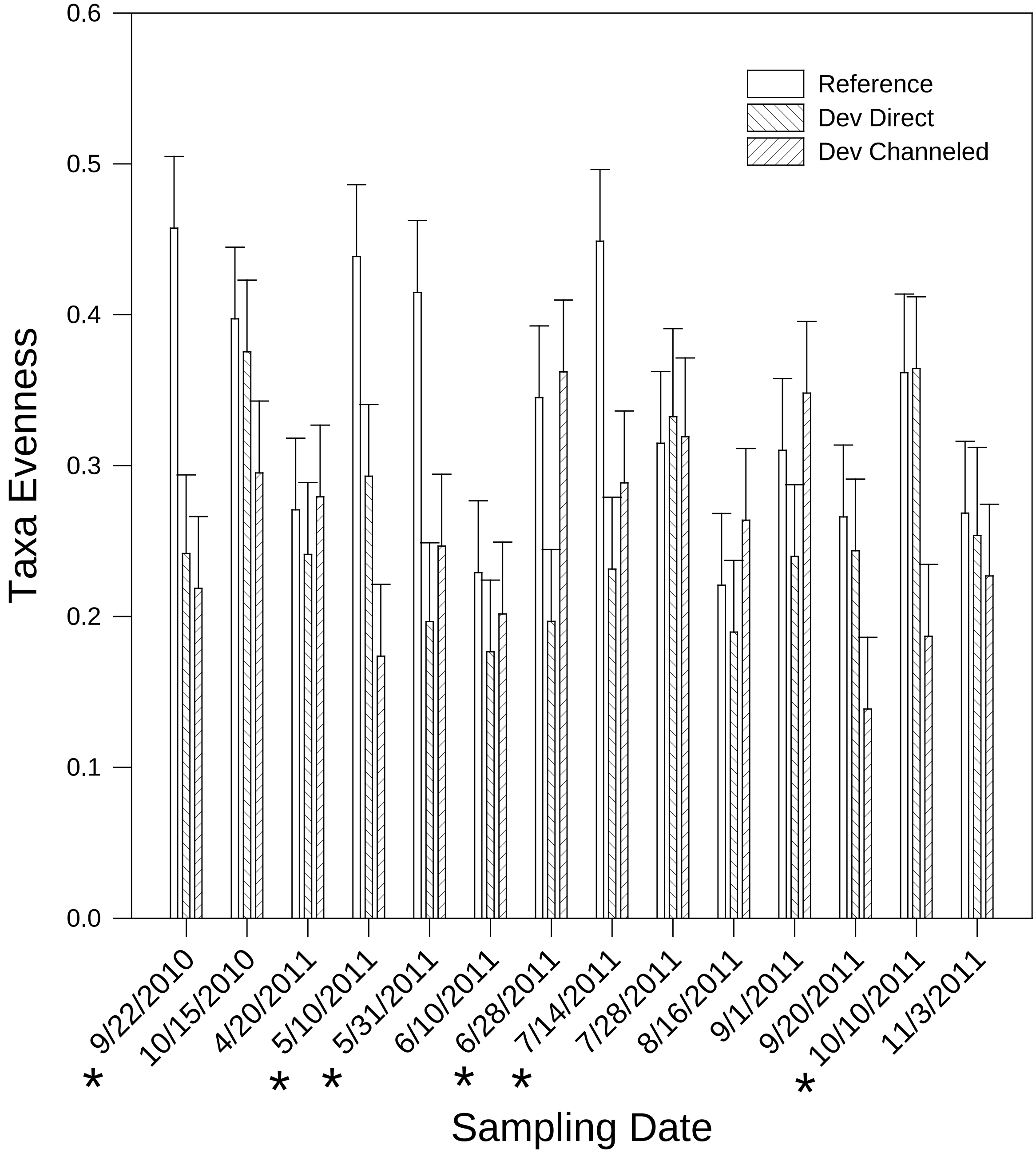

Figure 3.13. Macroinvertebrate evenness (mean + one SD) between sampling dates and wetland types at the DFE LCOW. Asterisks indicate dates with significant evenness / wetland type differences (Holm-Sidak pair-wise comparison, $\alpha = 0.05$).

Table 3.12. Pair-wise multiple comparison procedures (Holm-Sidak method) for sampling dates where a significant (two-way ANOVA) Simpson's evenness / wetland comparison was observed. Sampling date, wetland comparison, difference of means, t level, unadjusted P, critical level and significance at α = 0.05 given

Date	Comparison	Dif. means	t	Unadj. P	Crit. level	Significant
9/22/2010	Reference vs. Dev Channeled	0.239	3.548	<0.001	0.017	Yes
	Reference vs. Dev Direct	0.216	3.056	0.003	0.025	Yes
	Dev Direct vs. Dev Channeled	0.0230	0.326	0.744	0.050	No
5/10/2011	Reference vs. Dev Channeled	0.265	3.936	<0.001	0.017	Yes
	Reference vs. Dev Direct	0.146	2.164	0.032	0.025	No
	Dev Direct vs. Dev Channeled	0.119	1.772	0.078	0.050	No
5/31/2011	Reference vs. Dev Direct	0.218	3.091	0.002	0.017	Yes
	Reference vs. Dev Channeled	0.168	2.499	0.013	0.025	Yes
	Dev Channeled vs. Dev Direct	0.0500	0.709	0.479	0.050	No
6/28/2011	Dev Channeled vs. Dev Direct	0.165	2.458	0.015	0.017	Yes
	Reference vs. Dev Direct	0.148	2.204	0.029	0.025	No
	Dev Channeled vs. Reference	0.0171	0.254	0.799	0.050	No
7/14/2011	Reference vs. Dev Direct	0.217	3.229	0.001	0.017	Yes
	Reference vs. Dev Channeled	0.160	2.380	0.018	0.025	Yes
	Dev Channeled vs. Dev Direct	0.0571	0.849	0.397	0.050	No
10/10/2011	Dev Direct vs. Dev Channeled	0.177	2.637	0.009	0.017	Yes
	Reference vs. Dev Channeled	0.175	2.475	0.014	0.025	Yes
	Dev Direct vs. Reference	0.00276	0.0392	0.969	0.050	No

Differences between Site Characteristics

In addition to the previously described independent variables, sites were characterized based upon their submersed aquatic vegetation establishment (good > 75% cover, fair = 75-25% cover and poor < 25% cover) in their immediate vicinity (0-5 m) as well as their proximity to emergent wetland vegetation shoreline (close = 0-1m, medium = 1-3 m, and far >3 m). Taxa richness was significantly different between vegetation establishment types (p=0.003) and Simpson's index of diversity and Simpson's evenness were significantly different between shoreline distances (P= 0.027 and 0.004) respectively (one-way ANOVAs). Statistical interactions between vegetation and shoreline distance previously described independent variables such as wetlands were not possible because not all levels were present in each treatment. Tables 3.13 - 3.15 and Figures 3.14 - 3.16 illustrate and summarize these statistical descriptions.

Table 3.13. Summary table of a one-way analysis of variance (ANOVA) comparing macroinvertebrate taxa richness with macrophyte establishment (n=3). Power of performed test with $\alpha = 0.05$: 0.828

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Vegetation	2	167.241	83.620	6.091	0.003
Residual	241	3308.837	13.730		
Total	243	3476.078			

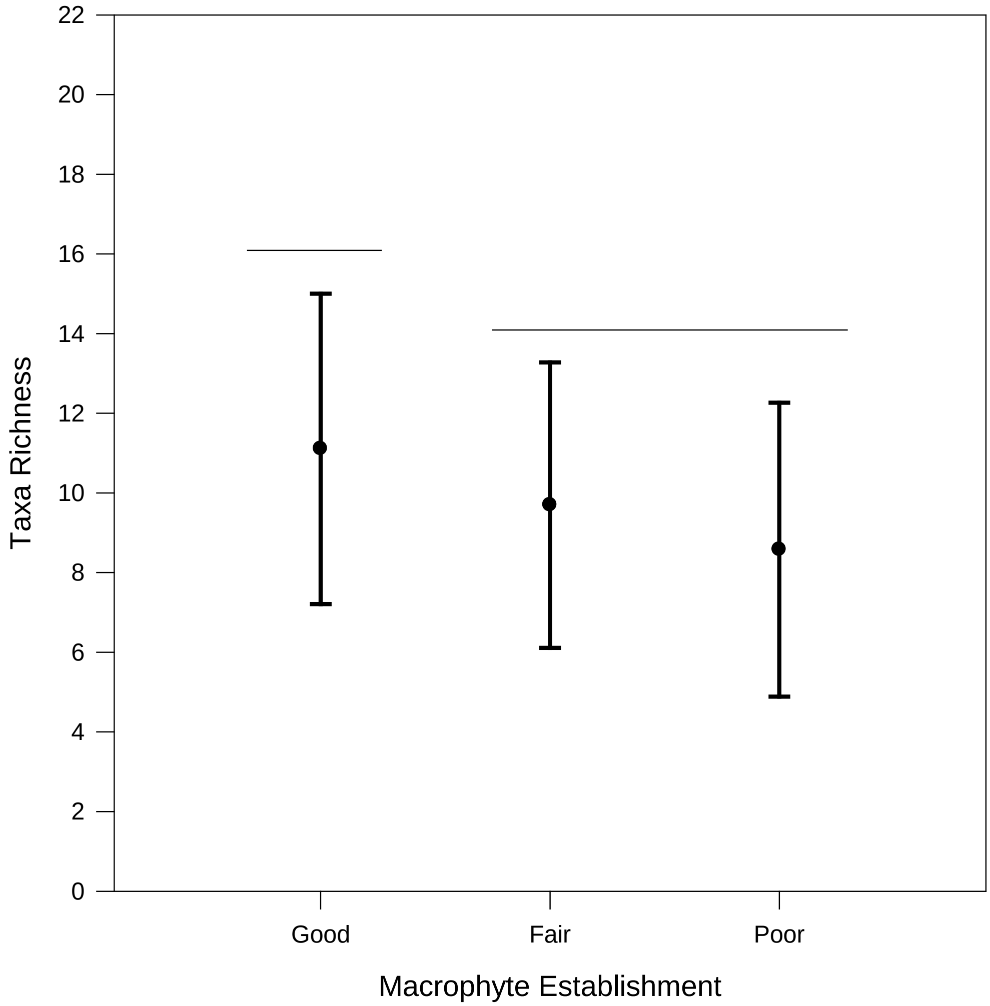

Figure 3.14. Macroinvertebrate taxa richness (mean ± SD) between macrophyte establishment at the DFE LCOW. Lines indicate statistically similar groups (Holm-Sidak pair-wise comparison, $\alpha = 0.05$)

Table 3.14. Summary table of a one-way analysis of variance (ANOVA) comparing Simpson's Index of Diversity with shoreline distance (n=3). Power of performed test with $\alpha = 0.05$: 0.516

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
SID	2	0.303	0.151	3.659	0.027
Residual	241	9.977	0.0414		
Total	243	10.280			

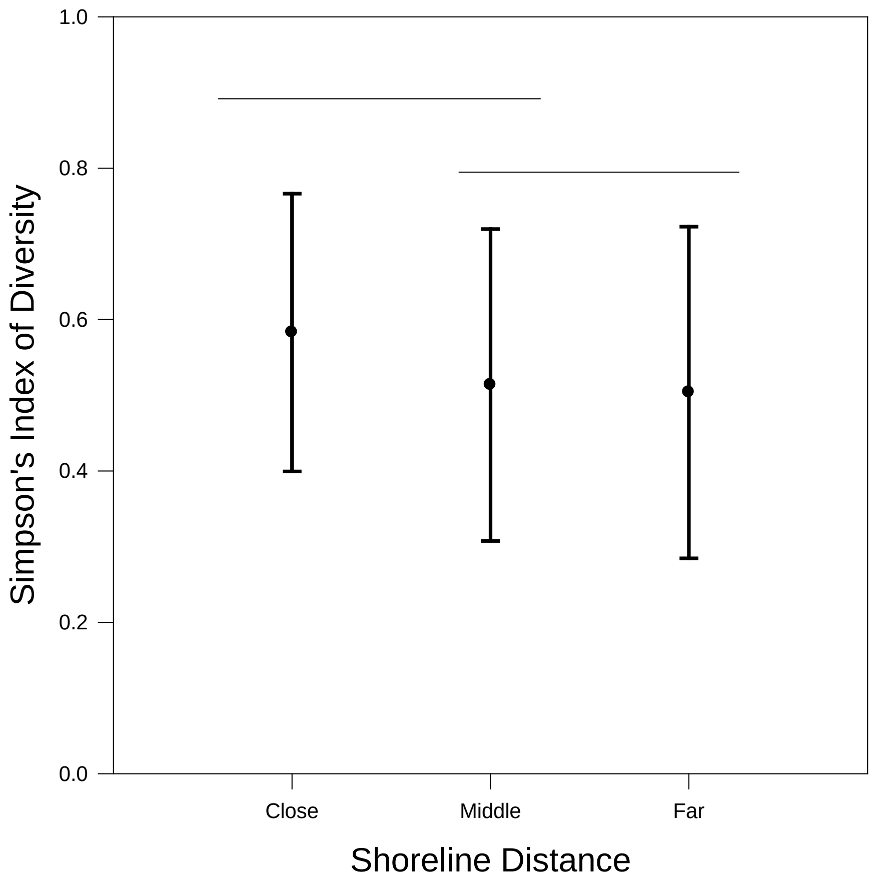

Figure 3.15. Macroinvertebrate Simpson's index of diversity (mean ± SD) between shoreline distance at the DFE LCOW. Lines indicate statistically similar groups (Holm-Sidak pair-wise comparison, $\alpha = 0.05$)

Table 3.15. Summary table of a one-way analysis of variance (ANOVA) comparing Simpson's taxa evenness with shoreline distance (n=3). Power of performed test with $\alpha = 0.05$: 0.794

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Evenness	2	0.195	0.0976	5.722	0.004
Residual	241	4.110	0.0171		
Total	243	4.306			

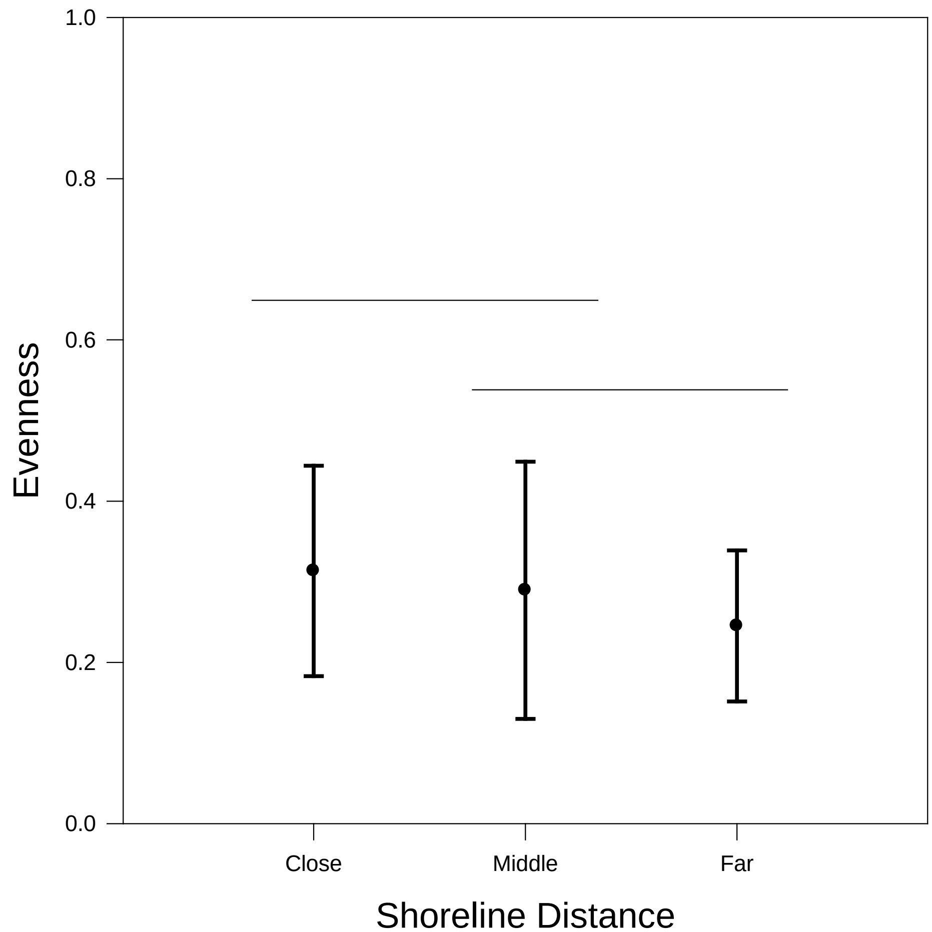

Figure 3.16. Macroinvertebrate Simpson's taxa evenness (mean ± SD) between shoreline distances at the DFE LCOW. Lines indicate statistically similar groups (Holm-Sidak pair-wise comparison, $\alpha = 0.05$)

Water Quality

Water quality, temperature (°C), pH, dissolved oxygen or D.O. (mg/l), and conductivity (µs/cm) differed and ranged from high to low extremes throughout the sampling regime and across wetland types (Table 3.16). Significant differences (one-way ANOVAs) in pH, D.O., and conductivity ($P<0.001$) occurred between wetlands types (Tables 3.17 - 3.19 and Figures 3.17 - 3.19).

Table 3.16. Water quality means and ranges throughout the sampling period and across wetland types in the DFE LCOW.

	Range High	Range low	Mean
TEMP (°C)	34.84	14.82	26.83
pH	10.06	6.67	7.81
D.O. (mg/l)	18.99	2.54	8.53
COND. (µs/cm)	882	385	678

pH mean calculated by transforming raw data to H^+ ion concentrations, then averaging and -log transforming back to pH

Table 3.17. Summary table of a one-way analysis of variance (ANOVA) comparing pH with wetland type (n=3). Power of performed test with $\alpha = 0.05$: 0.971

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Wetlands	2	7.278	3.639	9.255	<0.001
Residual	241	94.765	0.393		
Total	243	102.043			

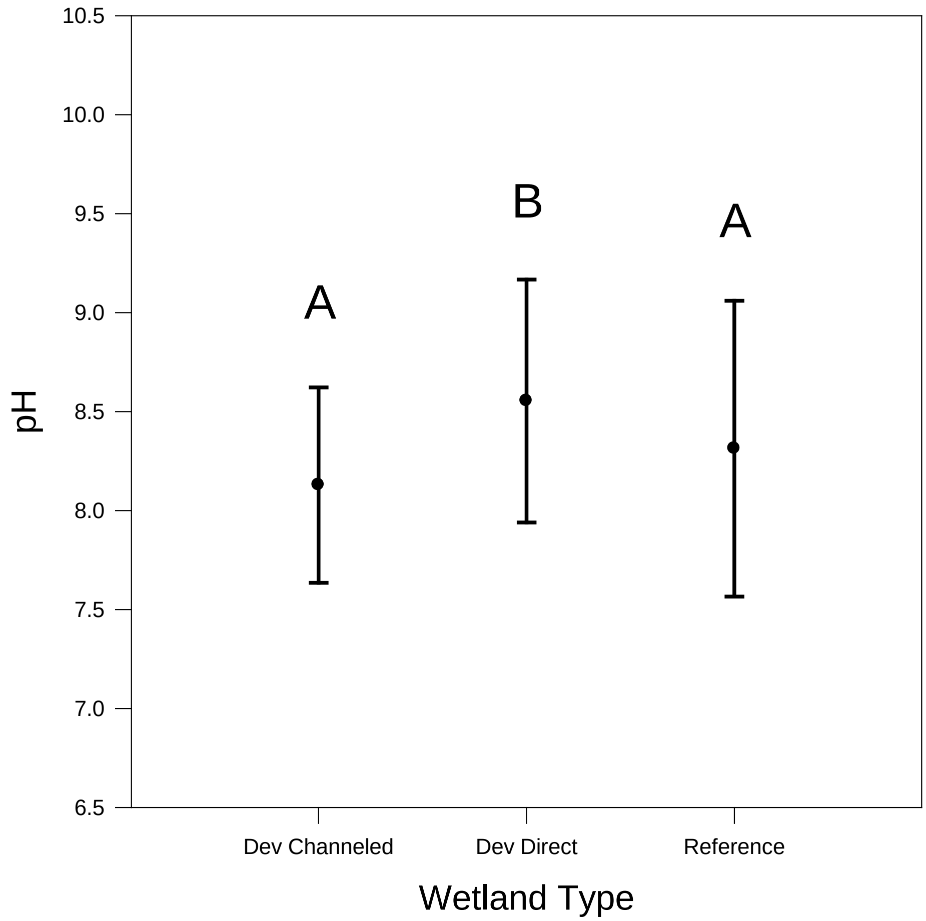

Figure 3.17. pH (mean ± SD) between wetland types at the DFE LCOW. Letters indicate statistically similar groups (Holm-Sidak pair-wise comparison, α = 0.05).

Table 3.18. Summary table of a one-way analysis of variance (ANOVA) comparing dissolved oxygen (mg/L) with wetland type (n=3). Power of performed test with α = 0.05: 1.000

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Wetlands	2	285.401	142.701	21.671	<0.001
Residual	241	1586.961	6.585		
Total	243	1872.362			

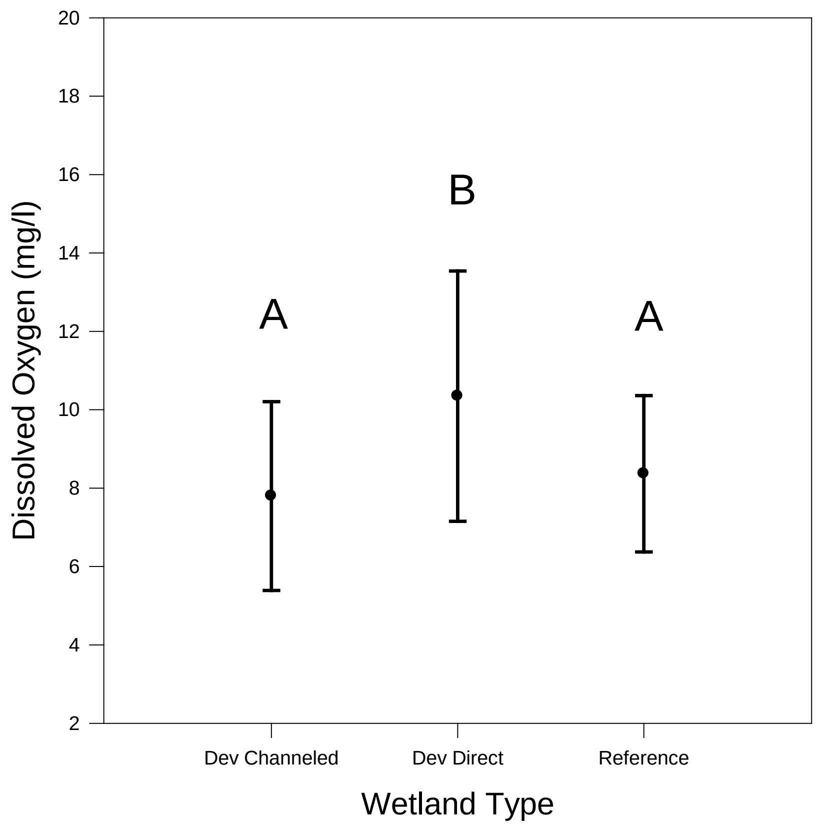

Figure 3.18. Dissolved oxygen (mg/L) (mean ± SD) between wetland types at the DFE LCOW. Letters indicate statistically similar groups (Holm-Sidak pair-wise comparison, α = 0.05).

Table 3.19. Summary table of a one-way analysis of variance (ANOVA) comparing conductivity (μs) with wetland type (n=3). Power of performed test with α = 0.05: 1.000

Source of Variation	DF	SS	MS	F	P
Wetlands	2	645853.279	322926.639	25.078	<0.001
Residual	241	3103340.639	12876.932		
Total	243	3749193.918			

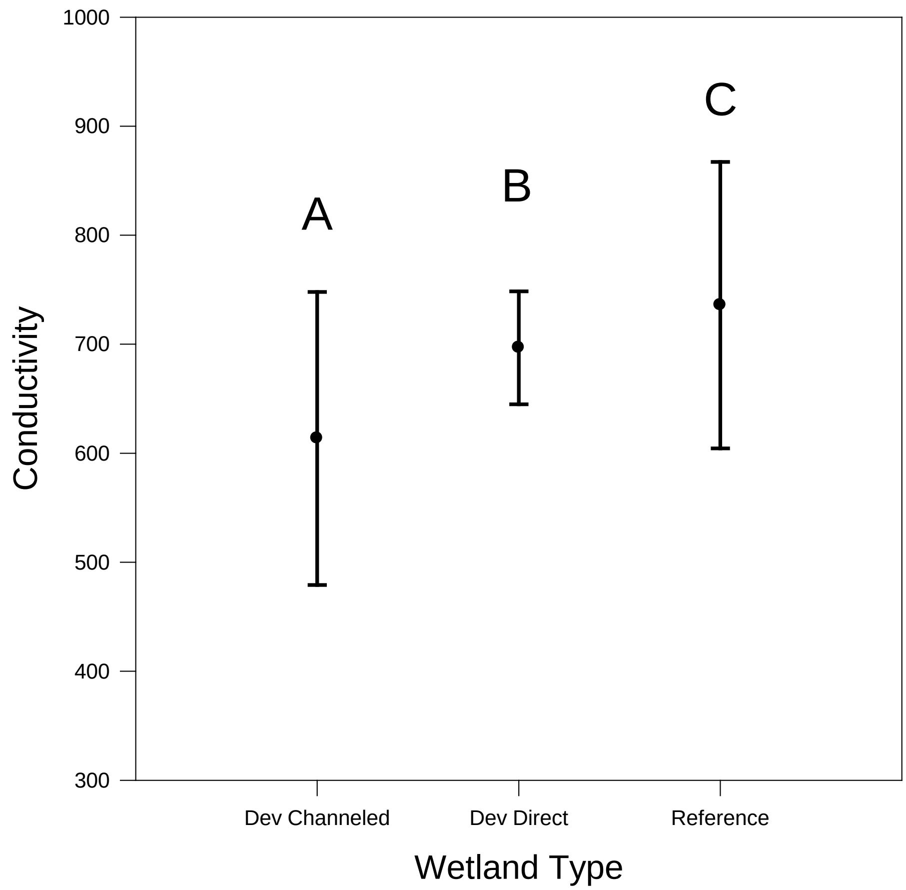

Figure 3.19. Conductivity (µs) (mean ± SD) between wetland types at the DFE LCOW. Letters indicate statistically similar groups (Holm-Sidak pair-wise comparison, α = 0.05).

Multiple regressions were done using dependent variables taxa richness, abundance (no. / m^2), Simpson's index of diversity, and Simpson's evenness and independent water quality variables temperature °C, pH, dissolved oxygen (mg/l), and conductivity (µs/cm). All models were found to be statistically significant (ANOVA, P<0.0001), though accounting for minimal variance from 2.6 to 13.8% (richness adjusted R^2 = 0.07, diversity R^2 = 0.08, abundance R^2 = 0.13, evenness R^2 = 0.02).

The response variable richness and the measured water quality predictor variables are related in the following way: richness = -6.546 + (0.150 * Temp) + (1.693 * pH) - (0.245 * DO)

+ (0.000730 * Cond), with temperature ($P = 0.005$) and pH ($P = 0.004$) accounting for the majority of predicting ability.

The response variable diversity and the measured water quality predictor variables are related in the following way: diversity = -0.349 + (0.00549 * Temp) + (0.102 * pH) - (0.0269 * DO) + (0.000173 * Cond) with DO ($P < 0.001$) and pH ($P = 0.001$) accounting for the majority of predicting ability.

The response variable abundance ($\log_{10}$ transformed) and the measured water quality predictor variables are related in the following way: abundance = 3.462 - (0.0152 * Temp) + (0.119 * pH) + (0.0165 * DO) - (0.000769 * Cond), with temperature ($P = 0.002$), pH ($P = 0.027$), and conductivity ($P < 0.001$) accounting for the majority of predicting ability.

The response variable evenness ($\log_{10}$ transformed) and the measured water quality predictor variables are related in the following way: evenness = -0.699 - (0.00138 * Temp) + (0.0319 * pH) - (0.0189 * DO) + (0.0000668 * Cond), with DO ($P = 0.006$) accounting for the majority of predicting ability.

Using simple linear regressions, statistically significant relationships were assessed between the following variables: abundance and pH ($n = 244$, $r^2 = 0.063$) with abundance = -11845.249 + (2180.428 * pH) (Figure 3.20); taxa richness and pH ($n = 244$, $r^2 = 0.034$) with taxa richness = 1.085 + (1.078 * pH) (Figure 3.21); taxa richness and temperature ($n = 244$, $r^2 = 0.052$) with taxa richness = 4.905 + (0.185 * Temp) (Figure 3.22); evenness and pH ($n = 244$, $r^2 = 0.024$) with evenness = 0.348 - (0.00749 * DO) (Figure 3.23). Although these relationships were found to be statistically significant, the biologically significant explanation for these relationships remains to be seen. This is apparent from the low coefficient of determination or r^2 values and the proceeding figures.

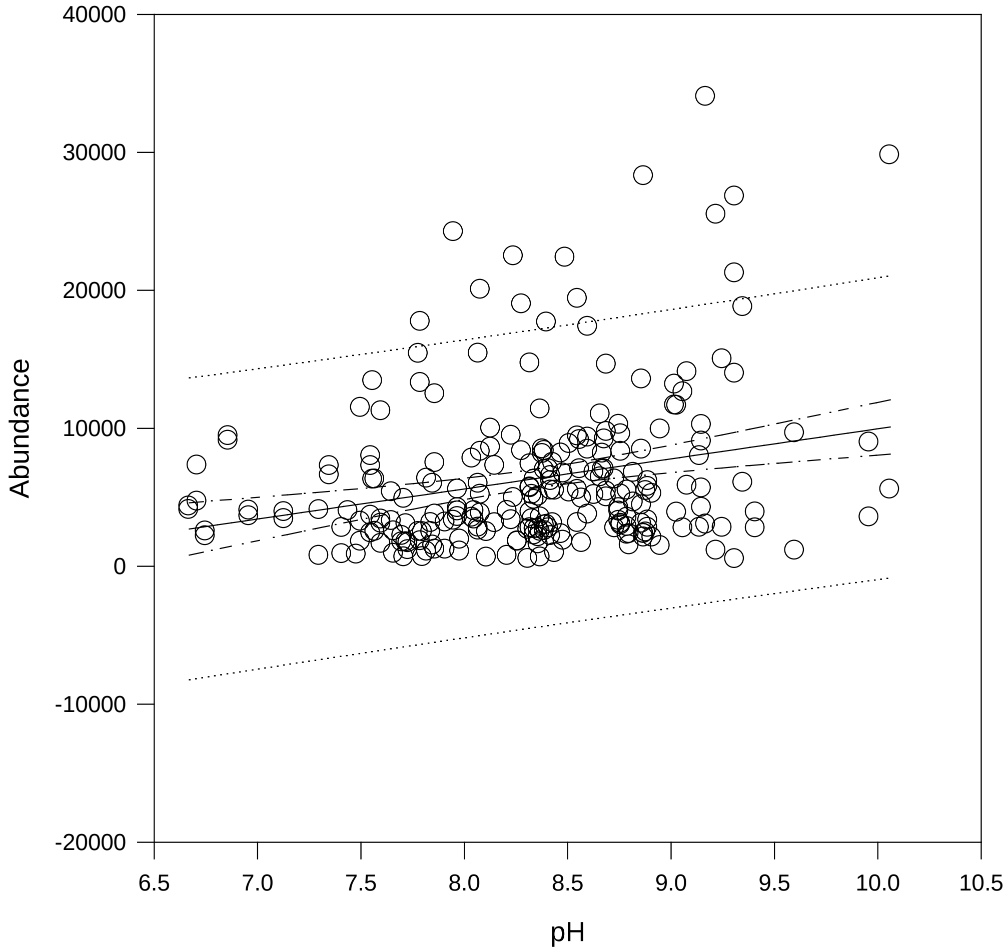

Figure 3.20. Simple linear regression model of macroinvertebrate abundance and pH (n = 244, r^2 = 0.063) with abundance = -11845.249 + (2180.428 * pH). Raw data, 95% population confidence interval, 95% regression confidence interval, and regression line given.

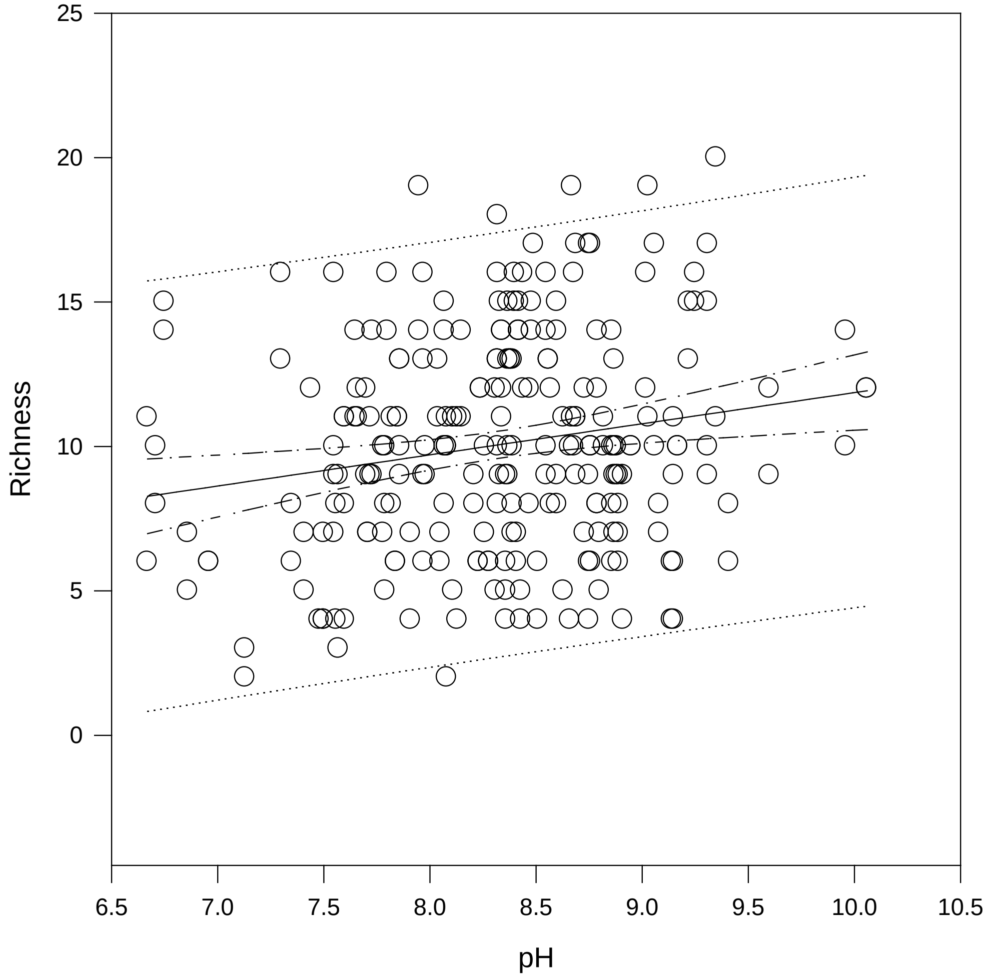

Figure 3.21. Simple linear regression model of macroinvertebrate taxa richness and pH (n = 244, $r^2 = 0.034$) with taxa richness = 1.085 + (1.078 * pH). Raw data, 95% population confidence interval, 95% regression confidence interval, and regression line given.

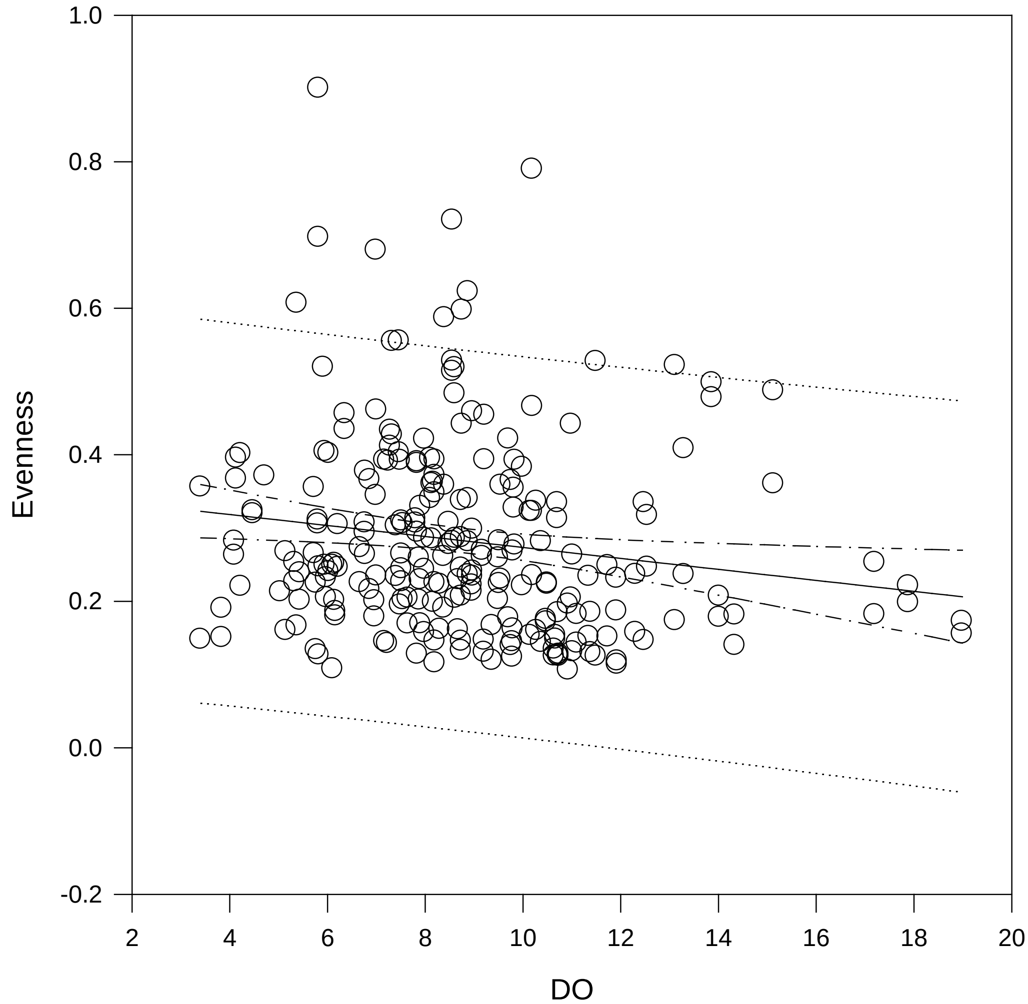

Figure 3.22. Simple linear regression model of macroinvertebrate evenness and pH (n = 244, r^2 = 0.024) with evenness = 0.348 - (0.00749 * DO)). Raw data, 95% population confidence interval, 95% regression confidence interval, and regression line given.

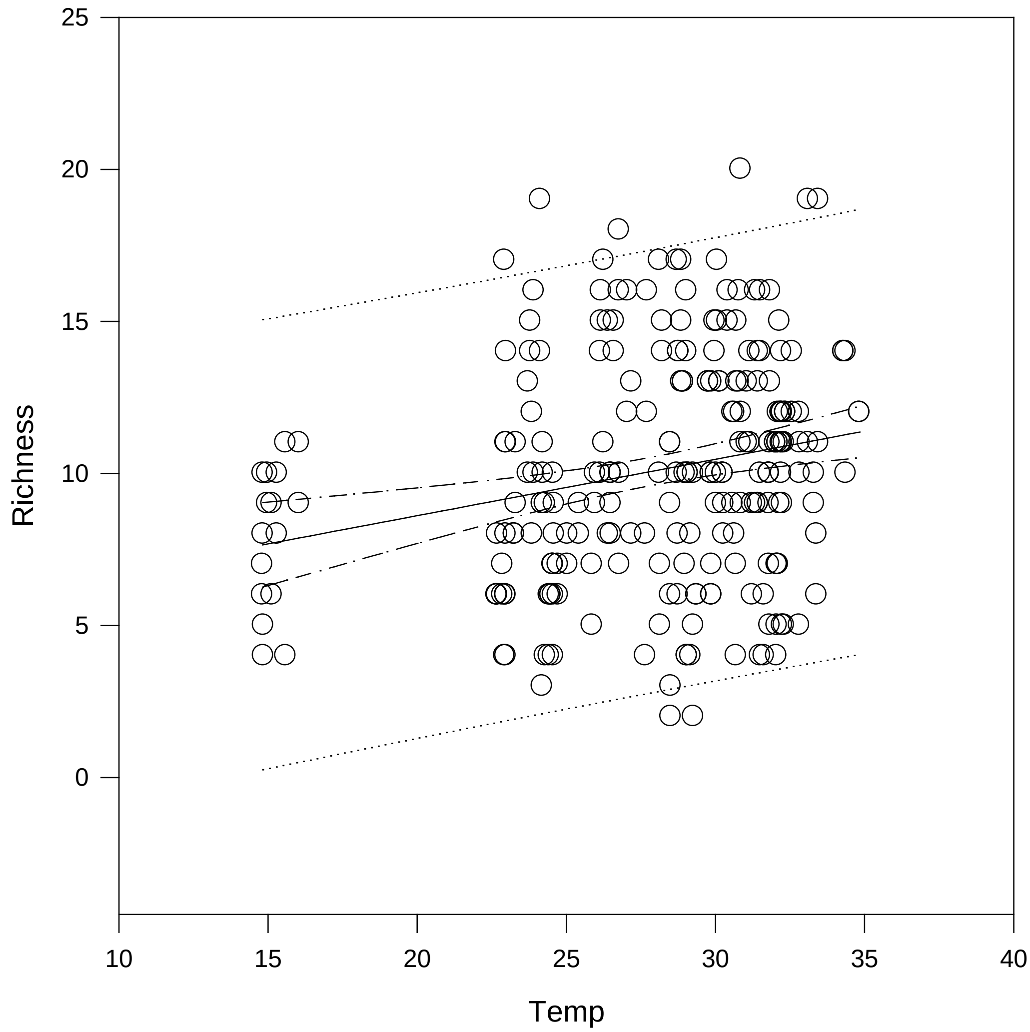

Figure 3.23. Simple linear regression model of macroinvertebrate taxa richness and temperature (n = 244, r^2 = 0.052) with taxa richness = 4.905 + (0.185 * Temp). Raw data, 95% population confidence interval, 95% regression confidence interval, and regression line given.

Overbanking and Flooding Events

The DFE LCOW receives flood waters from the Trinity River after heavy rains coupled with reservoir releases when the river reaches approximately 30 ft at the USGS monitoring station near downtown Dallas, TX. Two separate overbanking or flooding events of the Trinity

River occurred in the DFE LCOW during this project. The first, occurring in September 2010 (two weeks prior to sampling) crested at 41.39 ft and lasted 3.5 days (Figure 3.24) The second, less severe overbanking, occurred in May 2011 crested at 31.99 ft and lasted only one day (Figure 3.25) (NOAA NWS, USGS, Fort Worth, TX). Figures 3.26 and 3.27 illustrate taxa richness and diversity differences through the sampling regime with over-banking events highlighted.

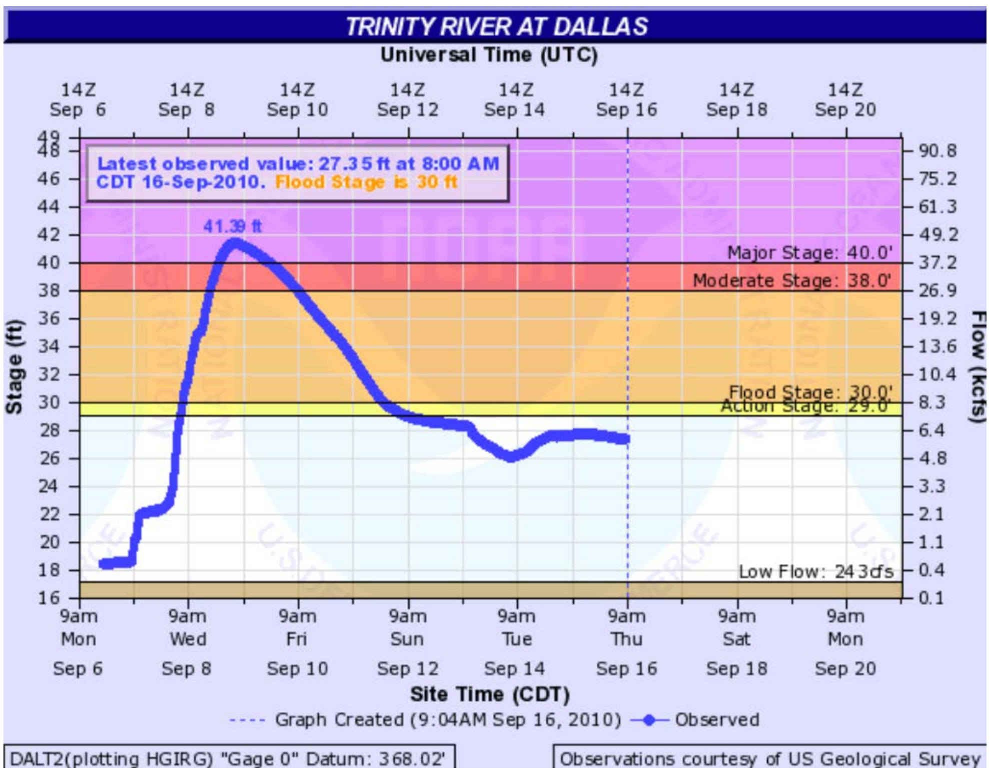

Figure 3.24. Trinity River height near downtown Dallas, TX in September 2010 showing various flood stages (USGS)

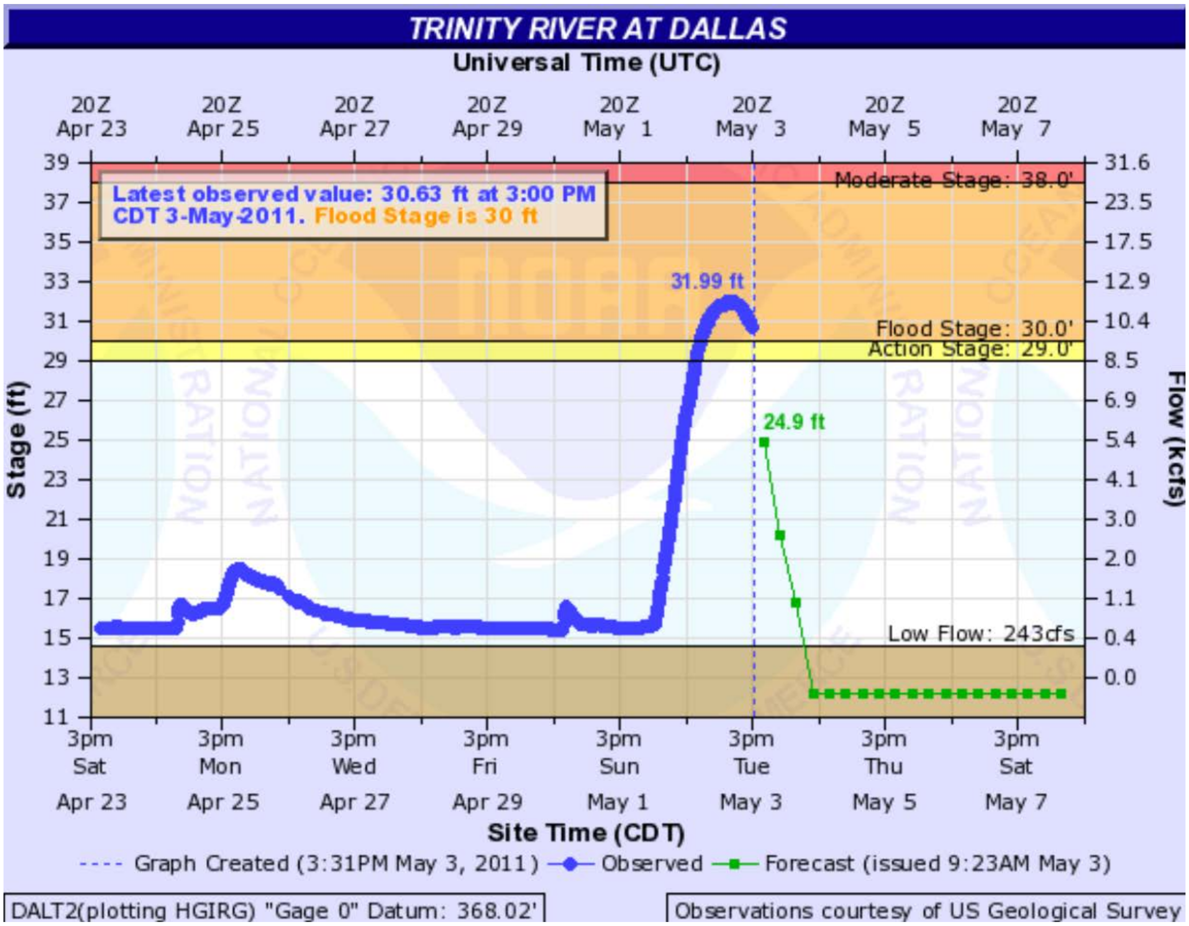

Figure 3.25. Trinity River height near downtown Dallas, TX in May2011 showing various flood stages (USGS).

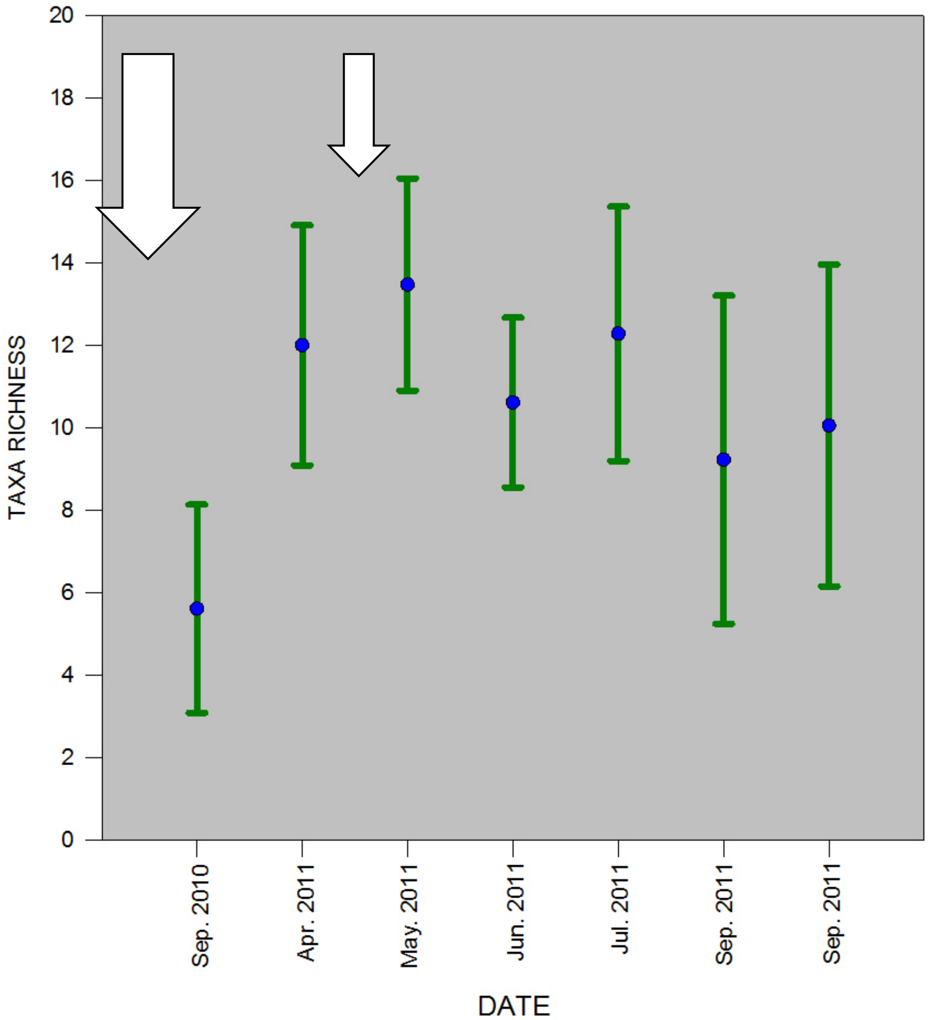

Figure 3.26. Taxa richness mean ± SD across all samples over seven sampling dates at the DFE LCOW. Overbanking events are highlighted in magnitude with arrows.

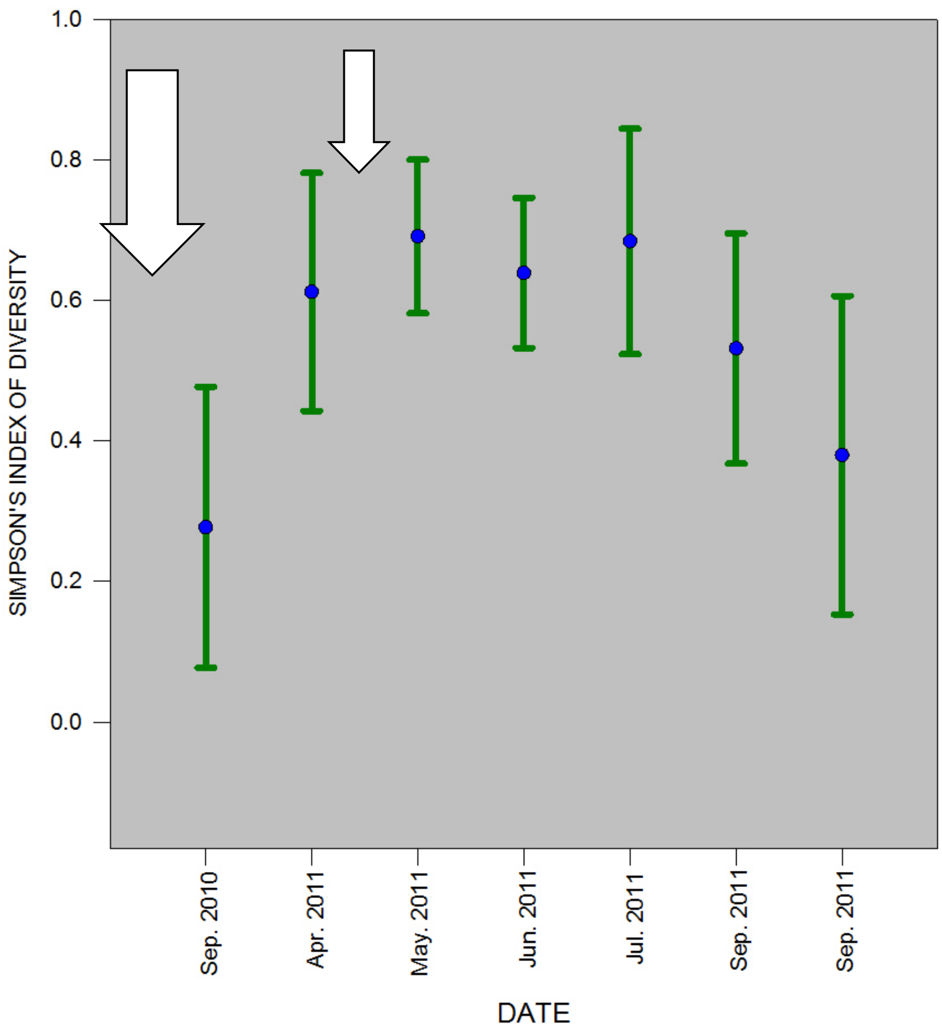

Figure 3.27. Simpson's Index of Diversity mean ± SD across all samples over seven sampling dates at the DFE LCOW. Overbanking events are highlighted in magnitude with arrows.

Description of *Enallagma civile* Development Classes

Enallagma civile nymphs were separated into five developmental classes for annual secondary production estimations based on physiological and morphological characteristics. Table 3.20 gives the five *E. civile* developmental size classes used for annual secondary productivity estimations along with numbers sampled for ash-free dry weight (AFDW) biomass estimations as well as mean AFDW (mg) of each size class.

Table 3.20. *Enallagma civile* developmental size class ash-free dry weight (AFDW) biomass (mg) estimations

Size Class	*n*	Mean individual AFDW mg
I	41	0.032
II	12	0.175
III	7	0.443
IV	7	1.043
V	3	5.300

Secondary Production of *Enallagma civile*

Annual production of *Enallagma civile* among *Heteranthera dubia* in three wetlands of the DFE LCOW, Dallas, TX, September 2010 - November 2011 was calculated to be 1099.60 AFDW mg/m^2/yr. Standing stock biomass was 120.05 AFDW mg/m^2/yr. Cohort production / biomass ratio was calculated to be 3.86/yr and the annual production / biomass ratio was 9.16/yr (Table 3.21).

Table 3.21. Summary of production by *Enallagma civile* among *Heteranthera dubia* in three wetlands of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Size class	Density (no./m^2)	Mass (mg)	No. lost (no./m^2)	Biomass (mg/m^2)	Mass at loss (mg)	Biomass lost (mg/m2)	Times no. size classes
I	37	0.03	8	1.19	0.10	0.88	4.38
II	29	0.17	-4	5.06	0.31	-1.27	-6.33
III	33	0.44	19	14.62	0.74	14.47	72.34
IV	14	1.04	-2	14.13	3.17	-6.34	-31.71
V	16	5.30	16	85.05	5.30	85.05	425.26

Total			B =	120.05		P uncorrected =	463.94
			Cohort P/B =	3.86		P corrected =	1099.60
			Annual P/B =	9.16			

Density, mean number of individuals collected per m2 plant surface area; mass, mass (mg of one individual among each size class; no. lost, density lost between each size class; biomass, standing stock biomass (mg/m2); mass at loss (mg); biomass lost (mg/m^2); Times no. size class, biomass lost * no. size class. Mean standing stock biomass (B), uncorrected and (CPI = 154 d) corrected annual production (P) (AFDW mg/m^2/yr), cohort and annual P/B (production to biomass ratio) given.

Annual production of *Enallagma civile* among *Potamogeton nodosus* in three wetlands of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011 was calculated to be 1704.98 AFDW mg/m^2/yr. Standing stock biomass was 153.48 AFDW mg/m^2/yr. The cohort production / biomass ratio was calculated to be 4.69/yr and the annual production / biomass ratio was 11.11/yr (Table 3.22).

Table 3.22. Summary of production by *Enallagma civile* among *Potamogeton nodosus* in three wetlands of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Size class	Density (no./m^2)	Mass (mg)	No. lost (no./m^2)	Biomass (mg/m^2)	Mass at loss (mg)	Biomass lost (mg/m2)	Times no. size classes
I	161	0.03	103	5.10	0.10	10.67	53.34
II	58	0.17	11	10.08	0.31	3.35	16.77
III	47	0.44	23	20.70	0.74	17.01	85.07
IV	24	1.04	6	24.85	3.17	20.09	100.43
V	18	5.30	18	92.75	5.30	92.75	463.75
Total			B =	153.48		P uncorrected =	719.36
			Cohort P/B =	4.69		P corrected =	1704.98
			Annual P/B =	11.11			

Density, mean number of individuals collected per m2 plant surface area; mass, mass (mg) of one individual among each size class; no. lost, density lost between each size class; biomass, standing stock biomass (mg/m2); mass at loss (mg); biomass lost (mg/m^2); Times no. size class, biomass lost * no. size class. Mean standing stock biomass (B), uncorrected and (CPI = 154 d) corrected annual production (P) (AFDW mg/m^2/yr), cohort and annual P/B (production to biomass ratio) given.

Annual production by *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in the reference Cell D wetland of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011 was calculated to be 1549.76 AFDW mg/m^2/yr. Standing stock biomass was 131.17 AFDW mg/m^2/yr. The cohort production / biomass ratio was calculated to be 4.98/ yr and the annual production / biomass ratio was 11.81 /yr (Table 3.23).

Table 3.23. Summary of production by *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in the reference Cell D wetland of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Size class	Density (no./m^2)	Mass (mg)	No. lost (no./m^2)	Biomass (mg/m^2)	Mass at loss (mg)	Biomass lost (mg/m2)	Times no. size classes
I	110	0.03	51	3.50	0.10	5.31	26.56
II	59	0.17	17	10.30	0.31	5.12	25.60
III	42	0.44	18	18.73	0.74	13.19	65.93
IV	25	1.04	11	25.59	3.17	34.09	170.46
V	14	5.30	14	73.06	5.30	73.06	365.32
Total			B =	131.17		P uncorrected =	653.87
			Cohort P/B =	4.98		P corrected =	1549.76
			Annual P/B =	11.81			

Density, mean number of individuals collected per m2 plant surface area; mass, mass (mg) of one individual among each size class; no. lost, density lost between each size class; biomass, standing stock biomass (mg/m2); mass at loss (mg); biomass lost (mg/m^2); Times no. size class, biomass lost * no. size class. Mean standing stock biomass (B), uncorrected and (CPI = 154 d) corrected annual production (P) (AFDW mg/m^2/yr), cohort and annual P/B (production to biomass ratio) given.

Annual production of *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in the developing direct effluent Cell E wetland of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011 was calculated to be 1754.49 AFDW mg/m^2/yr. Standing stock biomass was 198.55 AFDW mg/m^2/yr. The cohort production / biomass ratio was calculated to be 3.73 / yr and the annual production / biomass ratio was 8.84 /yr (Table 3.24).

Table 3.24. Summary of production by *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in the developing direct effluent Cell E wetland of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Size class	Density (no./m^2)	Mass (mg)	No. lost (no./m^2)	Biomass (mg/m^2)	Mass at loss (mg)	Biomass lost (mg/m2)	Times no. size classes
I	85	0.03	37	2.71	0.10	3.84	19.21
II	48	0.17	-4	8.43	0.31	-1.24	-6.18
III	52	0.44	31	22.82	0.74	23.11	115.54
IV	20	1.04	-7	21.30	3.17	-20.95	-104.77
V	27	5.30	27	143.29	5.30	143.29	716.45
Total			B =	198.55		P uncorrected =	740.25
			Cohort P/B =	3.73		P corrected =	1754.49
			Annual P/B =	8.84			

Density, mean number of individuals collected per m2 plant surface area; mass, mass (mg) of one individual among each size class; no. lost, density lost between each size class; biomass, standing stock biomass (mg/m2); mass at loss (mg); biomass lost (mg/m^2); Times no. size class, biomass lost * no. size class. Mean standing stock biomass (B), uncorrected and (CPI = 154 d) corrected annual production (P) (AFDW mg/m^2/yr), cohort and annual P/B (production to biomass ratio) given.

Annual production of *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in the developing channeled effluent Cell G wetland of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011 was calculated to be 872.09 AFDW mg/m^2/yr. Standing stock biomass was 80.57 AFDW mg/m^2/yr. The cohort production / biomass ratio was calculated to be 4.57 / yr and the annual production / biomass ratio was 10.82 /yr (Table 3.25).

Table 3.25. Summary of production by *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in the developing channeled effluent Cell G wetland of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Size class	Density (no./m^2)	Mass (mg)	No. lost (no./m^2)	Biomass (mg/m^2)	Mass at loss (mg)	Biomass lost (mg/m2)	Times no. size classes
I	102	0.03	79	3.23	0.10	8.16	40.81
II	23	0.17	-3	3.98	0.31	-0.95	-4.74
III	26	0.44	15	11.44	0.74	10.93	54.65
IV	11	1.04	2	11.58	3.17	5.10	25.48
V	10	5.30	10	50.35	5.30	50.35	251.75
Total			B =	80.57		P uncorrected =	367.95
			Cohort P/B =	4.57		P corrected =	872.09
			Annual P/B =	10.82			

Density, mean number of individuals collected per m2 plant surface area; mass, mass (mg) of one individual among each size class; no. lost, density lost between each size class; biomass, standing stock biomass (mg/m2); mass at loss (mg); biomass lost (mg/m^2); Times no. size class, biomass lost * no. size class. Mean standing stock biomass (B), uncorrected and (CPI = 154 d) corrected annual production (P) (AFDW mg/m^2/yr), cohort and annual P/B (production to biomass ratio) given.

Annual production of *Enallagma civile* among *Heteranthera dubia* in three wetlands of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011 was calculated to be 1392.90 AFDW mg/m^2/yr. Standing stock biomass was 136.77 AFDW mg/m^2/yr. The cohort production / biomass ratio was calculated to be 4.30 / yr and the annual production / biomass ratio was 10.18 /yr (Table 3.26). A summary of annual secondary production estimation metrics are given in Table 3.27.

Table 3.26. Summary of production by *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in three wetlands of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Size class	Density (no./m^2)	Mass (mg)	No. lost (no./m^2)	Biomass (mg/m^2)	Mass at loss (mg)	Biomass lost (mg/m2)	Times no. size classes
I	99	0.03	56	3.14	0.10	5.77	28.86
II	43	0.17	3	7.57	0.31	1.04	5.22
III	40	0.44	21	17.66	0.74	15.74	78.71
IV	19	1.04	2	19.49	3.17	6.08	30.39
V	17	5.30	17	88.90	5.30	88.90	444.51
Total			B =	136.77		P uncorrected =	587.69
			Cohort P/B =	4.30		P corrected =	1392.90
			Annual P/B =	10.18			

Density, mean number of individuals collected per m2 plant surface area; mass, mass (mg) of one individual among each size class; no. lost, density lost between each size class; biomass, standing stock biomass (mg/m2); mass at loss (mg); biomass lost (mg/m^2); Times no. size class, biomass lost * no. size class. Mean standing stock biomass (B), uncorrected and (CPI = 154 d) corrected annual production (P) (AFDW mg/m^2/yr), cohort and annual P/B (production to biomass ratio) given.

Table 3.27. Summary of production by *Enallagma civile* among *Heteranthera dubia* and *Potamogeton nodosus* in three wetlands of the DFE LCOW, Dallas, TX, Sep. 2010 - Nov. 2011.

Variable	B	P	Cohort P/B	Annual P/B
H. dubia	120.05	1099.60	3.86	9.16
P. nodosus	153.48	1704.98	4.69	11.11
Reference	131.17	1549.76	4.98	11.81
Dev. direct	198.55	1754.49	3.73	8.84
Dev. chan.	80.57	872.09	4.57	10.82
Total DFE	136.77	1392.90	4.30	10.18

Variable, *E. civile* production among macrophytes (n=2), wetlands (n=3) and combined; B, mean standing stock biomass; P, corrected (CPI = 154 d) annual production (AFDW $mg/m^2/yr$); cohort and annual P/B, production to biomass ratio.

CHAPTER 4

DISCUSSION

Macroinvertebrate Community Structure

The following alternative hypotheses were supported statistically by rejecting their null hypothesis counterparts. Community structure metrics found to be significantly different as well as tests that were not supported are in parentheses:

H_a: Macrophyte type has significant effect on macroinvertebrate community structure (abundances).

- H_a: Wetland type has significant effect on macroinvertebrate community structure (abundances, taxa richness, Simpson's index of diversity, and evenness).
- H_a: Interaction of macrophyte and wetland has significant effect on macroinvertebrate community structure (not statistically supported).
- H_a: Macroinvertebrate communities are significantly different between wetland cells or among sampling sites (not statistically supported).
- H_a: Sampling date has significant effect on macroinvertebrate community structure, along with its interaction with wetland and plant type (wetland type - abundances, taxa richness, Simpson's index of diversity, and evenness; interaction statistically apparent between dates and wetlands).

It was been widely accepted that plant morphology significantly effects macroinvertebrate community structure (Downing et al. 1985, Beckett et al. 1992, Collier et al. 1999). In terms of this study, only macroinvertebrate abundances were found to be significantly different between different macrophytes. Typically, the difference relates to plant surface area; the more highly dissected and thus more surface area a macrophyte has produces higher faunal abundances. This was not the case in this study. *Potamogeton nodosus* (the less dissected macrophyte) demonstrated higher taxa abundances than *Heteranthera dubia*. This could be attributed to the greater establishment success and denser submersed aquatic vegetation communities resulting from *P. nodosus* in this particular lentic system. Many factors could have played a role in this, including water quality, herbivory preferences, and littoral zone establishment abilities. In the next section, site characteristics that played a role in this dynamic, such as vegetation establishment and site shoreline distances, are discussed.

The majority of variance in this study in terms of macroinvertebrate community structure was observed between wetland types and sampling dates. No statistical differences were found among sampling sites. It is not surprising that community structure differed between sampling dates as this is common in these types of studies because of life cycle differences, water quality changes, and emergence patterns (Balci and Kennedy 2003). However, differences between wetland types indicate a dynamic unrelated to macrophyte type sampled that influenced community colonization and assemblages through time. This could be wetland establishment in terms of age (established vs. developing) or a variation in water source (direct effluent vs. wetland-channeled effluent).

Established reference and developing channeled effluent wetland types demonstrated the highest taxa richness and Simpson's index of diversity and evenness, while the developing direct effluent wetland type exhibited the lowest. This indicates that to create more productive lentic ecosystems with wastewater effluent sources, adequate time may be needed for the development of appropriate native aquatic vegetation. Alternatively, a mechanism that mimics a wetland-channeled water source may be needed to supplement vegetation establishment. When developing an urban wetland floodway, these dynamics should be of top priority in predicting how quickly these systems will become ecologically functional.

Site Characteristics

The following alternative hypothesis was supported statistically by rejecting its null hypothesis counterpart. Community structure metrics found to be significantly different as well as tests that were not supported are in parentheses:

- H_a: Site characteristics, such as vegetation establishment and shoreline distance have significant effects on macroinvertebrate community structure (vegetation - taxa richness; shoreline distances - Simpson's index of diversity and evenness).

Macroinvertebrate assemblages were found to be richer and more diverse depending on certain site characteristics such as vegetations establishment success and proximity of site to the emergent vegetation shoreline. Not surprisingly, taxa richness was highest when vegetation establishment was "good" and lowest when it was "poor". In addition, Simpson's index of diversity and evenness increased with proximity to the shoreline and decreased with distance from the shoreline. These statistical relationships add to the common narrative of the relationship between productive functioning aquatic systems and the development of robust submersed aquatic and emergent vegetation in freshwater ecosystems.

Not including ubiquitous fauna in the DFE LCOW, macroinvertebrate taxa associated with a closer proximity to the emergent vegetation shoreline included: *Sminthurides* (Collembola: Sminthuridae), *Stratiomys* (Diptera: Stratiomyidae), *Metrobates* (Hemiptera: Gerridae), *Pelocaris* (Hemiptera: Naucoridae), and *Ranatra* (Hemiptera: Nepidae). Those associated with a larger distance from the shoreline included: *Baetis* and *Callibaetis* (Ephemeroptera: Baetidae), Hymenopterans, *Anax* (Odonata: Aeshnidae), *Hydrophyshe* (Trichoptera: Hydroptilidae), *Corbicula* (Veneroida: Corbiculidae), and *Fossaria* (Basommatophora: Lymnaidae).

Water Quality Influences

The following alternative hypotheses were supported statistically by rejecting their null hypothesis counterparts. Water quality and community structure metrics found to be significantly different or have significant linear relationships are in parentheses:

- H_a: Water quality (temperature ºC, pH, dissolved oxygen mg/L, conductivity µs/cm) is significantly different between wetlands or among sampling sites (wetlands - pH, dissolved oxygen and conductivity; no differences among sites).
- H_a: Significant correlation between macroinvertebrate community and water quality (temperature ºC, pH, dissolved oxygen mg/L, conductivity µs/cm) (positive linear relationship - abundance / pH, taxa richness / pH and temperature; negative linear relationship taxa evenness / dissolved oxygen).

Conductivity decreased in magnitude from wetlands reference > developing direct > developing channeled. pH and dissolved oxygen were significantly higher in magnitude in the developing direct effluent wetland. This, in addition to wetland development and vegetation establishment, adds to the explanation of variance observed in macroinvertebrate community structure.

Overbanking Influences

The following alternative hypothesis was not supported statistically.

- H_a: Overbanking or flood events have significant effect on macroinvertebrate community structure (not statistically supported; not proper sample size).

Macroinvertebrate community sampling had not commenced before the first major over-banking event. For this reason statistical tests were not used to evaluate community structure differences due to flood events from the Trinity River. For example, differences were not able to be assessed in a before / after manner. Additionally, differences observed at the same time the next year might have been due to wetland and community structure development through time. However, it was still useful to describe and illustrate the data to understand these floodway dynamics more thoroughly. From the previous illustrations and statistical descriptions, initial indicators are that although severe over-banking events influence epiphytic macroinvertebrate community structure, the assemblages are not detrimentally affected and are able to recover.

Enallagma civile Annual Secondary Productivity

Annual secondary production of the familiar bluet *Enallagma civile* ranged from 872 - 1754 AFDW mg/m^2/yr and annual production to biomass ratio or 9 - 12. Production across independent variables macrophytes and wetland types increased as follows: macrophytes - *P. nodosus* (1705 AFDW mg/m^2/yr, P/B = 11.11) > *H. dubia* (1100 AFDW mg/m^2/yr, P/B = 9.16); wetland types - developing direct effluent (1754 AFDW mg/m^2/yr, P/B = 8.84) > reference (1550 AFDW mg/m^2/yr, P/B = 11.81) > developing channeled (872 AFDW mg/m^2/yr, P/B = 10.82). Similarly to general community structure assessments and differences between independent variables, *P. nodosus* resulted in a more productive *E. civile* population than *H. dubia* and annual P/B ratios between wetland types increased similarly to structural metrics taxa richness, diversity and evenness (reference > developing channeled > developing direct). This further demonstrates and supports statistical differences and determinations observed in the macroinvertebrate community across these independent variables.

Table 4.1, adapted from Braccia et al. (2007) with additional sources and this study included, presents previous annual secondary production research on odonata species. This study's *E. civile* production estimates are higher (872 – 1754) than previously reported from Braccia et al. (116 – 437) for *E. civile.* Although not generally out of line for an odonate production estimate from an established lentic system, the numbers were on the higher side. Several factors could have contributed to this including the more established wetland system undergoing native aquatic vegetation community establishment in this study. This resulted in larger macrophyte stands thus creating refugia for higher densities of macroinvertebrates and other fauna used as food resources by the predatory odonate. The submersed aquatic vegetation habitat also created increased climbing structure for macroinvertebrates such as *E. civile* to find cover as well as stalk its prey. However, comparisons of production estimates to different studies should be made with caution because of the variability in biotic and abiotic factors, paucity of replicable studies, and the nature of ecological field studies. Although this wetland chain was evaluated as having high *E. civile* production estimates, indicating its prey assemblage was diverse and abundant, similar studies are warranted to create additional baselines for quantitative metrics assessing ecological function.

Table 4.1. Odonata production estimates from published literature including this study; adapted from Braccia et al. (2007)

Taxon		P	P/B	Habitat	Location	Source
				Anisoptera		
Aeshnidae	Anax junius	266 – 1826	6 – 8	Fishless New ponds	Virginia, US	Braccia et al. 2007
	Boyeria vinosa	575 – 745	5	Stream	Georgia, US	Benke et al. 1984
		12 – 1847	2	Stream	Virginia, US	Smock et al. 1992; Smith & Smock 1992
Cordulegastridae	Cordulegaster maculata	160 – 612	3	Stream	Virginia, US	Smock et al. 1992; Smith & Smock 1992
Gomphidae	Dromogomphus spinosus	600 – 2900	6 – 7	Stream	Virginia, US	Kedzierski & Smock 2001
	Gomphus exilis	6 – 41	4 – 5	Fishless New ponds	Virginia, US	Braccia et al. 2007
	Gomphus cavillaris	97 – 359	2	Stream	Virginia, US	Smock et al. 1992; Smith & Smock 1992
	Hagenius brevistylus	0 – 2	–	Stream	Virginia US	Smith & Smock 1992
	Heliogomphus scorpio	182	4	Stream	Hong Kong, Japan	Dudgeon 1989a
	Onychogomphus sinicus	236	4	Stream	Hong Kong, Japan	Dudgeon 1989a
	Progomphus obscurus	0 – 10	–	Stream	Virginia, US	Smith & Smock 1992
		6842	4	Stream	East Texas, US	Phillips 2001
Libellulidae	Celithemis fasciata	2170	4	Farm pond	South Carolina, US	Benke 1976
	Epitheca spp.*	1980	4	Farm pond	South Carolina, US	Benke 1976
	Ladona deplanata	1740	4	Farm pond	South Carolina, US	Benke 1976
	Neurocordulia molesta	651 – 1867	5	Stream	Georgia, US	Benke et al. 2001
	Sp.	300-2000	3-4	Lake	Michigan, US	Babler et. al 2008
				Zygoptera		
Calopterygidae	Calopteryx dimidiate	71 – 1243	4	Stream	Virginia, US	Smock et al. 1992; Smith & Smock 1992
Coenagrionidae	Argia tibialis	44 – 372	5	Stream	Washington, US	Gaines et al. 1992
	Argia translate	13 – 345	4 – 5	Stream	West Virginia, US	Kirk & Perry 1994
	Enallagma civile	116 – 437	12 – 16	Fishless New pond	Virginia, US	Braccia et al. 2007
		872 – 1754	9 – 12	New wetlands	Dallas, US	This study
	Pyrrhosoma nymphula	700	3 – 4	Pond	England, Durham	Lawton 1971
	Telebasis salva	7900	10	Travertine spring	Arizona, US	Runck & Blinn 1993
	Sp.	410-580	2	Lake	Michigan, US	Babler et. al 2008
Euphaeidae	Euphaea decorate	132 – 167	4 – 5	Stream	Hong Kong, Japan	Dudgeon 1989b

*P, corrected (CPI = 154 d) annual production (AFDW $mg/m^2/yr$); P/B, annual production to biomass ratio.

Difficulties and Potential Enhancements

The primary difficulty with this project was with inconsistent establishment of submersed aquatic vegetation because of herbivory. Crayfish (chiefly), turtles, common carp, and waterfowl all attributed to problem. If starting this project over, one would be advised to (A) begin establishment efforts in the year prior to fauna sampling, (B) use a sub-2 cm protective exclosure mesh size including a lid from the beginning, and (C) install multiple plants per exclosure per site. These methods would ensure or at least increase the probability of appropriate plant material to sample to assess the macroinvertebrate community. Additional project difficulties included failure of the water source pump used to maintain the reference wetland's water level in the year of plant establishment.

Future Research

At this point in aquatic epiphytic macroinvertebrate research, a few things are clear and supported by the literature. These include the positive relationship between macroinvertebrate community structure and abundance and morphology of aquatic vegetation (Downing et al. 1985, Beckett et al. 1992, Collier et al. 1999). There are an increasing number of quantitative functional studies such as species-specific annual secondary production estimations. However, only few have assessed these functional parameters in correlation with macrophyte type and surface area (Balci and Kennedy 2003). There is also a dearth of information on the ecological function of created urban wetlands. An increase in these types of faunal energy flow and production studies resulting from vegetative restoration or community establishment efforts in urban settings are warranted to assess individual species function and quantify restoration efforts. This cumulative scientific narrative will continue to assist and provide resources to restoration ecologists and conservation biologists to develop and maintain the most ecologically beneficial urban ecosystems.

APPENDIX A

RAW MACROINVERTEBRATE COMMUNITY STRUCTURE, WATER QUALITY, AND SITE CHARACTERIZATION DATA PER DATE, PLANT, AND WETLAND SAMPLED

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
9/22/2010	Dev Channeled	Inlet	HET	0.62	0.04	6256.54	8	0.218	0.160	29.18	7.56	5.15	386	Fair	Middle
9/22/2010	Dev Channeled	Inlet	PNOD	0.51	0.01	13400.45	4	0.065	0.267	29.18	7.56	5.15	386	Fair	Middle
9/22/2010	Dev Channeled	Middle	HET	0.85	0.06	3210.13	4	0.113	0.282	29.06	7.50	4.10	387	Good	Far
9/22/2010	Dev Channeled	Middle	PNOD	0.59	0.01	11472.78	4	0.048	0.263	29.06	7.50	4.10	387	Good	Far
9/22/2010	Dev Channeled	Outlet	HET	0.64	0.04	2373.71	7	0.249	0.190	28.99	7.55	3.84	385	Good	Far
9/22/2010	Dev Channeled	Outlet	PNOD	0.55	0.01	7243.03	10	0.335	0.150	28.99	7.55	3.84	385	Good	Far
9/22/2010	Dev Direct	Inlet	HET	0.05	0.00	17699.12	5	0.128	0.229	29.27	7.79	7.90	541	Poor	Close
9/22/2010	Dev Direct	Middle	PNOD	0.42	0.01	2475.49	6	0.433	0.294	29.88	7.84	6.77	575	Fair	Far
9/22/2010	Dev Direct	Middle	HET	0.17	0.01	3123.37	6	0.457	0.307	29.88	7.84	6.77	575	Fair	Far
9/22/2010	Dev Direct	Outlet	HET	0.59	0.04	8326.01	6	0.065	0.178	29.38	8.28	6.97	535	Fair	Middle
9/22/2010	Dev Direct	Outlet	PNOD	0.35	0.01	18966.95	6	0.168	0.200	29.38	8.28	6.97	535	Fair	Middle
9/22/2010	Reference	Inlet	PNOD	0.22	0.01	4063.60	6	0.638	0.461	28.50	6.67	7.01	467	Good	Close
9/22/2010	Reference	Inlet	HET	0.95	0.06	4316.10	11	0.612	0.234	28.50	6.67	7.01	467	Good	Close
9/22/2010	Reference	Middle	PNOD	0.24	0.01	3410.91	2	0.444	0.900	28.51	7.13	5.82	422	Fair	Middle
9/22/2010	Reference	Middle	HET	0.17	0.01	3904.22	3	0.521	0.697	28.51	7.13	5.82	422	Fair	Middle
9/22/2010	Reference	Outlet	PNOD	0.09	0.01	9086.82	7	0.289	0.201	28.16	6.86	6.15	418	Fair	Close
9/22/2010	Reference	Outlet	HET	0.34	0.02	9413.50	5	0.205	0.252	28.16	6.86	6.15	418	Fair	Close
10/15/2010	Dev Channeled	Inlet	HET	2.61	0.18	2486.47	9	0.331	0.166	24.20	7.57	5.38	434	Fair	Middle
10/15/2010	Dev Channeled	Inlet	PNOD	0.50	0.01	6269.76	3	0.450	0.606	24.20	7.57	5.38	434	Fair	Middle
10/15/2010	Dev Channeled	Middle	HET	2.64	0.18	2474.97	10	0.071	0.108	24.57	7.78	6.11	428	Good	Far
10/15/2010	Dev Channeled	Middle	PNOD	1.60	0.03	15377.40	7	0.426	0.249	24.57	7.78	6.11	428	Good	Far
10/15/2010	Dev Channeled	Outlet	HET	2.63	0.18	639.32	7	0.644	0.402	24.56	7.71	6.03	432	Good	Far
10/15/2010	Dev Channeled	Outlet	PNOD	1.79	0.03	4871.89	7	0.406	0.240	24.56	7.71	6.03	432	Good	Far
10/15/2010	Dev Direct	Inlet	HET	0.23	0.02	5322.56	4	0.574	0.587	22.98	8.51	8.40	704	Poor	Close
10/15/2010	Dev Direct	Inlet	PNOD	0.35	0.01	8845.57	6	0.535	0.358	22.98	8.51	8.40	704	Poor	Close
10/15/2010	Dev Direct	Middle	PNOD	0.24	0.01	3316.16	6	0.684	0.528	24.49	8.23	8.56	711	Fair	Far
10/15/2010	Dev Direct	Middle	HET	1.53	0.10	9437.60	6	0.408	0.282	24.49	8.23	8.56	711	Fair	Far
10/15/2010	Dev Direct	Outlet	HET	0.32	0.02	9310.47	9	0.343	0.169	25.44	8.60	7.91	699	Fair	Middle
10/15/2010	Dev Direct	Outlet	PNOD	0.62	0.01	17335.22	8	0.621	0.329	25.44	8.60	7.91	699	Fair	Middle
10/15/2010	Reference	Inlet	PNOD	0.54	0.01	6577.48	8	0.561	0.285	22.70	7.35	8.14	543	Good	Close
10/15/2010	Reference	Inlet	HET	0.12	0.01	7251.72	6	0.538	0.361	22.70	7.35	8.14	543	Good	Close
10/15/2010	Reference	Middle	PNOD	0.96	0.02	3364.43	7	0.521	0.298	22.87	8.05	8.97	530	Fair	Middle

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
10/15/2010	Reference	Middle	HET	0.30	0.02	3982.30	6	0.636	0.458	22.87	8.05	8.97	530	Fair	Middle
10/15/2010	Reference	Outlet	PNOD	0.39	0.01	3608.12	6	0.699	0.554	22.68	6.96	7.33	536	Fair	Close
10/15/2010	Reference	Outlet	HET	0.47	0.03	4016.82	6	0.609	0.427	22.68	6.96	7.33	536	Fair	Close
4/20/2011	Dev Channeled	Inlet	HET	1.00	0.07	1725.66	9	0.485	0.216	23.32	7.72	6.87	784	Fair	Middle
4/20/2011	Dev Channeled	Inlet	PNOD	0.66	0.02	3036.83	11	0.751	0.366	23.32	7.72	6.87	784	Fair	Middle
4/20/2011	Dev Channeled	Middle	HET	1.84	0.12	1042.07	11	0.703	0.306	22.98	7.82	7.55	764	Good	Far
4/20/2011	Dev Channeled	Middle	PNOD	1.05	0.02	6336.19	8	0.381	0.202	22.98	7.82	7.55	764	Good	Far
4/20/2011	Dev Channeled	Outlet	HET	0.85	0.06	3262.19	11	0.533	0.195	23.00	7.65	7.49	746	Good	Far
4/20/2011	Dev Channeled	Outlet	PNOD	2.35	0.03	5352.57	14	0.818	0.392	23.00	7.65	7.49	746	Good	Far
4/20/2011	Dev Direct	Inlet	HET	1.01	0.07	7009.55	16	0.837	0.383	23.92	8.68	9.99	705	Poor	Close
4/20/2011	Dev Direct	Inlet	PNOD	2.76	0.04	9183.38	10	0.547	0.221	23.92	8.68	9.99	705	Poor	Close
4/20/2011	Dev Direct	Middle	HET	1.17	0.08	5168.54	10	0.590	0.244	24.23	8.08	7.52	711	Fair	Far
4/20/2011	Dev Direct	Middle	PNOD	0.43	0.01	20028.26	11	0.599	0.226	24.23	8.08	7.52	711	Fair	Far
4/20/2011	Dev Direct	Outlet	HET	1.15	0.08	7464.41	13	0.392	0.126	23.73	7.86	5.83	678	Fair	Middle
4/20/2011	Dev Direct	Outlet	PNOD	0.78	0.02	12454.70	10	0.595	0.247	23.73	7.86	5.83	678	Fair	Middle
4/20/2011	Reference	Inlet	HET	1.22	0.08	3288.36	14	0.509	0.145	24.14	7.95	8.20	796	Good	Close
4/20/2011	Reference	Inlet	PNOD	1.78	0.03	24201.19	19	0.545	0.116	24.14	7.95	8.20	796	Good	Close
4/20/2011	Reference	Middle	HET	1.06	0.07	1669.73	12	0.802	0.421	23.86	8.57	9.71	791	Fair	Middle
4/20/2011	Reference	Middle	PNOD	1.91	0.03	4892.95	8	0.294	0.177	23.86	8.57	9.71	791	Fair	Middle
4/20/2011	Reference	Outlet	PNOD	3.35	0.04	5475.22	14	0.808	0.372	23.81	8.42	8.20	791	Fair	Close
4/20/2011	Reference	Outlet	HET	0.40	0.03	6526.55	15	0.830	0.393	23.81	8.42	8.20	791	Fair	Close
5/10/2011	Dev Channeled	Inlet	HET	2.00	0.14	3724.19	14	0.433	0.126	26.61	8.60	10.72	446	Fair	Middle
5/10/2011	Dev Channeled	Inlet	PNOD	2.83	0.04	8436.68	15	0.638	0.184	26.61	8.60	10.72	446	Fair	Middle
5/10/2011	Dev Channeled	Middle	HET	0.50	0.03	5398.23	11	0.536	0.196	26.26	8.69	10.93	446	Good	Far
5/10/2011	Dev Channeled	Middle	PNOD	0.96	0.02	14597.29	17	0.444	0.106	26.26	8.69	10.93	446	Good	Far
5/10/2011	Dev Channeled	Outlet	HET	3.10	0.21	2987.92	16	0.767	0.268	26.18	8.40	9.80	468	Good	Far
5/10/2011	Dev Channeled	Outlet	PNOD	1.28	0.02	17649.07	15	0.589	0.162	26.18	8.40	9.80	468	Good	Far
5/10/2011	Dev Direct	Inlet	HET	4.59	0.31	2740.98	8	0.681	0.392	26.51	8.32	9.84	657	Poor	Close
5/10/2011	Dev Direct	Inlet	PNOD	2.74	0.04	5700.17	10	0.639	0.277	26.51	8.32	9.84	657	Poor	Close
5/10/2011	Dev Direct	Middle	HET	1.78	0.12	2560.41	8	0.657	0.365	26.41	8.07	9.76	671	Fair	Far
5/10/2011	Dev Direct	Middle	PNOD	3.13	0.04	15394.27	15	0.521	0.139	26.41	8.07	9.76	671	Fair	Far
5/10/2011	Dev Direct	Outlet	HET	2.83	0.19	1052.77	10	0.675	0.308	26.50	7.98	8.49	648	Fair	Middle

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
5/10/2011	Dev Direct	Outlet	PNOD	3.47	0.05	1918.19	9	0.599	0.277	26.50	7.98	8.49	648	Fair	Middle
5/10/2011	Reference	Inlet	HET	0.86	0.06	2075.19	10	0.532	0.214	25.98	8.87	8.96	723	Good	Close
5/10/2011	Reference	Inlet	PNOD	0.96	0.02	2333.40	9	0.500	0.222	25.98	8.87	8.96	723	Good	Close
5/10/2011	Reference	Middle	HET	0.99	0.07	3069.04	14	0.790	0.340	26.15	8.86	8.88	721	Fair	Middle
5/10/2011	Reference	Middle	PNOD	0.81	0.02	4407.98	10	0.839	0.622	26.15	8.86	8.88	721	Fair	Middle
5/10/2011	Reference	Outlet	PNOD	0.74	0.02	1497.92	5	0.722	0.720	25.87	8.80	8.56	722	Fair	Close
5/10/2011	Reference	Outlet	HET	0.46	0.03	2308.58	7	0.722	0.514	25.87	8.80	8.56	722	Fair	Close
5/31/2011	Dev Channeled	Inlet	PNOD	1.46	0.02	8118.54	13	0.684	0.243	28.93	8.38	7.99	525	Fair	Middle
5/31/2011	Dev Channeled	Inlet	HET	0.91	0.06	8460.57	13	0.510	0.157	28.93	8.38	7.99	525	Fair	Middle
5/31/2011	Dev Channeled	Middle	HET	1.46	0.10	2485.15	13	0.817	0.421	28.87	8.37	7.99	524	Good	Far
5/31/2011	Dev Channeled	Middle	PNOD	1.08	0.02	11347.31	15	0.767	0.286	28.87	8.37	7.99	524	Good	Far
5/31/2011	Dev Channeled	Outlet	HET	1.21	0.08	5643.73	13	0.544	0.169	29.77	8.32	7.65	523	Good	Far
5/31/2011	Dev Channeled	Outlet	PNOD	1.33	0.02	14683.45	13	0.623	0.204	29.77	8.32	7.65	523	Good	Far
5/31/2011	Dev Direct	Inlet	HET	3.60	0.24	2953.95	17	0.711	0.204	28.72	8.76	8.62	713	Poor	Close
5/31/2011	Dev Direct	Inlet	PNOD	5.80	0.07	8282.32	10	0.650	0.286	28.72	8.76	8.62	713	Poor	Close
5/31/2011	Dev Direct	Middle	HET	3.62	0.25	3120.98	14	0.654	0.207	29.04	8.55	8.74	723	Fair	Far
5/31/2011	Dev Direct	Middle	PNOD	0.88	0.02	19369.67	16	0.569	0.145	29.04	8.55	8.74	723	Fair	Far
5/31/2011	Dev Direct	Outlet	PNOD	2.54	0.04	22348.89	17	0.586	0.142	28.87	8.49	7.23	716	Fair	Middle
5/31/2011	Reference	Inlet	HET	1.47	0.10	2739.15	10	0.617	0.261	28.13	9.06	9.17	751	Good	Close
5/31/2011	Reference	Inlet	PNOD	2.33	0.03	12601.02	17	0.782	0.269	28.13	9.06	9.17	751	Good	Close
5/31/2011	Reference	Middle	HET	0.93	0.06	4218.61	11	0.718	0.322	28.50	9.15	10.19	750	Fair	Middle
5/31/2011	Reference	Middle	PNOD	0.69	0.02	5621.81	9	0.859	0.790	28.50	9.15	10.19	750	Fair	Middle
5/31/2011	Reference	Outlet	PNOD	2.99	0.04	11642.35	16	0.841	0.393	27.72	9.02	9.22	753	Fair	Close
5/31/2011	Reference	Outlet	HET	0.59	0.04	13149.34	12	0.816	0.454	27.72	9.02	9.22	753	Fair	Close
6/10/2011	Dev Channeled	Inlet	HET	1.10	0.07	7012.60	13	0.655	0.223	30.15	8.56	10.50	520	Fair	Middle
6/10/2011	Dev Channeled	Inlet	PNOD	1.88	0.03	9126.36	13	0.658	0.225	30.15	8.56	10.50	520	Fair	Middle
6/10/2011	Dev Channeled	Middle	HET	2.94	0.20	3887.99	16	0.745	0.245	26.78	8.32	8.74	530	Good	Far
6/10/2011	Dev Channeled	Middle	PNOD	3.75	0.05	7376.58	18	0.582	0.133	26.78	8.32	8.74	530	Good	Far
6/10/2011	Dev Channeled	Outlet	HET	1.76	0.12	737.46	9	0.502	0.223	30.28	8.21	8.30	528	Good	Far
6/10/2011	Dev Channeled	Outlet	PNOD	0.97	0.02	3991.92	8	0.226	0.162	30.28	8.21	8.30	528	Good	Far
6/10/2011	Dev Direct	Inlet	HET	2.15	0.15	507.65	9	0.668	0.334	30.04	9.31	12.48	730	Poor	Close
6/10/2011	Dev Direct	Inlet	PNOD	0.43	0.01	21215.71	10	0.316	0.146	30.04	9.31	12.48	730	Poor	Close

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
6/10/2011	Dev Direct	Middle	HET	6.46	0.44	1118.75	15	0.437	0.118	30.72	9.22	11.93	725	Fair	Far
6/10/2011	Dev Direct	Middle	PNOD	0.83	0.02	25460.96	13	0.325	0.114	30.72	9.22	11.93	725	Fair	Far
6/10/2011	Dev Direct	Outlet	HET	3.36	0.23	2326.52	13	0.552	0.172	29.88	8.87	10.48	740	Fair	Middle
6/10/2011	Dev Direct	Outlet	PNOD	0.65	0.02	28261.73	7	0.184	0.175	29.88	8.87	10.48	740	Fair	Middle
6/10/2011	Reference	Inlet	HET	2.90	0.20	2771.84	16	0.602	0.157	30.43	9.25	12.31	402	Good	Close
6/10/2011	Reference	Inlet	PNOD	1.60	0.03	14984.12	15	0.718	0.236	30.43	9.25	12.31	402	Good	Close
6/10/2011	Reference	Middle	HET	2.62	0.18	6029.18	20	0.797	0.246	30.86	9.35	12.55	699	Fair	Middle
6/10/2011	Reference	Middle	PNOD	0.41	0.01	18769.98	11	0.713	0.317	30.86	9.35	12.55	699	Fair	Middle
6/10/2011	Reference	Outlet	HET	0.40	0.03	13938.05	15	0.712	0.231	30.07	9.31	11.92	707	Fair	Close
6/10/2011	Reference	Outlet	PNOD	0.75	0.02	26779.78	17	0.685	0.187	30.07	9.31	11.92	707	Fair	Close
6/28/2011	Dev Channeled	Inlet	HET	2.06	0.14	2319.79	8	0.791	0.597	30.65	8.47	8.76	578	Fair	Middle
6/28/2011	Dev Channeled	Inlet	PNOD	1.09	0.02	8161.33	12	0.811	0.441	30.65	8.47	8.76	578	Fair	Middle
6/28/2011	Dev Channeled	Middle	HET	2.49	0.17	2227.20	12	0.770	0.362	32.21	8.34	8.17	566	Good	Far
6/28/2011	Dev Channeled	Middle	PNOD	0.97	0.02	6257.61	11	0.542	0.198	32.21	8.34	8.17	566	Good	Far
6/28/2011	Dev Channeled	Outlet	HET	1.60	0.11	3106.56	11	0.706	0.309	31.16	8.15	7.52	565	Good	Far
6/28/2011	Dev Channeled	Outlet	PNOD	4.00	0.05	7257.23	14	0.730	0.264	31.16	8.15	7.52	565	Good	Far
6/28/2011	Dev Direct	Inlet	HET	1.83	0.12	1112.24	12	0.579	0.198	30.87	9.60	17.89	637	Poor	Close
6/28/2011	Dev Direct	Inlet	PNOD	0.53	0.01	9616.98	9	0.497	0.221	30.87	9.60	17.89	637	Poor	Close
6/28/2011	Dev Direct	Middle	HET	2.79	0.19	3520.79	14	0.607	0.182	32.22	9.96	17.20	657	Fair	Far
6/28/2011	Dev Direct	Middle	PNOD	0.49	0.01	8955.25	10	0.604	0.253	32.22	9.96	17.20	657	Fair	Far
6/28/2011	Dev Direct	Outlet	HET	3.80	0.26	5546.50	12	0.516	0.172	32.36	10.06	18.99	660	Fair	Middle
6/28/2011	Dev Direct	Outlet	PNOD	1.17	0.02	29771.43	12	0.463	0.155	32.36	10.06	18.99	660	Fair	Middle
6/28/2011	Reference	Inlet	HET	1.72	0.12	3009.88	10	0.646	0.282	30.26	9.17	9.52	714	Good	Close
6/28/2011	Reference	Inlet	PNOD	0.45	0.01	34005.49	10	0.554	0.224	30.26	9.17	9.52	714	Good	Close
6/28/2011	Reference	Middle	PNOD	0.38	0.01	2730.58	8	0.738	0.478	33.40	9.41	13.87	717	Fair	Middle
6/28/2011	Reference	Middle	HET	0.33	0.02	3888.44	6	0.665	0.498	33.40	9.41	13.87	717	Fair	Middle
6/28/2011	Reference	Outlet	HET	4.08	0.28	1453.24	10	0.565	0.230	29.09	8.95	9.55	739	Fair	Close
6/28/2011	Reference	Outlet	PNOD	0.55	0.01	9896.42	10	0.721	0.358	29.09	8.95	9.55	739	Fair	Close
7/14/2011	Dev Channeled	Inlet	HET	2.54	0.17	4935.78	12	0.346	0.127	34.84	8.24	7.84	562	Fair	Middle
7/14/2011	Dev Channeled	Inlet	PNOD	2.31	0.03	22445.66	12	0.786	0.390	34.84	8.24	7.84	562	Fair	Middle
7/14/2011	Dev Channeled	Middle	HET	6.48	0.44	2674.44	14	0.795	0.348	34.31	8.34	8.20	562	Good	Far
7/14/2011	Dev Channeled	Middle	PNOD	6.27	0.08	4797.60	14	0.683	0.225	34.31	8.34	8.20	562	Good	Far

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
7/14/2011	Dev Channeled	Outlet	HET	3.05	0.21	2785.43	10	0.735	0.377	34.38	8.07	6.78	571	Good	Far
7/14/2011	Dev Channeled	Outlet	PNOD	11.75	0.14	5959.35	14	0.729	0.264	34.38	8.07	6.78	571	Good	Far
7/14/2011	Dev Direct	Inlet	HET	1.96	0.13	2731.62	7	0.636	0.393	32.11	8.73	7.17	674	Poor	Close
7/14/2011	Dev Direct	Inlet	PNOD	1.74	0.03	6269.03	12	0.424	0.145	32.11	8.73	7.17	674	Poor	Close
7/14/2011	Dev Direct	Middle	HET	4.00	0.27	2437.32	9	0.571	0.259	33.32	8.88	9.50	673	Fair	Far
7/14/2011	Dev Direct	Middle	PNOD	0.94	0.02	5436.76	10	0.505	0.202	33.32	8.88	9.50	673	Fair	Far
7/14/2011	Dev Direct	Outlet	HET	3.73	0.25	3871.19	19	0.770	0.229	33.46	9.03	8.68	666	Fair	Middle
7/14/2011	Dev Direct	Outlet	PNOD	2.70	0.04	11613.57	11	0.435	0.161	33.46	9.03	8.68	666	Fair	Middle
7/14/2011	Reference	Inlet	HET	0.55	0.04	6972.38	11	0.791	0.434	33.12	8.67	6.36	735	Good	Close
7/14/2011	Reference	Inlet	PNOD	2.61	0.04	8143.24	19	0.885	0.456	33.12	8.67	6.36	735	Good	Close
7/14/2011	Reference	Middle	HET	2.19	0.15	4606.62	11	0.779	0.411	32.84	8.82	7.29	732	Fair	Middle
7/14/2011	Reference	Middle	PNOD	0.86	0.02	6749.54	10	0.769	0.433	32.84	8.82	7.29	732	Fair	Middle
7/14/2011	Reference	Outlet	HET	0.75	0.05	3500.49	14	0.823	0.403	32.58	8.79	7.47	734	Fair	Close
7/14/2011	Reference	Outlet	PNOD	1.28	0.02	5472.58	12	0.850	0.555	32.58	8.79	7.47	734	Fair	Close
7/28/2011	Dev Channeled	Inlet	PNOD	2.74	0.04	3984.84	12	0.608	0.213	32.20	7.44	5.04	639	Fair	Middle
7/28/2011	Dev Channeled	Middle	HET	3.00	0.20	1607.67	11	0.773	0.401	32.10	7.60	4.23	634	Good	Far
7/28/2011	Dev Channeled	Middle	PNOD	6.85	0.08	3367.96	11	0.587	0.220	32.10	7.60	4.23	634	Good	Far
7/28/2011	Dev Channeled	Outlet	HET	2.10	0.14	891.98	11	0.752	0.367	32.25	7.66	4.14	638	Good	Far
7/28/2011	Dev Channeled	Outlet	PNOD	6.06	0.07	2520.21	12	0.789	0.395	32.25	7.66	4.14	638	Good	Far
7/28/2011	Dev Direct	Inlet	PNOD	0.27	0.01	827.02	4	0.519	0.519	32.06	7.48	5.92	740	Poor	Close
7/28/2011	Dev Direct	Middle	HET	1.79	0.12	856.94	5	0.162	0.239	32.07	7.41	5.44	737	Fair	Far
7/28/2011	Dev Direct	Middle	PNOD	0.93	0.02	2762.43	7	0.290	0.201	32.07	7.41	5.44	737	Fair	Far
7/28/2011	Dev Direct	Outlet	HET	0.94	0.06	1757.36	7	0.615	0.371	32.09	7.50	4.72	751	Fair	Middle
7/28/2011	Reference	Inlet	PNOD	1.50	0.02	1767.12	10	0.718	0.355	31.81	8.26	5.73	784	Good	Close
7/28/2011	Reference	Inlet	HET	1.07	0.07	1791.97	7	0.461	0.265	31.81	8.26	5.73	784	Good	Close
7/28/2011	Reference	Middle	HET	2.29	0.16	624.75	9	0.636	0.305	31.80	8.37	5.81	798	Fair	Middle
7/28/2011	Reference	Middle	PNOD	1.01	0.02	3530.99	10	0.678	0.311	31.80	8.37	5.81	798	Fair	Middle
7/28/2011	Reference	Outlet	HET	1.18	0.08	1149.94	9	0.725	0.404	31.44	7.73	5.95	791	Fair	Close
7/28/2011	Reference	Outlet	PNOD	8.70	0.10	1649.36	14	0.713	0.249	31.44	7.73	5.95	791	Fair	Close
8/16/2011	Dev Channeled	Inlet	HET	0.72	0.05	1188.14	9	0.521	0.232	31.44	7.86	5.98	699	Fair	Middle
8/16/2011	Dev Channeled	Inlet	PNOD	1.21	0.02	3733.11	13	0.624	0.205	31.44	7.86	5.98	699	Fair	Middle
8/16/2011	Dev Channeled	Middle	HET	5.25	0.36	738.87	13	0.759	0.319	30.80	7.30	4.48	707	Good	Far

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
8/16/2011	Dev Channeled	Middle	PNOD	3.09	0.04	4050.71	16	0.807	0.323	30.80	7.30	4.48	707	Good	Far
8/16/2011	Dev Channeled	Outlet	HET	5.77	0.39	2159.99	14	0.517	0.148	29.99	6.75	3.41	702	Good	Far
8/16/2011	Dev Channeled	Outlet	PNOD	2.88	0.04	2511.12	15	0.813	0.356	29.99	6.75	3.41	702	Good	Far
8/16/2011	Dev Direct	Inlet	HET	1.25	0.08	1486.73	11	0.302	0.130	32.02	7.85	9.21	746	Poor	Close
8/16/2011	Dev Direct	Inlet	PNOD	1.53	0.02	5960.73	11	0.380	0.147	32.02	7.85	9.21	746	Poor	Close
8/16/2011	Dev Direct	Middle	HET	0.96	0.07	1567.11	9	0.268	0.152	32.25	8.36	11.35	742	Fair	Far
8/16/2011	Dev Direct	Middle	PNOD	0.95	0.02	5022.19	5	0.145	0.234	32.25	8.36	11.35	742	Fair	Far
8/16/2011	Dev Direct	Outlet	PNOD	5.57	0.07	3399.11	15	0.565	0.153	32.16	8.33	10.15	753	Fair	Middle
8/16/2011	Dev Direct	Outlet	HET	0.38	0.03	5162.24	9	0.655	0.322	32.16	8.33	10.15	753	Fair	Middle
8/16/2011	Reference	Inlet	HET	3.99	0.27	513.82	12	0.695	0.273	32.82	8.31	6.67	834	Good	Close
8/16/2011	Reference	Inlet	PNOD	1.68	0.03	2623.40	5	0.112	0.225	32.82	8.31	6.67	834	Good	Close
8/16/2011	Reference	Middle	HET	2.93	0.20	609.10	11	0.549	0.202	32.31	8.11	7.88	840	Fair	Middle
8/16/2011	Reference	Middle	PNOD	2.29	0.03	2456.59	5	0.227	0.259	32.31	8.11	7.88	840	Fair	Middle
8/16/2011	Reference	Outlet	HET	1.08	0.07	3960.45	13	0.586	0.186	31.85	7.97	6.17	843	Fair	Close
8/16/2011	Reference	Outlet	PNOD	7.82	0.09	4194.89	16	0.653	0.180	31.85	7.97	6.17	843	Fair	Close
9/1/2011	Dev Channeled	Inlet	PNOD	0.98	0.02	2091.51	6	0.655	0.483	31.64	8.36	8.61	754	Fair	Middle
9/1/2011	Dev Channeled	Inlet	HET	0.35	0.02	2697.01	4	0.518	0.519	31.64	8.36	8.61	754	Fair	Middle
9/1/2011	Dev Channeled	Middle	HET	2.38	0.16	3507.60	13	0.671	0.234	31.07	8.04	7.41	759	Good	Far
9/1/2011	Dev Channeled	Middle	PNOD	1.19	0.02	7782.92	11	0.700	0.303	31.07	8.04	7.41	759	Good	Far
9/1/2011	Dev Channeled	Outlet	HET	7.10	0.48	646.06	14	0.765	0.304	31.52	7.80	6.22	760	Good	Far
9/1/2011	Dev Channeled	Outlet	PNOD	5.46	0.07	2454.22	16	0.746	0.246	31.52	7.80	6.22	760	Good	Far
9/1/2011	Dev Direct	Inlet	PNOD	0.27	0.01	3951.32	6	0.329	0.248	31.24	8.75	11.74	756	Poor	Close
9/1/2011	Dev Direct	Inlet	HET	0.46	0.03	4200.33	9	0.264	0.151	31.24	8.75	11.74	756	Poor	Close
9/1/2011	Dev Direct	Middle	HET	0.69	0.05	5151.55	5	0.239	0.263	31.83	8.63	11.02	759	Fair	Far
9/1/2011	Dev Direct	Middle	PNOD	3.08	0.04	6776.93	11	0.306	0.131	31.83	8.63	11.02	759	Fair	Far
9/1/2011	Dev Direct	Outlet	PNOD	0.71	0.02	6435.52	4	0.434	0.441	31.51	8.66	10.99	761	Fair	Middle
9/1/2011	Dev Direct	Outlet	HET	0.66	0.04	10994.90	10	0.510	0.204	31.51	8.66	10.99	761	Fair	Middle
9/1/2011	Reference	Inlet	HET	1.77	0.12	1191.61	7	0.585	0.344	30.70	7.91	7.00	877	Good	Close
9/1/2011	Reference	Inlet	PNOD	3.05	0.04	3148.94	4	0.632	0.679	30.70	7.91	7.00	877	Good	Close
9/1/2011	Reference	Middle	HET	1.21	0.08	1718.72	9	0.509	0.226	30.59	7.70	5.33	882	Fair	Middle
9/1/2011	Reference	Middle	PNOD	2.72	0.04	2176.52	12	0.670	0.253	30.59	7.70	5.33	882	Fair	Middle
9/1/2011	Reference	Outlet	HET	3.44	0.23	3640.15	9	0.505	0.224	31.35	7.55	5.77	882	Fair	Close

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
9/1/2011	Reference	Outlet	PNOD	5.86	0.07	7961.18	16	0.533	0.134	31.35	7.55	5.77	882	Fair	Close
9/20/2011	Dev Channeled	Inlet	HET	2.85	0.19	5185.53	10	0.283	0.140	29.86	8.76	14.34	731	Fair	Middle
9/20/2011	Dev Channeled	Inlet	PNOD	2.32	0.03	9549.37	10	0.447	0.181	29.86	8.76	14.34	731	Fair	Middle
9/20/2011	Dev Channeled	Middle	HET	3.59	0.24	1832.36	14	0.427	0.125	28.23	8.48	10.74	758	Good	Far
9/20/2011	Dev Channeled	Middle	PNOD	4.50	0.06	6702.78	15	0.477	0.127	28.23	8.48	10.74	758	Good	Far
9/20/2011	Dev Channeled	Outlet	HET	2.61	0.18	2175.66	14	0.428	0.125	28.77	8.42	10.64	768	Good	Far
9/20/2011	Dev Channeled	Outlet	PNOD	6.80	0.08	6148.79	14	0.468	0.134	28.77	8.42	10.64	768	Good	Far
9/20/2011	Dev Direct	Inlet	PNOD	0.19	0.01	3797.12	2	0.051	0.527	29.27	8.08	11.50	672	Poor	Close
9/20/2011	Dev Direct	Inlet	HET	0.72	0.05	8275.98	10	0.199	0.125	29.27	8.08	11.50	672	Poor	Close
9/20/2011	Dev Direct	Middle	HET	0.25	0.02	3067.85	4	0.111	0.281	27.66	7.60	10.38	683	Fair	Far
9/20/2011	Dev Direct	Middle	PNOD	1.32	0.02	11222.93	8	0.130	0.144	27.66	7.60	10.38	683	Fair	Far
9/20/2011	Dev Direct	Outlet	HET	0.42	0.03	8428.15	6	0.194	0.207	28.75	8.86	14.02	654	Fair	Middle
9/20/2011	Dev Direct	Outlet	PNOD	2.27	0.03	13525.13	8	0.297	0.178	28.75	8.86	14.02	654	Fair	Middle
9/20/2011	Reference	Inlet	HET	2.88	0.20	932.07	16	0.824	0.354	27.06	8.44	9.82	834	Good	Close
9/20/2011	Reference	Inlet	PNOD	2.26	0.03	5452.68	12	0.745	0.327	27.06	8.44	9.82	834	Good	Close
9/20/2011	Reference	Middle	HET	1.41	0.10	2531.43	8	0.135	0.144	27.20	8.39	9.79	833	Fair	Middle
9/20/2011	Reference	Middle	PNOD	2.26	0.03	6953.70	13	0.376	0.123	27.20	8.39	9.79	833	Fair	Middle
9/20/2011	Reference	Outlet	HET	1.38	0.09	2939.16	7	0.543	0.313	26.79	8.39	10.71	835	Fair	Close
9/20/2011	Reference	Outlet	PNOD	1.73	0.03	8343.09	10	0.701	0.334	26.79	8.39	10.71	835	Fair	Close
10/10/2011	Dev Channeled	Inlet	HET	1.35	0.09	5812.30	8	0.123	0.142	25.05	9.08	11.11	756	Fair	Middle
10/10/2011	Dev Channeled	Inlet	PNOD	0.72	0.02	14047.52	7	0.214	0.182	25.05	9.08	11.11	756	Fair	Middle
10/10/2011	Dev Channeled	Middle	HET	2.29	0.16	2775.95	9	0.250	0.148	24.60	8.89	10.67	766	Good	Far
10/10/2011	Dev Channeled	Middle	PNOD	3.82	0.05	3299.52	8	0.184	0.153	24.60	8.89	10.67	766	Good	Far
10/10/2011	Dev Channeled	Outlet	HET	0.35	0.02	2064.90	4	0.257	0.336	24.30	8.91	10.28	776	Good	Far
10/10/2011	Dev Channeled	Outlet	PNOD	6.28	0.08	5234.58	9	0.305	0.160	24.30	8.91	10.28	776	Good	Far
10/10/2011	Dev Direct	Inlet	HET	0.08	0.01	2765.49	6	0.658	0.487	24.57	9.14	15.13	716	Poor	Close
10/10/2011	Dev Direct	Inlet	PNOD	0.71	0.02	7964.75	4	0.306	0.360	24.57	9.14	15.13	716	Poor	Close
10/10/2011	Dev Direct	Middle	HET	0.18	0.01	5735.82	6	0.680	0.522	24.73	8.89	13.12	716	Fair	Far
10/10/2011	Dev Direct	Middle	PNOD	1.19	0.02	6159.49	7	0.176	0.173	24.73	8.89	13.12	716	Fair	Far
10/10/2011	Dev Direct	Outlet	HET	0.17	0.01	9023.08	4	0.387	0.408	24.43	9.15	13.30	739	Fair	Middle
10/10/2011	Dev Direct	Outlet	PNOD	0.84	0.02	10224.48	6	0.294	0.236	24.43	9.15	13.30	739	Fair	Middle
10/10/2011	Reference	Inlet	HET	0.73	0.05	3273.12	4	0.356	0.388	22.94	8.75	7.84	846	Good	Close

Date	Wetland	Location	Plant	Plant DW	Plant SA	Abundance	Richness	Diversity	Evenness	Temp	pH	DO	Cond	Vegetation	Shoreline distance
10/10/2011	Reference	Inlet	PNOD	2.34	0.03	10232.90	17	0.800	0.294	22.94	8.75	7.84	846	Good	Close
10/10/2011	Reference	Middle	HET	1.03	0.07	2262.51	8	0.633	0.340	23.26	8.79	8.11	850	Fair	Middle
10/10/2011	Reference	Middle	PNOD	1.96	0.03	2826.61	8	0.683	0.395	23.26	8.79	8.11	850	Fair	Middle
10/10/2011	Reference	Outlet	HET	0.55	0.04	3057.12	6	0.574	0.391	22.97	8.76	7.25	853	Fair	Close
11/3/2011	Dev Channeled	Inlet	HET	1.07	0.07	5513.74	10	0.161	0.119	14.99	8.55	9.37	749	Fair	Middle
11/3/2011	Dev Channeled	Inlet	PNOD	1.97	0.03	9398.39	9	0.333	0.167	14.99	8.55	9.37	749	Fair	Middle
11/3/2011	Dev Channeled	Middle	HET	2.33	0.16	3101.78	4	0.259	0.337	14.85	8.43	8.74	759	Good	Far
11/3/2011	Dev Channeled	Middle	PNOD	1.05	0.02	7469.50	5	0.302	0.287	14.85	8.43	8.74	759	Good	Far
11/3/2011	Dev Channeled	Outlet	HET	0.14	0.01	2739.15	7	0.453	0.261	14.82	8.41	8.38	767	Good	Far
11/3/2011	Dev Channeled	Outlet	PNOD	2.30	0.03	7012.90	6	0.124	0.190	14.82	8.41	8.38	767	Good	Far
11/3/2011	Dev Direct	Inlet	PNOD	0.48	0.01	8574.29	4	0.463	0.466	15.60	8.13	10.20	735	Poor	Close
11/3/2011	Dev Direct	Inlet	HET	0.45	0.03	9963.95	11	0.613	0.235	15.60	8.13	10.20	735	Poor	Close
11/3/2011	Dev Direct	Outlet	HET	0.70	0.05	4972.61	11	0.299	0.130	16.05	8.69	11.39	736	Fair	Middle
11/3/2011	Dev Direct	Outlet	PNOD	3.38	0.04	9712.10	9	0.398	0.185	16.05	8.69	11.39	736	Fair	Middle
11/3/2011	Reference	Inlet	HET	2.80	0.19	1801.52	8	0.592	0.307	15.31	7.79	7.81	830	Good	Close
11/3/2011	Reference	Inlet	PNOD	1.37	0.02	13268.32	10	0.680	0.312	15.31	7.79	7.81	830	Good	Close
11/3/2011	Reference	Middle	HET	0.47	0.03	3546.10	9	0.605	0.281	15.14	7.97	8.88	829	Fair	Middle
11/3/2011	Reference	Middle	PNOD	1.27	0.02	5545.84	6	0.294	0.236	15.14	7.97	8.88	829	Fair	Middle
11/3/2011	Reference	Outlet	PNOD	1.02	0.02	4663.54	8	0.466	0.234	14.84	6.71	8.97	828	Fair	Close
11/3/2011	Reference	Outlet	HET	1.06	0.07	7277.23	10	0.585	0.241	14.84	6.71	8.97	828	Fair	Close

APPENDIX B

RAW COLLECTION DATA AND DEVELOPMENTAL CLASS SORTING

FOR *Enallagma civile* Hagen

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
9/22/2010	Dev. Direct	Middle	PNOD	0.013	2	159.71	I
9/22/2010	Dev. Direct	Middle	PNOD	0.013	1	79.85	II
9/22/2010	Dev. Channeled	Inlet	PNOD	0.014	1	74.04	I
9/22/2010	Dev. Channeled	Middle	HET	0.058	1	17.35	II
10/15/2010	Reference	Inlet	PNOD	0.014	7	505.96	I
10/15/2010	Reference	Middle	HET	0.020	3	147.49	I
10/15/2010	Reference	Outlet	PNOD	0.012	1	82.00	IV
10/15/2010	Dev. Direct	Inlet	PNOD	0.012	4	340.21	I
10/15/2010	Dev. Direct	Outlet	HET	0.022	4	184.37	I
10/15/2010	Dev. Direct	Outlet	HET	0.022	4	184.37	III
10/15/2010	Dev. Direct	Outlet	PNOD	0.015	25	1699.53	I
10/15/2010	Dev. Direct	Outlet	PNOD	0.015	10	679.81	II
10/15/2010	Dev. Direct	Outlet	PNOD	0.015	5	339.91	III
10/15/2010	Dev. Channeled	Inlet	HET	0.177	6	33.91	I
10/15/2010	Dev. Channeled	Inlet	HET	0.177	8	45.21	II
10/15/2010	Dev. Channeled	Inlet	HET	0.177	5	28.26	III
10/15/2010	Dev. Channeled	Inlet	HET	0.177	2	11.30	IV
10/15/2010	Dev. Channeled	Middle	HET	0.179	1	5.59	I
10/15/2010	Dev. Channeled	Middle	PNOD	0.025	99	3893.51	I
10/15/2010	Dev. Channeled	Outlet	HET	0.178	38	213.11	I
10/15/2010	Dev. Channeled	Outlet	HET	0.178	3	16.82	II
10/15/2010	Dev. Channeled	Outlet	PNOD	0.028	13	472.65	I
4/20/2011	Reference	Inlet	HET	0.083	7	84.63	I
4/20/2011	Reference	Inlet	HET	0.083	12	145.07	II
4/20/2011	Reference	Inlet	HET	0.083	1	12.09	V
4/20/2011	Reference	Inlet	PNOD	0.027	96	3504.24	I
4/20/2011	Reference	Inlet	PNOD	0.027	5	182.51	II
4/20/2011	Reference	Middle	HET	0.072	17	236.54	I
4/20/2011	Reference	Middle	HET	0.072	9	125.23	II
4/20/2011	Reference	Middle	HET	0.072	2	27.83	III
4/20/2011	Reference	Outlet	HET	0.027	5	184.37	I
4/20/2011	Reference	Outlet	HET	0.027	2	73.75	III
4/20/2011	Reference	Outlet	HET	0.027	2	73.75	IV
4/20/2011	Reference	Outlet	PNOD	0.045	5	112.20	I
4/20/2011	Reference	Outlet	PNOD	0.045	4	89.76	II
4/20/2011	Reference	Outlet	PNOD	0.045	2	44.88	V
4/20/2011	Dev. Direct	Inlet	HET	0.068	6	87.62	I
4/20/2011	Dev. Direct	Inlet	HET	0.068	6	87.62	II
4/20/2011	Dev. Direct	Inlet	HET	0.068	7	102.22	III
4/20/2011	Dev. Direct	Inlet	HET	0.068	1	14.60	V

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
4/20/2011	Dev. Direct	Inlet	PNOD	0.038	1	26.24	I
4/20/2011	Dev. Direct	Inlet	PNOD	0.038	5	131.19	II
4/20/2011	Dev. Direct	Inlet	PNOD	0.038	1	26.24	III
4/20/2011	Dev. Direct	Inlet	PNOD	0.038	1	26.24	IV
4/20/2011	Dev. Direct	Middle	HET	0.079	2	25.21	I
4/20/2011	Dev. Direct	Middle	HET	0.079	6	75.64	II
4/20/2011	Dev. Direct	Middle	HET	0.079	5	63.03	III
4/20/2011	Dev. Direct	Middle	HET	0.079	2	25.21	V
4/20/2011	Dev. Direct	Middle	PNOD	0.013	1	79.16	II
4/20/2011	Dev. Direct	Middle	PNOD	0.013	1	79.16	IV
4/20/2011	Dev. Direct	Middle	PNOD	0.013	1	79.16	V
4/20/2011	Dev. Direct	Outlet	HET	0.078	2	25.65	I
4/20/2011	Dev. Direct	Outlet	HET	0.078	3	38.48	II
4/20/2011	Dev. Direct	Outlet	HET	0.078	3	38.48	III
4/20/2011	Dev. Direct	Outlet	HET	0.078	1	12.83	IV
4/20/2011	Dev. Direct	Outlet	HET	0.078	1	12.83	V
4/20/2011	Dev. Direct	Outlet	PNOD	0.016	4	243.02	I
4/20/2011	Dev. Direct	Outlet	PNOD	0.016	1	60.75	II
4/20/2011	Dev. Direct	Outlet	PNOD	0.016	2	121.51	III
4/20/2011	Dev. Direct	Outlet	PNOD	0.016	1	60.75	IV
4/20/2011	Dev. Direct	Outlet	PNOD	0.016	1	60.75	V
4/20/2011	Dev. Channeled	Inlet	HET	0.068	2	29.50	V
4/20/2011	Dev. Channeled	Inlet	PNOD	0.015	3	198.05	III
4/20/2011	Dev. Channeled	Middle	HET	0.125	1	8.02	I
4/20/2011	Dev. Channeled	Middle	HET	0.125	1	8.02	IV
4/20/2011	Dev. Channeled	Middle	HET	0.125	1	8.02	V
4/20/2011	Dev. Channeled	Middle	PNOD	0.019	1	51.51	I
4/20/2011	Dev. Channeled	Outlet	HET	0.058	6	104.11	I
4/20/2011	Dev. Channeled	Outlet	HET	0.058	1	17.35	IV
4/20/2011	Dev. Channeled	Outlet	PNOD	0.034	26	773.15	I
4/20/2011	Dev. Channeled	Outlet	PNOD	0.034	4	118.95	III
4/20/2011	Dev. Channeled	Outlet	PNOD	0.034	2	59.47	IV
4/20/2011	Dev. Channeled	Outlet	PNOD	0.034	2	59.47	V
5/10/2011	Reference	Inlet	HET	0.058	4	68.60	I
5/10/2011	Reference	Inlet	HET	0.058	1	17.15	II
5/10/2011	Reference	Inlet	HET	0.058	2	34.30	III
5/10/2011	Reference	Middle	HET	0.067	21	312.86	I
5/10/2011	Reference	Middle	HET	0.067	13	193.68	II
5/10/2011	Reference	Middle	HET	0.067	8	119.19	III
5/10/2011	Reference	Middle	HET	0.067	1	14.90	IV
5/10/2011	Reference	Middle	PNOD	0.017	8	476.54	I
5/10/2011	Reference	Middle	PNOD	0.017	1	59.57	II

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
5/10/2011	Reference	Outlet	HET	0.031	4	128.25	I
5/10/2011	Reference	Outlet	HET	0.031	5	160.32	II
5/10/2011	Reference	Outlet	HET	0.031	1	32.06	III
5/10/2011	Dev. Direct	Inlet	HET	0.047	2	42.14	I
5/10/2011	Dev. Direct	Inlet	HET	0.047	1	21.07	II
5/10/2011	Dev. Direct	Inlet	HET	0.047	3	63.21	III
5/10/2011	Dev. Direct	Inlet	HET	0.047	3	63.21	IV
5/10/2011	Dev. Direct	Inlet	HET	0.047	9	189.63	V
5/10/2011	Dev. Direct	Inlet	PNOD	0.038	12	316.68	I
5/10/2011	Dev. Direct	Inlet	PNOD	0.038	5	131.95	II
5/10/2011	Dev. Direct	Inlet	PNOD	0.038	6	158.34	III
5/10/2011	Dev. Direct	Inlet	PNOD	0.038	5	131.95	IV
5/10/2011	Dev. Direct	Inlet	PNOD	0.038	2	52.78	V
5/10/2011	Dev. Direct	Middle	HET	0.121	41	339.73	I
5/10/2011	Dev. Direct	Middle	HET	0.121	3	24.86	III
5/10/2011	Dev. Direct	Middle	HET	0.121	3	24.86	IV
5/10/2011	Dev. Direct	Middle	HET	0.121	13	107.72	V
5/10/2011	Dev. Direct	Outlet	HET	0.192	1	5.21	I
5/10/2011	Dev. Direct	Outlet	HET	0.192	12	62.54	II
5/10/2011	Dev. Direct	Outlet	HET	0.192	5	26.06	III
5/10/2011	Dev. Direct	Outlet	HET	0.192	4	20.85	IV
5/10/2011	Dev. Direct	Outlet	HET	0.192	4	20.85	V
5/10/2011	Dev. Direct	Outlet	PNOD	0.046	3	65.39	I
5/10/2011	Dev. Direct	Outlet	PNOD	0.046	3	65.39	II
5/10/2011	Dev. Direct	Outlet	PNOD	0.046	3	65.39	III
5/10/2011	Dev. Direct	Outlet	PNOD	0.046	2	43.60	IV
5/10/2011	Dev. Direct	Outlet	PNOD	0.046	1	21.80	V
5/10/2011	Dev. Channeled	Inlet	HET	0.136	1	7.37	I
5/10/2011	Dev. Channeled	Inlet	HET	0.136	7	51.62	II
5/10/2011	Dev. Channeled	Inlet	HET	0.136	6	44.25	III
5/10/2011	Dev. Channeled	Inlet	HET	0.136	3	22.12	IV
5/10/2011	Dev. Channeled	Inlet	HET	0.136	1	7.37	V
5/10/2011	Dev. Channeled	Inlet	PNOD	0.039	1	25.72	IV
5/10/2011	Dev. Channeled	Middle	PNOD	0.018	3	162.80	I
5/10/2011	Dev. Channeled	Middle	PNOD	0.018	3	162.80	II
5/10/2011	Dev. Channeled	Outlet	HET	0.210	42	199.83	I
5/10/2011	Dev. Channeled	Outlet	HET	0.210	13	61.85	II
5/10/2011	Dev. Channeled	Outlet	HET	0.210	2	9.52	III
5/10/2011	Dev. Channeled	Outlet	PNOD	0.022	6	273.63	III
5/31/2011	Reference	Inlet	HET	0.100	4	40.13	I
5/31/2011	Reference	Inlet	HET	0.100	4	40.13	II
5/31/2011	Reference	Inlet	HET	0.100	6	60.20	III

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
5/31/2011	Reference	Inlet	HET	0.100	2	20.07	IV
5/31/2011	Reference	Inlet	HET	0.100	2	20.07	V
5/31/2011	Reference	Inlet	PNOD	0.033	16	478.90	I
5/31/2011	Reference	Inlet	PNOD	0.033	4	119.72	II
5/31/2011	Reference	Inlet	PNOD	0.033	2	59.86	III
5/31/2011	Reference	Inlet	PNOD	0.033	3	89.79	IV
5/31/2011	Reference	Inlet	PNOD	0.033	3	89.79	V
5/31/2011	Reference	Middle	HET	0.063	9	142.73	I
5/31/2011	Reference	Middle	HET	0.063	8	126.88	II
5/31/2011	Reference	Middle	HET	0.063	2	31.72	III
5/31/2011	Reference	Middle	HET	0.063	3	47.58	IV
5/31/2011	Reference	Middle	HET	0.063	1	15.86	V
5/31/2011	Reference	Middle	PNOD	0.015	1	64.62	I
5/31/2011	Reference	Middle	PNOD	0.015	3	193.86	II
5/31/2011	Reference	Middle	PNOD	0.015	1	64.62	III
5/31/2011	Reference	Middle	PNOD	0.015	3	193.86	IV
5/31/2011	Reference	Middle	PNOD	0.015	1	64.62	V
5/31/2011	Reference	Outlet	HET	0.040	6	149.99	I
5/31/2011	Reference	Outlet	HET	0.040	9	224.99	II
5/31/2011	Reference	Outlet	HET	0.040	7	174.99	III
5/31/2011	Reference	Outlet	PNOD	0.041	2	49.23	I
5/31/2011	Reference	Outlet	PNOD	0.041	4	98.46	II
5/31/2011	Reference	Outlet	PNOD	0.041	11	270.75	III
5/31/2011	Reference	Outlet	PNOD	0.041	7	172.30	IV
5/31/2011	Reference	Outlet	PNOD	0.041	3	73.84	V
5/31/2011	Dev. Direct	Inlet	HET	0.244	56	229.43	I
5/31/2011	Dev. Direct	Inlet	HET	0.244	48	196.66	II
5/31/2011	Dev. Direct	Inlet	HET	0.244	28	114.72	III
5/31/2011	Dev. Direct	Inlet	HET	0.244	8	32.78	IV
5/31/2011	Dev. Direct	Inlet	HET	0.244	8	32.78	V
5/31/2011	Dev. Direct	Inlet	PNOD	0.071	12	168.17	I
5/31/2011	Dev. Direct	Inlet	PNOD	0.071	18	252.25	II
5/31/2011	Dev. Direct	Inlet	PNOD	0.071	23	322.32	III
5/31/2011	Dev. Direct	Inlet	PNOD	0.071	9	126.13	IV
5/31/2011	Dev. Direct	Inlet	PNOD	0.071	2	28.03	V
5/31/2011	Dev. Direct	Middle	HET	0.245	15	61.12	I
5/31/2011	Dev. Direct	Middle	HET	0.245	15	61.12	II
5/31/2011	Dev. Direct	Middle	HET	0.245	33	134.45	III
5/31/2011	Dev. Direct	Middle	HET	0.245	14	57.04	IV
5/31/2011	Dev. Direct	Middle	HET	0.245	4	16.30	V
5/31/2011	Dev. Direct	Middle	PNOD	0.018	2	113.94	I
5/31/2011	Dev. Direct	Middle	PNOD	0.018	1	56.97	IV

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
5/31/2011	Dev. Direct	Middle	PNOD	0.018	2	113.94	V
5/31/2011	Dev. Direct	Outlet	PNOD	0.036	24	672.15	I
5/31/2011	Dev. Direct	Outlet	PNOD	0.036	10	280.06	II
5/31/2011	Dev. Direct	Outlet	PNOD	0.036	5	140.03	III
5/31/2011	Dev. Direct	Outlet	PNOD	0.036	1	28.01	IV
5/31/2011	Dev. Direct	Outlet	PNOD	0.036	2	56.01	V
5/31/2011	Dev. Channeled	Inlet	HET	0.062	2	32.42	I
5/31/2011	Dev. Channeled	Inlet	HET	0.062	1	16.21	III
5/31/2011	Dev. Channeled	Inlet	HET	0.062	1	16.21	IV
5/31/2011	Dev. Channeled	Inlet	PNOD	0.024	22	920.66	I
5/31/2011	Dev. Channeled	Inlet	PNOD	0.024	1	41.85	III
5/31/2011	Dev. Channeled	Middle	HET	0.099	1	10.10	I
5/31/2011	Dev. Channeled	Middle	PNOD	0.020	7	354.60	I
5/31/2011	Dev. Channeled	Middle	PNOD	0.020	1	50.66	II
5/31/2011	Dev. Channeled	Middle	PNOD	0.020	3	151.97	III
5/31/2011	Dev. Channeled	Middle	PNOD	0.020	1	50.66	IV
5/31/2011	Dev. Channeled	Middle	PNOD	0.020	1	50.66	V
5/31/2011	Dev. Channeled	Outlet	HET	0.082	1	12.19	I
5/31/2011	Dev. Channeled	Outlet	HET	0.082	2	24.38	II
5/31/2011	Dev. Channeled	Outlet	HET	0.082	3	36.57	III
5/31/2011	Dev. Channeled	Outlet	PNOD	0.022	1	44.50	IV
6/10/2011	Reference	Inlet	HET	0.197	5	25.43	I
6/10/2011	Reference	Inlet	HET	0.197	11	55.95	II
6/10/2011	Reference	Inlet	HET	0.197	3	15.26	III
6/10/2011	Reference	Inlet	HET	0.197	3	15.26	IV
6/10/2011	Reference	Inlet	PNOD	0.025	7	275.30	I
6/10/2011	Reference	Inlet	PNOD	0.025	4	157.31	II
6/10/2011	Reference	Inlet	PNOD	0.025	1	39.33	III
6/10/2011	Reference	Inlet	PNOD	0.025	2	78.66	IV
6/10/2011	Reference	Middle	HET	0.178	4	22.52	I
6/10/2011	Reference	Middle	HET	0.178	6	33.78	III
6/10/2011	Reference	Middle	HET	0.178	2	11.26	IV
6/10/2011	Reference	Middle	HET	0.178	3	16.89	V
6/10/2011	Reference	Outlet	PNOD	0.016	1	61.99	V
6/10/2011	Dev. Direct	Inlet	HET	0.146	1	6.86	I
6/10/2011	Dev. Direct	Inlet	HET	0.146	9	61.74	II
6/10/2011	Dev. Direct	Inlet	HET	0.146	3	20.58	IV
6/10/2011	Dev. Direct	Inlet	HET	0.146	6	41.16	V
6/10/2011	Dev. Direct	Inlet	PNOD	0.013	3	237.49	III
6/10/2011	Dev. Direct	Inlet	PNOD	0.013	5	395.82	V
6/10/2011	Dev. Direct	Middle	HET	0.438	4	9.13	I
6/10/2011	Dev. Direct	Middle	HET	0.438	21	47.95	II

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
6/10/2011	Dev. Direct	Middle	HET	0.438	34	77.63	III
6/10/2011	Dev. Direct	Middle	HET	0.438	13	29.68	IV
6/10/2011	Dev. Direct	Middle	HET	0.438	11	25.11	V
6/10/2011	Dev. Direct	Middle	PNOD	0.017	2	117.60	I
6/10/2011	Dev. Direct	Middle	PNOD	0.017	1	58.80	III
6/10/2011	Dev. Direct	Middle	PNOD	0.017	1	58.80	IV
6/10/2011	Dev. Direct	Middle	PNOD	0.017	2	117.60	V
6/10/2011	Dev. Direct	Outlet	HET	0.228	2	8.78	I
6/10/2011	Dev. Direct	Outlet	HET	0.228	10	43.90	II
6/10/2011	Dev. Direct	Outlet	HET	0.228	20	87.79	III
6/10/2011	Dev. Direct	Outlet	HET	0.228	10	43.90	IV
6/10/2011	Dev. Direct	Outlet	HET	0.228	5	21.95	V
6/10/2011	Dev. Direct	Outlet	PNOD	0.015	2	133.00	III
6/10/2011	Dev. Channeled	Inlet	PNOD	0.028	1	35.10	I
6/10/2011	Dev. Channeled	Inlet	PNOD	0.028	7	245.71	II
6/10/2011	Dev. Channeled	Inlet	PNOD	0.028	2	70.20	III
6/10/2011	Dev. Channeled	Middle	HET	0.199	16	80.27	I
6/10/2011	Dev. Channeled	Middle	HET	0.199	8	40.13	II
6/10/2011	Dev. Channeled	Middle	HET	0.199	10	50.17	III
6/10/2011	Dev. Channeled	Middle	HET	0.199	3	15.05	IV
6/10/2011	Dev. Channeled	Middle	HET	0.199	3	15.05	V
6/10/2011	Dev. Channeled	Middle	PNOD	0.049	4	81.73	I
6/10/2011	Dev. Channeled	Middle	PNOD	0.049	8	163.47	II
6/10/2011	Dev. Channeled	Middle	PNOD	0.049	3	61.30	III
6/10/2011	Dev. Channeled	Middle	PNOD	0.049	2	40.87	IV
6/10/2011	Dev. Channeled	Outlet	HET	0.119	3	25.14	II
6/10/2011	Dev. Channeled	Outlet	HET	0.119	2	16.76	III
6/10/2011	Dev. Channeled	Outlet	HET	0.119	1	8.38	IV
6/28/2011	Reference	Inlet	PNOD	0.013	2	155.63	I
6/28/2011	Reference	Inlet	PNOD	0.013	2	155.63	II
6/28/2011	Reference	Inlet	PNOD	0.013	2	155.63	III
6/28/2011	Reference	Middle	HET	0.022	2	89.39	I
6/28/2011	Reference	Middle	HET	0.022	1	44.69	II
6/28/2011	Reference	Middle	PNOD	0.012	1	82.74	I
6/28/2011	Reference	Outlet	PNOD	0.014	5	358.57	I
6/28/2011	Reference	Outlet	PNOD	0.014	1	71.71	III
6/28/2011	Dev. Direct	Middle	HET	0.189	74	391.20	I
6/28/2011	Dev. Direct	Middle	HET	0.189	40	211.46	II
6/28/2011	Dev. Direct	Middle	HET	0.189	28	148.02	III
6/28/2011	Dev. Direct	Middle	HET	0.189	17	89.87	IV
6/28/2011	Dev. Direct	Middle	HET	0.189	12	63.44	V
6/28/2011	Dev. Direct	Middle	PNOD	0.013	4	301.02	I

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
6/28/2011	Dev. Direct	Middle	PNOD	0.013	1	75.25	II
6/28/2011	Dev. Direct	Middle	PNOD	0.013	3	225.76	III
6/28/2011	Dev. Direct	Outlet	HET	0.258	18	69.86	I
6/28/2011	Dev. Direct	Outlet	HET	0.258	16	62.10	III
6/28/2011	Dev. Direct	Outlet	HET	0.258	12	46.58	IV
6/28/2011	Dev. Direct	Outlet	HET	0.258	15	58.22	V
6/28/2011	Dev. Direct	Outlet	PNOD	0.021	7	337.76	I
6/28/2011	Dev. Direct	Outlet	PNOD	0.021	2	96.50	II
6/28/2011	Dev. Direct	Outlet	PNOD	0.021	1	48.25	III
6/28/2011	Dev. Channeled	Inlet	PNOD	0.020	2	100.76	I
6/28/2011	Dev. Channeled	Inlet	PNOD	0.020	1	50.38	III
6/28/2011	Dev. Channeled	Middle	HET	0.169	13	77.00	I
6/28/2011	Dev. Channeled	Middle	HET	0.169	6	35.54	II
6/28/2011	Dev. Channeled	Middle	HET	0.169	5	29.62	III
6/28/2011	Dev. Channeled	Middle	HET	0.169	4	23.69	IV
6/28/2011	Dev. Channeled	Middle	PNOD	0.019	1	53.94	IV
6/28/2011	Dev. Channeled	Outlet	HET	0.108	1	9.22	II
6/28/2011	Dev. Channeled	Outlet	HET	0.108	1	9.22	III
6/28/2011	Dev. Channeled	Outlet	HET	0.108	2	18.44	IV
6/28/2011	Dev. Channeled	Outlet	HET	0.108	3	27.65	V
6/28/2011	Dev. Channeled	Outlet	PNOD	0.052	2	38.71	I
7/14/2011	Reference	Inlet	HET	0.037	1	26.82	IV
7/14/2011	Reference	Inlet	HET	0.037	1	26.82	V
7/14/2011	Reference	Inlet	PNOD	0.036	1	27.42	I
7/14/2011	Reference	Inlet	PNOD	0.036	2	54.84	II
7/14/2011	Reference	Inlet	PNOD	0.036	7	191.93	III
7/14/2011	Reference	Inlet	PNOD	0.036	7	191.93	IV
7/14/2011	Reference	Inlet	PNOD	0.036	2	54.84	V
7/14/2011	Reference	Middle	HET	0.148	1	6.73	I
7/14/2011	Reference	Middle	HET	0.148	5	33.67	II
7/14/2011	Reference	Middle	HET	0.148	5	33.67	III
7/14/2011	Reference	Middle	HET	0.148	1	6.73	IV
7/14/2011	Reference	Middle	HET	0.148	4	26.94	V
7/14/2011	Reference	Middle	PNOD	0.017	1	57.69	IV
7/14/2011	Reference	Middle	PNOD	0.017	4	230.75	V
7/14/2011	Dev. Direct	Inlet	HET	0.133	2	15.05	IV
7/14/2011	Dev. Direct	Inlet	HET	0.133	2	15.05	V
7/14/2011	Dev. Direct	Inlet	PNOD	0.027	3	111.28	I
7/14/2011	Dev. Direct	Inlet	PNOD	0.027	2	74.19	II
7/14/2011	Dev. Direct	Inlet	PNOD	0.027	2	74.19	III
7/14/2011	Dev. Direct	Middle	HET	0.271	27	99.56	I
7/14/2011	Dev. Direct	Middle	HET	0.271	33	121.68	II

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
7/14/2011	Dev. Direct	Middle	HET	0.271	20	73.75	III
7/14/2011	Dev. Direct	Middle	HET	0.271	12	44.25	IV
7/14/2011	Dev. Direct	Middle	HET	0.271	3	11.06	V
7/14/2011	Dev. Direct	Middle	PNOD	0.018	1	54.92	II
7/14/2011	Dev. Direct	Middle	PNOD	0.018	1	54.92	IV
7/14/2011	Dev. Direct	Middle	PNOD	0.018	7	384.42	V
7/14/2011	Dev. Direct	Outlet	HET	0.253	17	67.22	I
7/14/2011	Dev. Direct	Outlet	HET	0.253	33	130.49	III
7/14/2011	Dev. Direct	Outlet	HET	0.253	47	185.85	III
7/14/2011	Dev. Direct	Outlet	HET	0.253	16	63.27	IV
7/14/2011	Dev. Direct	Outlet	HET	0.253	21	83.04	V
7/14/2011	Dev. Direct	Outlet	PNOD	0.037	3	80.09	I
7/14/2011	Dev. Direct	Outlet	PNOD	0.037	2	53.40	II
7/14/2011	Dev. Channeled	Inlet	PNOD	0.033	18	542.31	I
7/14/2011	Dev. Channeled	Inlet	PNOD	0.033	8	241.03	II
7/14/2011	Dev. Channeled	Inlet	PNOD	0.033	3	90.39	III
7/14/2011	Dev. Channeled	Inlet	PNOD	0.033	2	60.26	IV
7/14/2011	Dev. Channeled	Inlet	PNOD	0.033	1	30.13	V
7/14/2011	Dev. Channeled	Middle	HET	0.439	8	18.21	V
7/14/2011	Dev. Channeled	Middle	PNOD	0.076	4	52.29	I
7/14/2011	Dev. Channeled	Middle	PNOD	0.076	3	39.22	II
7/14/2011	Dev. Channeled	Middle	PNOD	0.076	5	65.36	III
7/14/2011	Dev. Channeled	Middle	PNOD	0.076	4	52.29	IV
7/14/2011	Dev. Channeled	Middle	PNOD	0.076	1	13.07	V
7/14/2011	Dev. Channeled	Outlet	PNOD	0.136	1	7.33	I
7/14/2011	Dev. Channeled	Outlet	PNOD	0.136	3	21.99	II
7/14/2011	Dev. Channeled	Outlet	PNOD	0.136	9	65.97	III
7/14/2011	Dev. Channeled	Outlet	PNOD	0.136	2	14.66	IV
7/14/2011	Dev. Channeled	Outlet	PNOD	0.136	6	43.98	V
7/28/2011	Reference	Inlet	PNOD	0.024	1	41.10	I
7/28/2011	Reference	Inlet	PNOD	0.024	1	41.10	I
7/28/2011	Reference	Inlet	PNOD	0.024	2	82.19	III
7/28/2011	Reference	Inlet	PNOD	0.024	1	41.10	IV
7/28/2011	Reference	Inlet	PNOD	0.024	1	41.10	V
7/28/2011	Reference	Middle	HET	0.155	9	57.97	III
7/28/2011	Reference	Middle	HET	0.155	9	57.97	IV
7/28/2011	Reference	Middle	HET	0.155	4	25.76	V
7/28/2011	Reference	Middle	PNOD	0.019	1	52.70	III
7/28/2011	Reference	Middle	PNOD	0.019	1	52.70	V
7/28/2011	Reference	Outlet	HET	0.080	4	50.00	II
7/28/2011	Reference	Outlet	HET	0.080	5	62.50	III
7/28/2011	Reference	Outlet	HET	0.080	2	25.00	IV

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
7/28/2011	Reference	Outlet	HET	0.080	2	25.00	V
7/28/2011	Reference	Outlet	PNOD	0.103	1	9.70	I
7/28/2011	Reference	Outlet	PNOD	0.103	1	9.70	I
7/28/2011	Reference	Outlet	PNOD	0.103	6	58.21	II
7/28/2011	Reference	Outlet	PNOD	0.103	3	29.11	III
7/28/2011	Reference	Outlet	PNOD	0.103	1	9.70	IV
7/28/2011	Dev. Direct	Middle	HET	0.121	3	24.72	III
7/28/2011	Dev. Direct	Middle	HET	0.121	1	8.24	IV
7/28/2011	Dev. Direct	Outlet	HET	0.064	1	15.69	II
7/28/2011	Dev. Direct	Outlet	HET	0.064	1	15.69	III
7/28/2011	Dev. Direct	Outlet	HET	0.064	1	15.69	IV
7/28/2011	Dev. Direct	Outlet	HET	0.064	1	15.69	V
7/28/2011	Dev. Channeled	Inlet	PNOD	0.038	2	52.78	II
7/28/2011	Dev. Channeled	Inlet	PNOD	0.038	1	26.39	III
7/28/2011	Dev. Channeled	Middle	HET	0.203	3	14.75	I
7/28/2011	Dev. Channeled	Middle	HET	0.203	5	24.58	II
7/28/2011	Dev. Channeled	Middle	HET	0.203	4	19.67	III
7/28/2011	Dev. Channeled	Middle	HET	0.203	1	4.92	IV
7/28/2011	Dev. Channeled	Middle	PNOD	0.083	5	60.36	I
7/28/2011	Dev. Channeled	Middle	PNOD	0.083	3	36.21	II
7/28/2011	Dev. Channeled	Middle	PNOD	0.083	2	24.14	III
7/28/2011	Dev. Channeled	Outlet	HET	0.142	1	7.02	II
7/28/2011	Dev. Channeled	Outlet	HET	0.142	1	7.02	III
8/16/2011	Reference	Inlet	HET	0.271	1	3.70	III
8/16/2011	Reference	Inlet	HET	0.271	3	11.09	IV
8/16/2011	Reference	Middle	HET	0.199	4	20.14	III
8/16/2011	Reference	Middle	HET	0.199	1	5.03	IV
8/16/2011	Reference	Middle	PNOD	0.033	1	30.33	II
8/16/2011	Reference	Middle	PNOD	0.033	2	60.66	IV
8/16/2011	Reference	Outlet	HET	0.073	1	13.66	I
8/16/2011	Reference	Outlet	HET	0.073	1	13.66	II
8/16/2011	Reference	Outlet	HET	0.073	1	13.66	III
8/16/2011	Reference	Outlet	HET	0.073	1	13.66	IV
8/16/2011	Reference	Outlet	PNOD	0.093	3	32.10	I
8/16/2011	Reference	Outlet	PNOD	0.093	9	96.31	II
8/16/2011	Reference	Outlet	PNOD	0.093	5	53.51	III
8/16/2011	Reference	Outlet	PNOD	0.093	2	21.40	IV
8/16/2011	Reference	Outlet	PNOD	0.093	1	10.70	V
8/16/2011	Dev. Direct	Inlet	HET	0.085	1	11.80	III
8/16/2011	Dev. Direct	Inlet	HET	0.085	2	23.60	V
8/16/2011	Dev. Direct	Inlet	PNOD	0.025	1	40.55	IV
8/16/2011	Dev. Direct	Middle	PNOD	0.018	2	109.18	III

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
8/16/2011	Dev. Direct	Middle	PNOD	0.018	1	54.59	IV
8/16/2011	Dev. Direct	Outlet	HET	0.026	4	155.26	II
8/16/2011	Dev. Direct	Outlet	HET	0.026	4	155.26	III
8/16/2011	Dev. Direct	Outlet	HET	0.026	5	194.07	IV
8/16/2011	Dev. Direct	Outlet	HET	0.026	10	388.14	V
8/16/2011	Dev. Direct	Outlet	PNOD	0.069	1	14.53	II
8/16/2011	Dev. Direct	Outlet	PNOD	0.069	2	29.05	III
8/16/2011	Dev. Direct	Outlet	PNOD	0.069	2	29.05	IV
8/16/2011	Dev. Channeled	Inlet	HET	0.049	2	40.97	III
8/16/2011	Dev. Channeled	Inlet	HET	0.049	2	40.97	IV
8/16/2011	Dev. Channeled	Inlet	HET	0.049	1	20.49	V
8/16/2011	Dev. Channeled	Middle	HET	0.356	2	5.62	II
8/16/2011	Dev. Channeled	Middle	HET	0.356	10	28.09	III
8/16/2011	Dev. Channeled	Middle	HET	0.356	8	22.48	IV
8/16/2011	Dev. Channeled	Middle	HET	0.356	3	8.43	V
8/16/2011	Dev. Channeled	Middle	PNOD	0.042	2	47.94	III
8/16/2011	Dev. Channeled	Middle	PNOD	0.042	1	23.97	V
8/16/2011	Dev. Channeled	Outlet	HET	0.391	3	7.67	II
8/16/2011	Dev. Channeled	Outlet	HET	0.391	20	51.12	III
8/16/2011	Dev. Channeled	Outlet	HET	0.391	15	38.34	IV
8/16/2011	Dev. Channeled	Outlet	HET	0.391	7	17.89	V
8/16/2011	Dev. Channeled	Outlet	PNOD	0.039	2	50.73	IV
8/16/2011	Dev. Channeled	Outlet	PNOD	0.039	1	25.36	V
9/1/2011	Reference	Inlet	HET	0.120	5	41.66	II
9/1/2011	Reference	Inlet	HET	0.120	3	25.00	III
9/1/2011	Reference	Inlet	HET	0.120	4	33.33	IV
9/1/2011	Reference	Inlet	PNOD	0.041	3	72.67	I
9/1/2011	Reference	Inlet	PNOD	0.041	5	121.11	II
9/1/2011	Reference	Inlet	PNOD	0.041	2	48.45	V
9/1/2011	Reference	Middle	HET	0.082	5	60.95	I
9/1/2011	Reference	Middle	HET	0.082	4	48.76	II
9/1/2011	Reference	Middle	PNOD	0.038	3	79.63	III
9/1/2011	Reference	Middle	PNOD	0.038	6	159.26	IV
9/1/2011	Reference	Outlet	HET	0.233	3	12.86	IV
9/1/2011	Reference	Outlet	HET	0.233	4	17.15	V
9/1/2011	Reference	Outlet	PNOD	0.072	2	27.77	I
9/1/2011	Reference	Outlet	PNOD	0.072	4	55.55	II
9/1/2011	Reference	Outlet	PNOD	0.072	3	41.66	III
9/1/2011	Reference	Outlet	PNOD	0.072	2	27.77	IV
9/1/2011	Reference	Outlet	PNOD	0.072	1	13.89	V
9/1/2011	Dev. Direct	Middle	HET	0.047	2	42.75	II
9/1/2011	Dev. Direct	Middle	HET	0.047	3	64.13	III

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
9/1/2011	Dev. Direct	Middle	HET	0.047	2	42.75	IV
9/1/2011	Dev. Direct	Middle	PNOD	0.042	2	48.06	I
9/1/2011	Dev. Direct	Middle	PNOD	0.042	1	24.03	III
9/1/2011	Dev. Direct	Middle	PNOD	0.042	2	48.06	IV
9/1/2011	Dev. Direct	Middle	PNOD	0.042	2	48.06	V
9/1/2011	Dev. Direct	Outlet	HET	0.045	4	89.39	I
9/1/2011	Dev. Direct	Outlet	HET	0.045	4	89.39	II
9/1/2011	Dev. Direct	Outlet	HET	0.045	1	22.35	III
9/1/2011	Dev. Direct	Outlet	HET	0.045	3	67.04	V
9/1/2011	Dev. Channeled	Middle	HET	0.161	2	12.39	I
9/1/2011	Dev. Channeled	Middle	HET	0.161	1	6.20	II
9/1/2011	Dev. Channeled	Middle	HET	0.161	6	37.18	III
9/1/2011	Dev. Channeled	Middle	HET	0.161	3	18.59	IV
9/1/2011	Dev. Channeled	Middle	HET	0.161	1	6.20	V
9/1/2011	Dev. Channeled	Middle	PNOD	0.021	1	47.75	II
9/1/2011	Dev. Channeled	Middle	PNOD	0.021	1	47.75	IV
9/1/2011	Dev. Channeled	Outlet	HET	0.481	2	4.15	I
9/1/2011	Dev. Channeled	Outlet	HET	0.481	2	4.15	II
9/1/2011	Dev. Channeled	Outlet	HET	0.481	6	12.46	III
9/1/2011	Dev. Channeled	Outlet	HET	0.481	3	6.23	IV
9/1/2011	Dev. Channeled	Outlet	HET	0.481	4	8.31	V
9/1/2011	Dev. Channeled	Outlet	PNOD	0.068	10	147.84	III
9/1/2011	Dev. Channeled	Outlet	PNOD	0.068	1	14.78	IV
9/20/2011	Reference	Inlet	HET	0.195	11	56.33	I
9/20/2011	Reference	Inlet	HET	0.195	21	107.55	II
9/20/2011	Reference	Inlet	HET	0.195	9	46.09	III
9/20/2011	Reference	Inlet	HET	0.195	4	20.49	IV
9/20/2011	Reference	Inlet	PNOD	0.033	3	91.90	I
9/20/2011	Reference	Inlet	PNOD	0.033	1	30.63	III
9/20/2011	Reference	Inlet	PNOD	0.033	2	61.27	IV
9/20/2011	Reference	Inlet	PNOD	0.033	2	61.27	V
9/20/2011	Reference	Middle	PNOD	0.033	6	183.80	I
9/20/2011	Reference	Middle	PNOD	0.033	3	91.90	II
9/20/2011	Reference	Middle	PNOD	0.033	1	30.63	V
9/20/2011	Reference	Outlet	HET	0.094	7	74.82	I
9/20/2011	Reference	Outlet	HET	0.094	1	10.69	III
9/20/2011	Reference	Outlet	PNOD	0.027	1	37.25	II
9/20/2011	Reference	Outlet	PNOD	0.027	3	111.74	IV
9/20/2011	Reference	Outlet	PNOD	0.027	2	74.49	V
9/20/2011	Dev. Direct	Inlet	HET	0.049	1	20.49	I
9/20/2011	Dev. Direct	Middle	PNOD	0.022	1	44.71	III
9/20/2011	Dev. Direct	Outlet	HET	0.028	1	35.12	I

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
9/20/2011	Dev. Direct	Outlet	PNOD	0.033	14	427.43	I
9/20/2011	Dev. Direct	Outlet	PNOD	0.033	12	366.37	II
9/20/2011	Dev. Direct	Outlet	PNOD	0.033	1	30.53	V
9/20/2011	Dev. Channeled	Inlet	HET	0.193	13	67.28	I
9/20/2011	Dev. Channeled	Inlet	PNOD	0.033	1	30.03	II
9/20/2011	Dev. Channeled	Inlet	PNOD	0.033	1	30.03	IV
9/20/2011	Dev. Channeled	Middle	PNOD	0.057	2	35.00	III
9/20/2011	Dev. Channeled	Outlet	HET	0.177	2	11.30	I
9/20/2011	Dev. Channeled	Outlet	HET	0.177	1	5.65	II
9/20/2011	Dev. Channeled	Outlet	HET	0.177	4	22.60	III
9/20/2011	Dev. Channeled	Outlet	PNOD	0.082	1	12.15	I
9/20/2011	Dev. Channeled	Outlet	PNOD	0.082	2	24.30	II
9/20/2011	Dev. Channeled	Outlet	PNOD	0.082	3	36.46	III
9/20/2011	Dev. Channeled	Outlet	PNOD	0.082	1	12.15	IV
10/10/2011	Reference	Inlet	HET	0.049	2	40.41	I
10/10/2011	Reference	Inlet	HET	0.049	7	141.43	II
10/10/2011	Reference	Inlet	HET	0.049	6	121.23	III
10/10/2011	Reference	Inlet	HET	0.049	3	60.61	IV
10/10/2011	Reference	Inlet	PNOD	0.034	13	387.84	I
10/10/2011	Reference	Inlet	PNOD	0.034	28	835.34	II
10/10/2011	Reference	Inlet	PNOD	0.034	11	328.17	III
10/10/2011	Reference	Inlet	PNOD	0.034	1	29.83	IV
10/10/2011	Reference	Middle	HET	0.070	8	114.56	III
10/10/2011	Reference	Middle	HET	0.070	2	28.64	IV
10/10/2011	Reference	Middle	HET	0.070	1	14.32	V
10/10/2011	Reference	Middle	PNOD	0.029	4	136.22	I
10/10/2011	Reference	Middle	PNOD	0.029	7	238.39	II
10/10/2011	Reference	Middle	PNOD	0.029	3	102.17	III
10/10/2011	Reference	Middle	PNOD	0.029	2	68.11	IV
10/10/2011	Reference	Outlet	HET	0.037	1	26.82	I
10/10/2011	Reference	Outlet	HET	0.037	3	80.45	II
10/10/2011	Reference	Outlet	HET	0.037	4	107.27	III
10/10/2011	Reference	Outlet	HET	0.037	1	26.82	IV
10/10/2011	Dev. Direct	Inlet	HET	0.005	1	184.37	III
10/10/2011	Dev. Direct	Middle	HET	0.012	1	81.94	II
10/10/2011	Dev. Channeled	Inlet	HET	0.092	1	10.93	I
10/10/2011	Dev. Channeled	Middle	PNOD	0.050	1	20.12	IV
10/10/2011	Dev. Channeled	Outlet	PNOD	0.077	3	39.16	II
10/10/2011	Dev. Channeled	Outlet	PNOD	0.077	5	65.27	III
10/10/2011	Dev. Channeled	Outlet	PNOD	0.077	4	52.22	IV
11/3/2011	Reference	Inlet	HET	0.190	6	31.61	II
11/3/2011	Reference	Inlet	HET	0.190	14	73.75	III

Date	Cell	Location	Plant	Plant SA (m2)	Count	Animal / SA	Life Stage
11/3/2011	Reference	Inlet	HET	0.190	8	42.14	IV
11/3/2011	Reference	Inlet	PNOD	0.023	1	43.65	II
11/3/2011	Reference	Inlet	PNOD	0.023	9	392.81	III
11/3/2011	Dev. Direct	Outlet	PNOD	0.045	1	22.28	III
11/3/2011	Dev. Channeled	Inlet	HET	0.073	1	13.78	III
11/3/2011	Dev. Channeled	Inlet	HET	0.073	2	27.57	III
11/3/2011	Dev. Channeled	Inlet	PNOD	0.029	1	33.93	II
11/3/2011	Dev. Channeled	Inlet	PNOD	0.029	2	67.86	III
11/3/2011	Dev. Channeled	Middle	HET	0.158	1	6.33	III
11/3/2011	Dev. Channeled	Middle	PNOD	0.019	1	51.51	III
11/3/2011	Dev. Channeled	Outlet	HET	0.009	2	210.70	III
11/3/2011	Dev. Channeled	Outlet	PNOD	0.033	2	60.46	III
11/3/2011	Dev. Channeled	Outlet	PNOD	0.033	1	30.23	IV

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