COMPARISON OF *Heteranthera dubia* (Jacq.) MacM.-ASSOCIATED MACROINVERTEBRATES BETWEEN GEOGRAPHICAL REGIONS IN THE UNITED STATES

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Macroinvertebrates associated with the aquatic plant, water stargrass (*Heteranthera dubia*), were sampled from 12 waterbodies in four regions of the United States from June to August 2005. Taxa richness, evenness, and diversity were lowest in the Lower Midwest (LMW) region, and higher in Northern sites, especially the Upper Midwest (UMW), and Northeast (NE). While relative abundance varied from site to site and region to region, utilization of the plant by functional groups remained fairly constant. Collector-gatherers consistently comprised the largest portion of invertebrates sampled. The shredder/ herbivore functional group comprised an average of 17 % of total groups.

Through an exhaustive literature review, it was found that shredder/ herbivores of water stargrass have not been reported in the literature. Because of this, the herbivore group was analyzed separately and consisted of 2,383 specimens representing 23 species. The most common groups were *Rhopalosiphum* sp., *Nectopsyche* spp. and chironomids. No differences were found in herbivore diversity or evenness between sampling regions, but species richness was significantly different.

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CHAPTER 1.

ANALYSIS OF INVERTEBRATE COMMUNITIES ASSOCIATED WITH WATER STARGRASS (*Heteranthera dubia* (Jacq.) MacM)

Abstract

The aquatic plant *Heteranthera dubia* (water stargrass) and associated macroinvertebrates were sampled from July to September 2006, in 12 sites in four regions of the United States, including the lower midwest (LMW), northwest (NW), upper midwest (UMW) and northeast (NE). Density, diversity, richness and evenness of macroinvertebrates were compared between sites and regions. While the lowest overall density, diversity, richness, and evenness occurred in LMW sites, this is likely related to both poor plant species richness in LMW sites and high water temperature and conductivity. Correspondence analysis was used to group sites and regions based on similar taxa. In general, three distinct groups were found, consisting of LMW, NW, and UMW/NE. Chao's modified Jaccard similarity index was calculated for regions and LMW was most similar to NW, and NE and UMW were most similar, with similarity indices of 0.751 and 0.323, respectively. Macroinvertebrates were grouped into functional feeding groups and the relative abundance of these groups was compared between regions. Collector-gatherers made up the greatest proportion of the total with 34.5%, scrapers made up 25.5%, and shredders were the dominant group (34.8% of total) in LMW sites. Overall, functional group analysis produced trends that were common among all sites in all regions, though they varied slightly in lotic versus lentic waterbodies. These patterns may be useful to investigators concerned with the effects of disturbances on macroinvertebrate community structure in plant beds and also as a possible indicator of stress in the system.

Introduction

Aquatic vegetation provides many important functions, including excellent fish habitat (Engel 1985), refuge for forage species (Savino and Stein 1982), food for waterfowl (Martin and Uhler 1938) and substrate and food for invertebrates (Newman 1991). Native plant communities are also important in that they compete for resources with exotic species and, in that regard, have been used to preempt invasion in lake restoration projects (Doyle and Smart 1993).

Reservoirs in the southern United States generally lack developed aquatic plant communities because they are often formed in areas geographically isolated from potential source populations of native aquatic plants or insects (Smart and Dick 1999). For this reason, the United States Army Corps of Engineers (USACE) has successfully established native plants in many of these man-made systems (Smart et al. 1996). Plant species used in these projects include American pondweed (*Potamogeton nodosus* Poiret) (Doyle and Smart 1993), wild celery (*Vallisneria americana* Michx.), American elodea (*Elodea canadensis* Michx.) and water stargrass (*Heteranthera dubia* (Jacq.) MacM.) (Smart et al. 1996). *Heteranthera dubia* in particular, has been used extensively for restorative purposes by forming "founder colonies" (Doyle and Smart 1995, Smart and Dick 1999) at sites including Choke Canyon Reservoir, Texas (Howard Elder[1], per. comm.), Guntersville Reservoir, Alabama (Doyle and Smart 1995) and in Cooper Reservoir, Texas (Dick et al. 2004) among others. Likewise, in the Great Lakes Basin, *H. dubia* has been used in multiple restorative projects (Mitsch et al. 1994).

Ultimately the goal of lake restoration is the establishment of diverse macrophyte communities, which in turn provides ecosystem stability and preempts invasion by nuisance plants (Doyle and Smart 1993). In relatively new, vegetatively barren reservoirs, non-native macrophytes can become introduced and established, causing severe resource problems,

[1] Texas Parks and Wildlife Department, Jasper, TX 75951

including decreased boat access and limiting recreational uses. In addition, some invasive species form canopies, resulting in degraded water quality, including reduced dissolved oxygen and increased surface water temperature (Honnell et al. 1993). Diverse plant communities provide for a diverse macroinvertebrate fauna (McAbendroth et al. 2005), which in addition to being a food source for other organisms, serve to breakdown and process live plant tissue and detritus (Newman 1991).

Macroinvertebrates utilize macrophyte substrate in a variety of ways, and macroinvertebrate communities are affected by many factors. Researchers have reported relationships between invertebrate abundance and leaf surface area (Krecker 1939, Dvorak and Best 1982, Cheruvelil et al. 2002), although others conflict these results (Rooke 1984, Cyr and Downing 1988). In addition to plant community composition and water quality, regional (precipitation, mean temperature) and historical (land use) variables can play a role in macroinvertebrate community composition (Ricklefs 1987, Ricklefs and Schluter 1993). Diet (i.e. food availability and quality) and temperature have also been shown to affect distribution of invertebrates (Sweeny and Vannote 1986).

Many studies have compared macrophyte-associated macroinvertebrate communities between two or more species of plants (e.g. Feldman 2001, Chilton 1990) in which the primary variable was plant species. In separate studies (Beckett et al. 1991, and Peets et al. 1994), investigators examined macroinvertebrate communities of *P. nodosus*, in addition to other plants. They each reported invertebrate densities which varied substantially from one another.

Variables other than plant species are responsible for determining associated fauna and the factors that contribute to invertebrate communities are probably complex and connected. There appear to be five substrate characteristics which determine colonization by invertebrates:

Surface area (Krecker 1939, Dvorak and Best 1982, Cheruvelil et al. 2002), macrophyte exudates (Pip and Stewart 1976), food availability (Lodge 1985), degree of refuge (Schramm et al. 1987, Ormerod 1988) and architectural complexity (Kershner and Lodge 1990). These differences can be eliminated from consideration, or at least reduced, by investigating communities associated with only one plant species, in similar growth and reproductive stages. In addition, analyses of macroinvertebrate communities from a ubiquitous plant species might lead to a better understanding of factors influencing macroinvertebrate community structure and composition. One such aquatic plant species in the U.S. is *H. dubia*.

Heteranthera dubia (Figs. 1.1, 1.2) is a freshwater hydrophyte, which grows in a wide range of environmental conditions, and is found throughout southern Canada, most of the United States, and northern Mexico (Horn 1983). *Heteranthera dubia* will range into both soft and alkali waters (Moyle 1945), but has been reported to proliferate on mineral soils where salinities range from 0 to 0.5 ppt (Stutzenbaker 1999). Moyle reports a total alkalinity range of 22.5-245.0 ppm, sulphate ion range of 0.0-317.6 ppm, and optimal pH of 7.6-9.0. *Heteranthera dubia* is found in canals and quiet waters (Correll and Correll 1972), riffles (Horn 1983), and can display an emersed morphotype (the mudflat form), which develops as the submersed plants become emergent (Horn 1983), often due to receding water levels. *Heteranthera dubia* can grow at depths of up to 7 m (Sheldon and Boylen 1977), but is generally found in shallow waters (Horn 1983).

Hypothesis/ Objectives

Because *H. dubia* is an important species in vegetation projects and is ubiquitous in the United States, its role as a substrate for invertebrates will provide researchers with baseline data, useful to conservation and restoration efforts. The patterns derived from these data could be compared against those in newly restored or disturbed sites. Substantial deviations from these baseline patterns might warrant action on the parts of conservationists or plant managers.

Because species-level identifications may be desired but are sometimes difficult to obtain, an alternative is using functional feeding groups to examine communities. The functional group classification is based on food type and the method of foraging (Merritt and Cummins 2008), and has been used previously to analyze both lentic (Chilton 1990) and lotic (Vannote et al. 1980, Cummins et al. 1981) freshwater invertebrate communities. Analysis of this kind allows for a broader, ecological comparison of communities based on relative abundance, and allows an assessment of what food resources are being utilized in an aquatic system (Merritt and Cummins 1996).

The objective of this study is to examine the invertebrate communities associated with *H. dubia* by sampling plants from sites in multiple, geographically separate regions. This study furthers our understanding of patterns in macroinvertebrate communities associated with aquatic plants.

Hypotheses to be Tested

Ho_1: Macroinvertebrate density will not be significantly different between geographic regions.

Ho_2: Macroinvertebrate density does not positively correlate to plant dry weight.

Ho_3 : Macroinvertebrate diversity will not be significantly different between geographic regions.

Ho_4: Macroinvertebrate community composition will not be different between geographic regions.

Ho_5: Functional group percentages will not be significantly different overall.

Materials and Methods

During the summer of 2006, *H. dubia* and associated invertebrates were collected from three sites in each of four regions of the United States: lower Midwest (LMW; Choke Canyon reservoir, TX, Coleto Creek reservoir, TX, Richland Chambers reservoir, TX), Northwest (NW; Yakima River, WA, Selah Pond, WA, Parker Pond, WA), Upper Midwest (UMW; Apple River, WI, Leech Lake, MN, Norway Lake, MN), and Northeast (NE; Little Lake, VT, Lake Hortonia, VT, Saratoga Lake, NY) (Figure 1.3, Table 1.1). Site descriptions and information is included in Appendix 1. Due to time and financial restraints, each region was visited and sampled once, from July through September. Southern populations of *H. dubia* were sampled from late June to mid July and northern populations sampled from mid July to late September.

Sites were chosen for sampling based on several criteria. The water body must have been within the predetermined geographic region and contain *H. dubia*. Sample sites included lakes, reservoirs, ponds, and rivers. Specific sites were chosen based on access and relative proximity of other regional sampling sites. Sites and sampling dates are listed in Table 1.1. Site descriptions and individual results from each site can be found in Appendix I.

Sample Collection

Plant samples were collected with a nylon-mesh bag sampling device (Figure 1.4). The device has an opening diameter of 40cm, is conical in shape, 60 cm deep, and constructed of 500 μm mesh. The sampler was lowered into the water column around plants until fully submersed. The plants were then broken at the base of the sampler and the sampler was then inverted and retrieved. Once removed from the water, the entire sample, sampling device included, was placed in a plastic bag and sealed for later processing. Three samples were taken at each site, nine per geographic region. Roots/ sediment were not sampled.

Qualitative field notes were taken regarding other plant species present at sampling sites because epiphytic invertebrate diversity is affected by habitat complexity (Downes et al. 1998). Sampling preference was made for monotypic beds of *H. dubia*. All samples contained plants which were at the water's surface.

In addition to plant-invertebrate collections, pH, water temperature, and conductivity were recorded at each site. All were measured with a Combination pH/EC/TDS meter, model HI 98129 (Hanna instruments®, Inc., Woonsocket, RI). Dissolved oxygen was not measured because the dissolved oxygen meter was broken in the field after only recording data from two sites.

Sample Processing

Plant samples were initially processed in the field. Plants were thoroughly washed over a benthic-washing bucket (mesh size 500 µm) and any invertebrates dislodged from the plant were preserved in 70% ETOH. Washed plants were then shipped overnight via FedEx to the Lewisville Aquatic Ecosystem Research Facility (LAERF), Lewisville, TX, in insulated containers. Plant material was subsequently dried at 55 degrees C until constant weight achieved.

All macroinvertebrates were identified to the lowest practical taxon, which was, in most cases, genus. Chironomid (Diptera) specimens were slide-mounted in CMC-10 mounting media (Masters Co., Wood Dale, IL) for identification. Two reference collections will be established; one will be permanently housed in the Elm Fork Natural Heritage Museum at the University of North Texas. The other will be archived at the United States Army Corps of Engineers LAERF. Most insects were identified using Merritt and Cummins (1996), Merrit and Cummins (2008), and Thorp and Covich (2001). In those cases where species identifications were desired representative specimens were sent to experts in specific taxonomic groups for assistance (Table 1.2).

Gastropods

All gastropod specimens were identified to species with assistance from Rob Dillon (Table 1.2). Because of this taxonomic resolution, gastropods were included in all analyses and also analyzed as a separate group.

Functional Feeding Groups

Macroinvertebrates were grouped into one of five functional feeding groups (Merritt and Cummins 1996), including shredder/herbivore, collector-filterer, collector-gatherer, scraper, and predators. Several chironomid taxa were included in the shredder/herbivore category, and because species identifications were not made, it is likely that many only occasionally feed on plant tissue.

Natural vs. Man-Made Waterbodies

Sites were grouped into categories describing whether a site was man-made or natural. The two categories chosen were natural and man-made (Table 1.1). Man-made refers to impoundments and reservoirs/ ponds and natural refers to all other waterbodies sampled. Grouping sites into these categories allows investigation of the differences in invertebrate densities between the two site types. For these analyses, Little Lake was considered natural because it is an impounded wetland; essentially an extension of Lake Saint Catherine, a natural lake. It is expected that the plant/ invertebrate communities would be nearly identical between the two waterbodies.

Lentic vs. Lotic Sites

Sites were also compared based on flow regime, i.e. "lotic" and "lentic" (Table 1.1). The two categories were chosen arbitrarily, based on observed flow at the sites. Norway Lake, Little Lake, and Lake Hortonia were included in the "lotic" category because sites where plants were collected occurred near the out-flow of each lake, in a constricted area with increased flow.

Plant Bed Diversity

Waterbodies were categorized based on the richness of plant species at the sample site, because habitat complexity and macrophyte richness has been associated with increased macroinvertebrate diversity. The categories of "1-2" plant species and ">2" plant species were chosen arbitrarily, but most sites either had poor (1-2; 5 of 12 sites) plant species richness or better-than-poor (>2; 7 of 12 sites) plant species richness (Table 1.1).

Data Analyses

Abundance data were standardized by plant dry weight. Because only one plant species was sampled, density was used to compare between sites (Biochino and Biochino 1980) and regions.

In order to meet the normality (Shapiro Wilk's W test) assumption of ANOVA, density data (both overall density and functional group density) were $\log_{10}$-transformed, and found to be normal. Data were then analyzed using STATISTICA version 8.0 (StatSoft, Inc., 2007, Tulsa, OK) and included analysis of variance (ANOVA) and Neuman-Keuls (NK) for mean separation. Statements of significance refer to an alpha level 0.05 unless otherwise noted. Non-transformed data are presented in the results and discussion, as well as in graphs.

Power analysis was evaluated for each ANOVA which did not gain statistical significance using STATISTICA version 8. Sample size required for statistically significant results was determined with standard deviation and means from original statistics at a power of 0.95.

Shannon's diversity (natural log), Shannon's evenness, and taxa richness was calculated for each site and region and then compared using ANOVA. These data were determined to be normal (Shapiro Wilk), so transformation was not necessary.

Data used in analyses of differences in sites consisted of three samples per site (N = 36). In order to avoid pseudo-replication, data used in analyses of regions consisted of averaged samples from sites, three sampling units per region (one per site). This results in low sample size when comparing regions ($N = 12$), but is necessary because samples taken at each site are not considered the sampling unit when comparing regions. Averaged data met the normality assumption (Shapiro Wilk) so were not transformed for analyses.

The relationship between invertebrate density and other measured variables, including plant dry weight, water temperature, conductivity, and pH was measured using Pearson's product-moment correlation. Pearson's product-moment correlation was also used to examine the relationship between richness, diversity, evenness and invertebrate density.

Macroinvertebrate community composition based on site and region were analyzed by correspondence analysis (CA). CA results are presented as ordination biplots for sites and regions.

Chao's Jaccard abundance-based similarity (Cjab) index was calculated for each site pair and region pair (Chao et al. 2005). Chao's abundance-based version of Jaccard's index of similarity is influenced by common and rare taxa and gives a more accurate estimate of similarity between samples than Jaccard's classic index. This is calculated as where U and V represent the relative abundance of individuals in samples 1 and 2, respectively. This is just a slight modification of the Jaccard's similarity index. A Cjab value of "1" reflects complete similarity between communities while "0" represents total dissimilarity between communities. Cjab was also used to examine similarity in natural and man-made sites as well as between lentic and lotic sites.

Sample-based rarefaction curves were constructed for each region using EstimateS version 8.2.0 (Robert K. Colwell, University of Connecticut, USA). This was accomplished by plotting T_{obs} vs sample number for each region. T_{obs} represents the cumulative number of taxa in the additively pooled samples. Sample-based rarefaction, although less accurate then individual-based rarefaction, was necessary because of the sample size and because samples were taken from geographically separated populations in each region. Sample-based rarefaction is produced by the repeated re-sampling of pooled individuals as a function of sample size (Gotelli and Colwell 2001). The curve produced by this procedure represents the statistical expectation for a corresponding taxa accumulation curve.

In addition to ANOVA, because gastropods were identified to species, differences in gastropod community structure based on site and region were analyzed by correspondence analysis (COA). COA results are presented as ordination biplots for sites and regions.

Results

Recorded water quality parameters are listed in Table 1.1. Mean water temperatures at the time of sample were significantly different between regions (Fig. 1.5) and ranged from 20.1 ºC in the Apple River, WI to 32.1 ºC in Coleto Creek Reservoir, TX. LMW and NW had higher mean temperatures than UMW and NE. Conductivity varied from 96 µS in Little Lake, VT to 971 µS in Selah Ponds, WA. pH ranged from 7.24 in Parker Ponds, WA to 9.12 in Selah Pond, WA. Invertebrate density was inversely correlated ($r = -0.65$, $P < 0.05$) to conductivity at sites (Fig. 1.6) but not to pH, or water temperature.

Macroinvertebrate density was significantly different between sites (Fig. 1.7) but not between regions therefore the null hypothesis (Ho_1) that macroinvertebrate density would not be significantly different between geographic regions was accepted. Power analysis determined that a sample size of 11 replicates per region would be required to achieve statistical differences between regions at a power of 0.95. UMW had the greatest mean density of invertebrates with 73 individuals per g plant dry weight, followed by NE (67 individuals / g plant dry weight) which is dominated by the large numbers of *Dreissena polymorpha* Pallas (zebra mussels) collected from sites in the region (average density of 20 individuals / plant dry weight, with maximum of 72 individuals / plant dry weight at Saratoga Lake, NY). NW and LMW had 40 and 19 individuals / g plant dry weight, respectively. In addition, macroinvertebrate abundance was not correlated to plant dry weight, so the null hypothesis (Ho_2) was accepted.

A total of 17,712 organisms were collected, representing 116 taxa (Table 1.3). The most abundant taxa were Gastropoda (27.7% of total), Diptera (17.9% of total), Oligochaeta (9.3% of total), Amphipoda (8.6% of total), Ephemeroptera (6.9% of total), Podocopida (5.2% of total), Trichoptera (4.8 % of total), and Ctenopoda (4.2 % of total). These groups accounted for greater than 80% of the total organisms in all samples.

A total of 4,901 Gastropod individuals, representing 16 species in six families were found associated with *H. dubia* (Table 1.4). The most abundant gastropod family was Hydrobiidae, with 2,910 specimens; the most numerous species overall was *Amnicola limosa* (Say).

The most abundant dipteran family was Chironomidae, which was dominated by *Glyptotendipes* spp. (12.7 % of total chironomids), *Ablabesmyia* spp. (12.9% of total), and

Paratanytarsus spp. (13.7% of total). Other abundant chironomids included *Chironomus* spp. (10.3% of total), *Microspectra* spp. (7.2% of total), and *Polypedilum* spp. (5.2% of total).

Hyalella azteca Saussure made up nearly 100% of all amphipod specimens. *Hyallela azteca* are small, 3 to 8 mm, and found in shallow freshwaters of North and Central America, where they feed on algae or detritus. Ctenopods were completely represented by *Sida* sp.

Ephemeroptera included four families: Tricorythidae, Baetidae, Heptageniidae, and Caenidae. Tricorythidae (*Tricorythodes* sp.) were by far the most abundant, with 770 specimens of the 1219 Ephemeroptera collected. Over 93 %, or 719 individuals, of *Tricorythodes* sp. were collected from the Yakima River. *Tricorythodes* sp. were also collected from two other sites: Parker Pond (15 individuals), and the Apple River (36 individuals).

Trichoptera were represented by 10 genera and at least 17 species, in five families: Hydropsychidae (*Hydropsyche* sp.), Leptoceridae (*Leptocerus americanus* Banks, and *Triaenodes injusta* (Hagen), four species of *Oecetis*, *Ylodes* sp., and four species of *Nectopsyche*), Hydroptilidae (*Orthotrichia* spp., *Hydroptila* spp. and *Oxyethira* spp.), Polycentropidae (*Cyrnellus fraternus* (Banks)), and Psychomyiidae. Psychomyiids were not identifiable past family because they were early instar individuals.

There were no statistically significant differences in mean diversity or evenness between regions but there were significant differences between sites (Figs. 1.8 & 1.9). The null hypothesis (Ho_2) that macroinvertebrate diversity would not be statistically different between regions was, therefore, accepted. Power analysis determined that a sample size of 18 replicates per region would be required to achieve statistical differences in diversity between regions at a power of 0.95. In addition, a sample size of 54 replicates per region would be required to achieve statistical differences in evenness between regions at the same power. Sites with high diversity values included Little Lake, VT (2.67), Parker Ponds, WA (2.35), and Norway Lake, MN (2.21) (Table 1.6). Sites with high evenness values include Little Lake, VT (0.85), Parker Ponds, WA (0.78), and Leech Lake, MN (0.76).

Taxa richness was significantly different between sites and between regions; NE had the most taxa (34 average number of taxa), followed by UMW (29 average number of taxa), NW (25 average number of taxa), and LMW (19 average number of taxa) (Figure 1.10). Norway Lake, MN, had the highest taxa richness, with an average of 28 taxa per sample (36 taxa overall) (Figure 1.12). In contrast, Richland Chambers Reservoir, TX had a mean taxa richness of 13 (18 taxa overall). Overall, taxa richness was negatively correlated with water temperature (r = -0.73, $P < 0.05$) (Fig. 1.12) and positively correlated with invertebrate density (r = 0.71, $P < 0.05$) (Fig. 1.13).

Both CA biplots (Figs. 1.14 and 1.15) are represented by the first two axes deemed significant by the CA. The percent of total inertia (variance) explained collectively by the two axes was 78.29% for sites and 97.64% for regions. When examing the ordination biplot of sites, there are two general groups, including sites from LMW/NW and UMW/NE grouped together. Examining the regional ordination biplot, three groups are obvious; the null hypothesis (Ho_3) that macroinvertebrate community composition would not be statistically different between regions was rejected.

Similarity indices were calculated for sites and regions (Tables 1.6 and 1.7). While the similarity indices agree with the results of the CA in that the UMW and NE are most similar (Cjab = 0.75), the LMW is most similar to the UMW (Cjab = 0.32), which is contradictory to the CA grouping. In fact, the strongest similarity is between the UMW and NE which share 38.2% of taxa, while the weakest similarity is between the LMW and the NW (Cjab = 0.27), sharing

26.9% of taxa. This is in direct conflict with the grouping of LMW and NW sites by CA but not in the separation of regions by CA.

Sample-based rarefaction curves were created for each region (Figures 1.16-1.19). From the graphs, we can estimate that approximately 75% of the taxa expected in each region were represented in these collections.

Gastropods

Pearson's product-moment correlation revealed a relationship between gastropod density and water temperature (r = -0.59, P < 0.05, Fig. 1.20), but no relationship was found between gastropod density and pH or conductivity. This negative relationship is evident in LMW sites where water temperatures were higher than any other region (Fig. 1.5).

Sixteen species of gastropods were collected; the most numerous overall was *Amnicola limosa* (Say). *Amnicola limnosa* was present at 50% of the sites; this includes all UMW and NE sites, and none of the LMW and NW sites. Gastropoda was the most diverse group collected, represented by six families: Ancylidae (336 specimens from seven sites, *Ferrissia parallela* (Haldeman)), Hydrobiidae (including *A. limosa* and *Cincinnatia integra* (Say)), Physidae (including *Physa acuta* Draparnaud and *Physa gyrina* Say), Planorbidae (including *Gyraulus parvus* (Say), *G. deflectus* (Say), *Helisoma anceps* (Menke), and *Menetus opercularis* (Gould)), Thiaridae (*Melanoides tuberculata* Muller), and Valvatidae (*Valvata tricarinata* (Say)). Rare species collected in this study included *Promenetus exacuous* Say and *Gyraulus deflectus* Say. *Promenetus exacuous* was collected only from Little Lake, VT and *G. deflectus* from Saratoga Lake, NY, both sites in the NE region.

Gastropod diversity (Shannon's diversity index) ranged from 0.86 in the UMW to 0.21 in LMW but was not significantly different between regions. Power analysis determined that a sample size of 22 replicates per region would be required to achieve statistical differences in gastropod diversity between regions at a power of 0.95. Diversity differed among sites, but was greatest at Leech Lake, MN (1.307) followed by Little Lake, VT (1.21) (Fig. 1.21). Evenness was not significantly different between regions but was different between sites; Leech Lake and Little Lake had the highest evenness with 0.89 and 0.84, respectively (Fig. 1.22). Power analysis determined that a sample size of 20 replicates per region would be required to achieve statistical differences in gastropod evenness between regions at a power of 0.95.

Gastropod species richness was greatest in the NE region, with an average richness of 6, compared with 2 in LMW (Fig. 1.23). There were also significant differences in species richness between sites; two of the sites with the highest richness were Saratoga Lake, NY with a mean species richness of 5, and Little Lake, VT with a mean species richness of 5 (Fig. 1.24). Although LMW sites had, in general, poor species richness, Coleto Creek reservoir had a very unique gastropod fauna compared to all other sites. Of the four species collected from Coleto Creek Reservoir, three, *Biomphalaria obstructa* Morelet, *Cinncinatia integra* Say, and *Melanoides tuberculata* Gould, were not found associated with *H. dubia* at any other sites. Overall, gastropod species richness was negatively correlated to both water temperature (r = -0.70, $P < 0.05$, Fig. 1.25) and conductivity (r = -0.60, $P < 0.05$, Fig. 1.26,).

Cjab similarity index was calculated for each site and region combination based on snail density (Tables 1.8 and1.9). The highest similarity was between NE and UMW (Cjab = 0.98) and the lowest similarity is between LMW and UMW (Cjab = 0.058). In fact, NE and UMW shared six species, or 60.0% of total gastropod species collected from the two regions. Species that were common to the majority of sites were *Physa acuta* (in 11 of 12 sites), *Gyraulus parvus* and *Ferrissia paralella* (both 7 of 12 sites). In addition, the most numerous snail, *A.limosa* was found in half of the sites sampled, including all of the UMW and NE sites.

Both CA biplots are represented by the first two axis deemed significant by the CA. The percent of total inertia (variance) explained collectively by the two axes was 78.29% for sites and 97.64% for regions. In both instances, three groups were obvious (Figs. 1.27 and 1.28).

Functional Feeding Groups

ANOVA identified statistically significant differences in functional group density (Fig. 1.29) overall. The most abundant functional groups were collector-gatherers (34.5% of total, including oligochaetes, podocopids, ctenopods, several chironomids, *Hyalella azteca*, *Sida* sp., and *Trichorythodes* sp.), followed by scrapers (25.5 % of total, primarily *Amnicola limosa* and *Physa acuta*), shredders (20.4 % of total, including *Glyptotendipes* spp., *Chironomus* spp., *Polypedilum* spp., *Nectopsyche* spp., *Orthotrichia* spp., and *Rhopalosiphum* spp.), predators (16.9% of total, 42.8% of which was *Enallagma* spp.), and collector-filterers (2.68%, primarily *D. polymorpha*). Zebra mussels account for 71% of collector-filterers found overall, but were only found at two sites. Excluding zebra mussels, collector filterers make up only 1% of the total functional group invertebrate density, and are represented by *Simulium* sp., *Hydropsyche* sp., and *Cyrnellus fraternus*. 57% of collector-filterers (again, excluding zebra mussels) were found in two sites, Yakima River, WA and Apple River, WI.

ANOVA also identified statistically significant differences in the relative abundances of functional groups overall (Fig. 1.30), thereby rejecting the null hypothesis (No_5) that there would be no difference in relative abundances of functional groups. NK found five distinct groups, including the most abundant collector-gatherers (40.15 %), followed by scrapers (26.55%), then shredders (17.18 %), predators (14.61 %), and collector-filterers (1.51 %).

Natural vs. Man-Made Waterbodies

ANOVA found significant differences in macroinvertebrate density in natural sites as opposed to man-made sites (Fig. 1.31), with natural sites supporting higher densities of macroinvertebrates. Despite this, there were no differences in diversity, evenness, or taxa richness between natural and man-made waterbodies. Power analysis determined sample sizes of 89, 1582, and 30 replicates per waterbody type to achieve significant differences in diversity, evenness, and richness, respectively.

Natural and man-made sites share 47, or 45.6% of the taxa (Cjab = 0.789). UMW/NE natural sites and UMW/NE man-made sites share 34, or 44.0% of the taxa (Cjab = 0.879), while northern (NW/UMW/NE) man-made sites and southern (LMW) man-made sites share only 20, or 25.3 % of taxa (CJAB = 0.369). Because all southern sites were manmade, there is no southern natural category.

Lotic vs. Lentic

Lotic sites had significantly higher macroinvertebrate densities than did lentic sites (Fig. 1.32). In addition, lotic sites supported higher relative abundances of collector-gatherers (50.3% vs. 32.9%, Fig. 1.33), but shredders were found in greater relative abundances in lentic sites (23.5% vs. 8.3%, Fig. 1.34). Relative abundances of predators, scrapers, and collector-filterers were not significantly different.

Plant Bed Diversity

There were no statistically significant differences in diversity or evenness between sites where *H. dubia* was the only species present and sites with more than two plant species in the sample vicinity. Power analysis determined a sample size of 47 and 49 replicates per site type was needed to attain significant differences in diversity and evenness, respectively. There was, however a statistically significant difference in richness between those same sites (Fig. 1.35).

Discussion

Physical-chemical differences among sites play a role in determining presence/ absence of taxa, as well as abundance of taxa present. Mean water temperatures were highest in LMW sites and lowest in NE sites. Water temperature is important to development in macroinvertebrates, and this importance is evident in the richness differences between regions. With a measured temperature of 32.1 °C, temperatures in some LMW sites might be approaching maximum thermal limits for some organisms (Gaufin and Hern 1971) as well as reducing dissolved oxygen levels. While some of the insect species found in LMW sites may be adapted to high temperatures and low oxygen levels, there are no natural lakes in Texas so many of the insects found in these sites are, in reality, probably not well adapted to these conditions.

Invertebrate density was negatively correlated to conductivity at sites. It has been shown that factors such conductivity are important in determining aquatic macroinvertebrate distribution (Baptista et al. 2001). In addition to base geology, high evaporation rates caused by increased air temperatures and low precipitation in many of the LMW and NW sites likely contributed to the conductivity values recorded. Also, stream macroinvertebrates in aquatic ecosystems adjacent to agricultural land (Shieh and Yang 2000) are affected by conductivity as well. Selah Pond, WA is a farm pond and had the highest recorded conductivity value of any site (971 µS). This, along with high water temperatures and high pH (9.12) likely contributed to the low density of invertebrates found at the site. In addition, Coleto Creek and Choke Canyon reservoirs had conductivity values of 597 µS and 795 µS, respectively, and were among the lowest in macroinvertebrate density values.

Water temperature, as well as unmeasured parameters such as turbidity, likely contributed to differences among sites. While turbidity was not quantified, it was observed that sites in LMW tended to be more turbid than in other regions. Both Choke Canyon and Coleto Creek reservoirs commonly have water level fluctuations, caused by rainfall or increased local water usage. This fluctuation in water level, coupled with a poorly established aquatic plant community, likely caused the turbidity observed at the sites. Turbidity also affects epiphytic algae/ diatom growth by limiting light penetration. Although algal epiphyton was not quantified in this study, it is likely that distribution of macroinvertebrates was affected by the abundance and distribution of epiphyton (Balci and Kennedy 2003).

In general, the evidence suggests that macroinvertebrate density differences are due to site variation and not because of geography, although an increased sample size would help detect differences between regions. The lack of detectable differences in macroinvertebrate density between regions is at least partly due to low sample size and high variability at sites. The required sample size of 11 replicates per region to achieve significance was not attainable in the current study. Because site samples were combined to avoid pseudoreplication, only three replicates per region were used for analysis. This means that 11 sites per region would need to be sampled, 44 sites overall. This is beyond the scope of the current investigation and beyond the funding available at the time the present research was conducted.

The taxa observed in this study are typical of those found in the macroinvertebrate communities associated with macrophytes. *Heteranthera dubia*-associated communities sampled by Balci and Kennedy (2002) were dominated by Chironomidae, making up 88% of all macroinvertebrates collected. In this study, chironomids made up 33 % of macroinvertebrates collected in Texas sites, and 18%, or 3074 specimens in all sites. This discrepancy is likely due to smaller mesh size used for sampling by the previous researchers. They were able to collect and rear early instar chironomids, while first instar chironomids were rarely collected during the current work. Another study, Parsons and Matthews (1995) found *H. azteca* to be abundant overall on aquatic plants, and the same was true for the present study, having been found at every site but Little Lake, VT. Various researchers (Cyr and Downing, 1988) have found positive relationships between plant biomass and invertebrate abundance but no correlation was found in the present study. This could be, in part, due to seemingly poor water quality in several sites and a low sample size.

Several taxa were found in large numbers at only a few sites, including *D. polymorpha* and *Tricorythodes* sp. *Dreissena polymorpha* is an invasive bivalve introduced into the Great Lakes in the 1980's through ballast water from ships originating in the Ukraine (Marsden et al. 1996), and is currently found in much of the Mississippi River drainage (Mackie and Schloesser 1996). The reason for only collecting one bivalve species is likely because, unlike other species that inhabit sandy, benthic substrates, *D. polymorpha* is able to attach to macrophytes and filter the water column. *Tricorythodes* sp. was collected from only three sites, but 93.4% were from Yakima River, WA. That two of the three sites were river systems is not surprising, because *Tricorythodes* is a lotic-erosional genus (Merritt and Cummins 1996).

Similar to density analyses, there were no significant differences in taxa diversity or evenness among regions, but sites showed statistical differences. In fact, the three highest diversity values calculated for sites were from three different regions; Little Lake (NE), Parker ponds (NW), and Leech Lake (UMW) each had Shannon's diversity values above 2.20. The sample sizes of 18 and 54 needed to achieve differences between regions in diversity and evenness, respectively, were not possible in the current study. This result supports the conclusion that differences in community structure, measured by macroinvertebrate density, diversity, and evenness, is influenced more by site variables than regional ones.

In contrast, taxa richness was found to be statistically different between both regions and sites, and ranged, with little variation, from a mean of 33 taxa in NE, to a mean of less than 20 taxa in LMW. Taxa richness is more influenced by temperature (regional variable) and habitat complexity (both regional and site variable) than density, diversity, and evenness. The negative correlation of taxa richness with temperature is evident because LMW and NW sites had both the highest recorded water temperatures at the sample date (Fig. 1.5), highest overall air temperatures leading up to the sample date (Fig. 1.40) and while LMW had the lowest taxa richness among regions (Fig. 1.10), NW also had poor richness. Plant bed diversity is discussed below and plays a significant role in macroinvertebrate richness in waterbodies.

CA were performed for both regions and sites and were calculated from densities of taxa; results are therefore influenced by not only abundance but the taxa themselves. For instance, UMW and NE were grouped and share 29 taxa, with a Cjab index value of 0.751, including a gastropod-Cjab value (discussed below) of 0.98. LMW and NW were distinctly separate. The result of CA of sites is more difficult to draw conclusions from. LMW and NW sites are generally distinct from UMW and NE sites, but the grouping is vague and broad. UMW and NE sites follow the regional trend and are grouped together.

Macroinvertebrate community structure and composition appear to be influenced by multiple variables. Geography plays a substantial role in what taxa are found in regional sites. In comparing regions, regional variables such as temperature and richness were the best measures of difference. In addition, CA allows for comparison using taxa abundance but may not provide the resolution desired if species-level identifications are not achieved. When examining differences at the site to site level, then local factors such as land use, flow regime, and water quality (conductivity, etc.), influence macroinvertebrate structure, as measured by density, diversity, and evenness.

Sample-based rarefaction curves were created for each region. In general, the regions with the lowest observed taxa richness (i.e. LMW and NW) appear to have been underrepresented. For instance, in LMW and NW we can estimate from figures 1.18 and 1.19, respectively, that we collected approximately 75% of expected taxa from each region. In contrast, regions with generally higher measured taxa richness appear to have been more extensively sampled. Estimates from figures 1.20 and 1.21 show an approximate taxa recovery of 77% and 78% for UMW and NE regions, respectively. This percentage would fluctuate with increasing or decreasing taxonomic resolution. Because most taxa were identified to genus, and some to species, the above estimates of sampled taxa are probably overestimates. If all specimens were identified to the species level, this would decrease the percentage of estimated collected species.

Gastropods

Not only are many snails susceptible to high temperatures (Mitchell and Brandt 2005) but increased temperatures can increase toxicity of certain chemicals in the water (Cairns et al. 1975). This might explain the negative correlation between snail density and water temperatures. Also, as mentioned previously, several of the sites with highest water temperatures (Choke Canyon, Coleto Creek) are also subject to nutrient inputs from adjacent farm and rangelands. Toxic compounds associated with agricultural runoff might be amplified in their effects in these high temperatures. In addition, no correlation was found between plant dry weight and snail density. It is likely that the lack of correlation between plant dry weight and snail density is a result of the differences in water quality and low sample size at sites. It could be expected that, in general, increasing plant biomass (i.e. surface area) might lead to increased epiphyton, and therefore increased snail numbers feeding on the epiphyton.

Hydrobiid snails are a common part of the phytomacrofauna (Chilton 1990, Kershner and Lodge 1990, Osenberg 1989, Sheldon 1987) and *Amnicola* sp., *Physa* sp., and *Gyraulus* sp. were also the most common gastropods collected by Chilton (1990) on aquatic plants in Wisconsin. Rare species collected in this study, in addition to those already mentioned, included *Promenetus exacuous* Say and *Gyraulus deflectus* Say. *Promenetus exacuous* was collected only from Little Lake, VT and *G. deflectus* from Saratoga Lake, NY, both sites in the NE region. *Promenetus exacuous* has a large geographic range, extending from the Atlantic to Pacific coasts of North America (Jokinen 1992), and is associated with living or decaying plant material so it is not surprising to encounter specimens. The range of *G. deflectus* is much narrower, apparently only occurring in the northern U.S. and Canada (Jokinen 1992). *Melanoides tuberculata* was collected from Coleto Creek reservoir, TX, is an introduced species native to subtropical and tropical parts of Africa and Asia (Neck 1985), and was first reported in Texas in 1963 (Murray 1964). Currently, *M. tuberculata* is reportedly in at least 24 waterbodies in Texas, and may be found in 15 other states (Karatayev et al. 2008).

Although collection of some congeneric gastropods is rare in homogeneous habitats (Hershler et al. 1999), several were collected during this study. *Helisoma anceps* and *H. campanulata* were both collected from Saratoga Lake, NY and Lake Hortonia, VT, in the NE region. In addition, the physids, P. acuta and P. gyrina were collected together at Leech Lake, MN. Each site where congeneric species were found tended to support higher richness of plant species and cooler water temperatures.

Gastropod diversity and evenness, similar to overall macroinvertebrate diversity and evenness, were not statistically different between regions, but were different between sites. The sample sizes of 22 and 20 replicates per region to achieve significance in diversity and evenness, respectively, were not possible in the current study. The fact that a total of approximately 80 sites would have to be sampled in order to achieve differences, again supports the conclusion that diversity and evenness measures are not useful in comparing geographic areas with a small sample size. Rather, the observed differences between sites strengthen the argument that local variables are more important in determining diversity and evenness.

Both Saratoga Lake and Little lake had several plant species present in the vicinity of where the samples were taken and this likely contributed to the gastropod species richness observed in those sites (discussion of influences of plant diversity below). It is surprising however, that snail richness was high in Saratoga Lake, because plant samples contained large amounts of zebra mussels. Zebra mussels were observed attached, in clumps, to *H. dubia* leaves and stems in Saratoga Lake. It is possible that filtering activity by the zebra mussels produced higher water clarity, allowing light penetration and higher levels of epiphytic growth, providing food for scraping macroinvertebrates such as snails. This however, is inconclusive, because neither water clarity nor epihyton were quantified.

Similar to overall macroinvertebrate richness and gastropod density, gastropod species richness was negatively correlated with water temperature. Again, this is not surprising because, as previously mentioned, gastropods may be susceptible to toxic compounds at high water temperatures. This would potentially limit the taxa that could survive in these conditions.

Gastropod species richness was negatively correlated to conductivity while density, not richness, of macroinvertebrates appeared to be influenced by conductivity. Because water temperatures and conductivity were correlated (r = 0.696), general conclusions are difficult to make. Sites with high water temperatures also generally had higher measured conductivity values, but this still may be a local influence as opposed to a regional one and wasn't true for all sites. For example, three sites with high water temperatures, Parker ponds (water temperature = 26.9 °C), Yakima River (water temperature = 31.0 °C), and Richland Chambers (water temperature = 28.4 °C), had relatively low conductivity values of 205 µS, 285 µS, and 250 µS respectively. The correlation found between water temperature and conductivity is probably influenced by the temperature and conductivity values of the relatively less-variable UMW and NE regions (i.e. most UMW and NE sites better followed the correlation).

CA found three groups when examining both regions and sites based on gastropod species. In fact, the grouping was much more distinct than that of overall macroinvertebrate CA. The highest similarity in species composition and density was between UMW and NE, with a Cjab value of 0.98. UMW and NE shared 60% of gastropod species, including *A. limosa*, *P. acuta*, *G. parvus*, and *F. parallela*, which were found at nearly all UMW and NE sites. These results confirm that sites within UMW and NE, and the regions in general, are taxonomically similar. While LMW and NW sites are grouped very closely (Fig. 1.27; with the exception of Parker ponds), the groups are distinctly different when analyzed as regions (Fig. 1.28). This grouping of LMW/NW and UMW/NE corresponds to the general trends seen in similarity of macroinvertebrate density, diversity, evenness and richness. The lowest calculated similarity was between LMW and NE (Cjab = 0.058). In fact, LMW was dissimilar from all regions, sharing only one species, *P. acuta*, with NW, UMW, and NE. The ubiquitous species *P. acuta* was found in all regions and in all but one site (Table 1.4).

CA of sites mirrored that of regions in that most sites from LMW and NW, and UMW and NE, are grouped. Parker Ponds (NW) forms a single group when comparing sites and is likely the reason that NW and LMW sites are not more closely grouped when analyzed as regions. Due to poor species richness in some sites (i.e. Choke Canyon and Richland Chambers each had one gastropod species present), similarity values are very high. In general, when examining similarity between sites, extreme values are calculated. For example many sites do not share a single gastropod species (Coleto Creek reservoir and Parker ponds) and some share nearly all species (Apple River and Norway Lake).

Many gastropod species were collected mostly, or entirely, from the UMW and NE regions. These included *A. limosa* (solely from the UMW and NE), *G. parvus* (only found at two NW sites, the rest collected in UMW or NE), and *H. anceps* (only found in UMW and NE). Four species, *V. tricarinata*, *P. exacuous*, *H. campanulata*, and *G. deflectus* were collected from only one or two sites each, but all from the NE. In general, the NE had the highest gastropod species richness of any region.

Although the NW had the second worst species richness, the Intermountain West historically supports a high diversity of gastropods (Hershler et al. 2007). *Fluminicola fuscus*, collected from only two sites during this study (Yakima River, and Selah Pond, WA) has a narrow range of the northwestern U.S. In fact, *F. fuscus* is originally found from the Columbia River basin and is now believed to be extinct in several areas of the River. *Fluminicola* generally are found in clean, flowing, highly oxygenated waters (Hershler et al. 2007) and so it is surprising to find *F. fuscus* associated with vegetation in a pond with very low gastropod species richness of two. In fact, the other species collected from Selah Pond was *P. acuta*, a holartic species adaptable to a wide range of habitats and conditions.

Overall, it is not surprising to find the distinct gastropod species assemblages differentiated by regions. Gastropod dispersal abilities, life histories, and environmental requirements are not as well suited for long distance dispersal as many other macroinvertebrate groups, and leads to high levels of endemism and the great diversity of gastropod species found in the U.S. (Lysne et al. 2008).

Functional Feeding Groups

There was a strong pattern of functional groups found on *H. dubia* during this study. Collector-gatherers were consistently the most abundant group, with the exception of the LMW sites. Although sampling took place over the course of the summer, and a pattern was found, it has been shown that the ratios of functional groups change seasonally (Chilton 1990). In addition, though relative degree days were substantially different among regions, it appears that sample timing was close enough to avoid temporal differences in functional feeding groups. Also, although taxa similarity was low between sites, the functional groups remained relatively constant throughout the study. This allows for generalizations about how aquatic plants are used by macroinvertebrates.

Macrophytes have recently been recognized for their importance to aquatic systems, and in addition to providing food for primary consumers, they provide substrate for predatory macroinvertebrates, epiphyton feeding organisms like scrapers and collector-gatherers, and even for collector-filterers. The majority of collector-filterers were collected from two lotic sites, which is not surprising because of the need for flow to obtain food. Although often overlooked, investigation of functional groups associated with macrophyte beds is important because invertebrates provide the link between primary producers and consumers, and are very productive (Balci and Kennedy 2003). This type of examination could provide researchers with information and perhaps a starting point for future trophic-level and energy transfer research in macrophyte beds.

Although among all sites, collector-gatherers were the dominant functional feeding group, shredders were the most abundant group (34.77% of total) in LMW. This shift from the rest of the regions sampled might be due to the water quality in LMW sites, because LMW sites had the highest conductivity and water temperatures. LMW shredders were largely composed of chironomids (mainly *Glyptotendipes*), of which some groups are more tolerant to poor environmental conditions than others (Blocksom and Winters 2006).

Macroinvertebrate variability is not only dependent on environmental factors, but often temporal factors come into play (Chilton 1990), such as photoperiod, minimum air temperature, and salinity. Sample dates were chosen so that southern sites were sampled first, and would have comparable degree days to more northern sites which were sampled later in the season. Although the goal was to provide the most appropriate sampling schedule based on degree days, LMW sites had already accumulated a great deal more degree days by the sample date, nearly three weeks earlier than NW and a month and a half to two months before UMW and NE, respectively. Air temperatures in LMW sites had already exceeded 38 °C by the first week of July (Fig. 1.36), and most other sites never reached those temperatures during the entire season.

Natural vs. Man-Made Waterbodies

Macroinvertebrate density was found to be significantly higher in natural as opposed to man-made sites. It is not clear, however, if this difference is attributable to the natural/manmade variable or geographic location. For instance, all three LMW sites and two NW sites are man-made (i.e. 83% of all LMW and NW sites), so it is not possible to distinguish between a natural/ man-made difference and differences noted earlier based on temperature, conductivity, etc. It is probable that Texas reservoirs are generally poor habitats for aquatic plant-dwelling invertebrates because they are often geographically isolated from potential source populations of native aquatic plants or insects (Smart and Dick 1999), and because of water quality parameters such as temperature and conductivity.

There does appear to be a trend in what taxa are shared between natural and manmade sites. While 45.6% of collected taxa overall are shared between natural and manmade lakes (when examining all sites in all regions), the same trend is seen within regions that are otherwise taxonomically similar. Because of their similarity of community composition and structure previously discussed, we can examine the differences in natural and manmade lakes in the UMW/NE separately from LMW/NW. UMW/NE natural and manmade sites share 44% of taxa. Because UMW and NE macroinvertebrate communities were found to be similar overall, it does appear that the natural or man-made status of a waterbody influences taxa present. Despite this trend, and because the available sample size is low, the evidence is insufficient to make determinations regarding differences in community structure based on the natural or man-made status of the waterbodies in this study.

Lotic vs. Lentic

Higher macroinvertebrate density at lotic sites might occur because food materials are transported downstream and plant beds may act as a ‘filter’, trapping food particles for macroinvertebrates. Organisms that inhabit macrophyte beds in flowing water are likely to not only be protected from the force of the current, but also have coarse and fine particulate organic matter collected for them by the plant bed. Nutrient transport, along with high dissolved oxygen in flowing waters may also support epiphyton, which explains the higher snail and collector-gatherer relative abundance at lotic sites (Fig. 1.33).

Plant Bed Diversity

The statistically significant difference in taxa richness between sites with "1-2" plant species and ">2" plant species (Fig. 1.35) was expected because complex habitats are normally richer in species (Downes et al. 1998). Because all LMW sites had 1-2 plant species present, and also low macroinvertebrate diversity and richness, it is not possible to correlate either invertebrate diversity or richness with increasing plant richness in the current study, but others have done so (Downes et al. 1998). In addition, one could argue that the structural difference between 1-2 species and >2 species may not be much, and the structure of the species themselves may be just as important as the number of species present. The fact that all LMW sites had such poor plant species richness has been addressed by the U.S. Army Corps of Engineers, who are working to establish native plant communities in reservoirs throughout the south (Smart et al. 1996). The lack of significant differences in diversity and evenness are due to small sample size at each site and too few sites of differing plant species diversity. Future work regarding the affect of plant diversity on macroinvertebrate community structure should include multiple sites of varying degrees of plant diversity, in contrast to the two categories used here.

Conclusion and Future Research

Although not examined, future research would benefit from an examination of insect communities associated with aquatic plants based on different distances from source populations. Applying the conventional theory of island biogeography would aid in further understanding the importance of plant species and diversity in determining macroinvertebrate community composition. While patterns in macroinvertebrate community composition and functional groups were found in the present study, research that examines differences in aquatic insect communities over a distance and plant diversity gradient would provide valuable insight into the complex relationship between aquatic insect colonization and importance of plant species. For example, is the density of waterbodies in a region more important to the insect community composition than plant species present or habitat complexity? During this study, a wide variety of sites were sampled but despite the different types of waterbodies (lakes, ponds, rivers) *H. dubia* was utilized in much the same way at each site and in each region.

Overall, the most important measures of difference in macroinvertebrate communities depend on the scale of analysis. When comparing regional communities, regional variables are important, such as temperature. Density of waterbodies also likely plays a substantial role in regional species richness, diversity and evenness, but waterbody density is probably influenced by the natural state/ age of the waterbodies in the region. In general, differences were not found between regions using basic diversity/evenness measures. When comparing sites, even sites separate by a large geographic distance, local variables are important. Although regional factors, such as species pools, will be reflected in the taxa present, they are less important when comparing distant sites based on density, diversity, etc. Local variables, such as land-use and conductivity, are more important to the structure of macroinvertebrate communities.

Another method of comparing sites that relies on local variables, more than regional ones, is functional group analysis. Although functional group analysis of macroinvertebrates occupying macrophyte beds is not common, it appears that there are patterns that exist in macrophyte use, and this type of examination may prove useful to conservation efforts and in attempts to identify disturbed sites. In general, there is a trend that collector-gatherers and scrapers are the most abundant (in both density and relative abundance) and collector-filterers are the least abundant groups collected from *H. dubia*, though this is dependent on the flow regime being sampled. Because there is not much site to site or regional variation in the relative abundances of functional groups collected from *H. dubia*, there is potential for their use in site assessment. Future work should focus on year-round functional group variation from plant species to plant species because variables such as leaf architecture and palatability, in addition to season, may play a role in the ratios of groups present. This would provide information as to how/if functional groups change relative to one another as plants senesce or die-back in winter months as well as if groups change temporally based on plant species.

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Figure 1.1. Bed of *H. dubia* on the Lower Rio Grande River, Texas. Photo courtesy of Chetta Owens.

Figure 1.2. Close-up photograph of *H. dubia* flower.

Figure 1.3. *H*. *dubia* collection sites in the United States.

Figure 1.4. Mesh bag sampling device used to sample macrophytes and associated macroinvertebrates.

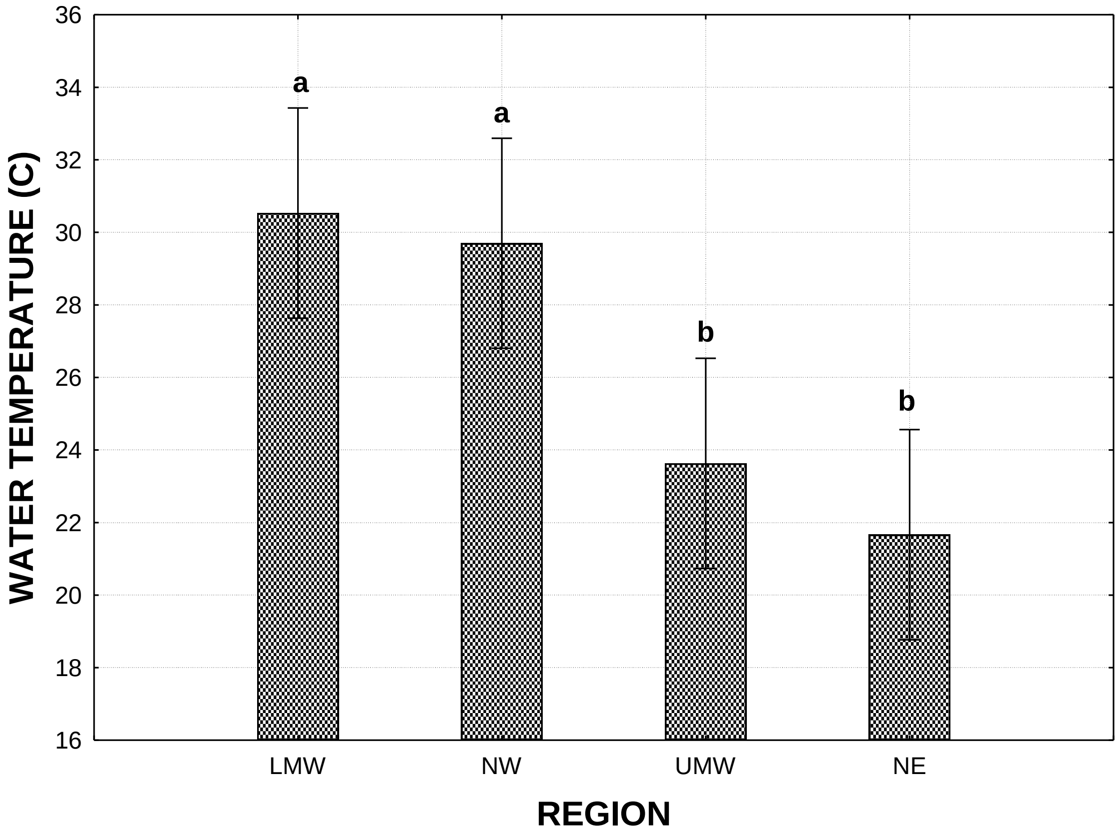

Figure 1.5. Mean water temperature among regions sampled (one-way ANOVA, df = 3,8 , F = 12.26, $P < 0.05$).Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

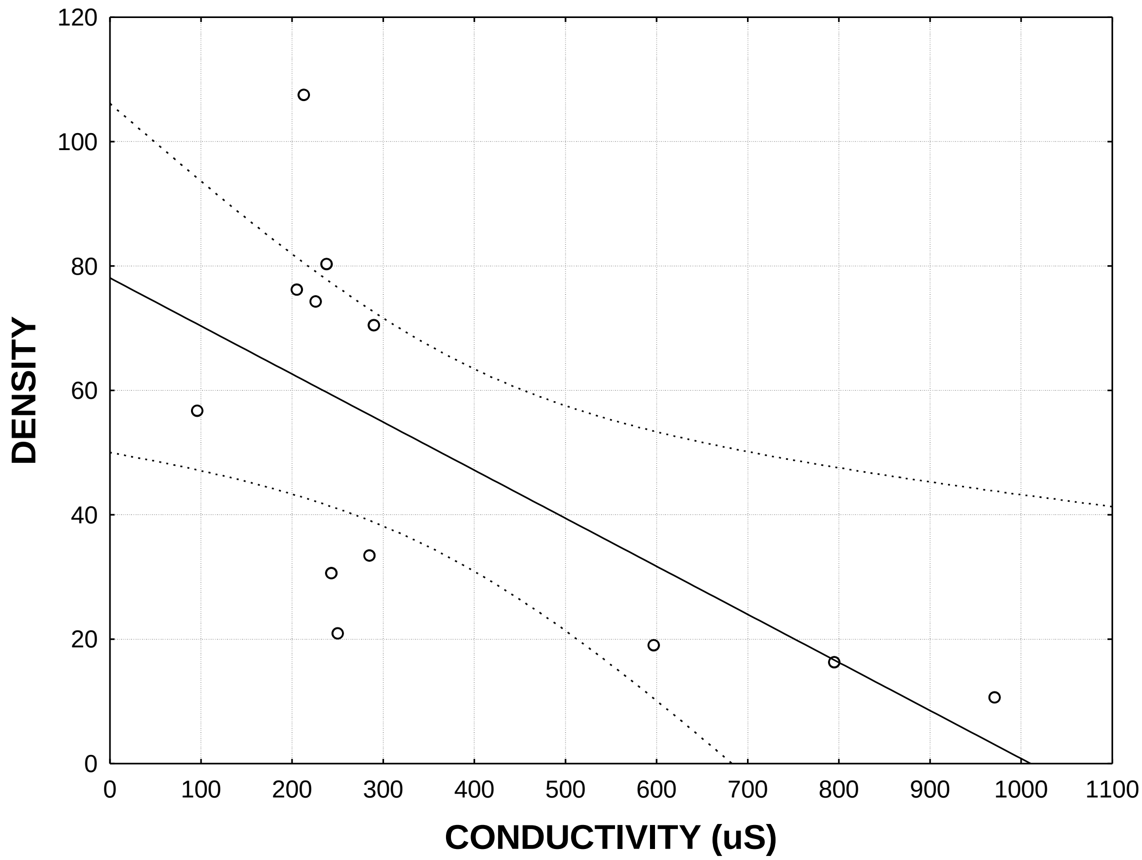

Figure 1.6. Pearson's product moment correlation between conductivity and invertebrate density overall (*r* = -0.67, P < 0.05), with 0.95 confidence bands.

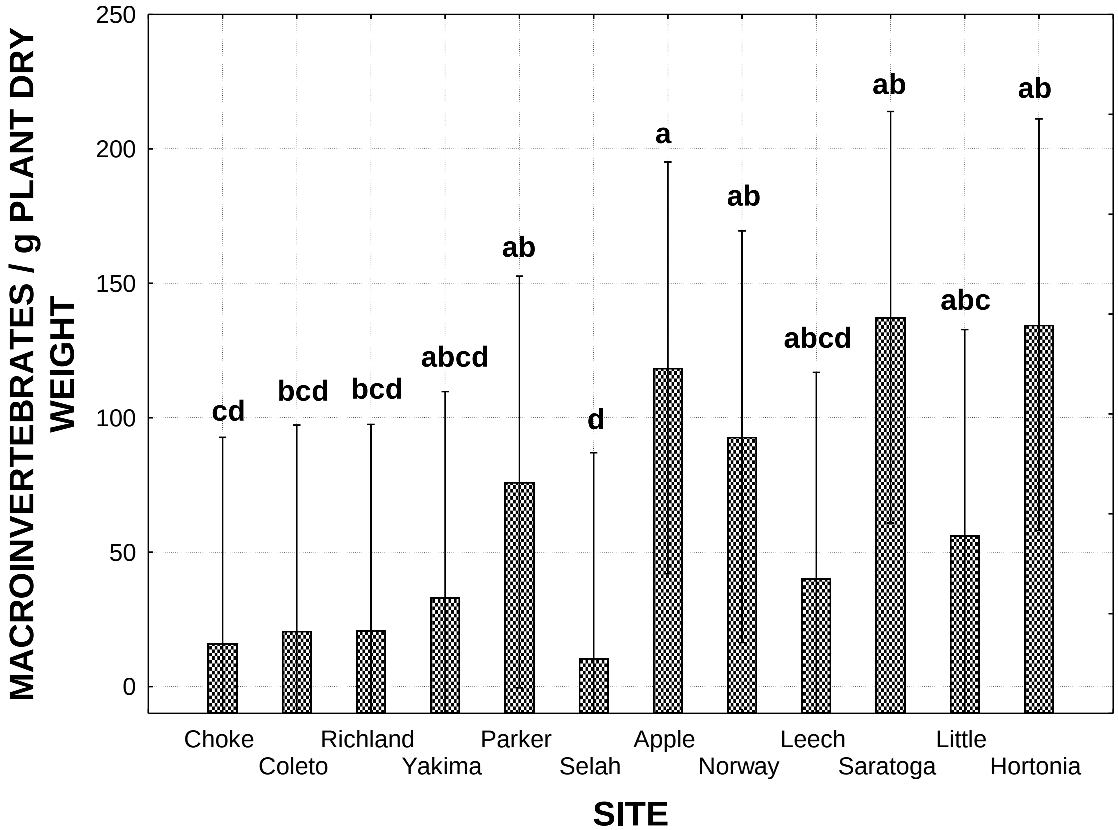

Figure 1.7. Mean invertebrate density between sites sampled (one-way ANOVA, df = 11,24 , F = 6.39, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

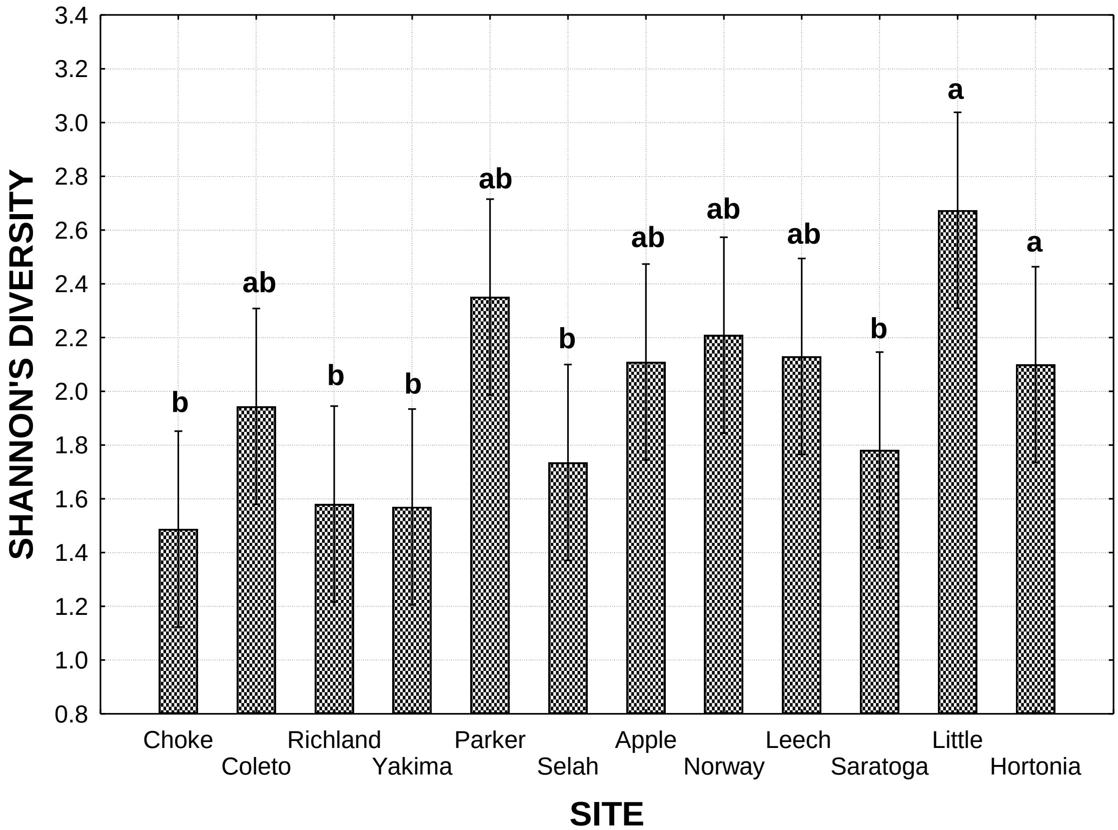

Figure 1.8. Mean macroinvertebrate diversity (Shannon's index) between all sites (one-way ANOVA, df = 11, 24, F = 4.06, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

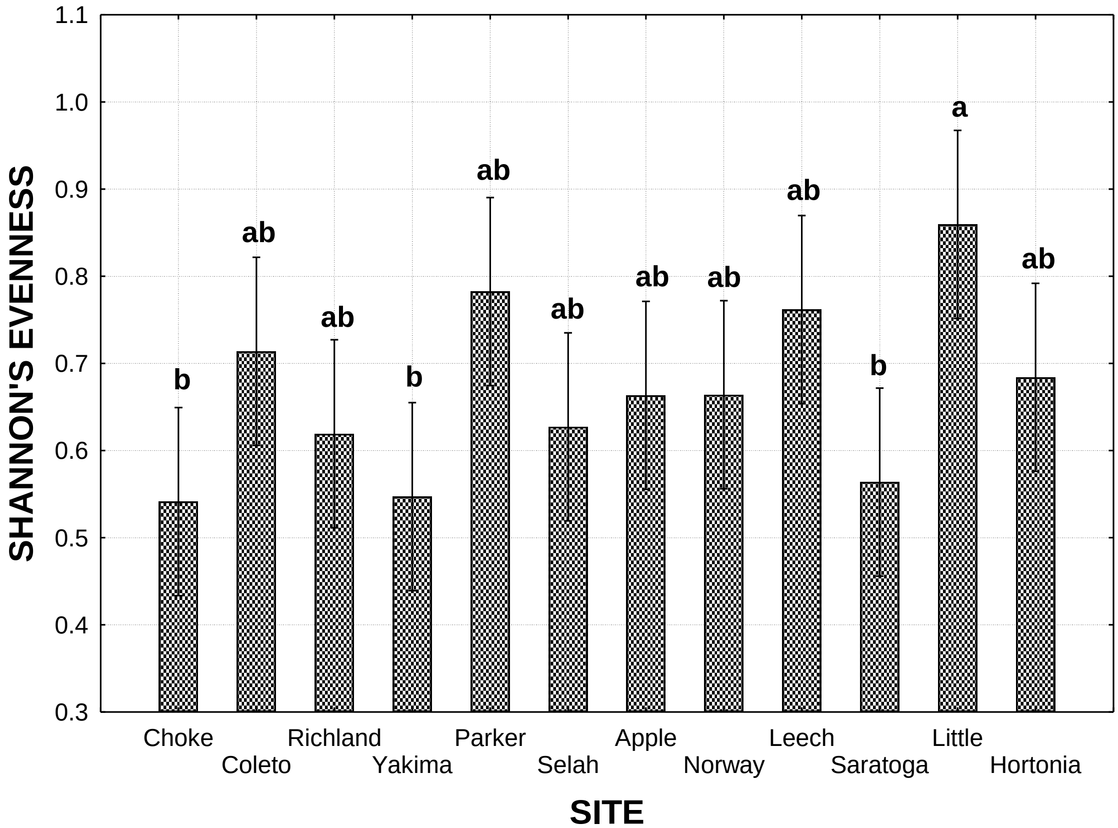

Figure 1.9. Mean macroinvertebrate evenness (Shannon's index) between all sites (one-way ANOVA, df = 11, 24, F = 3.54, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

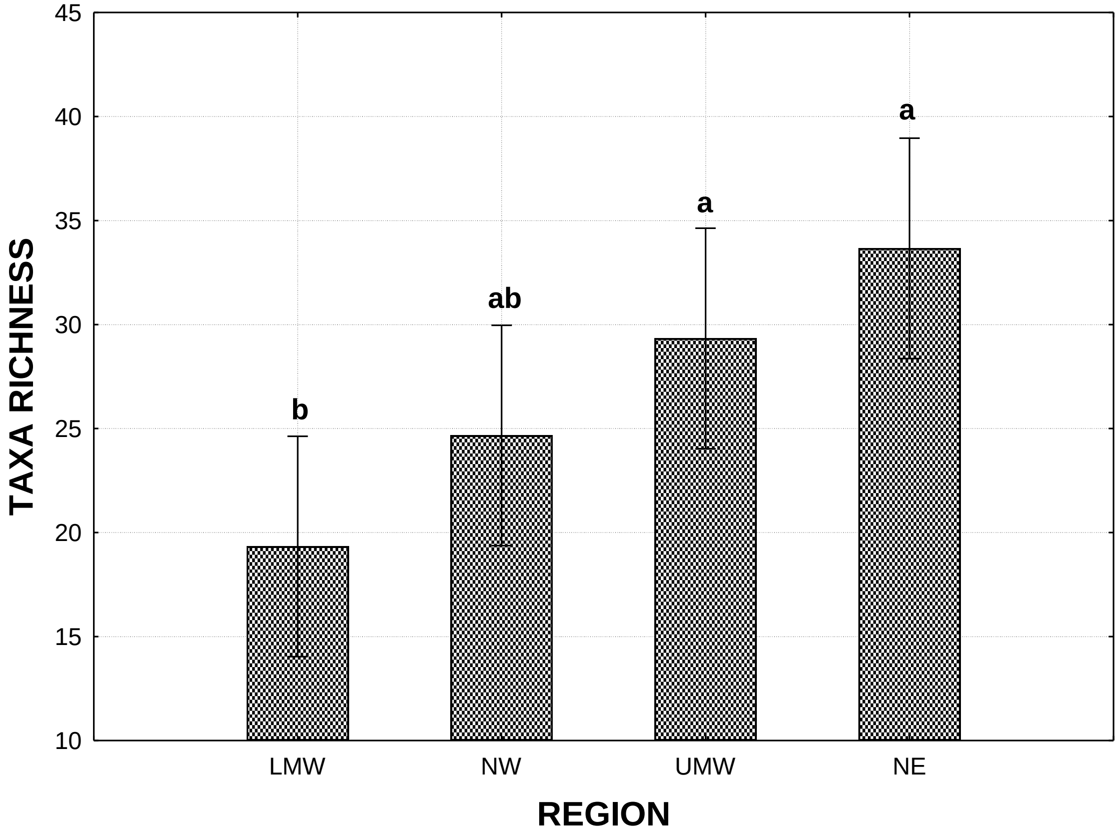

Figure 1.10. Mean macroinvertebrate taxa richness among regions sampled (one-way ANOVA, df = 3, 8, F = 7.19, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

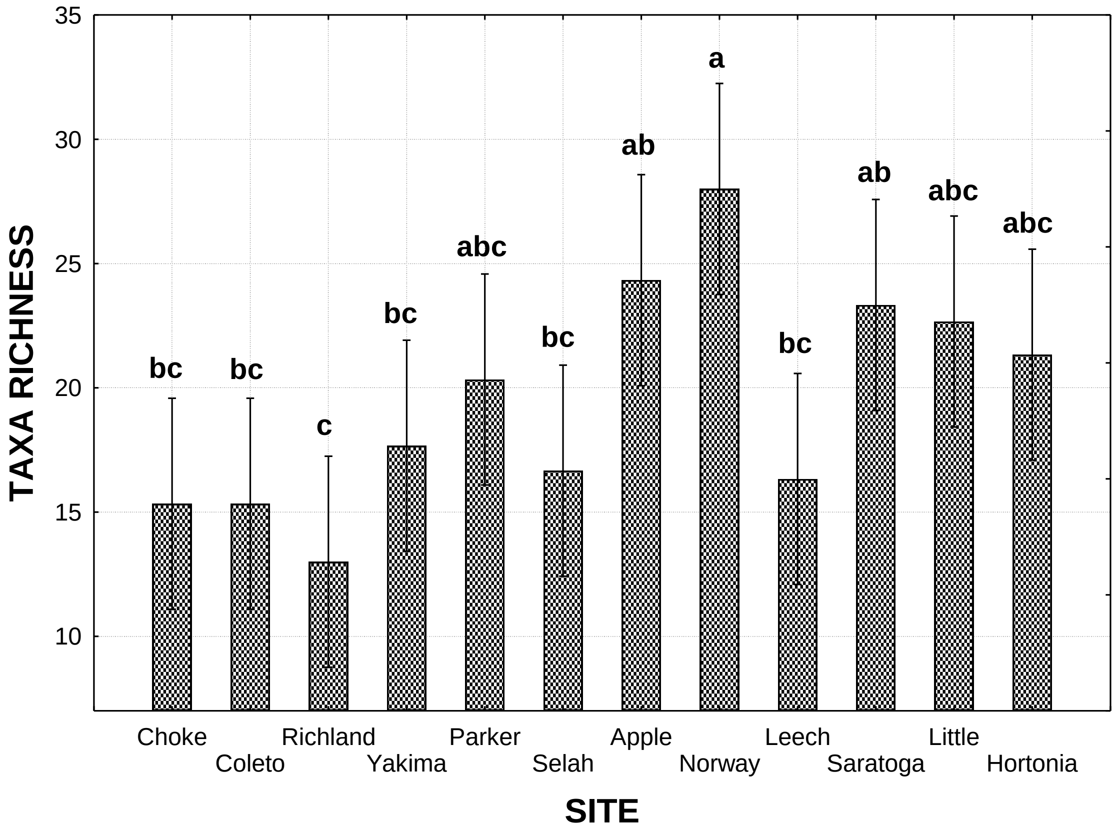

Figure 1.11. Mean macroinvertebrate taxa richness among all sites (one-way ANOVA, df = 11, 24, F = 4.79, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

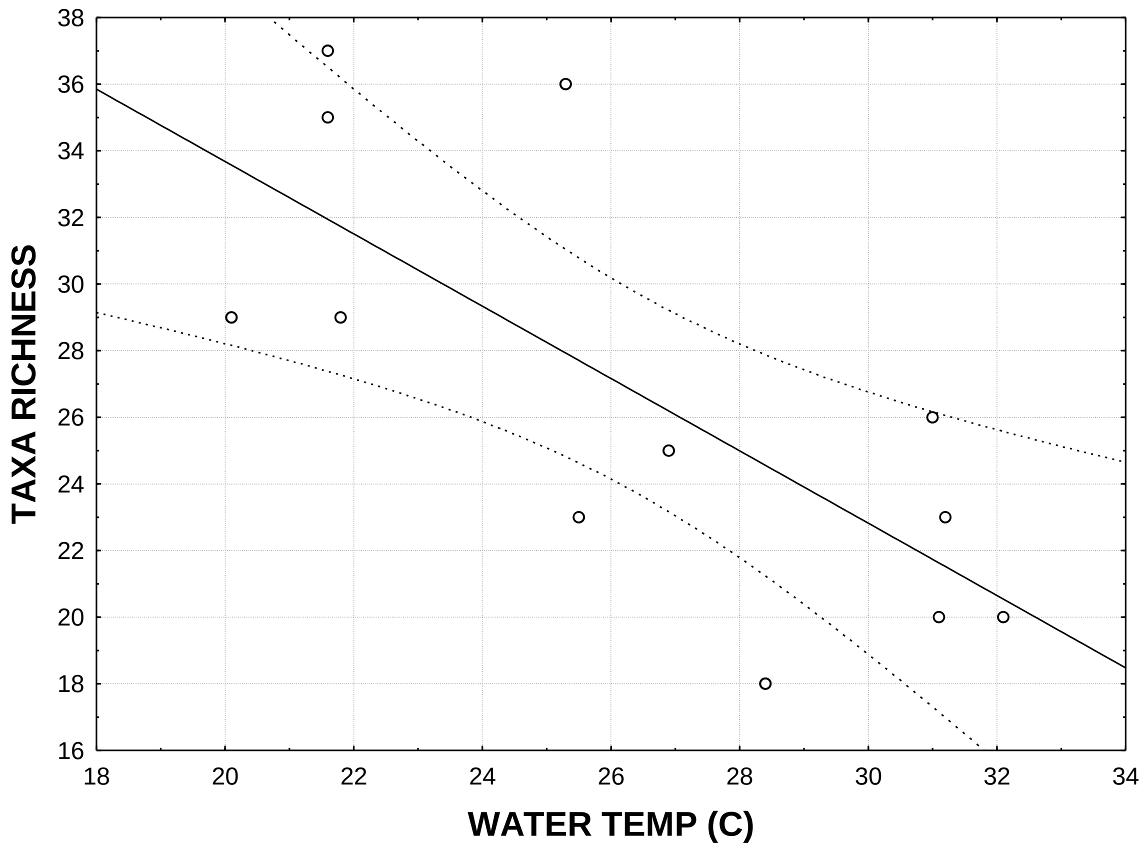

Figure 1.12. Pearson's product moment correlation between taxa richness and water temperature (r = -0.73, P < 0.05), with 0.95 confidence bands.

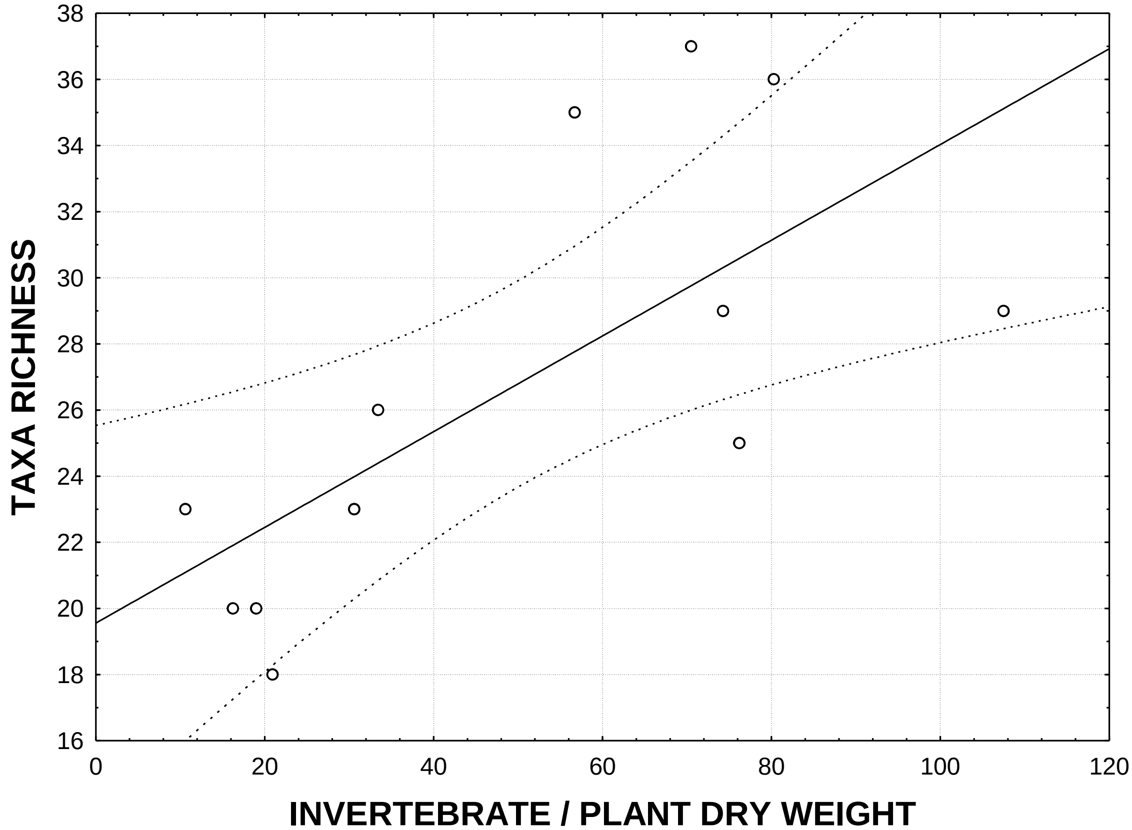

Figure 1.13. Pearson's product moment correlation between taxa richness and invertebrate density (r = 0.71, P < 0.05), with 0.95 confidence bands.

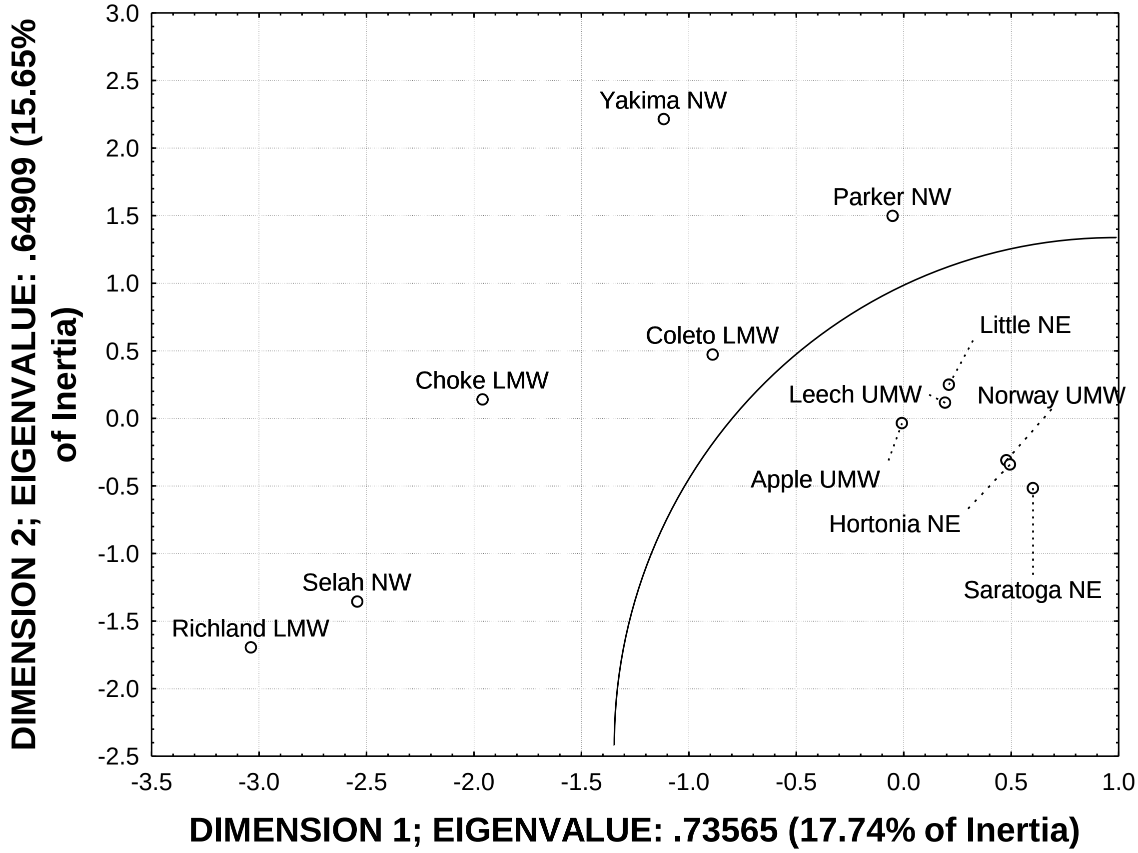

Figure 1.14. Correspondence analysis ordination of taxa and sites. Points are labeled as to the site and region sampled. Axis 1 & 2 explained a total of 33.39% of total inertia (variance).

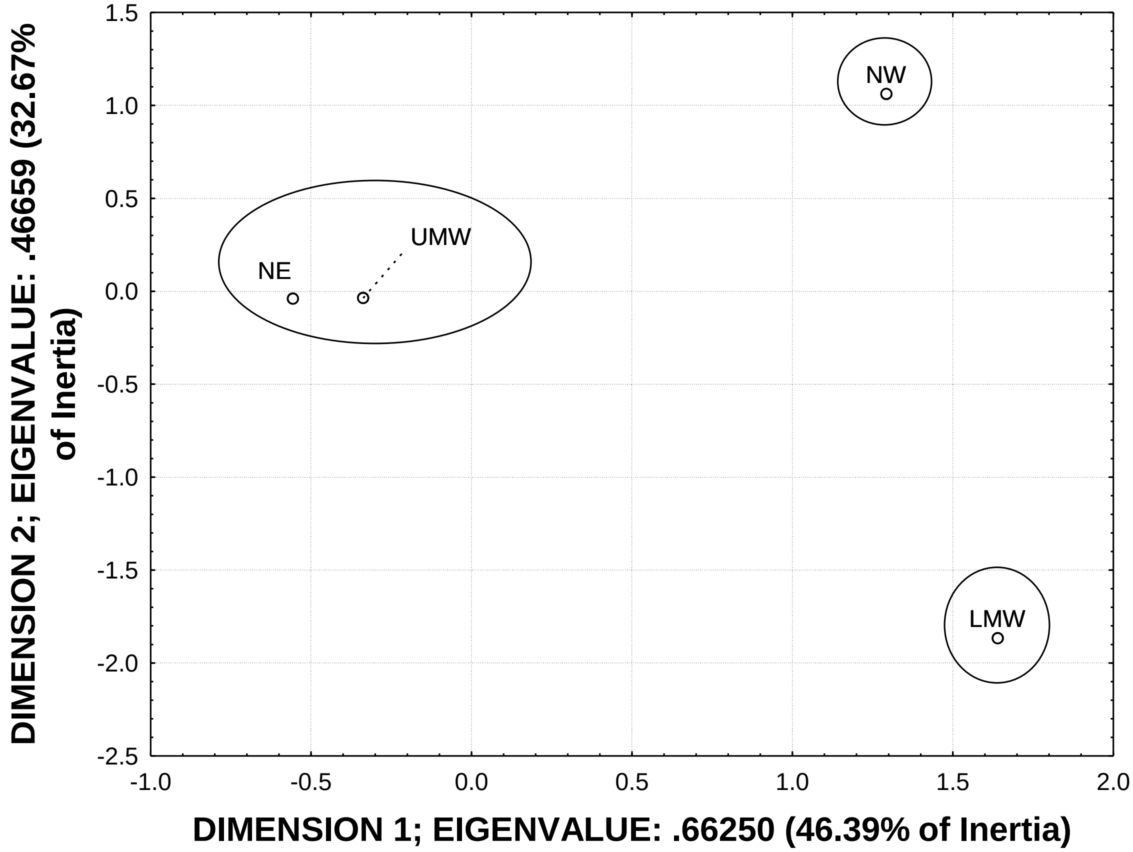

Figure 1.15. Correspondence analysis ordination of taxa and sites. Points are labeled as to the site and region sampled. Axis 1 & 2 explained a total of 79.06% of total inertia (variance).

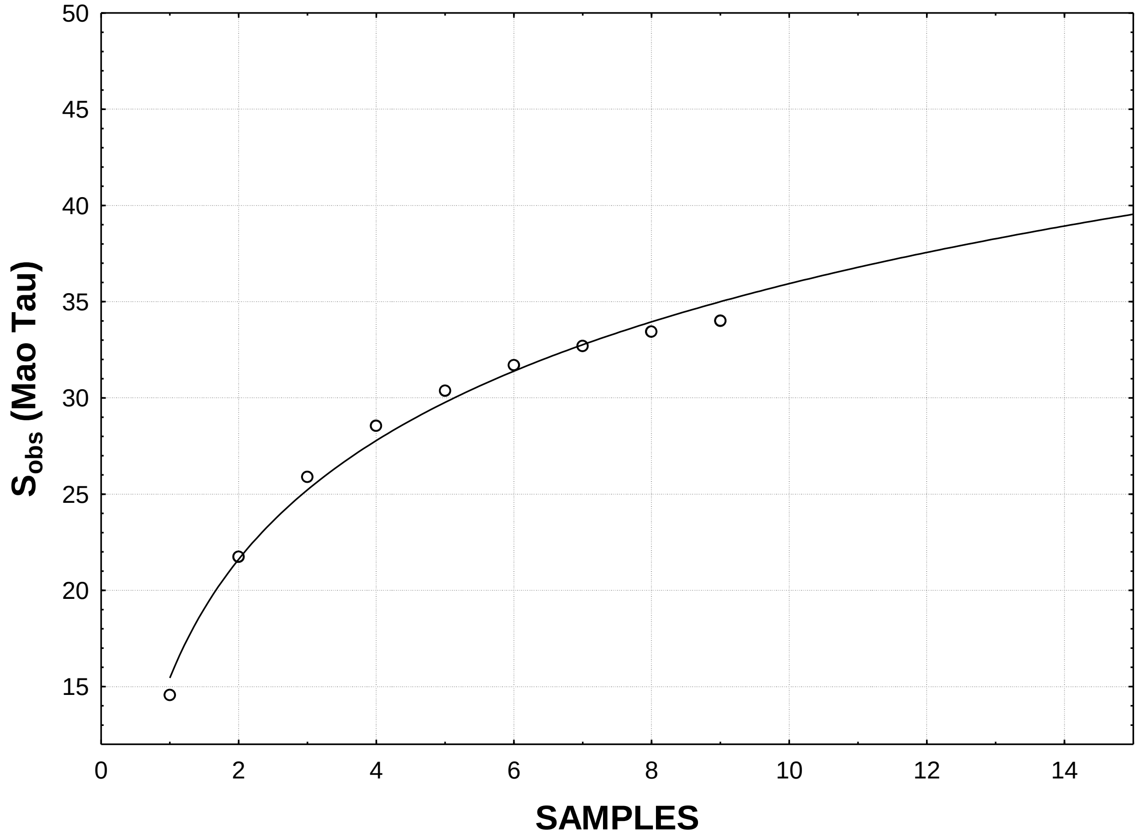

Figure 1.16. Sample-based rarefaction curve for LMW sites displaying the number of accumulated taxa collected with increasing sample size. S_{obs} (Mao Tau) is the number of cumulative observed taxa.

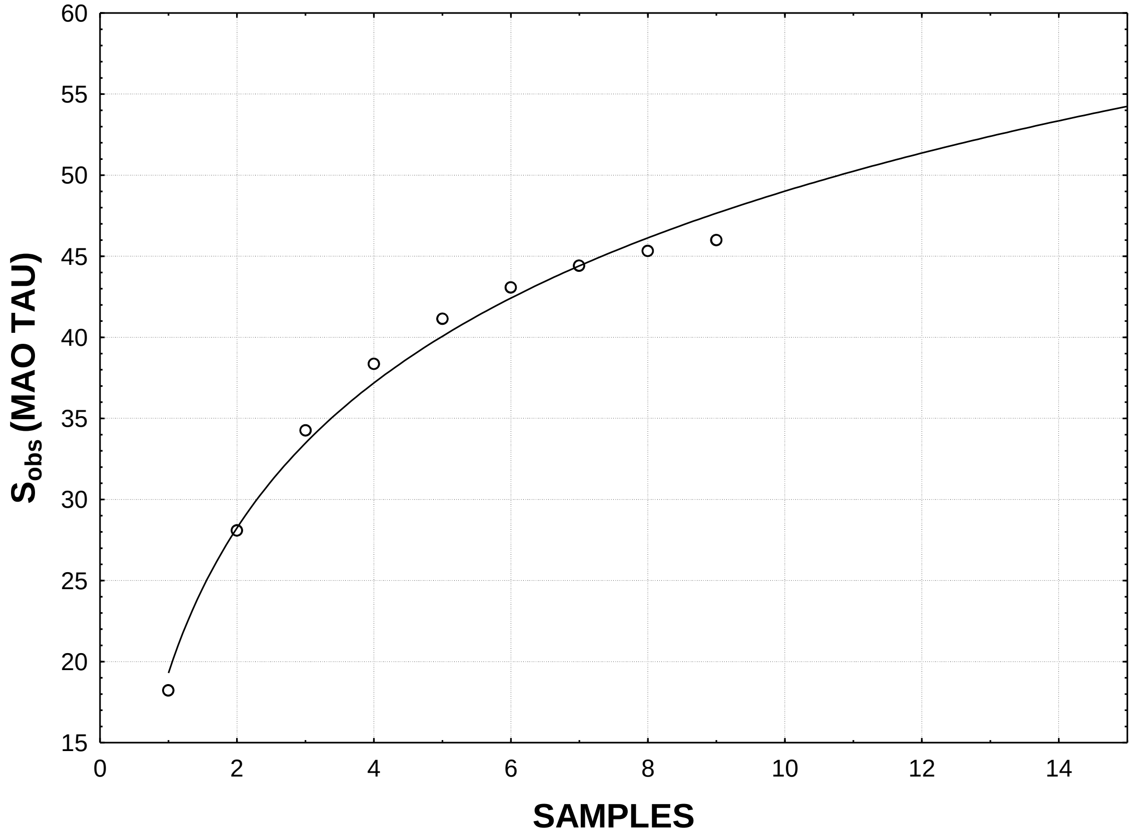

Figure 1.17. Sample-based rarefaction curve for NW sites displaying the number of accumulated taxa collected with increasing sample size. S_{obs} (Mao Tau) is the number of cumulative observed taxa.

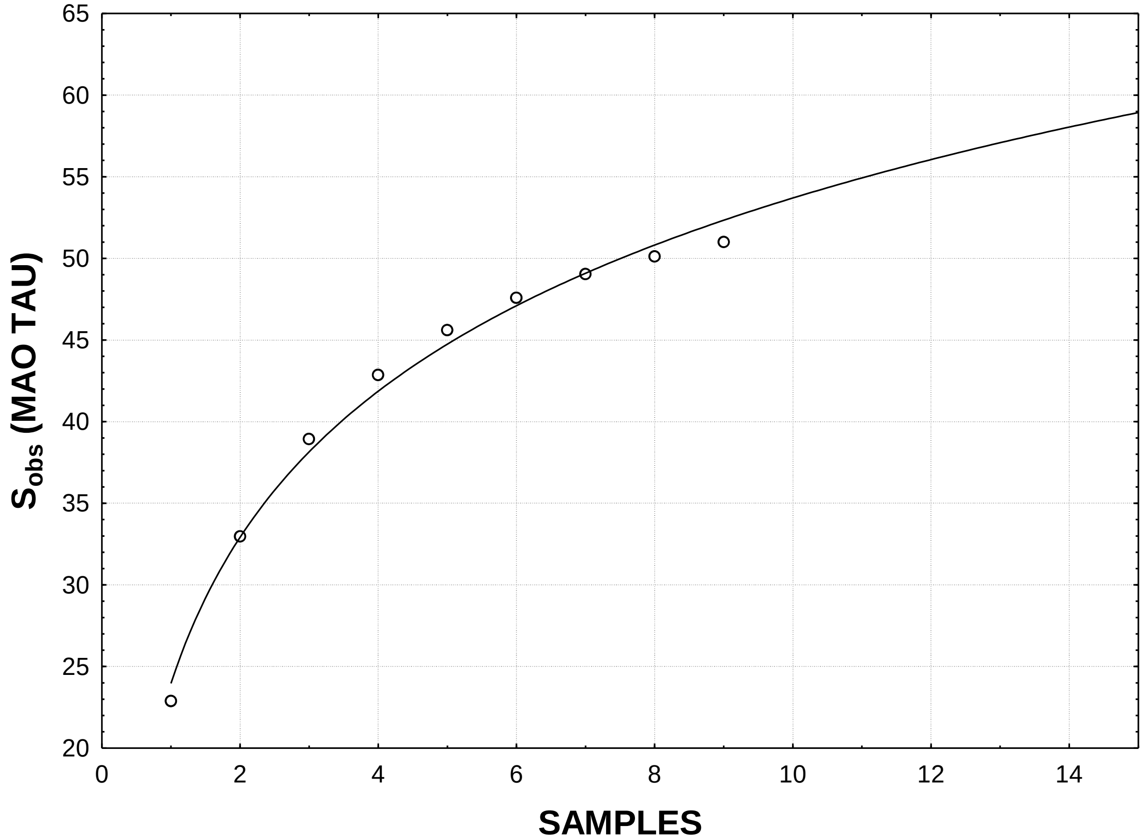

Figure 1.18. Sample-based rarefaction curve for UMW sites displaying the number of accumulated taxa collected with increasing sample size. S_{obs} (Mao Tau) is the number of cumulative observed taxa.

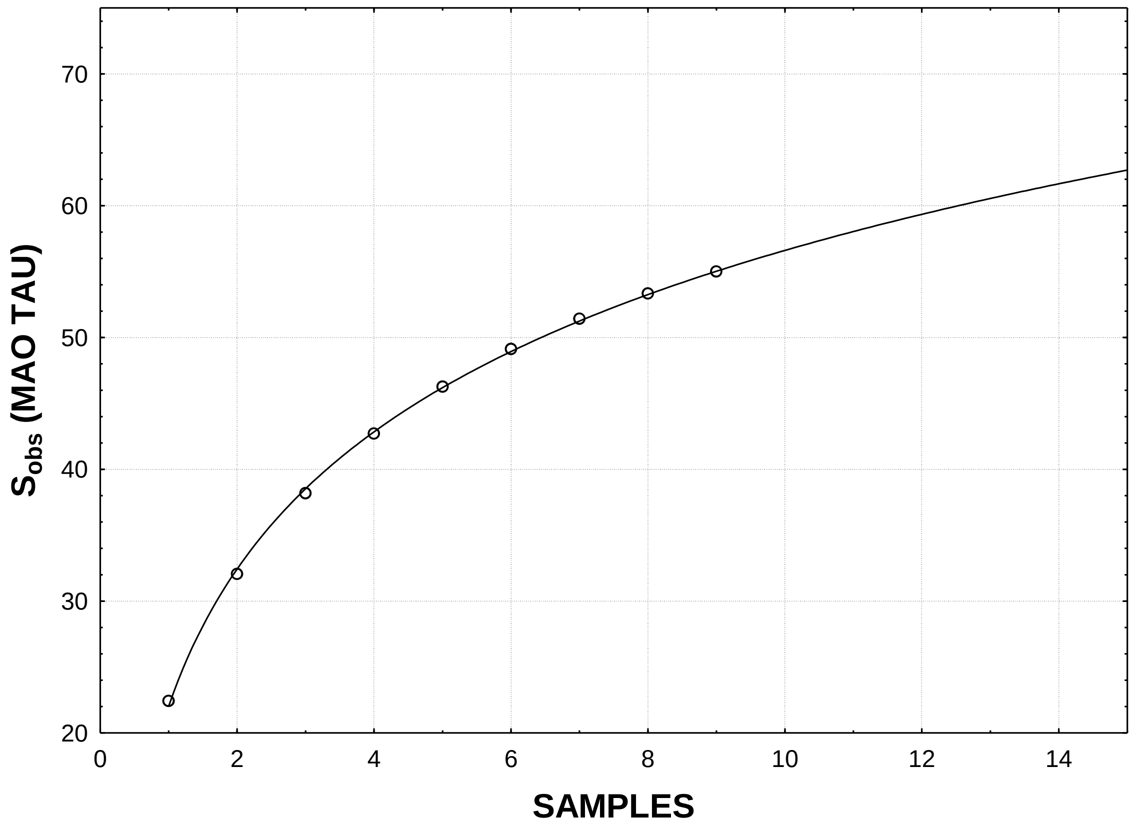

Figure 1.19. Sample-based rarefaction curve for NE sites displaying the number of accumulated taxa collected with increasing sample size. S_{obs} (Mao Tau) is the number of cumulative observed taxa.

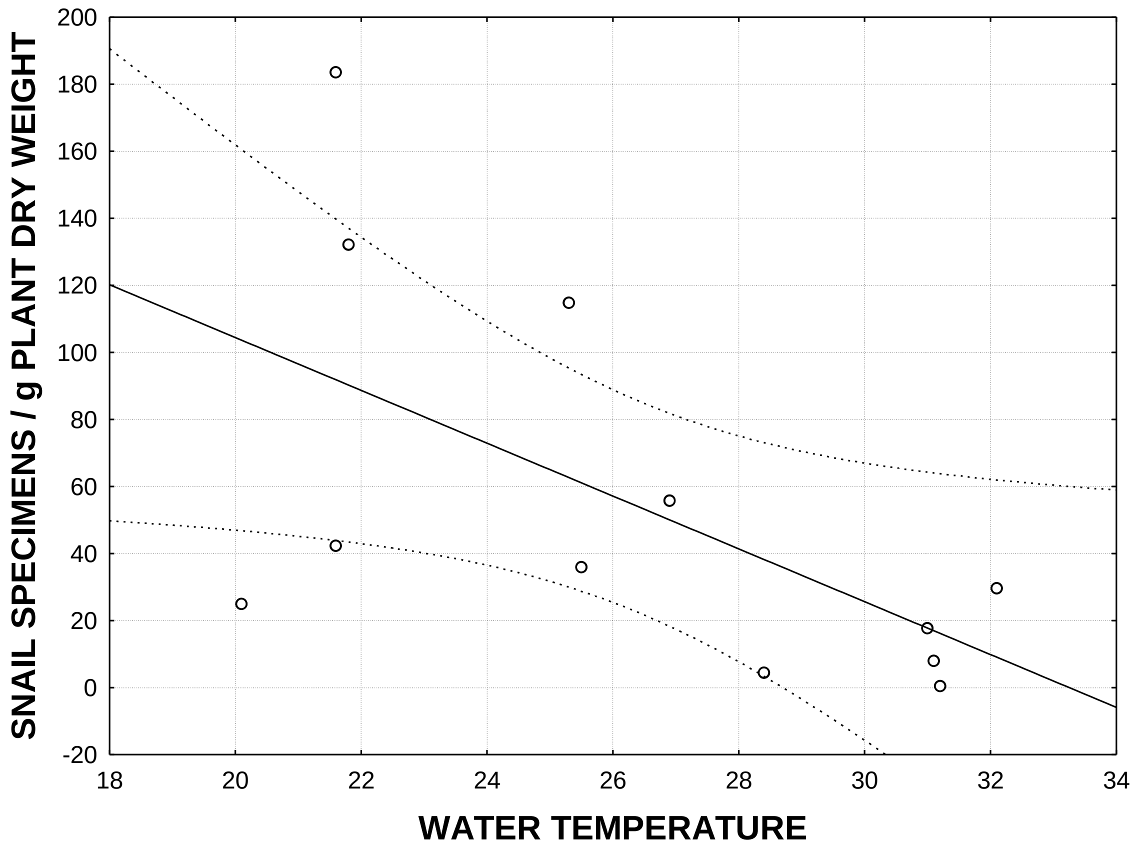

Figure 1.20. Pearson's product moment correlation between water temperature and snail density overall (r = -0.59, P < 0.05), with 0.95 confidence bands.

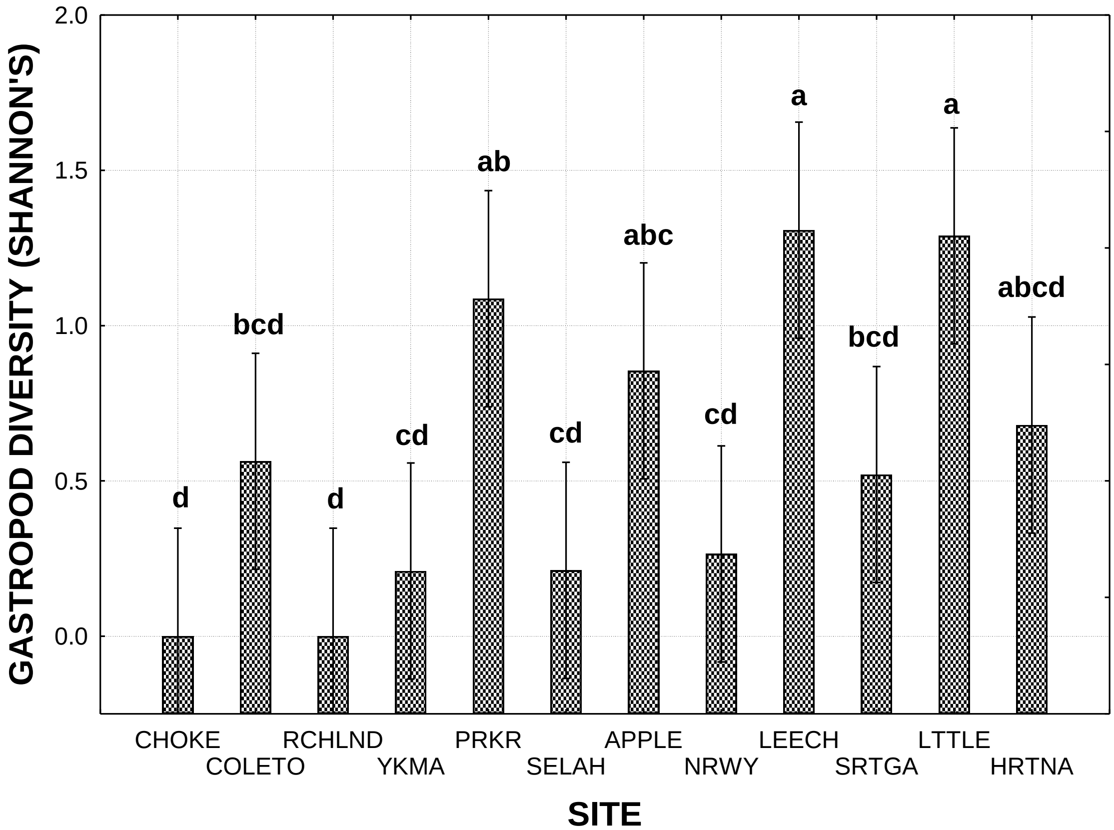

Figure 1.21. Mean gastropod diversity compared between regions (one-way ANOVA, df = 11, 24, F = 7.75, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

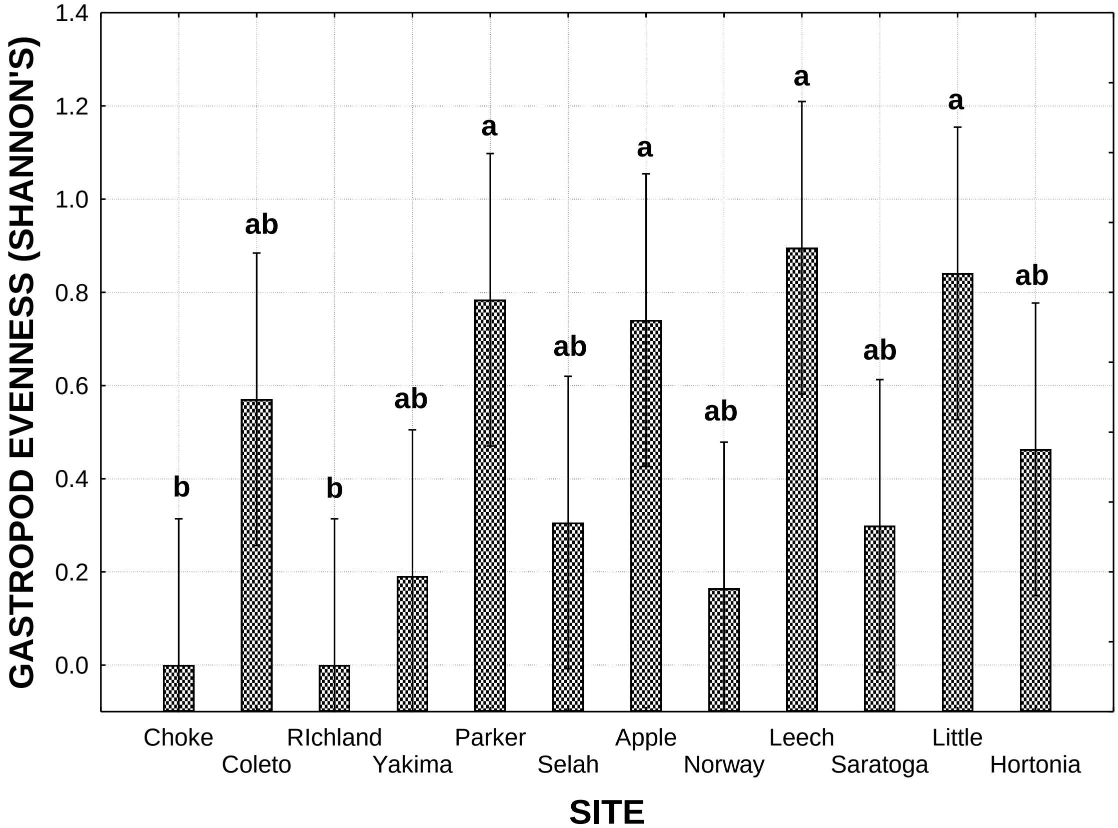

Figure 1.22. Mean gastropod evenness compared between regions (one-way ANOVA, df = 11, 24, F = 4.55, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

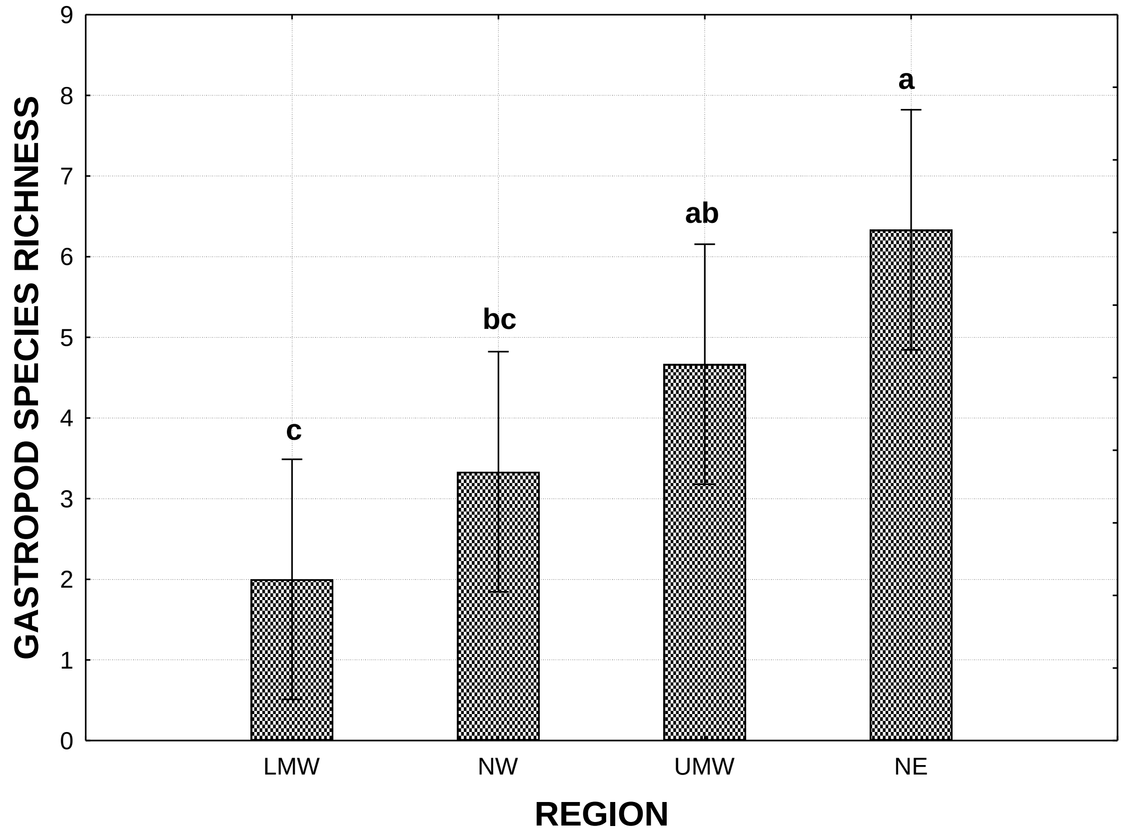

Figure 1.23. Mean gastropod species richness compared between regions (one-way ANOVA, df = 3, 8, F = 8.24, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

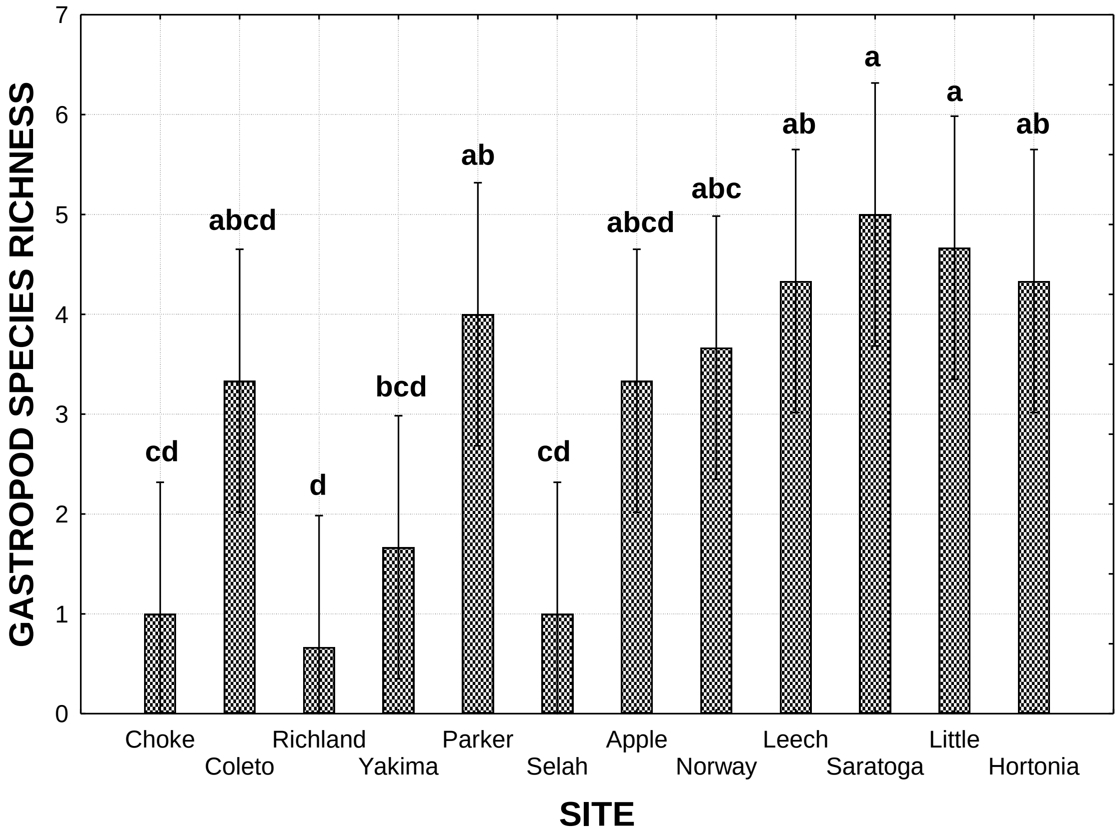

Figure 1.24. Mean gastropod species richness compared between sites (one-way ANOVA, df = 11, 24, F = 6.06, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

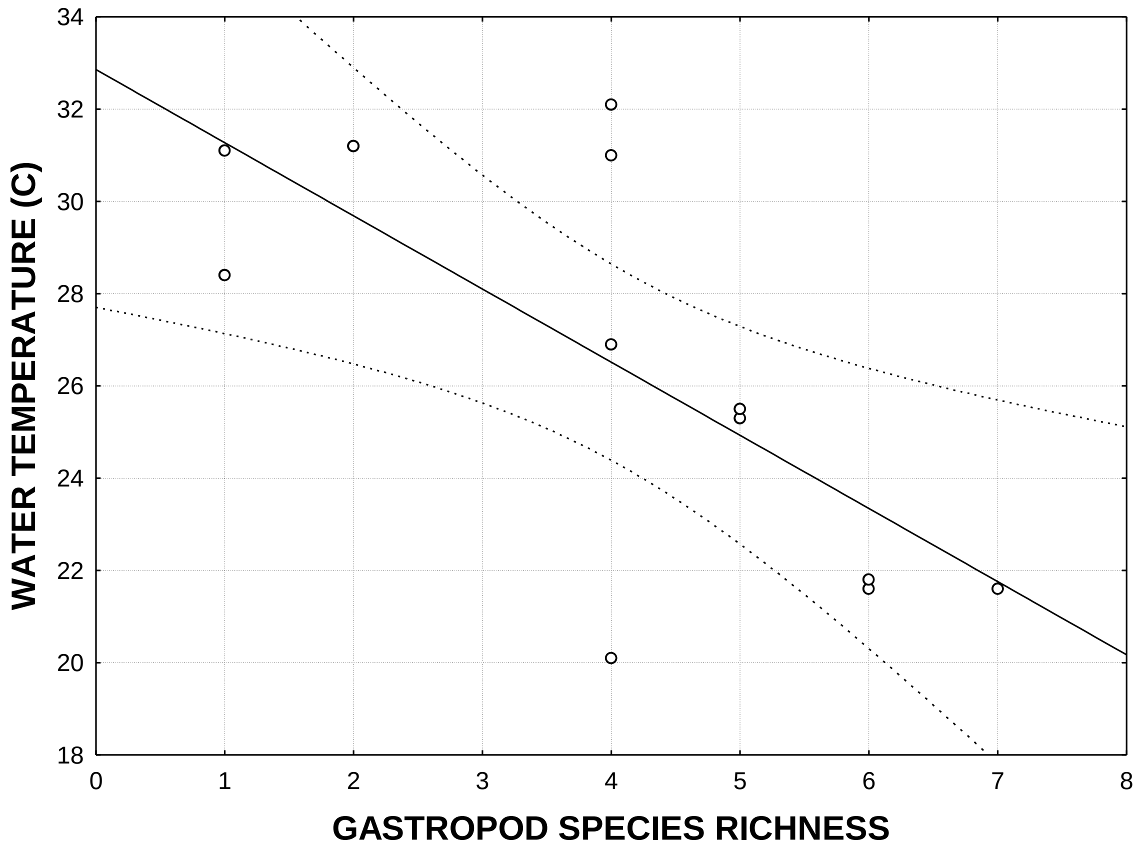

Figure 1.25. Pearson's product moment correlation between water temperature and gastropod species richness overall (r = -0.70, P < 0.05), with 0.95 confidence bands.

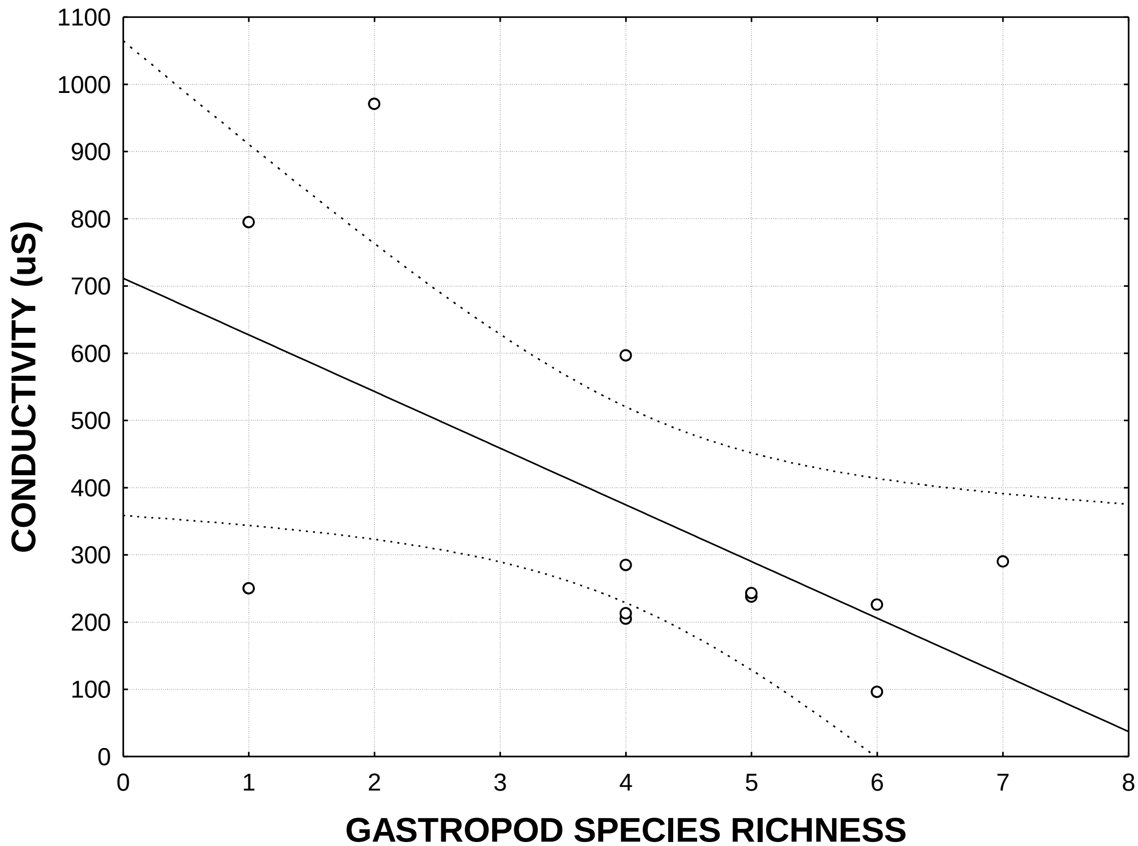

Figure 1.26. Pearson's product moment correlation between conductivity and gastropod species richness overall (r = -0.60, P < 0.05), with 0.95 confidence bands.

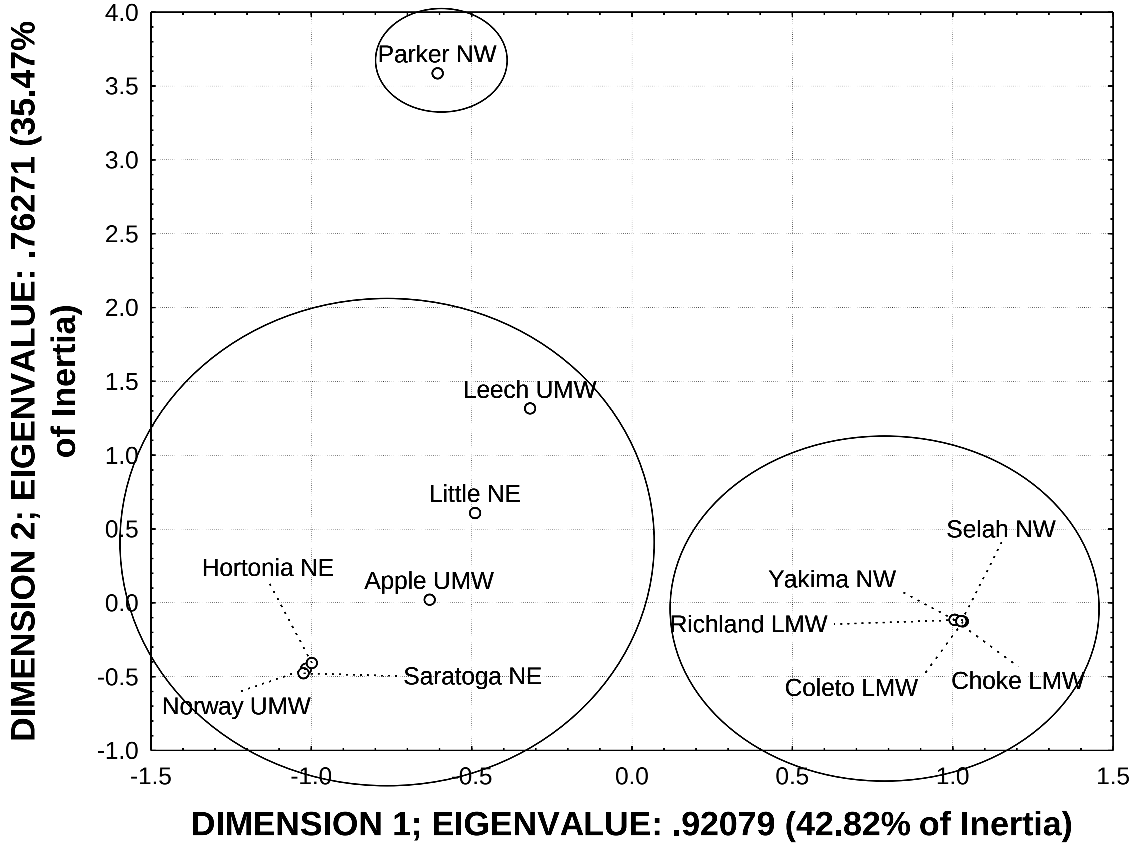

Figure 1.27. Correspondence analysis ordination of gastropod species and sites. Points are labeled as to the site and region sampled. Axis 1 & 2 explained a total of 78.29% of total inertia (variance).

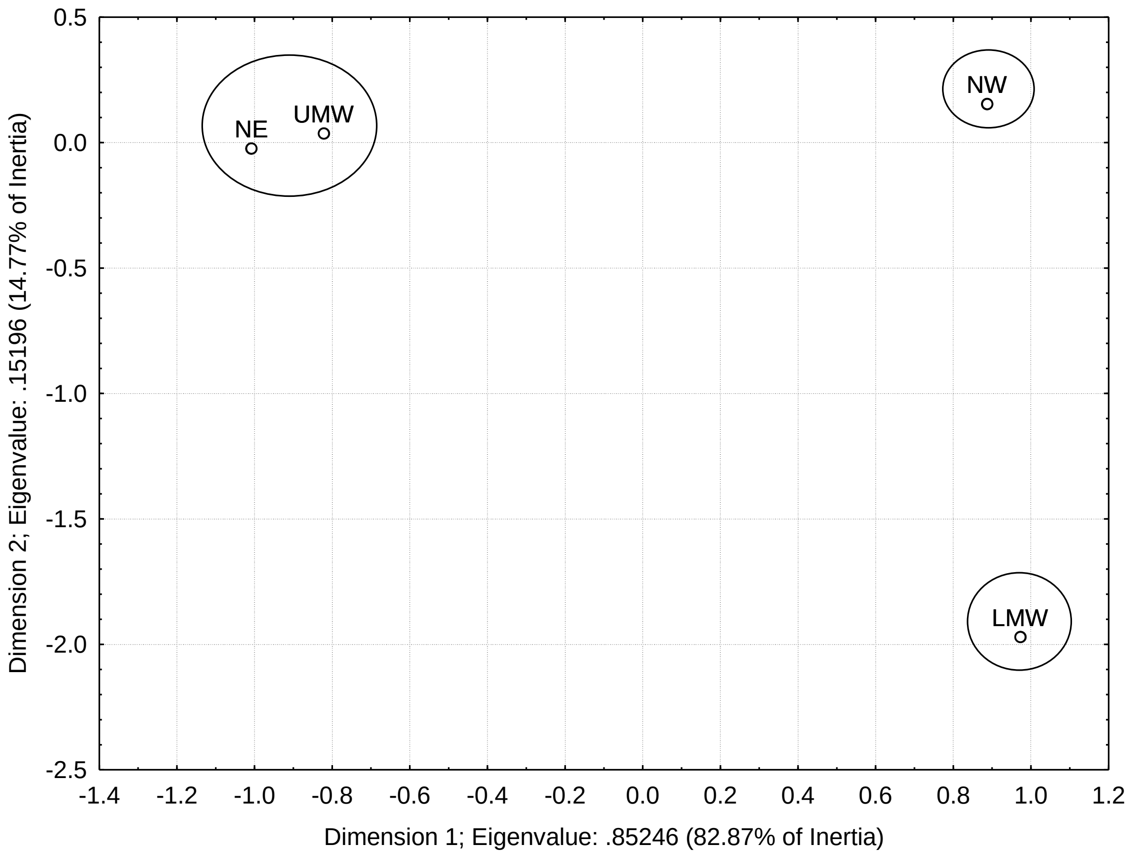

Figure 1.28. Correspondence analysis ordination of gastropod species and regions. Points are labeled as to the region sampled. Axis 1 & 2 explained a total of 97.64% of total inertia (variance).

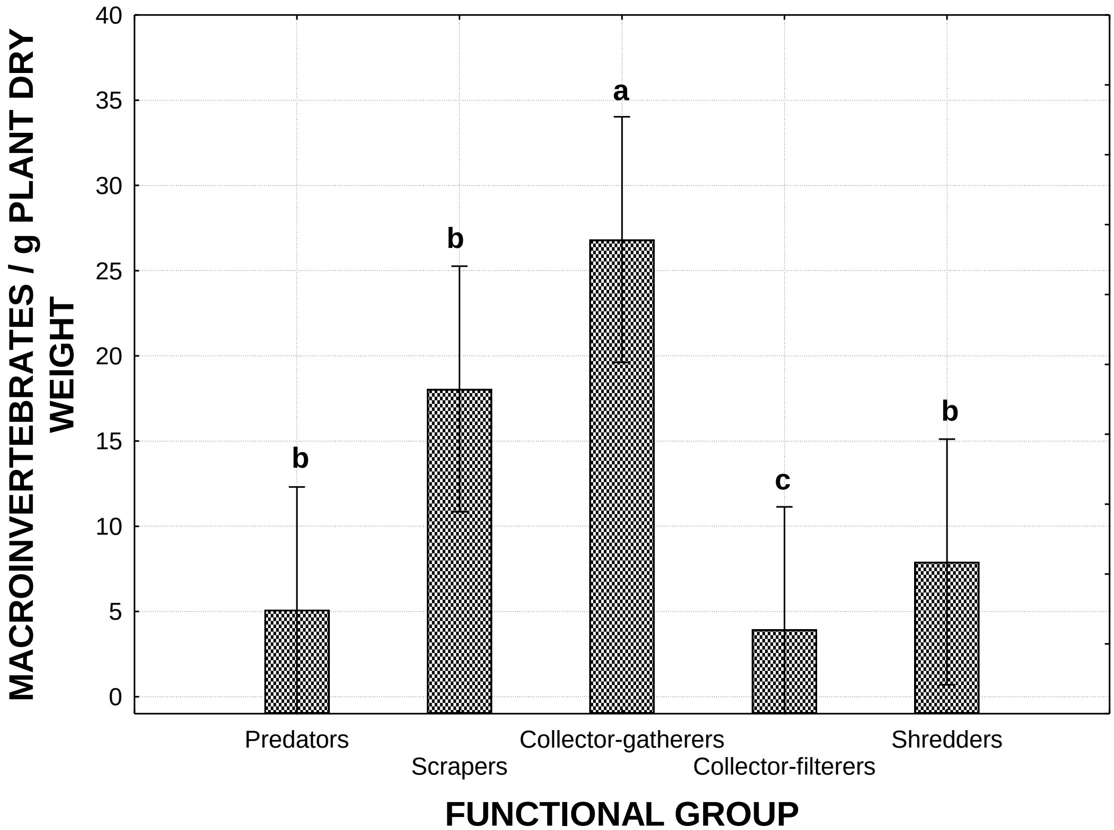

Figure 1.29. Overall functional feeding groups mean Log_{10} (density) in specimens per g plant dry weight (one-way ANOVA, df = 4, 175, F = 17.57, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

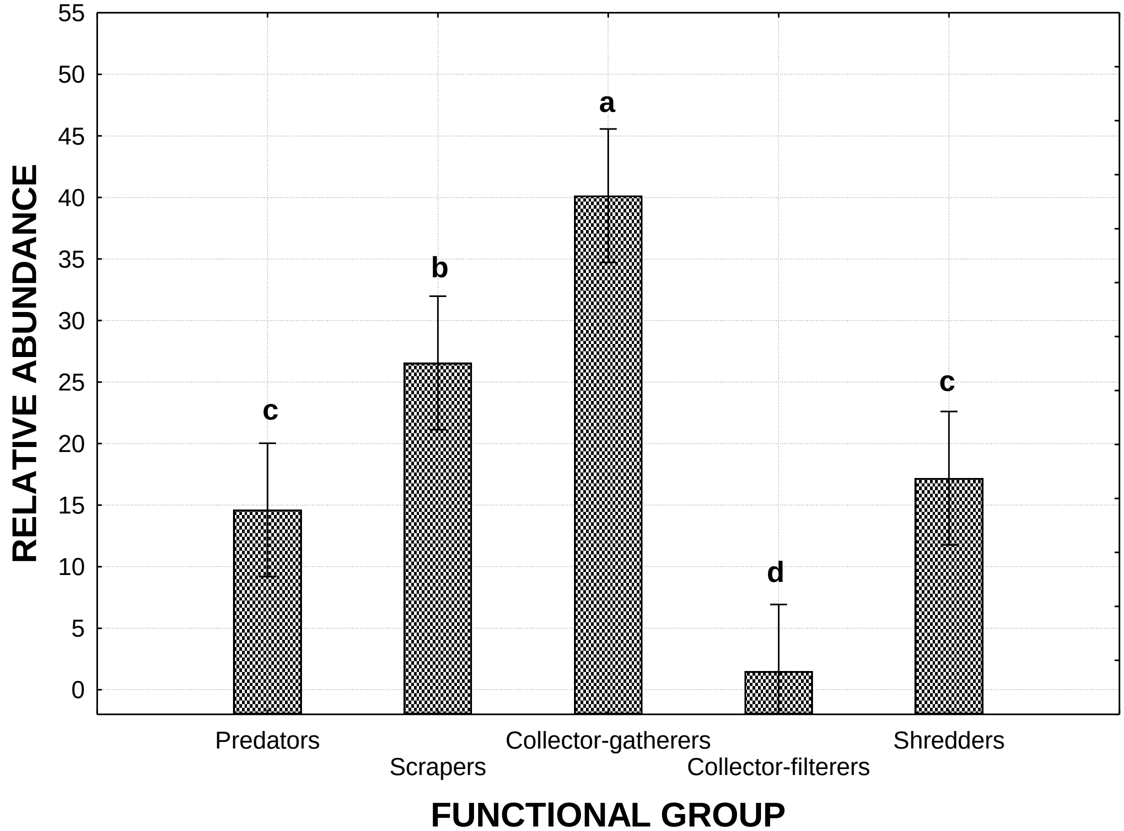

Figure 1.30. Mean relative abundances of functional feeding groups associated with *H. dubia* (one-way ANOVA, df = 4, 175, F = 27.44, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

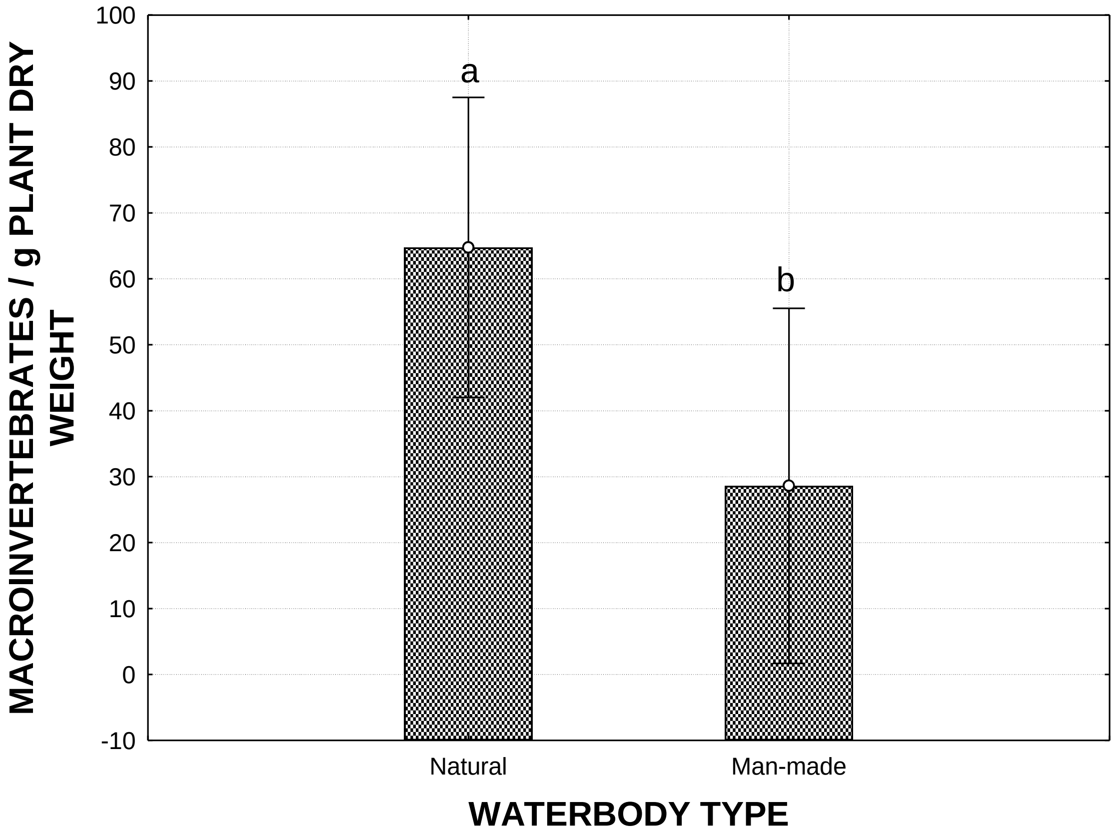

Figure 1.31. Mean water stargrass-associated invertebrate density, compared between natural and man-made waterbodies (one-way ANOVA, df = 1, 10, F = 5.22, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

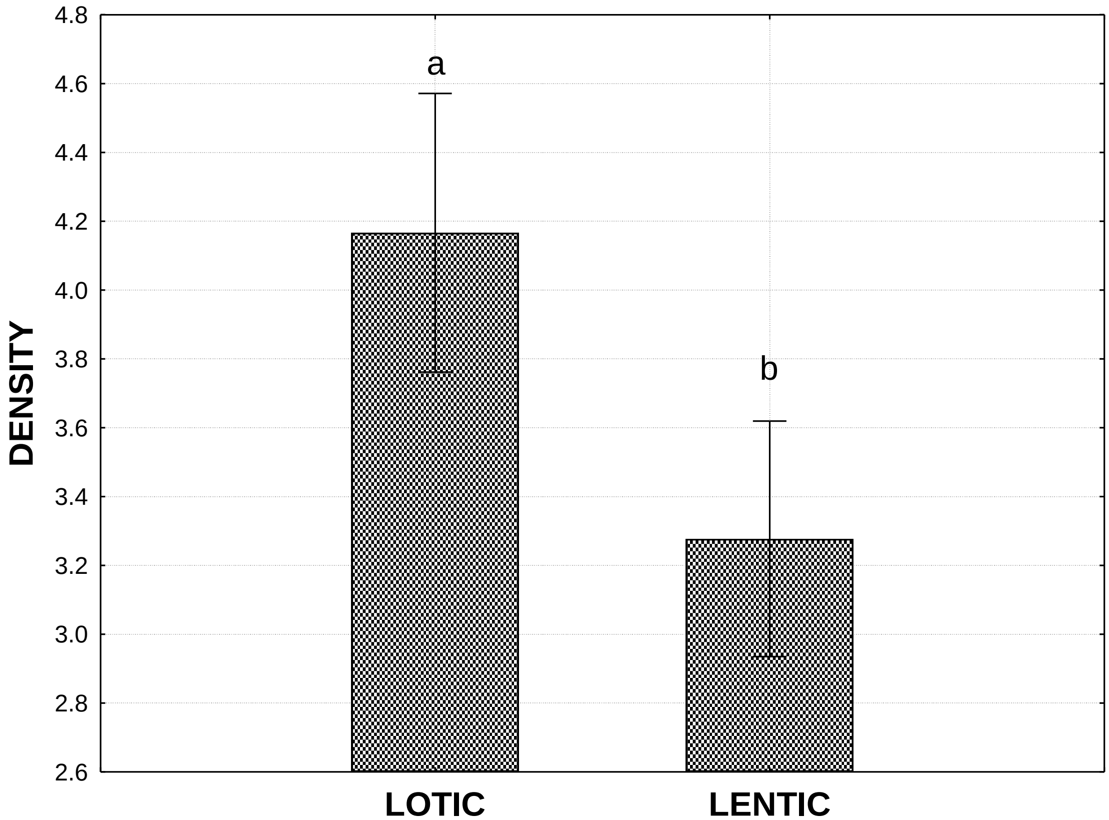

Figure 1.32. Mean invertebrate densities (individuals / g plant dry weight) of two flow regimes (one-way ANOVA, df = 1, 34, F = 11.63, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

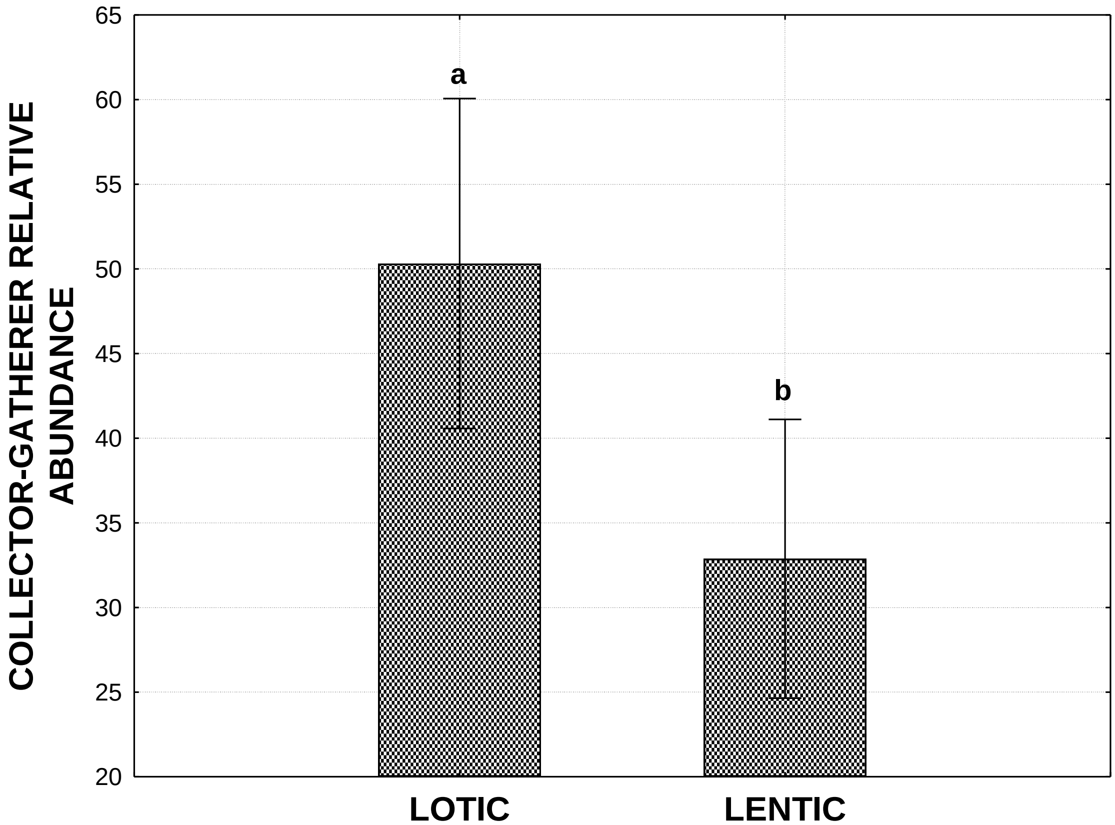

Figure 1.33. Mean collector-gatherer relative abundance for lotic and lentic sites one-way ANOVA, df = 1,34, $F = 7.72$, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

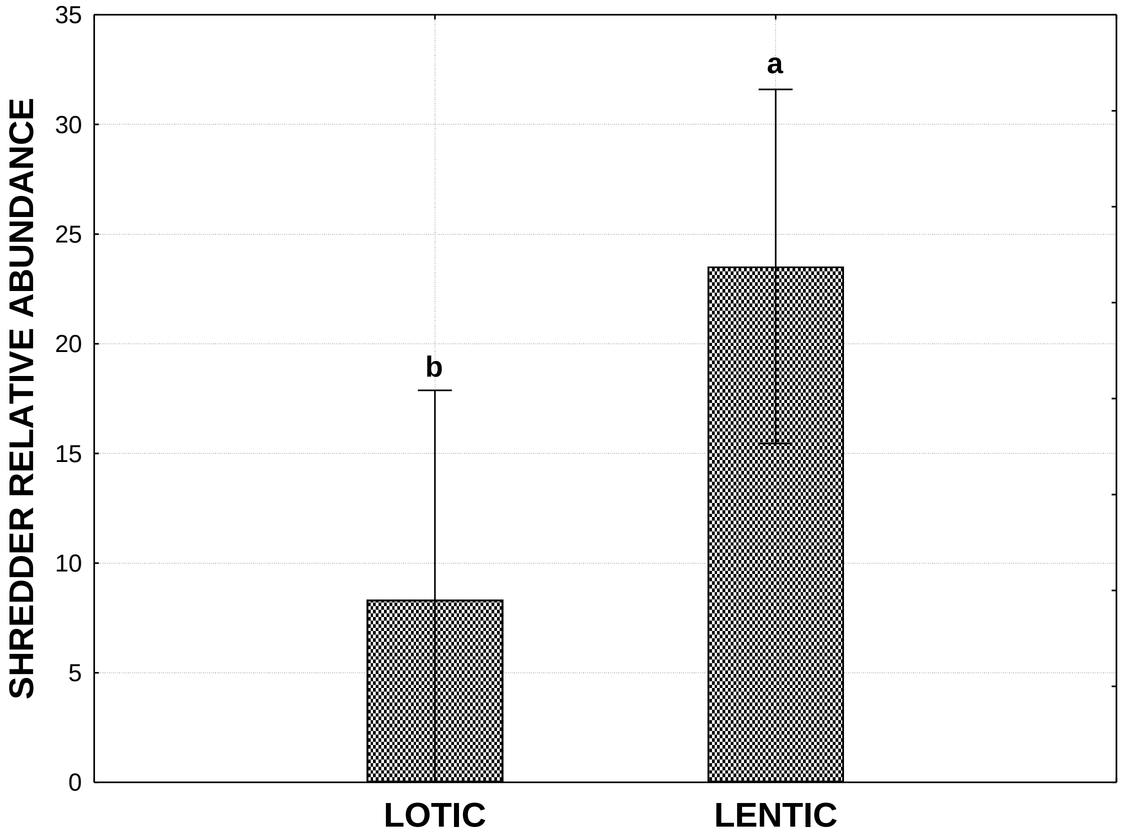

Figure 1.34. Mean shredder relative abundance for lotic and lentic sites (one-way ANOVA, df = 1,34, F = 6.10, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

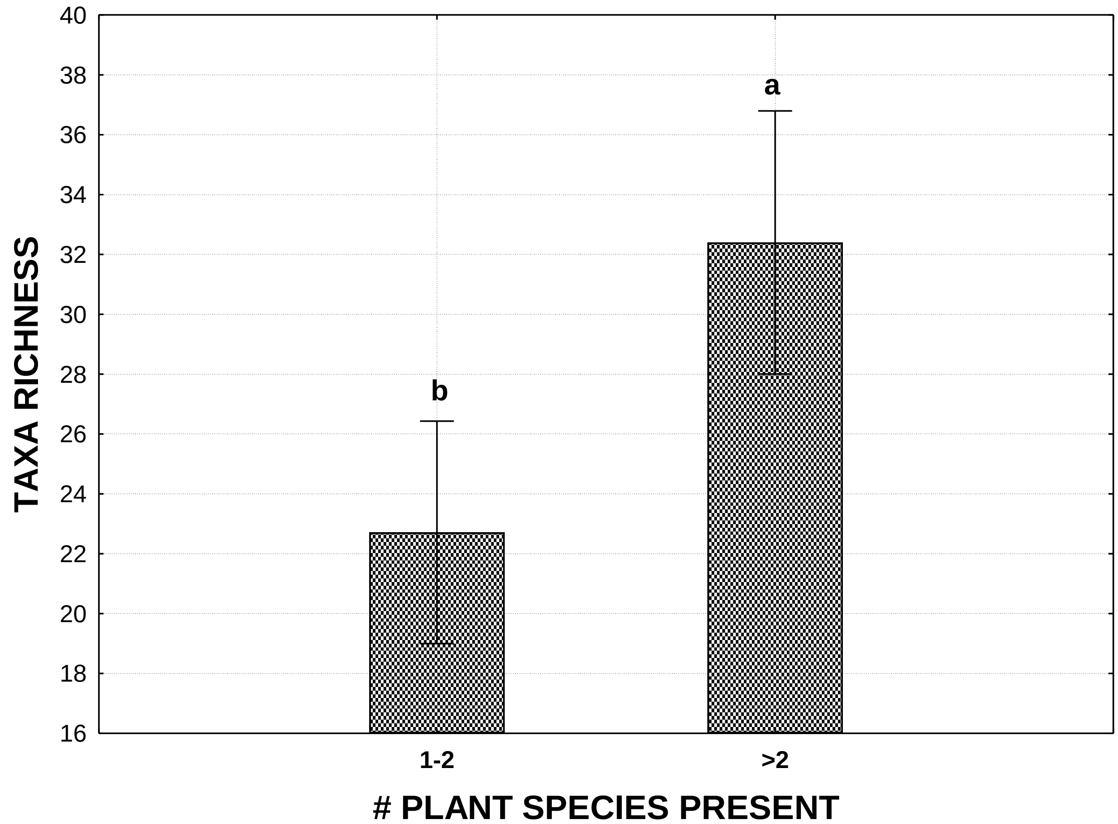

Figure 1.35. Mean taxa richness compared between sites where there were 1-2 plant species present in vicinity of sample and sites where there were more than two species present in vicinity (one-way ANOVA, df = 1,10, F = 14.06, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

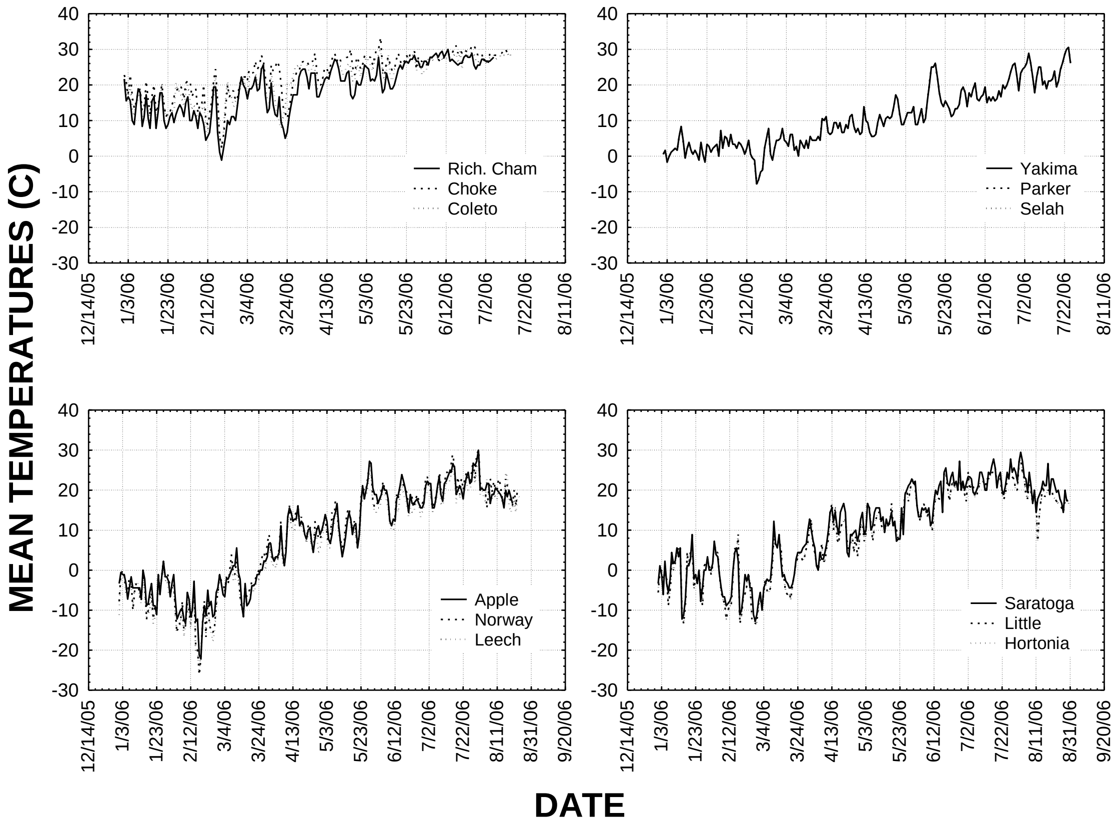

Figure 1.36. Mean daily air temperatures for sites from January 1st, 2006 to sample date.

Table 1.1. Collection sites, dates, and water parameters. Plant diversity refers to field notes regarding the number of aquatic plant species present at a site, in addition to *H. dubia*. "Nat" and "Man" refer to natural and man-made waterbodies, respectively.

Site	**Region**	**Collection Date**	**Water Temp (ºC)**	**Conductivity (μS)**	**pH**	**Natural/ Man-made**	**Flow**	**Plant diversity**
Richland Chambers, TX	LMW	6-VII-2006	28.4	250	8.38	Man	Lentic	1-2
Choke Canyon Reservoir, TX	LMW	10-VII-2006	31.1	795	8.51	Man	Lentic	1-2
Coleto Creek Reservoir, TX	LMW	11-VII-2006	32.1	597	8.19	Man	Lentic	1-2
Yakima River, WA	NW	24-VII-2006	31	285	8.82	Nat	Lotic	1-2
Parker Ponds, WA	NW	24-VII-2006	26.9	205	7.24	Man	Lentic	>2
Selah Ponds, WA	NW	25-VII-2006	31.2	971	9.12	Man	Lentic	>2
Apple River, WI	UMW	20- VIII-2006	20.1	213	7.80	Nat	Lotic	>2
Leech Lake, MN	UMW	23- VIII-2006	25.5	243	8.85	Nat	Lentic	1-2
Norway Lake, MN	UMW	23- VIII-2006	25.3	238	8.47	Man	Lotic	>2
Saratoga Lake, NY	NE	29- VIII-2006	21.6	290	8.38	Nat	Lentic	>2
Lake Hortonia, VT	NE	30-VIII-2006	21.8	226	7.87	Man	Lotic	>2
Little Lake, VT	NE	30-VIII-2006	21.6	96	7.90	Nat	Lotic	>2

Table 1.2. Experts who assisted in identification of invertebrates.

Taxa	Expert	Affiliation
Nectopsyche, *Triaenodes* (Trichoptera: Leptoceridae)	Jim Glover	South Carolina Department of Health and Environmental Control, Columbia, SC, 29201, USA
Nectopsyche, *Triaenodes* (Trichoptera: Leptoceridae)	Ken Manuel	Duke Energy, Huntersville, NC, 28078, USA
Lepidoptera	Alma Solis	Systematic Entomology Laboratory, USDA-ARS, Beltsville, MD, 20705, USA
Gastropods	Rob Dillon	Department of Biology, College of Charleston, Charleston, SC, 29424, USA
Cinncinatia (Gastropoda: Hydrobiidae)	Robert Hershler	National Museum of Natural History, Smithsonian Institution, Washington D.C., 20560,USA
Diapriidae (Hymenoptera)	Lubomir Masner	Agriculture & Agrifood Canada, Ottawa, Ontario, K1A 0C6, Canada
Braconidae (Hymenoptera)	Bob Kula	Systematic Entomology Laboratory, USDA-ARS, 10300 Baltimore Ave., Beltsville, MD, 20705, USA
Curculionidae (Coleoptera)	Bob Anderson	Research Division, Canadian Museum of Nature, Ottawa, Ontario, K1P 6P4, Canada

Table 1.3. Taxa list and functional feeding groups of macroinvertebrates collected from *H. dubia* at all sites.

Collector- filterers

Bivalvia
  Dreissenoidea
    Dreissena polymorpha (Pallas, 1771)
Diptera
  Chironomidae
    Rheotanytarsus Bause and Thienemann, 1913
    Tanytarsus Van Der Wulp, 1874
Simulidae
    Simulium Latreille, 1802
Trichoptera
  Hydropsychiidae
    Hydropsyche Pictet, 1834
  Polycentropidae
    Cyrnellus fraternus (Banks, 1905)
Spinicaudata
  Cyzcidae
    Cyzicus Audouin, 1837
Lynceidae
    Lynceus Müller, 1776

Collector-gatherers

Amphipoda
  Gammaridae
    Gammarus Fabricius, 1775
  Hyalellidae
    Hyalella azteca Saussure, 1858

Anomopoda
  Chydoridae
    Eurycercus Baird, 1843
    Pleuroxus Baird, 1843
  Daphniidae
    Ceriodaphnia quadrangula Müller, 1785
    Daphnia Müller, 1785
Ctenopoda
  Sididae
    Sida Straus, 1820
Diptera
  Chironomidae
    Constempellina Brundin, 1947

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Corynoneura
Dicrotendipes Kieffer, 1913
Goeldichironomus
Microspectra
Nanocladius Kieffer, 1913
Paratanytarsus Thienemann & Bause, 1913
Psectrocladius Kieffer, 1906
Sergentia
Stilocladius
Corynoneura
Zavreliella
Ephemeroptera
Baetidae
Acerpenna Waltz and McCafferty, 1987
Baetis Leach, 1815
Callibaetis Eaton, 1881
Caenidae
Caenis Stephens, 1835
Tricorythidae
Tricorythodes Ulmer, 1920
Oligochaeta
Ostracoda
Podocopida
Trichoptera
Hydroptilidae
Oxyethira Eaton, 1873

Scrapers

Ephemeroptera
Heptageniidae
Stenonema femoratum (Say, 1823)
Gastropoda
Hydrobiidae
Amnicola limosa (Say, 1817)
Cincinnatia integra (Say, 1829)
Fluminicola fuscus (Haldeman, 1847)
Physidae
Physa acuta Draparnaud, 1805
Physa gyrina (Say, 1821)
Planorbidae
Biomphalaria obstructa (Morelet, 1849)
Gyraulus parvus (Say, 1817)
Gyraulus deflectus (Say, 1824)

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Helisoma anceps (Menke, 1830)
Helisoma campanulata (Say, 1821)
Menetus opercularis (Gould, 1847)
Promenetus exacuous (Say, 1821)
Ancylidae
Ferrissia paralella (Haldeman, 1841)
Valvatidae
Valvata tricarinata (Say, 1817)
Thiaridae
Melanoides tuberculata (Muller, 1774)

Shredders

Coleoptera
Curculionidae
Bagous floridanus Tanner, 1943
Hydrophilidae
Berosus Leach, 1817
Tropisternus Solier, 1834
Diptera
Chironomidae
Chironomus
Cricotopus Wulp, 1874
Endochironomus Kieffer, 1918
Glyptotendipes Kieffer, 1913
Polypedilum Kieffer, 1913
Ephydridae
Hydrellia Robineau- Desvoidy, 1830
Homoptera
Aphididae
Rhopalosiphum Koch, 1854
Isopoda
Asellidae
Caecidotea Packard, 1871
Lepidoptera
Crambidae
Paraponyx Hubner, 1825
Synclita obliteralis Walker, 1859
Synclita occidentalis Lange, 1956
Trichoptera
Hydroptilidae
Hydroptila Dalman, 1819
Orthotrichia Eaton, 1873

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Leptoceridae

Leptocerus americanus Banks, 1899
Nectopsyche diarina (Ross, 1944)
Nectopsyche albida (Walker, 1852)
Nectopsyche minuta (Banks, 1900)
Nectopsyche tavara (Ross, 1944)
Oecetis cinerascens (Hagen, 1861)
Oecetis eddlestoni Ross, 1938
Triaenodes injustus (Hagen, 1861)
Ylodes Milne, 1934

Predators

Arachnida
Acariformes
Coleoptera
Dytiscidae
Laccodytes Régimbart, 1895
Elmidae
Dubiraphia Sanderson, 1954
Stenelmis Dufour, 1835
Gyrinidae
Gyrinus Geoffroy, 1762
Diptera
Ceratopogonidae
Bezzia Kieffer, 1899
Chironomidae
Ablabesmyia Johannsen, 1905
Cardiocladius Kieffer, 1912
Labrundinia
Parachironomus Lenz, 1921
Pentaneura
Procladius Skuse, 1889
Hemiptera
Gerridae
Trepobates Uhler, 1871
Hebridae
Merragata hebroides White, 1877
Pleidae
Neoplea Esaki and China, 1928
Hirudinea Lamarck, 1818
Hymenoptera
Diapriidae

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Braconidae
Megaspilidae
Conostigmus Dahlbom, 1858
Odonata
Coenagrionidae
Coenagrion/ *Enallagma*
Enallagma Charpentier, 1840
Corduliidae
Epitheca Burmeister, 1839
Lestidae
Lestes Leach, 1815
Libellulidae
Tramea Hagen, 1861
Gomphidae
Arigomphus Needham, 1897
Turbellaria

Diptera
Chironomidae
**Acricotopus*
**Lipiniella*
**Rheosmittia* Brundin, 1956

*It is not clear what feeding group these belong to.

Table 1.4. Gastropod species associated with *H. dubia*.

	Choke Canyon	Coleto Creek	Richland Chambers	Yakima River	Parker Pond	Selah Pond	Apple River	Norway Lake	Leech Lake	Saratoga Lake	Little Lake	Lake Hortonia
Amnicola limosa							*	*	*	*	*	*
Biomphalaria obstructa		*										
Cinncinatia integra		*										
Ferrissia parallela				*	*		*	*	*	*	*	
Fluminicola fuscus				*		*						
Gyraulus deflectus										*		
Gyraulus parvus				*	*		*	*	*		*	*
Helisoma anceps								*		*	*	*
Helisoma campanulata										*		*
Melanoides tuberculata		*										
Menetus opercularis					*							
Physa acuta	*	*	*	*		*	*	*	*	*	*	*
Physa gyrina					*				*			
Promenetus exacuous											*	
Valvata tricarinata										*		*

Table 1.5. Descriptive indices of sites.

Site	# of Specimens	Taxa Richness	Shannon's Diversity	Shannon's Evenness
Richland Chambers	1024	18	1.71	0.59
Choke Canyon	1904	20	1.96	0.65
Coleto Creek	818	20	2.09	0.070
Yakima River	1277	26	1.76	0.54
Parker Ponds	1524	25	2.43	0.76
Selah Ponds	349	23	1.82	0.58
Apple River	1935	29	2.29	0.68
Leech Lake	927	23	2.47	0.79
Norway Lake	3878	36	2.27	0.63
Saratoga Lake	1826	37	1.80	0.50
Lake Hortonia	1887	29	2.16	0.64
Little Lake	363	35	2.86	0.80

Table 1.6. Similarity between regions sampled, displayed as the Chao-modified Jaccard's abundance-based index. 'LMW' is lower Midwest, 'NW' is northwest, 'UMW' is upper midwest, and 'NE' is northeast. Tobs refers to number of observed taxa in the sample.

First Region	Second Region	T_{obs} First Sample	T_{obs} Second Sample	Shared Taxa Observed	Chao-Jaccard-Raw Abundance-based
LMW	NW	34	46	17	0.27
LMW	UMW	34	51	16	0.32
LMW	NE	34	55	18	0.30
NW	UMW	46	51	26	0.45
NW	NE	46	55	24	0.31
UMW	NE	51	55	29	0.75

Table 1.7. Similarity between sites sampled, displayed as the Chao-modified Jaccard's abundance-based index. T_{obs} refers to number of observed taxa in the sample.

First Site	Second Site	T_{obs} First Sample	T_{obs} Second Sample	Shared Taxa Observed	Chao-Jaccard-Raw Abundance-based
Choke	Coleto	20	20	10	0.26
Choke	Richland Chambers	20	18	12	0.66
Choke	Yakima	20	26	9	0.23
Choke	Parker	20	25	5	0.079
Choke	Selah	20	23	10	0.68
Choke	Apple	20	29	7	0.25
Choke	Norway	20	36	11	0.20
Choke	Leech	20	23	10	0.23
Choke	Saratoga	20	37	10	0.15
Choke	Little	20	35	9	0.38
Choke	Hortonia	20	29	11	0.24
Coleto	Richland Chambers	20	18	8	0.19
Coleto	Yakima	20	26	8	0.20
Coleto	Parker	20	25	6	0.094
Coleto	Selah	20	23	9	0.25
Coleto	Apple	20	29	7	0.48
Coleto	Norway	20	36	9	0.25
Coleto	Leech	20	23	9	0.35
Coleto	Saratoga	20	37	11	0.21
Coleto	Little	20	35	8	0.24
Coleto	Hortonia	20	29	9	0.35
Richland Chambers	Yakima	18	26	8	0.13
Richland Chambers	Parker	18	25	7	0.072
Richland Chambers	Selah	18	23	10	0.66
Richland Chambers	Apple	18	29	7	0.13
Richland Chambers	Norway	18	36	10	0.15

Richland Chambers	Leech	18	23	9	0.17
Richland Chambers	Saratoga	18	37	11	0.14
Richland Chambers	Little	18	35	8	0.083
Richland Chambers	Hortonia	18	29	9	0.16
Yakima	Parker	26	25	13	0.51
Yakima	Selah	26	23	11	0.16
Yakima	Apple	26	29	12	0.60
Yakima	Norway	26	36	13	0.18
Yakima	Leech	26	23	11	0.23
Yakima	Saratoga	26	37	12	0.15
Yakima	Little	26	35	10	0.21
Yakima	Hortonia	26	29	10	0.20
Parker	Selah	25	23	10	0.10
Parker	Apple	25	29	11	0.39
Parker	Norway	25	36	14	0.29
Parker	Leech	25	23	11	0.42
Parker	Saratoga	25	37	13	0.18
Parker	Little	25	35	11	0.33
Parker	Hortonia	25	29	10	0.31
Selah	Apple	23	29	11	0.24
Selah	Norway	23	36	12	0.16
Selah	Leech	23	23	9	0.18
Selah	Saratoga	23	37	12	0.15
Selah	Little	23	35	10	0.12
Selah	Hortonia	23	29	11	0.19
Apple	Norway	29	36	17	0.63
Apple	Leech	29	23	14	0.61
Apple	Saratoga	29	37	16	0.60
Apple	Little	29	35	14	0.45
Apple	Hortonia	29	29	15	0.65
Norway	Leech	36	23	19	0.73
Norway	Saratoga	36	37	25	0.61
Norway	Little	36	35	21	0.66
Norway	Hortonia	36	29	22	0.79
Leech	Saratoga	23	37	16	0.51
Leech	Little	23	35	15	0.50
Leech	Hortonia	23	29	17	0.68

Saratoga	Little	37	35	21	0.63
Saratoga	Hortonia	37	29	24	0.88
Little	Hortonia	35	29	18	0.73

Table 1.8. Similarity, based on gastropod fauna, between regions sampled, displayed as the Chao-modified Jaccard's abundance-based index. 'LMW' is lower Midwest, 'NW' is northwest, 'UMW' is upper midwest, and 'NE' is northeast. T_{obs} refers to number of observed taxa in the sample.

First Region	Second Region	Sobs First Sample	Sobs Second Sample	Shared Species Observed	Chao-Jaccard-Raw Abundance-based
LMW	NW	4	6	1	0.23
LMW	UMW	4	6	1	0.079
LMW	NE	4	10	1	0.058
NW	UMW	6	6	4	0.22
NW	NE	6	10	4	0.15
UMW	NE	6	10	6	0.98

Table 1.9. Similarity, based on gastropod fauna, between sites sampled, displayed as the Chao-modified Jaccard's abundance-based index.

First Region	Second Region	Sobs First Sample	Sobs Second Sample	Shared Species Observed	Chao-Jaccard-Raw Abundance-based
Choke	Coleto	1	4	1	0.78
Choke	Richland	1	1	1	1
Choke	Yakima	1	3	1	0.99
Choke	Parker	1	4	0	0
Choke	Selah	1	2	1	0.78
Choke	Apple	1	4	1	0.16
Choke	Norway	1	5	1	0.016
Choke	Leech	1	5	1	0.23
Choke	Saratoga	1	7	1	0.016
Choke	Little	1	6	1	0.19
Choke	Hortonia	1	6	1	0.021
Coleto	Richland	4	1	1	0.78
Coleto	Yakima	4	3	1	0.78
Coleto	Parker	4	4	0	0
Coleto	Selah	4	2	1	0.63
Coleto	Apple	4	4	1	0.15
Coleto	Norway	4	5	1	0.016
Coleto	Leech	4	5	1	0.22
Coleto	Saratoga	4	7	1	0.015
Coleto	Little	4	6	1	0.18
Coleto	Hortonia	4	6	1	0.021
Richland	Yakima	1	3	1	0.99
Richland	Parker	1	4	0	0
Richland	Selah	1	2	1	0.78
Richland	Apple	1	4	1	0.16
Richland	Norway	1	5	1	0.016
Richland	Leech	1	5	1	0.23
Richland	Saratoga	1	7	1	0.016
Richland	Little	1	6	1	0.19
Richland	Hortonia	1	6	1	0.021
Yakima	Parker	3	4	1	0
Yakima	Selah	3	2	2	1
Yakima	Apple	3	4	2	0.35
Yakima	Norway	3	5	2	0.025
Yakima	Leech	3	5	2	0.50
Yakima	Saratoga	3	7	1	0.016

First Region	Second Region	Sobs First Sample	Sobs Second Sample	Shared Species Observed	Chao-Jaccard-Raw Abundance-based
Yakima	Little	3	6	2	0.41
Yakima	Hortonia	3	6	2	0.052
Parker	Selah	4	2	0	0
Parker	Apple	4	4	2	0.18
Parker	Norway	4	5	2	0.011
Parker	Leech	4	5	3	0.46
Parker	Saratoga	4	7	1	0
Parker	Little	4	6	2	0.30
Parker	Hortonia	4	6	1	0.027
Selah	Apple	2	4	1	0.16
Selah	Norway	2	5	1	0.016
Selah	Leech	2	5	1	0.22
Selah	Saratoga	2	7	1	0.015
Selah	Little	2	6	1	0.18
Selah	Hortonia	2	6	1	0.021
Apple	Norway	4	5	4	0.99
Apple	Leech	4	5	4	0.99
Apple	Saratoga	4	7	3	0.77
Apple	Little	4	6	4	0.95
Apple	Hortonia	4	6	3	0.97
Norway	Leech	5	5	4	0.98
Norway	Saratoga	5	7	4	0.95
Norway	Little	5	6	5	0.99
Norway	Hortonia	5	6	4	0.99
Leech	Saratoga	5	7	3	0.69
Leech	Little	5	6	4	0.94
Leech	Hortonia	5	6	3	0.70
Saratoga	Little	7	6	4	0.75
Little	Hortonia	7	6	5	0.95
Little	Hortonia	6	6	4	0.84

CHAPTER 2.

INSECT HERBIVORES OF AQUATIC AND WETLAND PLANTS IN THE UNITED STATES: A CHECKLIST FROM LITERATURE

Abstract

Lacking a central database of insect herbivores and associated aquatic and wetland plants, a relatively thorough literature listing was compiled into an accessible table, providing plant species, associated insect herbivores, plant parts affected, and region of study. The intent was to determine what, if any, insect herbivores are found associated with water stargrass (*Heteranthera dubia*). Although a total of 761 plant-herbivore interactions were found in the literature, those representing water stargrass were absent. Reasons for this are unknown, but provide areas of research. The information presented here will provide aquatic plant managers, researchers, and other interested personnel access to information on the wide diversity of insect herbivores of aquatic plants and wetland plant species in the United States.

Introduction

Although overlooked for many years, herbivory of aquatic plants is a common and important factor contributing to structure and composition of plant communities (Carpenter and Lodge 1986, Lodge 1991, Newman 1991, Lodge et al. 1998). Herbivory has been shown to alter photosynthetic ability, thereby retarding growth, stressing plants, and reducing winter bud formation (Wallace and O'Hop 1985, Doyle et. al 2002, Doyle et. al 2005). These facts are especially important to researchers studying the ecology of freshwater systems, but also to those involved in aquatic ecorestoration, in which native plants are used to preempt invasion by more weedy, exotic species (Smart et al. 1998). In addition, knowledge of insect herbivory is the basis of many of the classical biological control programs in use throughout the world (Bennett and Buckingham 2000, Center et al 1998, Coombs et al. 2004).

Because herbivory is such an important determinant in plant competitive success in aquatic systems, it is necessary to understand what species impact aquatic plants and how their feeding influences plant growth and competitive ability. Although herbivory by other organisms, e.g., crayfish, turtles, waterfowl, and nutria is substantial (Dick et al. 1995, Doyle and Smart 1995, Doyle et al. 1997), this paper only compiled published information regarding insect species known to feed on native aquatic and wetland plants in the United States, although other works have focused on introduced plants and their biocontrol agents (Center et al. 1999, Coombs et al. 2004). In fact, there is often more information available in the literature regarding introduced biocontrol agents of exotic plants than that of native insect herbivores. Descriptions of the nature and magnitude of insect impacts on the various host plants is not reported here and is, in most cases, unknown. In that regard further work is warranted.

Materials and Methods

From 2005-2008 a literature review was conducted to summarize published information regarding insect herbivores of aquatic and wetland plants in the United States. Only native plants were considered in this review. With the exception of the Chironomidae (Diptera), only literature which reports actual herbivory was included, i.e., no inferences are made here regarding insect diet. It is well known that some chironomid taxa are obligate stem and leaf miners. Although some of those listed may not directly consume plant tissue, some larvae probably injure the plant through tunneling action and also increase the likelihood of pathogenic infection.

Results and Discussion

Results of the literature review are compiled in Table 2.1. Plant names are reported with the most current (as of 2009) taxonomic classification recognized by the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) (2009), and to the best of my knowledge, insect classifications are also current. In some instances information regarding "plant part affected" by herbivores was not available, and, hence, not included in the table. In addition, it was not always clear where the insect species was studied, so locale was not always included in the table.

A total of 761 plant-herbivore interactions comprising 313 insect and 167 plant species are reported. This includes the herbivore family Curculionidae (Coleoptera) and the genus *Hydrellia* (Diptera: Ephydridae), represented by 81 and 29 species respectively. Also included are the common aquatic lepidopterans and chrysomelids. There are likely associations in the literature which were not available throughout this review, and there are certainly new plant-herbivore interactions yet to be discovered. However, the information we provide herein offers the most comprehensive and extensive table to date regarding aquatic plants in the United States and the associated insect herbivore faunas.

A total of 80 literature sources were included in this study. Pondweeds (*Potamogeton* spp.) were the subject of the most citations, with 140 plant-herbivore associations documented in 14 sources. Smartweeds (*Polygonum* spp.) and waterlilies (*Nymphaeae* spp.) followed pondweeds in this regard, with 95 and 53 associations from 17 and 7 sources, respectively.

There are several species of submersed aquatic plants that lack, or have minimal reports of herbivore species in the literature. These include water stargrass (*Heteranthera dubia* (Jacq.) MacM.), elodea (*Elodea* spp.), and coontail (*Ceratophyllum demersum* L.), among others. The apparent lack of data from these plants probably results from their submersed nature and the difficulty of accurately sampling herbivores.

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Table 2.1. Aquatic and wetland plants of the United States and their associated insect herbivores.

Plant	Insect Order: Family	Insect Species	Part of Plant Affected	Author (year)	Study Region
Acorus sp.	Coleoptera: Chrysomelidae	*Donacia aequalis* Say	roots, leaves	Marx (1957)	
Acorus sp.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Marx (1957)	
Alisma plantago L.	Diptera: Ephydridae	*Hydrellia mutata Zetterstedt*		Hering (1957)	
Alnus oblongifolia Torr.	Coleoptera: Chrysomelidae	*Altica guatemalensis* Jacoby	leaves	LeSage (1995)	
Alnus oblongifolia Torr.	Coleoptera: Curculionidae	*Rhynchaenus griseus* Sleeper	leaves	Anderson (1989)	
Alnus rhombifolia Nutt.	Coleoptera: Chrysomelidae	*Altica ambiens ambiens* LeConte	leaves	LeSage (1995)	
Alnus rhombifolia Nutt.	Coleoptera: Curculionidae	*Rhynchaenus griseus* Sleeper	leaves	Anderson (1989)	
Alnus rubra Bong.	Coleoptera: Chrysomelidae	*Altica ambiens ambiens* LeConte	leaves	LeSage (1995)	
Alnus rubra Bong.	Coleoptera: Curculionidae	*Rhynchaenus griseus* Sleeper	leaves	Anderson (1989)	
Alnus rugosa (DuRoi) Spreng.	Coleoptera: Chrysomelidae	*Altica ambiens alni* Harris	leaves	LeSage (1995)	
Alnus tenuifolia Nutt.	Coleoptera: Curculionidae	*Rhynchaenus griseus* Sleeper	leaves	Anderson (1989)	
Amaranthus retroflexus L.	Coleoptera: Chrysomelidae	*Disonycha glabrata* Fabricius	stems, leaves	Center et. al (1999)	
Amaranthus spinosus L.	Coleoptera: Chrysomelidae	*Disonycha glabrata* Fabricius	stems, leaves	Center et. al (1999)	
Azolla caroliniana Willd.	Coleoptera: Chrysomelidae	*Pseudolampsis guttata* LeConte	floating leaves	Haag et al. (1986)	Florida, USA
Azolla caroliniana Willd.	Coleoptera: Curculionidae	*Stenopelmus rufinasus* Gyllenhal	floating leaves	Richerson and Grigarick (1967)	
Azolla filiculoides Lam.	Coleoptera: Curculionidae	*Stenopelmus rufinasus* Gyllenhal	floating leaves	Richerson and Grigarick (1967)	
Bacopa caroliniana (Walter) Robinson	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Herlong (1979)	South Carolina, USA
Bacopa caroliniana (Walter) Robinson	Lepidoptera: Crambidae	*Paraponyx maculalis* Clemens		Herlong (1979)	South Carolina, USA
Bacopa caroliniana (Walter) Robinson	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Herlong (1979)	South Carolina, USA
Betula glandulosa Michx.	Coleoptera: Chrysomelidae	*Altica subcostata* LeSage	leaves	LeSage (1995)	
Betula nigra L.	Coleoptera: Chrysomelidae	*Altica subcostata* LeSage	leaves	LeSage (1995)	
Betula nigra L.	Coleoptera: Curculionidae	*Rhynchaenus betuleti* Horn	leaves	Anderson (1989)	
Betula occidentalis Hook.	Coleoptera: Chrysomelidae	*Altica subcostata* LeSage	leaves	LeSage (1995)	

Plant	Insect Order: Family	Insect Species	Part of Plant Affected	Author (year)	Study Region
Brasenia schreberi J.F. Gmel.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Marx (1957)	
Brasenia schreberi J.F. Gmel.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	leaves	Center et. al (1999)	
Brasenia schreberi J.F. Gmel.	Coleoptera: Curculionidae	*Bagous cavifrons* LeConte	leaves	O'Brien and Marshall (1979)	
Brasenia schreberi J.F. Gmel.	Diptera: Chironomidae	*Polypedilum braseniae* Leathers	floating leaves	McGaha (1952)	Michigan, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Munroessa gyralis* Hulst		Herlong (1979)	South Carolina, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Herlong (1979)	South Carolina, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Stoops et al. (1998)	South Carolina, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Paraponyx icciusalis* Walker	floating leaves	McGaha (1952)	Michigan, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Paraponyx maculalis* Clemens		Forbes (1910)	Lake Quinsigamond
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Stoops et al. (1998)	South Carolina, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker		Herlong (1979)	South Carolina, USA
Brasenia schreberi J.F. Gmel.	Lepidoptera: Crambidae	*Synclita tinealis* Munroe		Stoops et al. (1998)	South Carolina, USA
Cabomba caroliniana Gray	Trichoptera: Leptoceridae	*Nectopsyche tavara* Ross		Haag et al. (1986)	Florida, USA
Carex sp.	Coleoptera: Curculionidae	*Bagous chandleri* Tanner		Tanner (1943)	
Carex sp.	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Hering (1957)	
Carex sp.	Lepidoptera: Crambidae	*Schoenobius melinellus dispersellus* Robinson		McCafferty and Minno (1979)	
Carex spp.	Coleoptera: Chrysomelidae	*Neocrepidodera pallida* Fall		Riley et. al (2002)	
Carex spp.	Coleoptera: Chrysomelidae	*Poecilocera harrisii* LeConte		Riley et. al (2002)	
Carex spp.	Coleoptera: Chrysomelidae	*Stenispa metallica* Fabricus		Riley et. al (2002)	
Carpinus caroliniana Walt.	Coleoptera: Curculionidae	*Rhynchaenus mixtus* Blatchley	leaves	Anderson (1989)	Tennessee, USA
Cephalanthus occidentalis L.	Coleoptera: Curculionidae	*Plocetes ulmi* LeConte	reproductive structures	Clark (1982), Anderson (1991)	
Cephalanuths occidentalis L.	Lepidoptera: Noctuidae	*Simyra henrici* Grote	leaves	Center et. al (1999)	
Cicuta maculata L. var. *maculata*	Orthoptera: Acrididae	*Gymnoscirtetes pusillus* Scudder		Squitier and Capinera (2002)	Florida, USA
Cicuta maculata L. var. *maculata*	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA

Plant	Insect Order: Family	Insect Species	Part of Plant Affected	Author (year)	Study Region
Cicuta maculata L. var. *maculata*	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Cicuta maculata L. var. *maculata*	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Corylus rostrata Ait.	Coleoptera: Curculionidae	*Rhynchaenus mixtus* Blatchley	leaves	Anderson (1989)	California, USA
Cyperaceae	Lepidoptera: Crambidae	*Nymphula akthlipsis* Grote		McCafferty and Minno (1979)	Illinois, USA
Cyperus virens Michx.	Coleoptera: Curculionidae	*Bagous texanus* Tanner		Tanner (1943)	
Dasiphora fruticosa (L.) Rydb. ssp. *floribunda* (Pursh) Kartesz	Coleoptera: Chrysomelidae	*Altica caurina* Blake	leaves	LeSage (1995)	
Echinodorus cordifolius (Linnaeus) Grisebach	Coleoptera: Curculionidae	*Listronotus echinodori* O'Brien	stems	O'Brien (1981)	
Eleocharis elongata Chapman	Lepidoptera: Crambidae	*Eoparargyractis floridalis* Lange	leaves	Munroe (1972)	
Eleocharis macrostachya Britton	Coleoptera: Curculionidae	*Listronotus grypidiodes* Dietz		O'Brien (1981)	
Eleocharis macrostachya Britton	Coleoptera: Curculionidae	*Listronotus teretirostris* LeConte		O'Brien (1981)	
Eleocharis obtusa (Willd.) Schult.	Diptera: Ephydridae	*Hydrellia tibialis* Cresson		Deonier (1971)	
Eleocharis palustris L.	Lepidoptera: Crambidae	*Chilo forbesellus* Fernald		Frohne (1939a)	Michigan, USA
Eleocharis palustris L.	Lepidoptera: Crambidae	*Schoenobius melinellus dispersellus* Robinson		Frohne (1939b)	Michigan, USA
Eleocharis parvula (R. + S.) Link	Diptera: Ephydridae	*Hydrellia americana* Cresson		LaSalle (1988)	
Eleocharis sp.	Coleoptera: Chrysomelidae	*Donacia fulgens* LeConte	roots, leaves	Marx (1957)	
Eleocharis sp.	Coleoptera: Chrysomelidae	*Donacia rugosa* LeConte	roots, leaves	Marx (1957)	
Eleocharis sp.	Coleoptera: Curculionidae	*Brachybamus electus* Schoenherr		Anderson (2002)	
Eleocharis vivipara Link	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Habeck (1974)	
Elodea canadensis Michx.	Diptera: Ephydridae	*Hydrellia discursa* Deonier	submerged leaves	Deonier (1971)	
Elodea canadensis Michx.	Diptera: Ephydridae	*Hydrellia harti* Cresson	submerged leaves	Deonier (1998)	
Elodea canadensis Michx.	Diptera: Ephydridae	*Hydrellia trichaeta* Cresson	submerged leaves	Deonier (1971)	
Elodea canadensis Michx.	Trichoptera: Leptoceridae	*Leptocella* spp.	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA

Plant	Insect Order: Family	Insect Species	Part of Plant Affected	Author (year)	Study Region
Elodea canadensis Michx.	Trichoptera: Leptoceridae	*Leptocerus americanus* Banks	submerged leaves, petioles, stems and buds	McGaha (1952)	Michigan, USA
Epilobium sp.	Coleoptera: Curculionidae	*Tyloderma foveolatum* Say	stems, taproots	Wibmer (1981)	
Epilobium spp.	Coleoptera: Chrysomelidae	*Bromius obscurus* Linnaeus	leaves	Riley et. al (2002)	
Equisetum spp.	Coleoptera: Curculionidae	*Grypus equiseti* Fabricus		Anderson (2002)	
Eriocaulon sp.	Coleoptera: Chrysomelidae	*Donacia liebecki* Schaeffer	roots, leaves	Marx (1957)	
Gaura villosa Torrey	Coleoptera: Curculionidae	*Tyloderma baridium* LeConte	roots	Wibmer (1981)	
Glyceria grandis S. Watson	Diptera: Ephydridae	*Hydrellia ischiaca* Loew		Deonier (1971)	
Glyceria obtusa (Muhl.) Trin.	Diptera: Ephydridae	*Hydrellia ischiaca* Loew		Deonier (1971)	
Hydrocotyle spp.	Orthoptera: Acrididae	*Gymnoscirtetes pusillus* Scudder		Squitier and Capinera (2002)	Florida, USA
Hydrocotyle spp.	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Hydrocotyle spp.	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Hydrocotyle spp.	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Hydrocotyle umbellata L.	Diptera: Agromyzidae	*Liriomyza munda* Frick	leaves	Stegmaier (1966)	
Isoetes muricata Durieu	Lepidoptera: Crambidae	*Eoparargyractis plevie* Dyar	leaves	Fiance and Moeller (1977)	New Hampshire, USA
Isoetes tuckermanii A. Braun	Lepidoptera: Crambidae	*Eoparargyractis plevie* Dyar	leaves	Fiance and Moeller (1977)	New Hampshire, USA
Juncus debilis A. Gray	Diptera: Ephydridae	*Hydrellia tibiospica* Deonier		Deonier (1995)	
Juncus effusus L.	Orthoptera: Acrididae	*Leptysma marginicollis* Serville		Squitier and Capinera (2002)	Florida, USA
Juncus effusus L.	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Juncus effusus L.	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Juncus effusus L.	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Juncus effusus L.	Orthoptera: Acrididae	*Stenacris vitreipennis* Marschall		Squitier and Capinera (2002)	Florida, USA
Juncus repens Michx.	Diptera: Ephydridae	*Hydrellia biloxiae* Deonier		Deonier (1971)	
Juncus sp.	Lepidoptera: Crambidae	*Chilo forbesellus* Fernald		Dyar and Heinrich (1927)	Minnesota, USA

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Juncus sp.	Lepidoptera: Noctuidae	*Archanara subflava* Grote	leaves	McCafferty and Minno (1979)	
Juncus spp.	Coleoptera: Chrysomelidae	*Myochrous whitei* Blake	leaves	Riley et. al (2002)	
Lachnanthes caroliana (Lamarck) Dandy	Coleoptera: Curculionidae	*Neobagoidus carlsoni* O'Brien		O'Brien (1990)	Florida, USA
Lemna minor L.	Diptera: Ephydridae	*Hydrellia personata* Deonier		Keiper et al. (2002)	
Lemna sp.	Lepidoptera: Crambidae	*Neargyractis magnificalis* Hübner		Solis (2008)	
Lemna spp.	Coleoptera: Curculionidae	*Tanysphyrus lemnae* Paykull	floating leaves	Haag et al. (1986)	Florida, USA
Lemna spp.	Diptera: Ephydridae	*Lemnaphila scotlandae* Cresson	leaves	Center et. al (1999)	
Lemna spp.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	leaves	Center et. al (1999)	
Lemna spp.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker		Stoops et al. (1998)	South Carolina, USA
Lemna spp.	Lepidoptera: Crambidae	*Synclita tinealis* Munroe		Stoops et al. (1998)	South Carolina, USA
Limnobium spongia (Bosc) Rich. ex Steud.	Coleoptera: Curculionidae	*Bagous lunatoides* O'Brien	leaves, stolons, petioles	Haag et al. (1986), O'Brien and Marshall (1979)	Florida, Georgia, Louisiana, Tennessee, USA
Limnobium spongia (Bosc) Rich. ex Steud.	Diptera: Ephydridae	*Hydrellia limnobii* Deonier		Deonier (1993)	Florida, USA
Limnobium spongia (Bosc) Rich. ex Steud.	Lepidoptera: Crambidae	*Munroessa gyralis* Hulst		Stoops et al. (1998)	South Carolina, USA
Limnobium spongia (Bosc) Rich. ex Steud.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Stoops et al. (1998)	South Carolina, USA
Lobelia dortmanna L.	Lepidoptera: Crambidae	*Eoparargyractis plevie* Dyar	leaves	Fiance and Moeller (1977)	New Hampshire, USA
Ludiwiga sphaerocarpa Ell.	Coleoptera: Curculionidae	*Tyloderma sphaerocarpae* Wibmer		Wibmer (1981)	
Ludwigia alterniflora L.	Coleoptera: Curculionidae	*Perigaster cretura* Herbst	leaves	Knab (1915)	Maryland, USA
Ludwigia octovalvis (Jacq.) P.H. Raven	Coleoptera: Chrysomelidae	*Altica litigata* Fall	leaves	Center et. al (1999)	
Ludwigia octovalvis (Jacq.) P.H. Raven	Coleoptera: Curculionidae	*Perigaster cretura* Herbst	leaves	Center et. al (1999)	
Ludwigia octovalvis (Jacq.) P.H. Raven	Lepidoptera: Sphingidae	*Eumorpha fasciata* Sulzer	stems, leaves	Center et. al (1999)	
Ludwigia octovalvis (Jacq.) P.H. Raven	Orthoptera: Acrididae	*Gymnoscirtetes pusillus* Scudder		Squitier and Capinera (2002)	Florida, USA
Ludwigia octovalvis (Jacq.) P.H. Raven	Orthoptera: Acrididae	*Leptysma marginicollis* Serville		Squitier and Capinera (2002)	Florida, USA
Ludwigia octovalvis (Jacq.) P.H. Raven	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA

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Ludwigia octovalvis (Jacq.) P.H. Raven	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Ludwigia octovalvis (Jacq.) P.H. Raven	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Ludwigia octovalvis (Jacq.) P.H. Raven	Orthoptera: Acrididae	*Stenacris vitreipennis* Marschall		Squitier and Capinera (2002)	Florida, USA
Ludwigia palustris (L.) Ell.	Coleoptera: Chrysomelidae	*Altica litigata* Fall	leaves	Center et. al (1999)	
Ludwigia palustris (L.) Ell.	Coleoptera: Curculionidae	*Perigaster liturata* Dietz		Majka et al. (2007)	
Ludwigia peploides (Kunth) P.H. Raven	Coleoptera: Curculionidae	*Perigaster cretura* Herbst	leaves	Clark (1976)	Texas, USA
Ludwigia peploides (Kunth) P.H. Raven	Coleoptera: Chrysomelidae	*Lysathia ludoviciana* Fall	leaves	Haag et al. (1986)	Florida, USA
Ludwigia repens Forst	Coleoptera: Curculionidae	*Hyperodes echinatus* Dietz		Mitchell and Pierce (1911)	Texas, USA
Ludwigia repens Forst	Coleoptera: Curculionidae	*Perigaster cretura* Herbst	leaves	Mitchell and Pierce (1911)	
Ludwigia repens Forst	Coleoptera: Curculionidae	*Tyloderma aquaticum* Wibmer		Wibmer (1981)	
Ludwigia repens Forst	Diptera: Ephydridae	*Hydrellia alabamae* Deonier		Deonier (1993)	Alabama, Mississippi, USA
Ludwigia sp.	Homoptera: Delphacidae	Pissonotus piceus Van Duzee		Haag et al. (1986)	Florida, USA
Ludwigia sp.	Lepidoptera: Crambidae	*Langessa nomophilalis* Dyar		Stoops et al. (1998)	South Carolina, USA
Ludwigia sp.	Lepidoptera: Crambidae	*Munroessa gyralis* Hulst		Herlong (1979)	South Carolina, USA
Ludwigia sp.	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Stoops et al. (1998)	South Carolina, USA
Ludwigia spp.	Coleoptera: Curculionidae	*Pelenomus* sp.		Haag et al. (1986)	Florida, USA
Ludwigia spp.	Coleoptera: Curculionidae	*Perigaster* sp.	leaves	Haag et al. (1986)	Florida, USA
Ludwigia spp.	Coleoptera: Curculionidae	*Perigasteromimus tetracanthus* Champion		Anderson (2002)	Florida, USA
Ludwigia spp.	Coleoptera: Curculionidae	*Tyloderma circumcaribbeum* Wibmer		Wibmer (1981)	
Ludwigia suffruticosa Walter	Coleoptera: Curculionidae	*Tyloderma punctatum* Casey		Wibmer (1981)	
Ludwigia suffruticosa Walter	Orthoptera: Acrididae	*Gymnoscirtetes pusillus* Scudder		Squitier and Capinera (2002)	Florida, USA
Ludwigia suffruticosa Walter	Orthoptera: Acrididae	*Leptysma marginicollis* Serville		Squitier and Capinera (2002)	Florida, USA
Ludwigia suffruticosa Walter	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA

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Ludwigia suffruticosa Walter	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Ludwigia suffruticosa Walter	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Ludwigia suffruticosa Walter	Orthoptera: Acrididae	*Stenacris vitreipennis* Marschall		Squitier and Capinera (2002)	Florida, USA
Luziola fluitans (Michx.) Terrell & Rob.	Diptera: Ephydridae	*Hydrellia spinicornis* Cresson		Deonier (1971)	
Luziola fluitans (Michx.) Terrell & Rob.	Lepidoptera: Crambidae	*Eoparargyractis floridalis* Lange	leaves	Munroe (1972)	
Luziola fluitans (Michx.) Terrell & Rob.	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Habeck (1974)	
Menyanthes trifoliata L.	Lepidoptera: Crambidae	*Hydrocampus formosalis*	leaves	Packard (1884)	Providence, R.I., USA
Micranthemum umbrosum (Gmel.) Blake	Lepidoptera: Crambidae	*Langessa nomophilalis* Dyar		Stoops et al. (1998)	South Carolina, USA
Micranthemum umbrosum (Gmel.) Blake	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Stoops et al. (1998)	South Carolina, USA
Mimosa spp.	Coleoptera: Chrysomelidae	*Dysphenges elongatus* Horn	leaves	Riley et. al (2002)	
Mimosa spp.	Coleoptera: Chrysomelidae	*Pseudochlamys semirufescens* Karren	leaves	Riley et. al (2002)	
Myrica gale L.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	emergent leaves	Scott (1924)	Michigan, USA
Myrica spp.	Coleoptera: Chrysomelidae	*Colaspis favosa* sp. group	leaves	Riley et. al (2002)	
Myriophyllum heterophyllum Michx.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	McGaha (1952)	Michigan, USA
Myriophyllum heterophyllum Michx.	Coleoptera: Curculionidae	*Perenthis vestitus* Dietz	emergent leaves and stems	McGaha (1952)	Michigan, USA
Myriophyllum heterophyllum Michx.	Coleoptera: Curculionidae	*Tyloderma myriophylli* Wibmer		Wibmer (1981)	
Myriophyllum heterophyllum Michx.	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker	submerged leaves	Habeck (1974)	
Myriophyllum heterophyllum Michx.	Trichoptera: Leptoceridae	*Mystacides longicornis* Linnaeus	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum heterophyllum Michx.	Trichoptera: Leptoceridae	*Oecetis cinerascens* Hagen	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum heterophyllum Michx.	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum heterophyllum Michx.	Trichoptera: Leptoceridae	*Triaenodes marginata* Sibley	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum heterophyllum Michx.	Trichoptera: Leptoceridae	*Triaenodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA

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Myriophyllum sibiricum Kom.	Diptera: Chironomidae	*Harnischia abortiva* Malloch	submerged leaves and stems	McGaha (1952)	Michigan, USA
Myriophyllum sibiricum Kom.	Diptera: Chironomidae	*Harnischia tenuicaudata* Malloch	submerged leaves and stems	McGaha (1952)	Michigan, USA
Myriophyllum sibiricum Kom.	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	leaves	McGaha (1952)	Michigan, USA
Myriophyllum sibiricum Kom.	Trichoptera: Leptoceridae	*Atripsodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum sibiricum Kom.	Trichoptera: Leptoceridae	*Leptocella exquisita* Walker	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum sibiricum Kom.	Trichoptera: Leptoceridae	*Leptocella* spp.	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Myriophyllum sibiricum Kom.	Trichoptera: Leptoceridae	*Mystacides longicornis* L.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Myriophyllum sp.	Coleoptera: Curculionidae	*Bagous tingi* Tanner		O'Brien and Marshall (1979)	
Myriophyllum sp.	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Herlong (1979)	South Carolina, USA
Myriophyllum spp.	Coleoptera: Chrysomelidae	*Lysathia ludoviciana* Fall	leaves	Riley et. al (2002)	
Myriophyllum spp.	Coleoptera: Curculionidae	*Eurychiopsis lecontei* Dietz		Spencer and Lekie (1974), Anderson (2002)	
Myriophyllum spp.	Coleoptera: Curculionidae	*Phytobius leucogaster* Marsham	flowers	Anderson (2002)	
Myriophyllum spp.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	leaves	Center et. al (1999)	
Najas guadalupensis (Spreng.) Magnus	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson	submersed leaves	Deonier (1998)	
Najas guadalupensis (Spreng.) Magnus	Diptera: Ephydridae	*Hydrellia najadis* Deonier	submersed leaves	Deonier (1993)	Florida, USA
Najas guadalupensis (Spreng.) Magnus	Trichoptera: Leptoceridae	*Nectopsyche tavara* Ross		Haag et al. (1986)	Florida, USA
Nasturtium officinale W.T. Aiton	Coleoptera: Curculionidae	*Amalorrhynchus melanarius* Stephens		Anderson (2002)	Northeast, USA
Nasturtium officinale W.T. Aiton	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Deonier (1971)	
Nelumbo lutea Willd.	Lepidoptera: Crambidae	*Ostrinia penitalis* Grote	leaves and petioles	Mutuura and Munroe (1970)	
Nelumbo lutea Willd.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	leaves and petioles	McCafferty and Minno (1979)	
Nuphar lutea (L.) Sm.	Coleoptera: Chrysomelidae	*Donacia piscatrix* Lacordaire	roots, leaves	Hoffman (1940), McGaha (1952)	Michigan, USA

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Nuphar lutea (L.) Sm.	Coleoptera: Chrysomelidae	*Donacia proxima* Kirby	roots, leaves	Hoffman (1940), McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	emergent and floating leaves	Scott (1924), McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Coleoptera: Coccinellidae	*Coleomegilla maculata* DeGeer	floating leaves	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Coleoptera: Coccinellidae	*Hippodamia 13-punctata tibialis* Say	floating leaves	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Anthomyiidae	*Hydromyza confluens* Loew	floating leaves	McGaha (1952), Haag et al. (1986)	Florida, USA
Nuphar lutea (L.) Sm.	Diptera: Chironomidae	*Polypedilum fallax* Johannsen	petioles	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Chironomidae	*Polypedilum tritum* Walker	petioles	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Chironomidae	*Tanytarsus quadripunctatus* Johannsen	petioles and flower peduncles	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Chironomidae	*Tendipes* sp.	petioles	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Empididae	*Hilara bella* Coquillet	flowers	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	flowers	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Diptera: Hileidae	*Atrichopogon fusinervis* Malloch	flowers	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	aerial and floating leaves	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Homoptera: Cicadellidae	*Draeculacephala inscripta* Van Duzee	emergent leaves	Haag et al. (1986)	Florida, USA
Nuphar lutea (L.) Sm.	Homoptera: Cicadellidae	*Draeculacephala* sp.	emergent leaves	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Homoptera: Delphacidae	*Megamelus davisi* Van Duzee		McGaha (1952), Haag et al. (1986)	Florida, USA
Nuphar lutea (L.) Sm.	Lepidoptera: Crambidae	*Ostrinia penitalis* Grote	leaves and petioles	Mutuura and Munroe (1970)	
Nuphar lutea (L.) Sm.	Lepidoptera: Crambidae	*Paraponyx maculalis* Clemens	submerged and floating leaves	Welch (1916), McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote	floating leaves	Berg (1950), McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Lepidoptera: Noctuidae	*Bellura gortynoides* Walker	leaves	McCafferty and Minno (1979)	
Nuphar lutea (L.) Sm.	Lepidoptera: Noctuidae	*Bellura melanopyga* Grote	emergent and floating leaves and petioles	McGaha (1952, 1954b)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Lemnephilidae	*Lemnephilus consocius* Walker	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA

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Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Atripsodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Leptocella exquisita* Walker	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Leptocella* spp.	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Triaenodes marginata* Sibley	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Triaenodes sepulchralis* Walker	submerged leaves	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Leptoceridae	*Triaenodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm.	Trichoptera: Phryganeidae	*Banksiola salina* Betten	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nuphar lutea (L.) Sm. ssp. *advena* (Aiton) Kartesz & Gandhi	Coleoptera: Curculionidae	*Onychylis nigrirostris* Boheman	emergent leaves, stems	Center et. al (1999)	
Nuphar lutea (L.) Sm. ssp. *advena* (Aiton) Kartesz & Gandhi	Lepidoptera: Noctuidae	*Homophoberia cristata* Morr.	leaves	Center et. al (1999)	
Nuphar sp.	Coleoptera: Chrysomelidae	*Donacia palmata* Oliver	roots, leaves	Marx (1957)	
Nuphar sp.	Coleoptera: Chrysomelidae	*Donacia piscatrix* Lacordaire	roots, leaves	Marx (1957)	
Nuphar sp.	Coleoptera: Chrysomelidae	*Donacia proxima* Kirby	roots, leaves	Marx (1957)	
Nuphar sp.	Coleoptera: Chrysomelidae	*Donacia texana* Crotch	roots, leaves	Marx (1957)	
Nuphar sp.	Diptera: Chironomidae	*Hyporhygma quadripunctatum* Malloch	leaves, petioles	Epler (2001)	North and South Carolina, USA
Nuphar sp.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	floating leaves	Brigham and Herlong (1982)	
Nuphar sp.	Lepidoptera: Noctuidae	*Neoerastria caduca* Grote	emergent leaves	McCafferty and Minno (1979)	Indiana, Illinois, Michigan, Ohio, USA
Nymphaea odorata Aiton	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	McGaha (1952)	Michigan, USA

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Nymphaea odorata Aiton	Coleoptera: Chrysomelidae	*Donacia pubescens* LeConte	roots, leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	emergent and floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Coleoptera: Coccinellidae	*Coleomegilla maculata* DeGeer	floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Coleoptera: Coccinellidae	*Hippodamia 13-punctata tibialis* Say	floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Coleoptera: Curculionidae	*Bagous americanus* LeConte	leaves and petioles	McGaha (1952), O'Brien and Marshall (1979)	Michigan, Florida, USA
Nymphaea odorata Aiton	Coleoptera: Curculionidae	*Bagous magister* LeConte		O'Brien and Marshall (1979)	
Nymphaea odorata Aiton	Coleoptera: Curculionidae	*Bagous tanneri* Tanner	petioles	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Coleoptera: Curculionidae	*Onychylis nigrirostris* Boheman	floating and emergent leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Diptera: Chironomidae	*Polypedilum braseniae* Leathers	floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Diptera: Chironomidae	*Polypedilum illinoense* Malloch	floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Diptera: Chironomidae	*Tanytarsus quadripunctatus* Johannsen	petioles and flower peduncles	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Diptera: Ephydridae	*Notiphila loewi* Cresson	flowers	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	aerial and floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Homoptera: Delphacidae	*Megamelus davisi* Van Duzee	Emergent and floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Langessa nomophilalis* Dyar		Herlong (1979), Stoops et al. (1998)	South Carolina, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Munroessa gyralis* Hulst		Herlong (1979), Stoops et al. (1998)	South Carolina, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Herlong (1979)	South Carolina, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker	leaves	McGaha (1952), Herlong (1979)	Michigan, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Paraponyx maculalis* Clemens	submerged and floating leaves	McGaha (1952), Habeck (1974), Herlong (1979), Stoops et al. (1998)	Michigan, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Stoops et al. (1998)	South Carolina, USA

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Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Herlong (1979)	South Carolina, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Paraponyx serralinealis* Barnes & Benjamin	leaves and petioles	McGaha (1952, 1954b)	Michigan, USA
Nymphaea odorata Aiton	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	floating leaves	Herlong (1979)	South Carolina, USA
Nymphaea odorata Aiton	Trichoptera: Leptoceridae	*Mystacides longicornis* Linnaeus	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Trichoptera: Leptoceridae	*Oecetis* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Trichoptera: Leptoceridae	*Triaenodes marginata* Sibley	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Trichoptera: Leptoceridae	*Triaenodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton	Trichoptera: Polycentropidae	*Polycentropus remotus* Banks	submerged leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Coleoptera: Chrysomelidae	*Donacia pubescens* LeConte	roots, leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Coleoptera: Coccinellidae	*Hippodamia 13-punctata tibialis* Say	floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Coleoptera: Curculionidae	*Bagous americanus* LeConte	leaves and petioles	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Coleoptera: Curculionidae	*Bagous tanneri* Tanner	petioles	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Diptera: Chironomidae	*Polypedilum illinoense* Malloch	floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Diptera: Ephydridae	*Notiphila loewi* Cresson	flowers	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	aerial and floating leaves	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Lepidoptera: Crambidae	*Paraponyx serralinealis* Barnes & Benjamin	leaves and petioles	McGaha (1952, 1954b)	Michigan, USA

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Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Trichoptera: Leptoceridae	*Mystacides longicornis* Linnaeus	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Trichoptera: Leptoceridae	*Oecetis* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea odorata Aiton ssp. *tuberosa* (Paine) Wiersma & Hellquist	Trichoptera: Leptoceridae	*Triaenodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Nymphaea sp.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Marx (1957)	
Nymphaea sp.	Coleoptera: Chrysomelidae	*Donacia liebecki* Schaeffer	roots, leaves	Marx (1957)	
Nymphaea sp.	Coleoptera: Chrysomelidae	*Donacia megacornis* Blatchley	roots, leaves	Marx (1957)	
Nymphaea sp.	Coleoptera: Chrysomelidae	*Donacia militaris* Lacordaire	roots, leaves	Marx (1957)	
Nymphaea sp.	Coleoptera: Chrysomelidae	*Donacia parvidens* Schaeffer	roots, leaves	Marx (1957)	
Nymphaea sp.	Coleoptera: Chrysomelidae	*Donacia rufescens* Lacordaire	roots, leaves	Marx (1957)	
Nymphaea spp.	Diptera: Chironomidae	*Hyporhygma quadripunctatum* Malloch	leaves, petioles	Epler (2001)	North and South Carolina, USA
Nymphaea spp.	Lepidoptera: Noctuidae	*Bellura gortynoides* Walker	leaves	McCafferty and Minno (1979)	
Nymphoides aquatica (J.F. Gmel.) Kuntze	Lepidoptera: Crambidae	*Langessa nomophilalis* Dyar		Herlong (1979), Stoops et al. (1998)	South Carolina, USA
Nymphoides aquatica (J.F. Gmel.) Kuntze	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Stoops et al. (1998)	South Carolina, USA
Nymphoides aquatica (J.F. Gmel.) Kuntze	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Habeck (1974), Herlong (1979), Stoops (1998)	South Carolina, USA
Nymphoides aquatica (J.F. Gmel.) Kuntze	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	floating leaves	Stoops et al. (1998)	South Carolina, USA
Oenothera albicaulis Pursh	Coleoptera: Curculionidae	*Tyloderma pseudofoveolatum* Wibmer	roots	Wibmer (1981)	
Oenothera biennis L.	Coleoptera: Curculionidae	*Tyloderma foveolatum* Say	stems, taproots	Wibmer (1981)	USA
Oenothera biennis L.	Coleoptera: Curculionidae	*Tyloderma pseudofoveolatum* Wibmer	roots	Wibmer (1981)	

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Oenothera laciniata Hill	Coleoptera: Curculionidae	*Tyloderma baridium* LeConte	roots	Wibmer (1981)	
Oenothera laciniata Hill	Coleoptera: Curculionidae	*Tyloderma foveolatum* Say	stems, taproots	Wibmer (1981)	
Oenothera sp.	Coleoptera: Chrysomelidae	*Altica copelandi* Ciegler	leaves	Ciegler (2006)	South Carolina, USA
Oenothera sp.	Coleoptera: Curculionidae	*Tyloderma angustulum* Casey		Wibmer (1981)	
Oenothera sp.	Coleoptera: Curculionidae	*Tyloderma pseudofoveolatum* Wibmer	roots	Wibmer (1981)	
Oenothera spp.	Coleoptera: Chrysomelidae	*Lysathia ludoviciana* Fall	leaves	Riley et. al (2002)	
Orontium aquaticum L.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Herlong (1979), Stoops et al. (1998)	South Carolina, USA
Orontium aquaticum L.	Lepidoptera: Crambidae	*Paraponyx maculalis* Clemens		Stoops et al. (1998)	South Carolina, USA
Orontium aquaticum L.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Stoops et al. (1998)	South Carolina, USA
Orontium aquaticum L.	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Herlong (1979)	South Carolina, USA
Panicum sp.	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Malloch (1915)	
Peltandra sp.	Coleoptera: Chrysomelidae	*Donacia rufa* Say	roots, leaves	Marx (1957)	
Peltandra virginica (L.) Schott	Coleoptera: Curculionidae	*Listronotus delumbis* Gyllenhal		O'Brien (1997)	
Phragmites australis (Cav.) Trin. ex Steud.	Coleoptera: Chrysomelidae	*Donacia pubicollis* Crotch	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Phragmites sp.	Coleoptera: Chrysomelidae	*Donaciella pubicollis* Suffrian	floating leaves	Riley et. al (2002)	
Polygonum amphibium L.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	emergent leaves	Scott (1924)	Michigan, USA
Polygonum amphibium L.	Lepidoptera: Arctiidae	*Estigmene acraea* Drury		Tietz (1972)	Florida, USA
Polygonum densiflorum Meissner	Coleoptera: Chrysomelidae	*Disonycha pensylvanica Illiger*	leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum glabrum Willd.	Coleoptera: Chrysomelidae	*Disonycha conjugata* Fabricus	leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum glabrum Willd.	Coleoptera: Curculionidae	*Lixus merula* Suffr.	stems, leaves	Center et. al (1999)	
Polygonum glabrum Willd.	Coleoptera: Curculionidae	*Lixus punctinasus* LeConte	stems, leaves	Center et. al (1999)	
Polygonum glabrum Willd.	Coleoptera: Curculionidae	*Rhinoncus longulus* LeConte	stems, leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum glabrum Willd.	Coleoptera: Curculionidae	*Tyloderma rufescens* Casey		Wibmer (1981)	
Polygonum glabrum Willd.	Diptera: Stratiomyidae	*Nothonomyia calopus* Loew		Heppner and Habeck (1977)	Florida, USA

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Polygonum glabrum Willd.	Lepidoptera: Crambidae	*Ostrinia penitalis* Grote	leaves and petioles	Heppner and Habeck (1976)	Florida, USA
Polygonum glabrum Willd.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum glabrum Willd.	Lepidoptera: Gelechiidae	*Aristotelia ansconditella* Walker		Heppner and Habeck (1976)	Florida, USA
Polygonum glabrum Willd.	Lepidoptera: Gelechiidae	*Chionodes discoocellella* Chambers	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum glabrum Willd.	Lepidoptera: Pyralidae	*Sylepta penumbralis* Grote	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum glabrum Willd.	Lepidoptera: Tortricidae	*Argyrotaenia ivana* Fernald	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum glabrum Willd.	Coleoptera: Curculionidae	*Bagous lunatoides* O'Brien		O'Brien and Marshall (1979)	Florida, USA
Polygonum hirsutum Walter	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Polygonum hirsutum Walter	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Polygonum hydropiperoides Michx.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	emergent leaves	Scott (1924)	Michigan, USA
Polygonum hydropiperoides Michx.	Coleoptera: Curculionidae	*Tyloderma rufescens* Casey		Wibmer (1981)	
Polygonum hydropiperoides Michx.	Coleoptera: Curculionidae	*Tyloderma subpubescens* Casey	stems	Wibmer (1981)	
Polygonum hydropiperoides Michx.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum hydropiperoides Michx.	Lepidoptera: Noctuidae	*Simyra henrici* Grote	leaves	Cassani (1985)	Florida, USA
Polygonum lapathifolium L.	Coleoptera: Curculionidae	*Tyloderma subpubescens* Casey	stems	Wibmer (1981)	
Polygonum punctatum Elliot	Coleoptera: Curculionidae	*Lixus merula* Suffr.	stems, leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum punctatum Elliot	Coleoptera: Curculionidae	*Lixus punctinasus* LeConte	stems, leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum punctatum Elliot	Coleoptera: Curculionidae	*Rhinoncus longulus* LeConte	stems	Heppner and Habeck (1977)	Florida, USA
Polygonum punctatum Elliot	Coleoptera: Curculionidae	*Tyloderma rufescens* Casey		Wibmer (1981)	
Polygonum punctatum Elliot	Coleoptera: Curculionidae	*Tyloderma subpubescens* Casey	stems	Mitchell and Pierce (1911)	Texas, USA
Polygonum punctatum Elliot	Diptera Chloropidae	*Elachiptera willistoni* Sabrosky	leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum punctatum Elliot	Homoptera: Aphididae	*Hyalomyzus tissoti* Nielsson & Habeck	leaves and stems	Heppner and Habeck (1977)	Florida, USA
Polygonum punctatum Elliot	Homoptera: Psyllidae	*Aphalara persicaria* Caldwell	leaves	Heppner and Habeck (1977)	Florida, USA
Polygonum punctatum Elliot	Hymenoptera: Tenthredinidae	*Ametastegia articulata* Klug.	leaves	Heppner and Habeck (1977)	Florida, USA

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Polygonum punctatum Elliot	Lepidoptera: Arctiidae	*Diacrisa virginica* Fabricus		Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Arctiidae	*Estigmene acraea* Drury		Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Coleophoridae	*Coleophora* sp.		Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Crambidae	*Ostrinia penitalis* Grote	leaves and petioles	Center et. al (1999)	
Polygonum punctatum Elliot	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Gelechiidae	*Aristotelia ansconditella* Walker		Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Gelechiidae	*Chionodes discoocellella* Chambers	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Geometridae	*Anacamptodes defectaria* Guenee	flowers, leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Noctuidae	*Acronicta oblinita* Abbot & Smith		Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Noctuidae	*Argyrogramma verruca* Fabricus	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Noctuidae	*Neoerastria apicosa* Haworth	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Noctuidae	*Palthis asopialis* Guenée	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Noctuidae	*Spodoptera dolichos* Fabricus	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Noctuidae	*Spodoptera eridania* Cramer	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Tortricidae	*Argyrotaenia ivana* Fernald	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Tortricidae	*Platynota rostrana* Walker	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Lepidoptera: Tortricidae	*Sparganothis sulfureana* Clemens	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum punctatum Elliot	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Polygonum punctatum Elliot	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Polygonum punctatum Elliot	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Polygonum setaceum Baldwin ex Elliott	Lepidoptera: Noctuidae	*Argyrogramma verruca* Fabricus	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum sp.	Homoptera: Delphacidae	*Pissonotus piceus* Van Duzee		Haag et al. (1986)	Florida, USA
Polygonum sp.	Lepidoptera: Arctiidae	*Apantesis arge* Drury	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Arctiidae	*Isia isabella* Abbot & Smith	leaves	Tietz (1972)	Florida, USA

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Polygonum sp.	Lepidoptera: Coleophoridae	*Coleophora shaleriella* Chambers	seeds	Forbes (1923)	
Polygonum sp.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Herlong (1979)	South Carolina, USA
Polygonum sp.	Lepidoptera: Crambidae	*Ostrinia penitalis* Grote	leaves and petioles	Heppner and Habeck (1976)	Florida, USA
Polygonum sp.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Habeck (1974), Herlong (1979)	South Carolina, USA
Polygonum sp.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum sp.	Lepidoptera: Gelechiidae	*Chionodes discoocellella* Chambers	leaves	Forbes (1923)	
Polygonum sp.	Lepidoptera: Geometridae	*Apicia confusaria* Hübner	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Euphyia centrostrigaria* Wolaston	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Euphyia multiferata* Walker	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Haematopsis grataria* Fabricus	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Melanolophia canadaria* Guenée	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Nycterosea obstipata* Fabricus	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Prochoerodes transversata* Drury	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Geometridae	*Timandra amaturaria* Walker	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Lycaenidae	*Lycaena thoe* Guérin-Méné-ville	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Dipterygia scabriuscula* L.	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Feltia subterranea* Fabricus	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Heliothis zea* Boddie	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Lithacodia carneola* Guenée	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Peridroma saucia* Hübner	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Plathypena scabra* Fabricus	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Noctuidae	*Simyra henrici* Grote	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Papilionidae	*Battus philenor* L.	leaves	Tietz (1972)	Florida, USA

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Polygonum sp.	Lepidoptera: Pyralidae	*Sylepta penumbralis* Grote	leaves	Heppner and Habeck (1976)	Florida, USA
Polygonum sp.	Lepidoptera: Sphingidae	*Hyles lineata* Fabricus	leaves	Tietz (1972)	Florida, USA
Polygonum sp.	Lepidoptera: Tortricidae	*Epiblema otiosana* Clemens	leaves	Tietz (1972)	Florida, USA
Polygonum spp.	Coleoptera: Chrysomelidae	*Disonycha glabrata* Fabricius	stems, leaves	Haag et al. (1986)	Florida, USA
Polygonum spp.	Coleoptera: Chrysomelidae	*Disonycha pensylvanica* Illiger	leaves	Haag et al. (1986)	Florida, USA
Polygonum spp.	Coleoptera: Curculionidae	*Amalus scortillum* Herbst	crown	Anderson (2002)	Northeast, USA
Polygonum spp.	Coleoptera: Curculionidae	*Homorosoma sulcipenne* LeConte		Anderson (2002)	
Polygonum spp.	Coleoptera: Curculionidae	*Neophytobius cavifrons* LeConte		Anderson (2002)	
Polygonum spp.	Coleoptera: Curculionidae	*Rhinoncus pyrrhopus* Bohemon		Hoebeke and Whitehead (1980)	
Polygonum spp.	Coleoptera: Curculionidae	*Rhinoncus* sp.		Haag et al. (1986)	Florida, USA
Polygonum spp.	Coleoptera: Curculionidae	*Tyloderma capitale* Wibmer		Wibmer (1981)	
Polygonum spp.	Lepidoptera: Noctuidae	*Acronycta oblinita* Abbot and Smith		Brigham and Herlong (1982)	
Polygonum spp.	Lepidoptera: Noctuidae	*Dipterygia scabriuscula* Linnaeus		Forbes (1954)	
Polygonum spp.	Lepidoptera: Noctuidae	*Neoerastria apicosa* Haworth	leaves	Tietz (1972)	Florida, USA
Polygonum spp.	Lepidoptera: Noctuidae	*Lithacodia carneola* Guenée		Forbes (1954)	
Pontederia cordata L.	Coleoptera: Curculionidae	*Onychylis nigrirostris* Boheman	emergent leaves, stems	Haag et al. (1986)	Florida, USA
Pontederia cordata L.	Diptera: Ephydridae	*Hydrellia pontederiae* Deonier		Deonier (1993)	Florida, USA
Pontederia cordata L.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	leaves	Center et. al (1999)	
Pontederia cordata L.	Lepidoptera: Noctuidae	*Bellura densa* Walker	stems and petioles	Vogel and Oliver (1969)	
Pontederia cordata L.	Lepidoptera: Noctuidae	*Bellura gortynoides* Walker	leaves	McCafferty and Minno (1979)	
Pontederia cordata L.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	leaves	McCafferty and Minno (1979)	
Pontederia cordata L.	Orthoptera: Acrididae	*Leptysma marginicollis* Serville		Squitier and Capinera (2002)	Florida, USA
Pontederia cordata L.	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA

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Pontederia cordata L.	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Pontederia cordata L.	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Pontederia cordata L.	Orthoptera: Acrididae	*Stenacris vitreipennis* Marschall		Squitier and Capinera (2002)	Florida, USA
Pontederia sp.	Coleoptera: Chrysomelidae	*Donacia fulgens* LeConte	roots, leaves	Marx (1957)	
Pontederia sp.	Coleoptera: Chrysomelidae	*Donacia rugosa* LeConte	roots, leaves	Marx (1957)	
Pontederia sp.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Marx (1957)	
Populus angustifolia James	Coleoptera: Curculionidae	*Isochnus rufipes* LeConte	leaves	Anderson (1989)	
Populus balsamifera L. ssp. *balsamifera*	Coleoptera: Chrysomelidae	*Altica prasina populi* Brown	leaves	LeSage (1995)	
Populus balsamifera L. ssp. *balsamifera*	Coleoptera: Curculionidae	*Tachyerges salicis* Linnaeus	leaves	Anderson (1989)	
Populus balsamifera L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw	Coleoptera: Chrysomelidae	*Altica prasina populi* Brown	leaves	LeSage (1995)	
Populus balsamifera L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw	Coleoptera: Chrysomelidae	*Altica prasina prasina* LeConte	leaves	LeSage (1995)	
Populus balsamifera L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook.) Brayshaw	Coleoptera: Curculionidae	*Tachyerges salicis* Linnaeus	leaves	Anderson (1989)	
Populus deltoides Marsh.	Coleoptera: Chrysomelidae	*Altica prasina populi* Brown	leaves	LeSage (1995)	
Populus deltoides Marsh.	Coleoptera: Chrysomelidae	*Altica prasina prasina* LeConte	leaves	LeSage (1995)	
Populus sp.	Lepidoptera: Geometridae	*Anacamptodes defectaria* Guenee	flowers, leaves	Kimball (1965)	Florida, USA
Populus spp.	Coleoptera: Chrysomelidae	*Chrysomela crotchi* Brown		Riley et. al (2002)	
Populus spp.	Coleoptera: Chrysomelidae	*Chrysomela invicta* Brown		Riley et. al (2002)	
Populus spp.	Coleoptera: Chrysomelidae	*Plagiodera californica* Rogers		Riley et. al (2002)	
Populus spp.	Coleoptera: Chrysomelidae	*Plagiodera californica* Rogers		Riley et. al (2002)	
Populus spp.	Coleoptera: Chrysomelidae	*Plagiodera versicolora* Laicharding		Riley et. al (2002)	
Populus spp.	Coleoptera: Curculionidae	*Rutidosoma decipiens* LeConte		Anderson (1997)	

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Populus spp.	Lepidoptera: Noctuidae	*Simyra henrici* Grote	leaves	Center et. al (1999)	
Populus tremuloides Michx.	Coleoptera: Curculionidae	*Tachyerges salicis* Linnaeus	leaves	Anderson (1989)	
Potamogeton alpinus Balbis	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Diptera: Anthomyiidae	*Hydromyza confluens* Loew	Roots	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Diptera: Ephydridae	*Hydrellia luctuosa* Cresson	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Diptera: Ephydridae	*Notiphila loewi* Cresson	Roots	Berg (1949)	Michigan, USA
Potamogeton alpinus Balbis	Trichoptera: Leptoceridae	*Triaenodes marginata* Sibley	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Cricotopus elegans* Johannsen	floating leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Cricotopus flavipes* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Cricotopus trifasciatus* Panzer	Floating leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Glyptotendipes lobiferus* Say	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Polypedilum sordens* van der Wulp	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Chironomidae	*Tanytarsus nigricans* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA

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Potamogeton amplifolius Tuck.	Diptera: Ephydridae	*Hydrellia luctuosa* Cresson	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Diptera: Ephydridae	*Hydrellia pulla* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	submerged leaves (rarely on floating leaves)	Berg (1949, 1950)	Michigan, Wisconsin, USA
Potamogeton amplifolius Tuck.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote	submerged leaves	Berg (1949, 1950)	Michigan, USA
Potamogeton amplifolius Tuck.	Trichoptera: Leptoceridae	*Leptocella albida* Walker	leaves, stems, stipules, petioles	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Trichoptera: Leptoceridae	*Triaenodes tarda* Milne	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton amplifolius Tuck.	Trichoptera: Phryganeidae	*Ptilostomis* sp.	Leaves	Berg (1949)	Michigan, USA
Potamogeton berchtoldii Fieber	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson		Deonier (1971)	
Potamogeton diversifolius Fernald	Lepidoptera: Crambidae	*Munroessa gyralis* Hulst		Stoops et al. (1998)	South Carolina, USA
Potamogeton diversifolius Fernald	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Stoops et al. (1998)	South Carolina, USA
Potamogeton diversifolius Fernald	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Stoops et al. (1998)	South Carolina, USA
Potamogeton diversifolius Fernald	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Stoops et al. (1998)	South Carolina, USA
Potamogeton diversifolius Fernald	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Stoops et al. (1998)	South Carolina, USA
Potamogeton epihydrus Raf.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton epihydrus Raf.	Diptera: Chironomidae	*Cricotopus flavipes* Johannsen	submerged leaves	Berg (1950)	Michigan, USA
Potamogeton epihydrus Raf.	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton epihydrus Raf.	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson		Deonier (1971)	
Potamogeton epihydrus Raf.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton epihydrus Raf.	Diptera: Ephydridae	*Hydrellia discursa* Deonier		Deonier (1971)	

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Potamogeton epihydrus Raf.	Diptera: Ephydridae	*Hydrellia trichaeta* Cresson		Deonier (1971)	
Potamogeton epihydrus Raf.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Herlong (1979)	South Carolina, USA
Potamogeton foliosis Raf.	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton foliosis Raf.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton friesii Rupr.	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton gramineus L.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton gramineus L.	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1950)	Michigan, USA
Potamogeton gramineus L.	Diptera: Chironomidae	*Glyptotendipes lobiferus* Say	stems, petioles, leaf mid-ribs	Berg (1950)	Michigan, USA
Potamogeton gramineus L.	Diptera: Chironomidae	*Polypedilum sordens* van der Wulp	stems, petioles, leaf mid-ribs	Berg (1950)	Michigan, USA
Potamogeton gramineus L.	Diptera: Chironomidae	*Tanytarsus nigricans* Johannsen	submerged leaves	Berg (1950)	Michigan, USA
Potamogeton gramineus L.	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson		Deonier (1971)	
Potamogeton gramineus L.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton gramineus L.	Diptera: Ephydridae	*Hydrellia discursa* Deonier		Deonier (1971)	
Potamogeton gramineus L.	Diptera: Ephydridae	*Hydrellia pulla* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton gramineus L.	Diptera: Ephydridae	*Hydrellia trichaeta* Cresson	submerged leaves (rarely on floating leaves)	Deonier (1971)	
Potamogeton gramineus L.	Trichoptera: Leptoceridae	*Leptocella albida* Walker	leaves, stems, stipules, petioles	Berg (1949)	Michigan, USA
Potamogeton illinoensis Morong	Coleoptera: Chrysomelidae	*Haemonia nigricornis* Kirby	roots, stipules, stems, leaves	Berg (1949)	Michigan, USA
Potamogeton illinoensis Morong	Diptera: Chironomidae	*Cricotopus flavipes* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton illinoensis Morong	Diptera: Chironomidae	*Tanytarsus nigricans* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton illinoensis Morong	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton illinoensis Morong	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson	submerged leaves (rarely on floating leaves)	Deonier (1998)	

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Potamogeton illinoensis Morong	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton natans L.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Potamogeton natans L.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Coleoptera: Chrysomelidae	*Donacia* sp.	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Potamogeton natans L.	Coleoptera: Chrysomelidae	*Haemonia nigricornis* Kirby	roots, stipules, stems, leaves	Hoffman (1940)	Northern Michigan, USA
Potamogeton natans L.	Diptera: Chironomidae	*Cricotopus elegans* Johannsen	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Chironomidae	*Cricotopus trifasciatus* Panzer	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Chironomidae	*Polypedilum bergi* Maschwitz	leaves	Epler (2001)	Minnesota, USA
Potamogeton natans L.	Diptera: Chironomidae	*Polypedilum illinoense* Malloch	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Chironomidae	*Polypedilum ophiodes* Townes	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Chironomidae	*Polypedilum sordens* van der Wulp	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Ephydridae	*Hydrellia bergi* Cresson	stems, petioles	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton natans L.	Diptera: Ephydridae	*Hydrellia ischiaca* Loew		Deonier (1971)	
Potamogeton natans L.	Diptera: Ephydridae	*Hydrellia luctuosa* Cresson	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton natans L.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Homoptera: Delphacidae	*Megamelus davisi* Van Duzee	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker	floating leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Lepidoptera: Crambidae	*Paraponyx allionealis itealis* Walker	submerged leaves	Berg (1949)	Michigan, USA

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Potamogeton natans L.	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton natans L.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton natans L.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker		Brigham and Herlong (1982)	
Potamogeton nodosus Poir.	Diptera: Chironomidae	*Cricotopus elegans* Johannsen	floating leaves	Berg (1949)	Michigan, USA
Potamogeton nodosus Poir.	Diptera: Chironomidae	*Cricotopus trifasciatus* Panzer	floating leaves	Berg (1949)	Michigan, USA
Potamogeton nodosus Poir.	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton nodosus Poir.	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson	submerged leaves (rarely on floating leaves)	Deonier (1971)	
Potamogeton nodosus Poir.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton nodosus Poir.	Diptera: Ephydridae	*Hydrellia discursa* Deonier	submerged leaves (rarely on floating leaves)	Deonier (1971)	
Potamogeton nodosus Poir.	Diptera: Ephydridae	*Hydrellia trichaeta* Cresson	submerged leaves (rarely on floating leaves)	Deonier (1971)	
Potamogeton nodosus Poir.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	Floating leaves	Berg (1949)	Michigan, USA
Potamogeton oakesianus J.W. Robbins	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton praelongus Wulfen	Diptera: Chironomidae	*Cricotopus flavipes* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton praelongus Wulfen	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton praelongus Wulfen	Diptera: Ephydridae	*Hydrellia caliginosa* Cresson	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton praelongus Wulfen	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton praelongus Wulfen	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton praelongus Wulfen	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote	submerged leaves	Berg (1949)	Michigan, USA

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Potamogeton praelongus Wulfen	Trichoptera: Leptoceridae	*Leptocella albida* Walker	Leaves, stems, stipules, petioles	Berg (1949)	Michigan, USA
Potamogeton pulcher Tuck.	Lepidoptera: Crambidae	*Munroessa gyralis* Hulst		Stoops et al. (1998)	South Carolina, USA
Potamogeton pulcher Tuck.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Herlong (1979)	South Carolina, USA
Potamogeton pulcher Tuck.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Herlong (1979), Stoops et al. (1998)	South Carolina, USA
Potamogeton pusillus L.	Coleoptera: Curculionidae	*Bagous restrictus* LeConte		O'Brien and Marshall (1979)	California, USA
Potamogeton pusillus L.	Coleoptera: Curculionidae	*Bagous transversus* LeConte		O'Brien and Marshall (1979)	Utah, USA
Potamogeton pusillus L.	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson		Deonier (1998)	
Potamogeton pusillus L.	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Habeck (1974)	
Potamogeton pusillus L. ssp. *pusillus*	Coleoptera: Curculionidae	*Bagous tingi* Tanner		Tanner (1943)	
Potamogeton pusillus L. ssp. *tenuissimus* (Mert. & W.D.J. Koch) Haynes & C.B. Hellquist	Lepidoptera: Crambidae	*Langessa nomophilalis* Dyar		Stoops et al. (1998)	South Carolina, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Coleoptera: Chrysomelidae	*Donacia cincticornis* Newman	roots, leaves	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Chironomidae	*Cricotopus flavipes* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Chironomidae	*Polypedilum sordens* van der Wulp	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Chironomidae	*Tanytarsus nigricans* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Ephydridae	*Hydrellia ascita* Cresson	submerged leaves	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Ephydridae	*Hydrellia bergi* Cresson	stems, petioles	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA

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*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Ephydridae	*Hydrellia luctuosa* Cresson	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Ephydridae	*Hydrellia pulla* Cresson	submerged leaves	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Diptera: Ephydridae	*Notiphila loewi* Cresson	Roots	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote	submerged leaves	Berg (1950)	Michigan, USA
*Potamogeton richardsonii (*Benn.) Rydb.	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton robbinsii Oakes	Diptera: Chironomidae	*Cricotopus flavipes* Johannsen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton robbinsii Oakes	Diptera: Chironomidae	*Glyptotendipes dreisbachi* Townes	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton robbinsii Oakes	Diptera: Chironomidae	*Glyptotendipes lobiferus* Say	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton robbinsii Oakes	Diptera: Chironomidae	*Polypedilum sordens* van der Wulp	stems, petioles, leaf mid-ribs	Berg (1949)	Michigan, USA
Potamogeton robbinsii Oakes	Trichoptera: Leptoceridae	*Leptocella albida* Walker	Leaves, stems, stipules, petioles	Berg (1949)	Michigan, USA
Potamogeton robbinsii Oakes	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves	Berg (1949)	Michigan, USA
Potamogeton sp.	Coleoptera: Curculionidae	*Bagous chandleri* Tanner		O'Brien and Marshall (1979)	Utah, USA
Potamogeton sp.	Coleoptera: Curculionidae	*Bagous tingi* Tanner		O'Brien and Marshall (1979)	
Potamogeton sp.	Diptera: Ephydridae	*Hydrellia fascitibia* von Rosser	submerged leaves (rarely on floating leaves)	Hering (1951)	
Potamogeton spp.	Coleoptera: Curculionidae	*Eurychiopsis lecontei* Dietz		Anderson (2002)	
Potamogeton zosteriformis Fernald	Diptera: Ephydridae	*Hydrellia bergi* Cresson	stems, petioles	Berg (1949)	Michigan, USA
Potamogeton zosteriformis Fernald	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton zosteriformis Fernald	Diptera: Ephydridae	*Hydrellia itascae* Deonier		Deonier (1971)	

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Potamogeton zosteriformis Fernald	Diptera: Ephydridae	*Hydrellia luctuosa* Cresson	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Potamogeton zosteriformis Fernald	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker	submerged leaves (rarely on floating leaves)	Berg (1949)	Michigan, USA
Rhexia mariana L.	Coleoptera: Curculionidae	*Tyloderma marshalli* Wibmer		Wibmer (1981)	
Rhexia virginica L.	Coleoptera: Curculionidae	*Tyloderma caseyi* Wibmer	leaves	Wibmer (1981)	
Ricciocarpus natans (L.) Corda	Coleoptera: Curculionidae	*Tanysphyrus ater* Blatchley	floating leaves	Anderson (2002)	
Roripa americana Gray	Coleoptera: Curculionidae	*Ceutorhynchus semirufus* LeConte		Blatchley (1922)	Indiana, USA
Rumex sp.	Lepidoptera: Gelechiidae	*Chionodes discoocellella* Chambers	leaves	Forbes (1923)	
Rumex spp.	Coleoptera: Chrysomelidae	*Mantura chrysanthemi* Koch	leaves	Riley et. al (2002)	
Rumex spp.	Coleoptera: Chrysomelidae	*Mantura floridana* Crotch	leaves	Riley et. al (2002)	
Rumex spp.	Lepidoptera: Noctuidae	*Dipterygia scabriuscula* Linnaeus		Forbes (1954)	
Rumex spp.	Lepidoptera: Noctuidae	*Lithacodia carneola* Guenée		Forbes (1954)	
Sagittaria cuneata Sheldon	Coleoptera: Curculionidae	*Listronotus rubtzoffi* O'Brien	stems, root collars	O'Brien (1981)	
Sagittaria englemanniana J. G. Smith	Coleoptera: Curculionidae	*Listronotus neocallosus* O'Brien	leaf petiole, root collar	O'Brien (1981)	
Sagittaria filiformis J.G. Sm.	Coleoptera: Curculionidae	*Listronotus neocallosus* O'Brien	leaf petiole, root collar	O'Brien (1981)	
Sagittaria filiformis J.G. Sm.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Habeck (1974)	
Sagittaria graminea Michx.	Coleoptera: Curculionidae	*Listronotus neocallosus* O'Brien	leaf petiole, root collar	O'Brien (1981)	
Sagittaria graminea Michx.	Coleoptera: Curculionidae	*Listronotus* sp.	fruiting heads, flower stalks	Haag et al. (1986)	Florida, USA
Sagittaria lancifolia Linnaeus	Coleoptera: Curculionidae	*Listronotus cryptops* Dietz	flower stalks	O'Brien (1981)	
Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Listronotus squamiger* Say		O'Brien (1997)	
Sagittaria latifolia Willd.	Coleoptera: Chrysomelidae	*Donacia aequalis* Say	roots, leaves	Hoffman (1940), McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Coleoptera: Coccinellidae	*Coleomegilla maculata* DeGeer	emergent leaves	McGaha (1952)	Michigan, USA

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Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Anchodemus angustus* LeConte	leaves and petioles	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Hyperodes solutus* Boh.	flowers	Blatchley (1928)	Florida, USA
Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Hyperodes* spp.	leaves, petioles and stems	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Listronotus appendiculatus* Boheman	leaves, petioles and stems	McGaha (1952), O'Brien (1981)	Michigan, USA
Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Listronotus delumbis* Gyllenhal		O'Brien (1997)	
Sagittaria latifolia Willd.	Coleoptera: Curculionidae	*Listronotus echinodori* O'Brien	flowers, stems	O'Brien (1981)	
Sagittaria latifolia Willd.	Diptera: Itonididae	*Porricondylini* sp.	aerial leaves	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	aerial and floating leaves	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Homoptera: Cicadellidae	*Draeculacephala* sp.	emergent leaves	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Herlong (1979)	South Carolina, USA
Sagittaria latifolia Willd.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Habeck (1974), Herlong (1979)	
Sagittaria latifolia Willd.	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Sagittaria latifolia Willd.	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Sagittaria latifolia Willd.	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Sagittaria latifolia Willd.	Trichoptera: Lemnephilidae	*Pycnopsyche* sp.	submerged leaves	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Leptocella* spp.	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Leptocerus americanus* Banks	submerged leaves and petioles	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Triaenodes ignita* Walker	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Triaenodes injusta* Hagen	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Triaenodes marginata* Sibley	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA

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Sagittaria latifolia Willd.	Trichoptera: Leptoceridae	*Triaenodes* sp.	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Polycentropidae	*Neureclipsis crepuscularis* Walker	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Sagittaria latifolia Willd.	Trichoptera: Polycentropidae	*Polycentropus* spp.	submerged leaves	McGaha (1952)	Michigan, USA
Sagittaria sp.	Coleoptera: Chrysomelidae	*Donacia aequalis* Say	roots, leaves	Marx (1957)	
Sagittaria sp.	Coleoptera: Chrysomelidae	*Donacia rufa* Say	roots, leaves	Marx (1957)	
Sagittaria sp.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	leaves	Center et. al (1999)	
Sagittaria sp.	Coleoptera: Curculionidae	*Onychylis angustus* LeConte		Tanner (1943)	
Sagittaria sp.	Coleoptera: Curculionidae	*Onychylis nigrirostris* Boheman	emergent leaves, stems	Tanner (1943)	
Sagittaria sp.	Diptera: Ephydridae	*Hydrellia deceptor* Deonier		Deonier (1971)	
Sagittaria sp.	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Lange et al. (1953)	
Sagittaria sp.	Coleoptera: Curculionidae	*Brachybamus electus* Schoenherr		Tanner (1943)	
Sagittaria spp.	Coleoptera: Curculionidae	*Listronotus turbatus* O'Brien	leaves, petioles	O'Brien (1981)	
Sagittaria spp.	Lepidoptera: Noctuidae	*Acronycta oblinita* Abbot and Smith		Brigham and Herlong (1982)	
Sagittaria spp.	Lepidoptera: Noctuidae	*Argyrogramma verruca* Fabricus	leaves	Kimball (1965)	Florida, USA
Sagittaria spp.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	leaves	McCafferty and Minno (1979)	
Salicornia virginica L.	Coleoptera: Curculionidae	*Listronotus salicorniae* O'Brien	stem nodes	O'Brien (1981)	
Salix amygdaloides Anderss.	Coleoptera: Chrysomelidae	*Altica bimarginata bimarginata* Say	leaves	LeSage (1995)	
Salix arctica Pall.	Coleoptera: Curculionidae	*Isochnus arcticus* Korotyaev	leaves	Anderson (1989)	Alaska, USA
Salix bebbiana Sarg.	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix caroliniana Michx.	Lepidoptera: Noctuidae	*Simyra henrici* Grote	leaves	Cassani (1985)	Florida, USA
Salix cordata Michx.	Coleoptera: Chrysomelidae	*Altica subplicata* LeConte	leaves	LeSage (1995)	
Salix discolor Muhl.	Coleoptera: Curculionidae	*Isochnus rufipes* LeConte	leaves	Anderson (1989)	
Salix exigua Nutt.	Coleoptera: Chrysomelidae	*Altica bimarginata bimarginata* Say	leaves	LeSage (1995)	

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Salix exigua Nutt.	Coleoptera: Chrysomelidae	*Altica prasina prasina* LeConte	leaves	LeSage (1995)	
Salix exigua Nutt.	Coleoptera: Curculionidae	*Tachyerges ephippiatus* Say	leaves	Anderson (1989)	
Salix exigua Nutt.	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix gooddingii Ball	Coleoptera: Curculionidae	*Tachyerges salicis* Linnaeus	leaves	Anderson (1989)	
Salix humilis Marsh. var. *tristis* (Aiton) Griggs	Coleoptera: Curculionidae	*Tachyerges ephippiatus* Say	leaves	Anderson (1989)	
Salix interior Rowlee	Coleoptera: Chrysomelidae	*Altica bimarginata bimarginata* Say	leaves	LeSage (1995)	
Salix interior Rowlee	Coleoptera: Chrysomelidae	*Altica subplicata* LeConte	leaves	LeSage (1995)	
Salix interior Rowlee	Coleoptera: Chrysomelidae	*Disonycha alternata* Illiger		Deswarte and Balsbaugh (1973)	
Salix lasiolepis Benth.	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix lasiolepis Benth.	Coleoptera: Curculionidae	*Tachyerges salicis* Linnaeus	leaves	Anderson (1989)	
Salix lasiolepis var. *bigelovii* (Torr.)	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix lemmonii Bebb.	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix lucida Muhl.	Coleoptera: Curculionidae	*Isochnus populicola* Silfverberg	leaves	Anderson (1989)	
Salix lucida Muhl. ssp. *caudata* (Nutt.) E. Murray	Coleoptera: Curculionidae	*Isochnus rufipes* LeConte	leaves	Anderson (1989)	Utah, USA
Salix nigra Marsh.	Coleoptera: Curculionidae	*Isochnus rufipes* LeConte	leaves	Anderson (1989)	
Salix nigra Marsh.	Coleoptera: Curculionidae	*Isochnus rufipes* LeConte	leaves	Anderson (1989)	
Salix nigra Marsh.	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix scouleriana Barrat	Coleoptera: Chrysomelidae	*Altica prasina prasina* LeConte	leaves	LeSage (1995)	
Salix scouleriana Barratt	Coleoptera: Curculionidae	*Tachyerges niger* Horn	leaves	Anderson (1989)	
Salix scouleriana Barratt	Coleoptera: Curculionidae	*Tachyerges salicis* Linnaeus	leaves	Anderson (1989)	
Salix sp.	Coleoptera: Chrysomelidae	*Altica bimarginata labradorensis* LeSage	leaves	LeSage (1995)	
Salix sp.	Coleoptera: Chrysomelidae	*Altica bimarginata plicipennis* Mannerheim	leaves	LeSage (1995)	
Salix sp.	Coleoptera: Curculionidae	*Acalyptus carpini* Herbst		Anderson (2002)	

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Salix sp.	Lepidoptera: Geometridae	*Anacamptodes defectaria* Guenee	flowers, leaves	Kimball (1965)	Florida, USA
Salix spp.	Coleoptera: Chrysomelidae	*Lexiphanes saponatus* Fabricus	leaves	Riley et. al (2002)	
Salix spp.	Coleoptera: Chrysomelidae	*Myochrous magnus* Schaeffer	leaves	Riley et. al (2002)	
Salix spp.	Coleoptera: Chrysomelidae	*Galerucella nymphaea* L.	leaves	Center et. al (1999)	
Salix spp.	Coleoptera: Chrysomelidae	*Plagiodera arizonae* Crotch		Riley et. al (2002)	
Salix spp.	Coleoptera: Chrysomelidae	*Plagiodera arizonae* Crotch		Riley et. al (2002)	
Salix spp.	Coleoptera: Chrysomelidae	*Plagiodera versicolora* Laicharding		Riley et. al (2002)	
Salix spp.	Lepidoptera: Noctuidae	*Acronycta oblinita* Abbot and Smith		Brigham and Herlong (1982)	
Saururus cernuus L.	Coleoptera: Curculionidae	*Tyloderma variegatum* Horn	stems	Wibmer (1981)	
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. *acutus*	Coleoptera: Curculionidae	*Endalus limatulus* Castelnau		Tanner (1943)	Utah, USA
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. *occidentalis* (S. Watson) S.G. Sm.	Lepidoptera: Crambidae	*Chilo forbesellus* Fernald		Frohne (1939a)	Michigan, USA
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. *occidentalis* (S. Watson) S.G. Sm.	Lepidoptera: Crambidae	*Occidentalia comptulatalis* Hulst		Frohne (1939b)	Michigan, USA
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. *occidentalis* (S. Watson) S.G. Sm.	Coleoptera: Chrysomelidae	*Donacia pubescens* LeConte	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. *occidentalis* (S. Watson) S.G. Sm.	Coleoptera: Chrysomelidae	*Donacia quadricollis* Say	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Schoenoplectus americanus (Pers.) Volkart ex Schinz & R. Keller	Lepidoptera: Crambidae	*Chilo forbesellus* Fernald		Brigham and Herlong (1982)	Michigan, USA
Schoenoplectus americanus (Pers.) Volkart ex Schinz & R. Keller	Lepidoptera: Crambidae	*Occidentalia comptulatalis* Hulst		Frohne (1939)	Michigan, USA

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Schoenoplectus americanus (Pers.) Volkart ex Schinz & R. Keller	Lepidoptera: Crambidae	*Schoenobius melinellus dispersellus* Robinson		McCafferty and Minno (1979)	
Schoenoplectus americanus (Pers.) Volkart ex Schinz & R. Keller	Coleoptera: Chrysomelidae	*Plateumaris flavipes* Schaeffer	leaves	Hoffman (1940)	Northern Michigan, USA
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	Coleoptera: Curculionidae	*Listronotus squamiger* Say		O'Brien (1997)	
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	Lepidoptera: Crambidae	*Chilo forbesellus* Fernald		Brigham and Herlong (1982)	Michigan, USA
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	Lepidoptera: Crambidae	*Occidentalia comptulatalis* Hulst		Frohne (1939b)	Michigan, USA
Scirpus atrovirens Willd.	Coleoptera: Curculionidae	*Dirabius rectirostris* LeConte		Blatchley (1928)	New Jersey, USA
Scirpus cyperinus (L.) Kunth	Coleoptera: Curculionidae	*Dirabius rectirostris* LeConte	stems	Majka et al. (2007)	
Scirpus sp.	Coleoptera: Chrysomelidae	*Donacia fulgens* LeConte	roots, leaves	Marx (1957)	
Scirpus sp.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Marx (1957)	
Scirpus sp.	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Lange et al. (1953)	
Scirpus sp.	Lepidoptera: Noctuidae	*Oligia diversicolor* Morrison		McCafferty and Minno (1979)	Indiana, USA
Scirpus sp.	Lepidoptera: Noctuidae	*Archanara subflava* Grote	leaves	McCafferty and Minno (1979)	
Scirpus spp.	Coleoptera: Chrysomelidae	*Poecilocera harrisii* LeConte		Riley et. al (2002)	
Scirpus spp.	Coleoptera: Chrysomelidae	*Stenispa metallica* Fabricus		Riley et. al (2002)	
Scirpus spp.	Lepidoptera: Noctuidae	*Archanara oblonga* Grote	leaves	McCafferty and Minno (1979)	
Sesbania herbacea (Mill.) McVaugh	Orthoptera: Acrididae	*Gymnoscirtetes pusillus* Scudder		Squitier and Capinera (2002)	Florida, USA
Sesbania herbacea (Mill.) McVaugh	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Sesbania herbacea (Mill.) McVaugh	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Sesbania herbacea (Mill.) McVaugh	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Solanum spp.	Coleoptera: Chrysomelidae	*Acallepitrix nitens* Horn	leaves	Riley et. al (2002)	
Sparganium americanum Nutt.	Lepidoptera: Crambidae	*Langessa nomophilalis* Dyar		Stoops et al. (1998)	South Carolina, USA
Sparganium americanum Nutt.	Lepidoptera: Crambidae	*Munroessa icciusalis* Walker		Stoops et al. (1998)	South Carolina, USA

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Sparganium americanum Nutt.	Lepidoptera: Crambidae	*Paraponyx badiusalis* Walker		Habeck (1974)	
Sparganium americanum Nutt.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Stoops et al. (1998)	South Carolina, USA
Sparganium americanum Nutt.	Lepidoptera: Crambidae	*Paraponyx seminealis* Walker		Stoops et al. (1998)	South Carolina, USA
Sparganium americanum Nutt.	Lepidoptera: Crambidae	*Synclita obliteralis* Walker		Stoops et al. (1998)	South Carolina, USA
Sparganium angustifolium Michx.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Sparganium angustifolium Michx.	Coleoptera: Chrysomelidae	*Donacia* sp.	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Sparganium angustifolium Michx.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Sparganium diversifolium Graebner	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Sparganium eurycarpum Engelm.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Hoffman (1940)	Northern Michigan, USA
Sparganium sp.	Coleoptera: Chrysomelidae	*Donacia aequalis* Say	roots, leaves	Marx (1957)	
Sparganium sp.	Coleoptera: Chrysomelidae	*Donacia assimilis* Lacordaire	roots, leaves	Marx (1957)	
Sparganium sp.	Coleoptera: Chrysomelidae	*Donacia fulgens* LeConte	roots, leaves	Marx (1957)	
Sparganium sp.	Coleoptera: Chrysomelidae	*Donacia hirticollis* Kirby	roots, leaves	Marx (1957)	
Sparganium sp.	Coleoptera: Chrysomelidae	*Donacia subtilis* Kunze	roots, leaves	Marx (1957)	North and South Carolina, USA
Sparganium sp.	Coleoptera: Curculionidae	*Sphenophorus pertinax* Oliver	roots	Claasen (1921)	
Sparganium sp.	Diptera: Chironomidae	*Glyptotendipes seminole* Townes	stems	Epler (2001)	
Sparganium sp.	Lepidoptera: Noctuidae	*Archanara laeta* Morrison	leaves	McCafferty and Minno (1979)	
Sparganium spp.	Lepidoptera: Noctuidae	*Archanara oblonga* Grote	leaves	Brigham and Herlong (1982)	
Sparganium spp.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	leaves	McCafferty and Minno (1979)	
Spartina alterniflora Loisel.	Diptera: Ephydridae	*Hydrellia valida* Loew		Stiling and Strong (1982)	Michigan, USA
Spirodela spp.	Coleoptera: Curculionidae	*Tanysphyrus lemnae* Paykull	floating leaves	Center et. al (1999)	
Stuckenia pectinata (L.) Böerner	Coleoptera: Curculionidae	*Bagous restrictus* LeConte		O'Brien and Marshall (1979)	California, USA
Stuckenia pectinata (L.) Böerner	Diptera: Ephydridae	*Notiphila loewi* Cresson	roots	Berg (1949)	
Taxodium distichum (L.) Rich.	Coleoptera: Curculionidae	*Eudociminus mannerheimi* Bohemon		Anderson (2002)	

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Typha domingensis Pers.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	stems, leaves	Center et. al (1999)	
Typha latifolia L.	Coleoptera: Chrysomelidae	*Plateumaris flavipes* Schaeffer	leaves	Hoffman (1940)	New York, USA
Typha latifolia L.	Coleoptera: Curculionidae	*Endalus limatulus* Castelnau		Tanner (1943)	Utah, USA
Typha latifolia L.	Coleoptera: Curculionidae	*Notaris aethiops* Fabricus		Anderson (2002)	
Typha latifolia L.	Coleoptera: Curculionidae	*Notaris puncticollis* LeConte	stems	Claasen (1921)	
Typha latifolia L.	Coleoptera: Curculionidae	*Sphenophorus pertinax* Oliver	roots, rhizomes	Claasen (1921)	
Typha latifolia L.	Coleoptera: Curculionidae	*Tournotaris bimaculata* Fabricus		Anderson (2002)	
Typha latifolia L.	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Grigarick (1959)	Florida, USA
Typha latifolia L.	Hemiptera: Aphididae	*Aphis avenae* Fabricus	leaves	Claasen (1921)	Kansas, USA
Typha latifolia L.	Hemiptera: Aphididae	*Rhopalosiphum dianthi* Schrank	leaves	Sanborn (1906)	
Typha latifolia L.	Hemiptera: Aphididae	*Rhopalosiphum nymphaeae* L.	leaves	Claasen (1921)	New York, USA
Typha latifolia L.	Hemiptera: Aphididae	*Rhopalosiphum persicae* Sulz.	leaves	Wilson and Vickery (1918)	
Typha latifolia L.	Hemiptera: Lygaeidae	*Kleidocerys resedae* LeConte	seeds	Claasen (1921)	New York, USA
Typha latifolia L.	Lepidoptera: Cosmopterigidae	*Lymnaecia phragmitella* Stainton	flowers, seeds, stems	Claasen (1921)	New York, USA
Typha latifolia L.	Lepidoptera: Noctuidae	*Archanara oblonga* Grote	stems, leaves	Claasen (1921)	New York, USA
Typha latifolia L.	Lepidoptera: Noctuidae	*Arsilonche albovenosa* Goeze	leaves	Claasen (1921)	New York, USA
Typha latifolia L.	Lepidoptera: Noctuidae	*Bellura densa* Walker	leaves	McCafferty and Minno (1979)	
Typha latifolia L.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	stems, leaves	Center et. al (1999)	
Typha latifolia L.	Lepidoptera: Noctuidae	*Simyra henrici* Grote	leaves	Cassani (1985)	New York, USA
Typha latifolia L.	Lepidoptera: Pyralidae	*Dicymolomia julianalis* Walker	flowers, seeds	Claasen (1921)	
Typha latifolia L.	Lepidoptera: Tortricidae	*Choristoneura obsoletana* Walker	leaves	Claasen (1921)	New York, USA
Typha spp.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	leaves	Center et. al (1999)	
Typha spp.	Lepidoptera: Noctuidae	*Acronycta oblinita* Abbot and Smith		Brigham and Herlong (1982)	New York, USA
Typha spp.	Lepidoptera: Noctuidae	*Bellura gortynoides* Walker	leaves	McCafferty and Minno (1979)	

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Typha spp.	Lepidoptera: Noctuidae	*Bellura obliqua* Walker	stems, leaves	Claasen (1921), McCafferty and Minno (1979)	Florida, USA
Typha spp.	Orthoptera: Acrididae	*Gymnoscirtetes pusillus* Scudder		Squitier and Capinera (2002)	Florida, USA
Typha spp.	Orthoptera: Acrididae	*Leptysma marginicollis* Serville		Squitier and Capinera (2002)	Florida, USA
Typha spp.	Orthoptera: Acrididae	*Paroxya atlantica* Scudder		Squitier and Capinera (2002)	Florida, USA
Typha spp.	Orthoptera: Acrididae	*Paroxya clavuliger* Serville		Squitier and Capinera (2002)	Florida, USA
Typha spp.	Orthoptera: Acrididae	*Romalea microptera* Beauvois		Squitier and Capinera (2002)	Florida, USA
Typha spp.	Orthoptera: Acrididae	*Stenacris vitreipennis* Marschall		Squitier and Capinera (2002)	
Typha spp.	Lepidoptera: Noctuidae	*Archanara oblonga* Grote	leaves	McCafferty and Minno (1979)	
Utricularia inflata Walter	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker		Habeck (1974)	Michigan, USA
Utricularia macrorhiza Leconte	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves, petioles, stems and young buds	McGaha (1952)	
Utricularia spp.	Homoptera: Aphididae	*Rhopalosiphum nymphaeae* L.	leaves	Center et. al (1999)	
Vallisneria americana Michx.	Diptera: Ephydridae	*Hydrellia gladiator* Deonier		Deonier (1971)	Illinois River, USA
Vallisneria americana Michx.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote	submerged leaves	Hart (1895)	Michigan, USA
Vallisneria americana Michx.	Lepidoptera: Crambidae	*Paraponyx allionealis* Walker	leaves	McGaha (1952)	South Carolina, USA
Vallisneria americana Michx.	Lepidoptera: Crambidae	*Paraponyx obscuralis* Grote		Herlong (1979)	Michigan, USA
Vallisneria americana Michx.	Trichoptera: Leptoceridae	*Leptocerus americanus* Banks	submerged leaves and petioles	McGaha (1952)	Michigan, USA
Vallisneria americana Michx.	Trichoptera: Leptoceridae	*Triaenodes aba* Milne	submerged leaves, petioles, stems and young buds	McGaha (1952)	Michigan, USA
Vallisneria americana Michx.	Trichoptera: Leptoceridae	*Triaenodes marginata* Sibley	submerged leaves, petioles and stems	McGaha (1952)	
Zannichellia palustris L.	Diptera: Ephydridae	*Hydrellia bilobifera* Cresson		Deonier (1971)	
Zannichellia palustris L.	Diptera: Ephydridae	*Hydrellia notiphiloides* Cresson		Deonier (1971)	Michigan, USA

Plant	Insect Order: Family	Insect Species	Part of Plant Affected	Author (year)	Study Region
Zizania aquatica L.	Diptera: Ephydridae	*Hydrellia cruralis* Coquillet	flowers	McGaha (1952)	
Zizania aquatica L.	Diptera: Ephydridae	*Hydrellia griseola* Fallen		Deonier (1971)	
Zizania aquatica L.	Diptera: Ephydridae	*Hydrellia ischiaca* Loew		Deonier (1971)	
Zizania aquatica L.	Lepidoptera: Noctuidae	*Apamea apamiformis Guenée*		MacKay and Rockburne (1958)	Michigan, USA
Zizania aquatica L.	Trichoptera: Phryganeidae	*Banksiola salina* Betten	submerged leaves, petioles and stems	McGaha (1952)	Michigan, USA
Zizania aquatica L.	Trichoptera: Polycentropidae	*Nyctiophylax vestitus* Hagen	submerged leaves and stems	McGaha (1952)	

CHAPTER 3.

INSECT HERBIVORY OF *Heteranthera dubia* (Jacq.) MacM. IN THE UNITED STATES

Abstract

This paper summarizes the results of a series of surveys of insect herbivores associated with *Heteranthera dubia* conducted from 2006-2008. This species was selected because of its importance to aquatic plant restoration projects and because of its broad distribution in the U.S. Plants were collected in the field, invertebrates removed, and signs of feeding damage noted. Herbivores were quantified and regions were compared based on taxa richness, evenness and diversity. A species list was created containing a minimum of 23 potential insect herbivores from nine sites in Texas, Washington, Minnesota, and Wisconsin. Of these, four species were collected from the order Lepidoptera, one from the Coleoptera, six from Diptera, and at least 11 from Trichoptera. *Hydrellia* spp. (Diptera: Ephydridae) larvae and pupae were commonly collected from *H. dubia* at sites in Washington, Minnesota, Wisconsin, and New York. *Paraponyx* spp., were collected at four sites in Wisconsin, New York, and Texas. While the majority of herbivores were identified as possessing generalist diets, several had unknown diets. *Bagous floridanus* Tanner, collected in Texas, has an unknown diet but it is well documented that many *Bagous* spp. are host specific. While *Hydrellia* species identifications could not be determined with any accuracy since only larval stages were collected, several of these may also prove to be host-specific. Damage observed in the field included extensive tunneling in the stems of the plant and, in some cases, substantial chewing damage to the leaves. As of a recent literature review, all represent new host plant-insect associations.

Introduction

Herbivory of aquatic plants is important, and contributes to species diversity and composition of plant communities (e.g. Lodge 1991, Carpenter and Lodge 1986, Newman 1991, Lodge et al. 1998). Herbivory, especially by insects, has been shown to slow plant growth, reduce viability of plant fragments and reduce winter bud formation (Doyle et. al 2002, Doyle et. al 2005, Wallace and O'Hop 1985). These facts have been exploited for years by practitioners of aquatic weed biocontrol in which native enemies of plant species aid in successful plant management (Coombs et al. 2004). In addition, herbivory is important to aquatic ecorestoration because feeding impacts plant growth and competition (Van et al. 1997). Although herbivory of many aquatic and wetland species is documented, there are several that lack published reports of herbivory. One species commonly used in restoration (Smart and Dick 2005, Doyle and Smart 1995, Mitsch et al. 1994), but lacking herbivore data, is *Heteranthera dubia* (Jacq.) MacMillan (water stargrass).

It is well documented that native species can, under certain circumstances, exhibit aggressive growth and become problematic (Hollingsworth 1966, Wise et al. 2009, pers. comm., C. Owens[2] 2009, pers. comm., J. Parsons[3] 2009). Reasons for this are not always obvious, but in addition to anthropogenic effects such as nutrient loading, one explanation could be the local absence of disease or herbivory.

Because insect herbivory can substantially alter plant competitive success in aquatic systems (Van et al. 1997), it is important to understand: 1) What herbivorous species impact aquatic plants, and 2) How plant growth and competitive ability are influenced by feeding.

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[3] Jenifer Parsons, Washington State Department of Ecology, Yakima, WA

For the above reasons, *H. dubia* was examined for insect herbivores in the United States in 2006 and 2008. This information, though specific to *H. dubia*, will provide a practical reference for future ecological studies regarding effect of herbivory and management of this important wetland species.

Materials and Methods

During the summer of 2006, *H. dubia* and associated invertebrates were collected from three sites in each of four regions of the United States: lower Midwest (LMW; Choke Canyon reservoir, TX, Coleto Creek reservoir, TX, Richland Chambers reservoir, TX), Northwest (NW; Yakima River, WA, Selah Pond, WA, Parker Pond, WA), Upper Midwest (UMW; Apple River, WI, Leech Lake, MN, Norway Lake, MN), and Northeast (NE; Little Lake, VT, Lake Hortonia, VT, Saratoga Lake, NY) (Figure 3.1, Table 3.1). Due to time and financial restraints, each region was visited and sampled once, from July through September. Southern populations of *H. dubia* were sampled from late June to mid July and northern populations sampled from mid July to late September.

Sites were chosen for sampling based on several criteria. The water body must have been within the predetermined geographic region and contain the target species. Sample sites included lakes, reservoirs, ponds, and rivers. Specific sites were chosen based on access and relative proximity of other regional sampling sites. Sites and sampling dates are listed in Table 3.1. Site descriptions and individual results from each site can be found in Appendix I. In 2008, only one site, the San Marcos River, TX, was sampled qualitatively.

Samples were collected using two methods: a mesh bag (500 µm mesh) sampling device (Chilton 1990, Fig. 2) and a throw-rake, which consisted of a double sided rake attached to 6.1 meters of rope. Rake samples were obtained from shoreline access or on fishing piers.

Sample Collection

Plant samples were collected with a mesh bag sampling device, with an opening diameter of 40cm, 60 cm deep, and constructed of 500 µm mesh, thus trapping invertebrates >500 µm. The sampler was lowered into the water column around *H. dubia* plants until the entire sampler was fully submersed. The plants were then broken at the base of the sampler and turned upright, capturing any plants or organisms within the sampled volume of water. Once removed from the water the entire sample, sampling device included, was placed in a plastic bag and sealed for later processing. Three samples were taken at each site, nine per geographic region.

In addition to a mesh bag sampler, a throw-rake was used to collect plant samples. The throw-rake consisted of a double-sided rake head attached to > 7.5 meters of rope. The rake was thrown randomly from the boat or shore into stands of *H. dubia* and collected plant material examined in the field.

Sample Processing

Mesh-bag plant samples were initially processed in the field. Plants were thoroughly washed over a benthic-washing bucket (mesh size 500 µm) and any invertebrates dislodged from the plant were preserved in 70% ETOH. Washed plants were then shipped via FedEx overnight to the Lewisville Aquatic Ecosystem Research Facility (LAERF), Lewisville, TX, in insulated containers. Plant material was subsequently dried at 55 degrees C until constant weight achieved.

Throw rake samples were initially examined in the field with a Leica (Bannockburn, IL) Stereozoom 4 microscope (7x-30x magnification), and dissected to reveal mining insects. Any insects discovered in this manner were preserved as previously mentioned.

All macroinvertebrates were identified to the lowest practical taxon, which was, in most cases, genus. Chironomid (Diptera) specimens were slide-mounted in CMC-10 mounting media

(Masters Co., Wood Dale, IL) for identification. In some instances, species identifications were desired and obtained by contacting experts for assistance.

Once macroinvertebrates were identified, they were grouped into one of five functional feeding groups (Merritt and Cummins 1996). Only the shredder/ herbivores (hereafter called herbivores) are analyzed and discussed here. We determined which insects were feeding on *H. dubia* by observation and from literature records.

Plant names (both scientific and common) are reported with the most current (as of 2009) taxonomic classification recognized by the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS 2009). Because very few of the insects reported here have accepted common names, they are referred to by scientific names only.

Statistical Analyses

For all analyses, abundance data were standardized by plant dry weight. Because only one plant species was sampled, density was used to compare between sites (Biochino and Biochino 1980) and regions. Statistical analyses were run on mesh-bag collected invertebrates only because throw-rake samples were not standardized or taken at every site.

Shannon’s diversity (log base 10) and evenness were calculated for sites and regions using SSC software’s Diversity Add-in for Microsoft® Excel™ (SSC, University of Reading 2007). Shannon’s diversity index reflects the amount of uncertainty in predicting to what species an individual chosen at random from a group of S species and N individuals will belong (Ludwig and Reynolds 1988). The diversity index is at a minimum when there is one species present, and at its maximum when all species are represented by the same number of individuals. Evenness refers to the way abundances of each taxa are distributed among the taxa.

Data were analyzed using STATISTICA version 8.0 (StatSoft ®, Inc., 2007, Tulsa, OK) and included analysis of variance (ANOVA) and Neuman-Keuls (NK) for mean separation. Statements of significance refer to an alpha level 0.05 unless otherwise noted. Density data were $\log_{10}$ transformed to meet the normality expectation of ANOVA. For discussion's purpose, the data are referred to in their raw form.

Power analysis was evaluated for each ANOVA which did not gain statistical significance. Sample size required for statistically significant results was determined with standard deviation and means from original statistics at a power of 0.95.

A one-way ANOVA was used to differentiate between diversity, evenness and richness in and between regions. Neuman-Keuls post-hoc test was used to separate the significant samples into statistically different groups.

Chao's Jaccard abundance-based similarity (Cjab) index was calculated for each site pair and region pair (Chao et al. 2005). Chao's abundance-based version of Jaccard's index of similarity is influenced by common and rare taxa and gives a more accurate estimate of similarity between samples. This is calculated as

where U and V represent the relative abundance of individuals in samples 1 and 2, respectively. This is just a slight modification of the Jaccard's similarity index. A Cjab value of "1" reflects complete similarity between communities while "0" represents total dissimilarity between communities. Cjab was also used to examine similarity in natural and man-made sites as well as between lentic and lotic sites.

Results and Discussion

Insect herbivores made up, on average, approximately 17 % of the epiphytic communities found on *H. dubia* among all sites sampled. A total of at least 23 herbivore species, represented by 2,383 individuals were identified (Table 3.2), including the most commonly collected: *Rhopalosiphum* sp. prob. *nympheae* (collected at 8 of 12 sites), *Synclita* spp. (collected from 5 of 12 sites), *Paraponyx* spp., and *Polypedilum* spp. (both collected from 4 of 12 sites). Table 3.2 lists both insects which feed on living vascular tissue as well as insects that only occasionally damage the plant through tunneling or other feeding activity.

There were no significant differences in herbivore density between regions ($P = 0.732$), but sites were significantly different (df = 11, 24, $F = 4.40$, $P < 0.05$, Fig. 3.2). Power analysis determined a sample size of 28 replicates per region would have been required to achieve statistical significance. This was not attainable given the funding and time restraints of the study. Parker Ponds, WA had a mean herbivore density of 33.68 individuals / g *H. dubia* dry weight, largely influenced by the number of *Rhopalosiphum* aphids (Fig. 3.3). It is not clear why Parker ponds had more aphids than other sites, but one explanation might be that there was an abundance of emergent aquatic vegetation in the vicinity of sampled *H. dubia*, and aphids feed on the emergent portions of plants. In addition, aphids were absent from all LMW sites. This is probably due to the fact that all LMW sites had recently received rainfall and plants were just below the water surface. With aphids removed from the analysis, there are no longer differences between sites ($P < 0.05$).

Among regions, there were no significant differences in herbivore taxa richness, diversity (Shannon’s index) or evenness (Shannon’s evenness). Power analysis determined that sample sizes of 12, 16, and 33 replicates per region were needed to achieve significance for taxa richness, diversity and evenness, respectively. Although not significant, there was a trend that LMW had lowest overall richness, followed by NE, NW, and UMW. LMW sites were lowest overall in total herbivore richness (5, mean richness of 2.67) and mean diversity (0.51), while UMW had the highest overall richness (12, mean richness of 5.67), mean diversity (1.11) and mean evenness (0.63). NW had the lowest evenness overall (0.48) which was largely influenced by *Rhopalosiphum* spp. Even though *H. dubia* collections were made from monotypic stands, there is likely immigration/ emigration of generalist herbivores between plant stands. It is not clear why NE sites had lower herbivore diversity, richness and evenness, but several were infested with *Dreissena polymorpha* Pallas (zebra mussel). Zebra mussels were found attached in large numbers to the leaves and stems of *H. dubia* and likely prevented, at least to some degree, colonization of other invertebrates, including herbivores.

Between sites, significant differences were found in herbivore richness (Fig. 3.4) and diversity (Fig. 3.5) but not evenness. Norway Lake, MN had the highest herbivore richness, diversity, and the second highest evenness. The lowest herbivore richness was found in Richland Chambers reservoir, Little lake VT, and Lake Hortonia, VT. Because there were no differences in richness, diversity, or evenness between regions, but were found between sites, it is clear that there is a great deal of variability in herbivore communities depending on location sampled. Although not known, the age of both plant stand in the waterbody and the age of the waterbody itself would affect colonization rates of macroinvertebrates, and especially those who depend on macrophyte tissue for food. In addition, density of waterbodies in the region, i.e. mean density from sample location to other waterbodies, would potentially affect the richness and diversity of taxa. Further research is needed in this regard.

The herbivore fauna of the LMW region was most similar to NW (Table 3, Cjab = 0.23), and least similar to UMW (Cjab = 0.0, zero shared taxa). NW was most similar to NE (Cjab = 0.44) and shared 6 taxa with UMW (Cjab = 0.25). In addition, herbivore density was greater in lentic sites as opposed to lotic ones (Fig. 3.6). This may be related to the fact that, because of flow, plants were often just below or barely at the water's surface. This would probably hide sites for oviposition or aerial cues for many insect species, and flow would exempt insects that are not adapted to such conditions. Although *H. dubia* does grow occasionally in lotic waters, it predominantly occurs in still waters and any insect herbivores that feed on *H. dubia* may also prefer still water conditions.

Rhopalosiphum spp. prob *nympheae* represented 23% of the total herbivores collected, with 549 individuals. A total of 399 individuals were collected from Parker Ponds and, excluding Parker ponds, *Rhopalosiphum* spp. made up only 6.3% of total herbivores. *Rhopalosiphum nympheae* is a terrestrial aphid that sucks sap from leaves and has been reported from a variety of aquatic and wetland plants (Center et al. 1999, McGaha 1952, Berg 1949). Specimens were likely washed from emergent or floating portions of the plants.

Five midge (Chironomidae) genera were collected during this survey, including *Chironomus*, *Cricotopus*, *Endochironomus*, and *Glyptotendipes* and *Polypedilum*. Midges altogether represented 21% of all herbivores collected. This is a lesser percentage than was found by Balciunas and Minno (1985) in their exploration of insect herbivores on *Hydrilla verticillata* L.f. Royle (hydrilla) in the U.S., and is probably a result of the difference in nativity between *H. verticillata* and *H. dubia*. Because *H. verticillata* is not native, it might be expected that fewer insect herbivores would be associated with it in its introduced range. A native plant species might support a greater richness and diversity of herbivore taxa. Midge larvae (*Glyptotendipes*) were commonly collected from tunnels in *H. dubia* stems, as well as washed from the surface of the plant. Despite this, it is not clear to what extent the midges damage *H. dubia* through their feeding and/or tunnel excavations. In this regard, further work is needed.

A sole specimen of *Bagous floridanus* Tanner was collected from washed *H. dubia* at Lake Richland Chambers, TX. The only other macrophyte species in the general vicinity was *H. verticillata* so I believe that *B. floridanus* was using *H. dubia* as a food source. A revisitation of the collection site is needed to collect more specimens to verify this host association. The biology of *B. floridanus* is unknown, as is the distribution in the U.S. Type specimens are recorded from Enterprise, FL, so distribution most likely extends across the southern U.S (Tanner 1943).

It is not known if the Ephydrid flies recovered in this study (*Hydrellia* spp.) are specific to *H. dubia* because species identifications from larvae are difficult. Ephydrids were recovered from *H. dubia* by Balci and Kennedy (2003) and not the other plant species in their study, but because they were not examining herbivory, these species were not examined and identifications were not obtained. The specimens collected in this study were not identified to species so it cannot be determined from the literature what host plants are used as food. Because the specimens were collected from monotypic stands and larvae are not likely to actively move over a long distance, *H. dubia* was probably a food source. In order to make an accurate estimate of density and to properly assess the specificity of the *Hydrellia* spp. collected, future collections should include rearing adults.

Four taxa of aquatic moths (Lepidoptera) were collected: *Acentria ephemerella* Olivier, *Paraponyx* spp., *Synclita obliteralis* Walker, and *Oxyelophila callista* Forbes. *Acentria ephemerella* was collected from Saratoga Lake, NY and Norway Lake, MN, two sites which had diverse plant communities at the time of sampling. *A. ephemerella* is known to have a generalist diet (Buckingham and Ross 1981) so *H. dubia* probably represents an additional host.

Both *S. obliteralis* and *Paraponyx* spp. were collected from several different sites (Table 2) and create distinctive cases from plant tissue. *Synclita obliteralis* has been reported from *Brasenia schreberi* J.F. Gmel. (watershield), *Lemna* spp. (duckweed), *Nuphar* spp. (spatterdock), *Nymphaea odorata* Aiton (blue waterlilly), *Polygonum* spp. (smartweed), and *Potamogeton natans* L. (floating pondweed). At the LAERF, *S. obliteralis* larvae have been collected from *N. mexicana* Zucc. (yellow waterlilly), *N. lutea* and *P. nodosus* Poir. (longleaf pondweed) (Nachtrieb and Grodowitz 2010, Harms, unpub. data). Likewise, *Paraponyx* host plants include *Potamogeton* spp. (pondweeds), *Elodea canadensis* Michx. (American waterweed), *Ceratophyllum demersum* L. (coontail) (Lange 1956), *Bacopa caroliniana* (Walter) Robinson (blue water hyssop), *B. schreberi*, *Vallisneria* spp. (eelgrass), and *N. odorata* Aiton (Brigham and Herlong 1982). Because species determinations were not made, additional *Paraponyx* collections should be made with an emphasis on rearing in order to determine the actual species associated with *H. dubia*.

Oxyelophila callista is a rare species with an unknown biology, in which the larvae are unknown, and we were unable to rear the larvae of *O. callista* to verify the species determinations by Dr. Alma Solis[4] (pers. comm). Some (Lange 1956, Munroe 1972) have postulated that *O. callista* will follow other closely related argyractin moths and feed on algae, though Balciunas and Minno (1985) found macrophyte tissue in gut analyses. As with *A. ephemerella*, additional studies are needed to determine *O. callista* feeding extent and preference.

[4] Dr. Alma Solis (Lepidoptera), Systematic Entomology Laboratory, Agricultural Research Service, U.S. Department of Agriculture.

At least 11 caddisfly species from were collected in association with *H. dubia*, from 10 sites. Norway Lake, MN had the most caddisfly species with five (Table 3.2). *Leptocerus americanus* Banks, the sole species in the genus *Leptocerus*, was collected only from Norway Lake, MN, but is widespread through the U.S. *Leptocerus americanus* has been reported to damage aquatic plants including hydrilla (Balciunas and Minno 1985) and has also been collected from *Myriophyllum spicatum* L. (Eurasian milfoil), *C. demersum*, and *Vallisneria americana* (American eelgrass) (Chilton 1990). Larval *L. americanus* are easily distinguishable from other North American caddisflies by the translucent case, hooked middle legs and anal tufts (Ross 1944).

Triaenodes injustus Hagen specimens were collected from two sites in Washington and Minnesota. This is further west than the previously reported range (Moulton and Stewart 1996), but adults have been collected as far west as southern British Columbia and southcentral Alaska (pers. comm., K. Manuel[5], pers. comm., J. Glover[6]). *Triaenodes injustus* larvae construct spiraled cases from pieces of plant material and have been associated with a wide range of macrophytes in both lotic and lentic habitats (Wiggins 1977), including *P. amplifolius* Tuck. (largeleaf pondweed), *P. richardsonii* (Benn.) Rydb. (Richardson's pondweed), *P. robbinsii* Oakes (Robbins' pondweed), and *P. friesii Rupr*. (Fries' pondweed) (Berg 1949).

Nectopsyche albida Walker, *N. diarina* Ross, *N. minuta* Banks, and an unknown *Nectopsyche* sp. were collected from sites in Minnesota, Wisconsin and Washington. *Nectopsyche* larvae generally construct long, slender cases from plant material or sediment and are primarily herbivores (Glover and Floyd 2004). *Nectopsyche albida* is restricted to the Glacial regions of Canada and North-central to Eastern U.S. (Haddock 1977), though records exist for

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Kentucky and Mississippi (Resh 1975, Holzenthal et al. 1982). Collections of this species were made during this survey in Leech Lake and Norway Lake, Minnesota, well within the previously reported range. *Nectopsyche albida* is reported to utilize a variety of food plants, including *Myriophyllum sibiricum* Kom. (shortspike watermilfoil), *P. pusillus* L. (small pondweed), *P. zosteriformis* Fernald (flatstem pondweed), *P. ampifolius, P. gramineus* L. (variableleaf pondweed), *P. praelongus* Wulfen (whitestem pondweed), *P. robbinsii*, and *Nitella* sp. (Berg 1949, Tozer et al 1981).

The Nearctic distribution of *N. diarina* includes most of the Northern United States and parts of southern Canada (Haddock 1977, Moulton and Stewart 1996), and does not extend into the Southern U.S. Haddock (1977) reports fast-flowing streams as the preferred habitat of *N. diarina*. During this survey, larval specimens were collected from the Apple River, WI. The diet of *N. diarina* is not known and warrants further research.

Little is known of *N. minuta* biology or diet, though larvae have been reported to feed on *Salix* sp. roots and *Elodea* sp. in Nevada. It is not clear whether *N. minuta* was feeding on *H. dubia* in the Yakima River, although *H. dubia* was the only macrophyte species present at the collection site. *Nectopsyche minuta* is found in the rivers of the Columbia plateau and western portions of the Great Basin and upper Mojave Desert (Haddock 1977) and its collection here from the Yakima River, WA corresponds with the previously reported range. One specimen of an unknown *Nectopsyche* sp. was collected from stargrass in the Yakima River, WA.

Four species of *Oecetis* were collected from sites in Texas, Minnesota and New York (Table 3.2). These include *O. cinerascens* Hagen, *O. eddlestoni*, and two other unknown species. These species probably only occasionally feed on aquatic plants but many leptocerid larvae display a wide range of food preferences (Wiggins 1977)

There is obviously little known regarding the phytophagous caddisflies and their food preference, impact on individual plant species, and their role in contributing to plant community structure. These are all areas which require further work.

Of the 23 taxa collected from *H. dubia*, I believe the *Hydrellia,* aquatic moths (Lepidoptera), and weevils (Curculionidae) probably exert the greatest pressure on plants, based on known feeding habits.

Summary

A total of 23 potential herbivore species were collected during these surveys. Because of the lack of reports of insect herbivores on *H. dubia* in the literature, all herbivores presented here represent new host-plant associations. While most belong to generalist taxa, it is not clear which, if any, are host-specific to *H. dubia*. Additional work should focus on the impact of both individual herbivore taxa and groups of herbivores on *H. dubia* growth (and aquatic plants, in general) and competitive ability.

There are several species of aquatic plants which are lacking published accounts of herbivory, many of them submersed in nature. While the reasons for this are still unclear, I have shown that a lack of publications does not necessarily mean that insect herbivory is nonexistent. In fact, several taxa of herbivorous insects were associated with *H. dubia* in every region and site sampled.

The information presented here may be useful to future researchers or plant managers interested in factors influencing plant growth and competition. Because *H. dubia* is used widely for restorative purposes, it might benefit managers to know what herbivore taxa are potentially present in their regions, and in what densities.

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Figure 3.1. *H. dubia* collection sites in the United States during summer 2006 and 2008. 2006 sites are represented by gray stars and the sole 2008 site is represented by the black star.

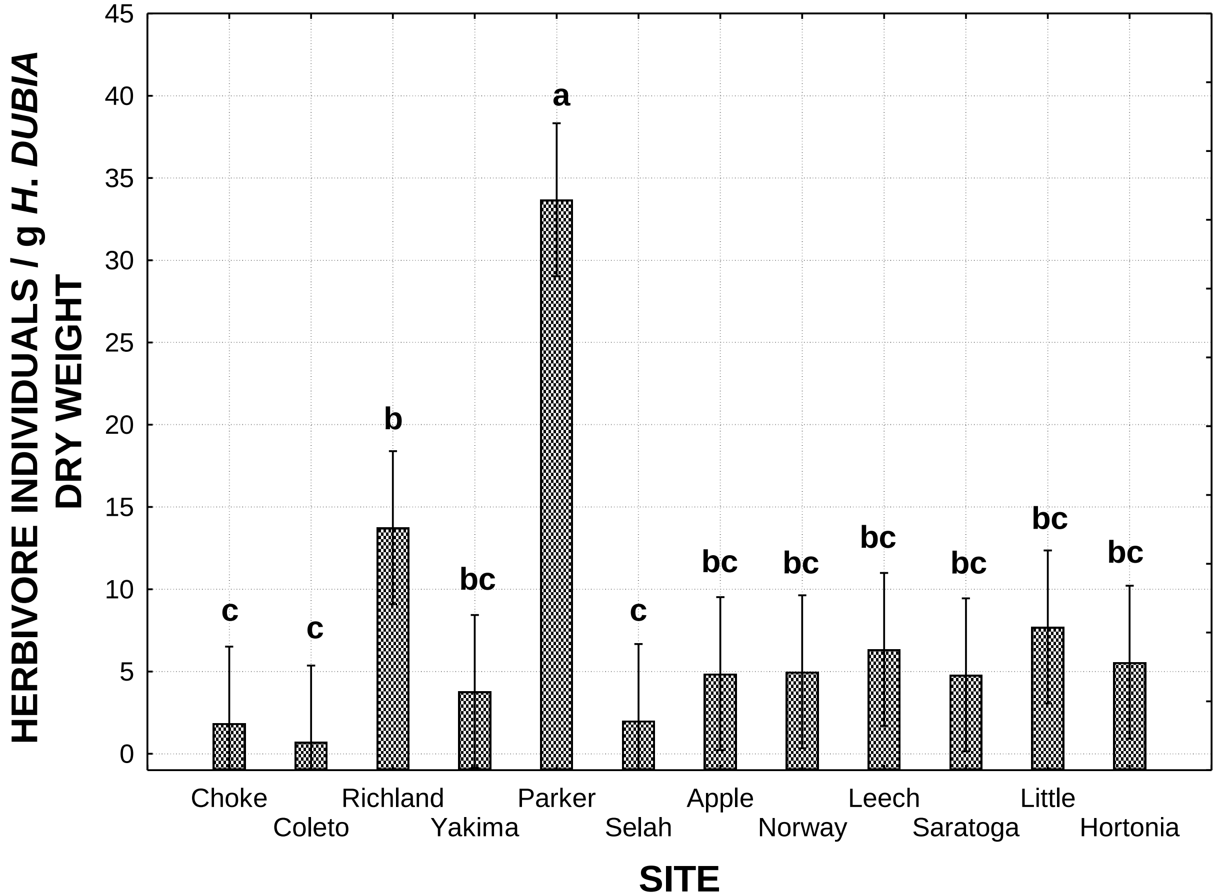

Figure 3.2. Mean herbivore density between sites (One-way ANOVA, df = 11, 24, F = 15.61, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

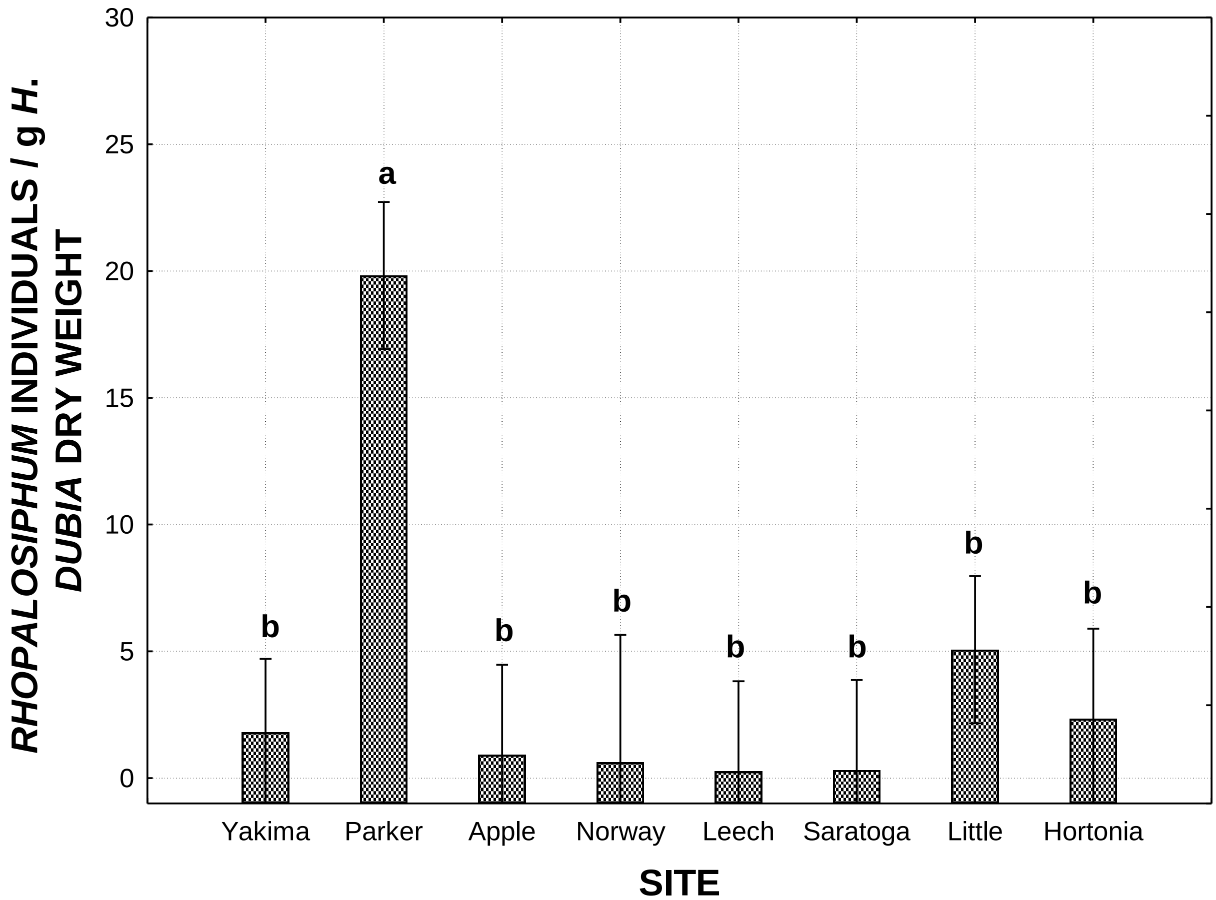

Figure 3.3. Rhopalosiphum spp. density (individuals / g H. dubia dry weight) between sites (One-way ANOVA, df = 7, 16, F = 39.08, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

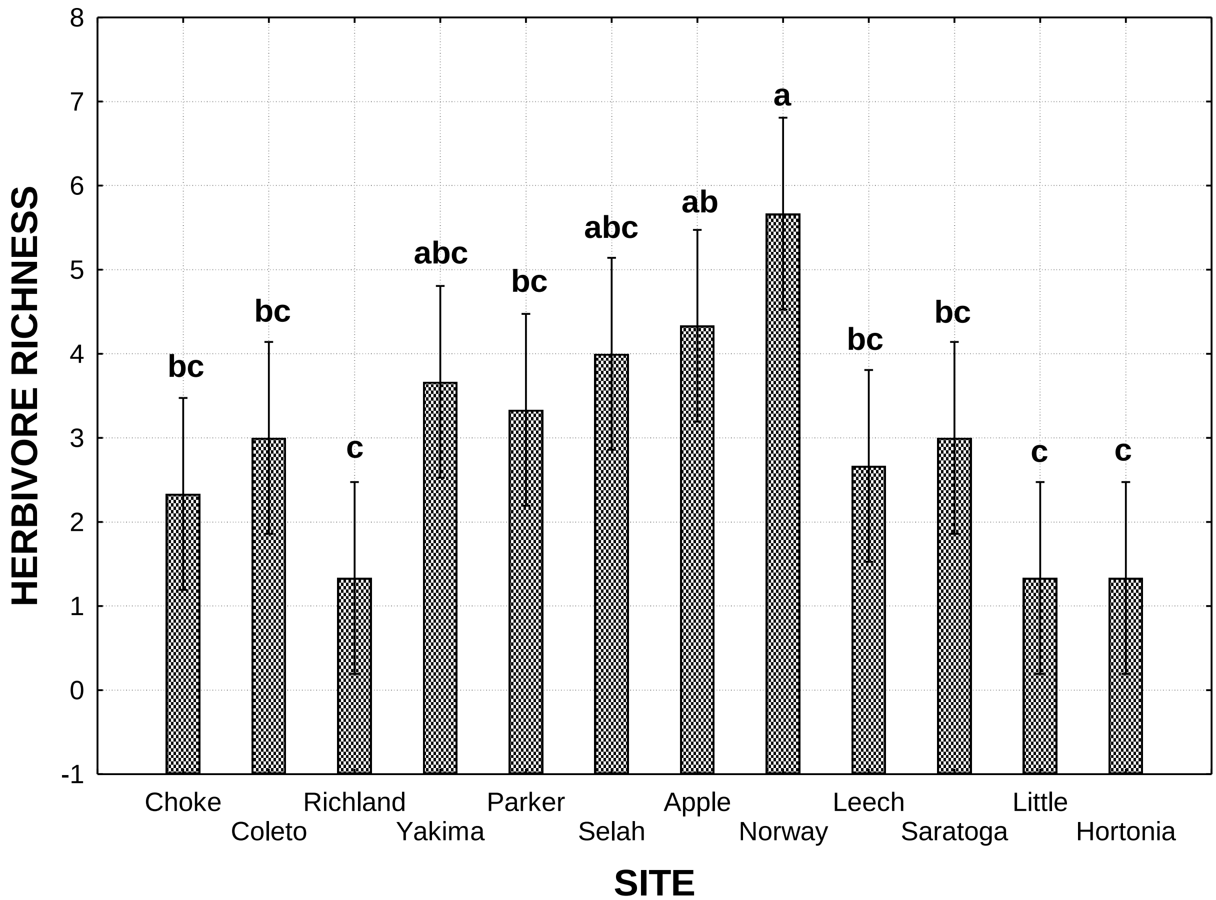

Figure 3.4. Mean herbivore taxa richness between sites (One-way ANOVA, df = 11, 24, F = 5.75, P < 0.05). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, α= 0.05).

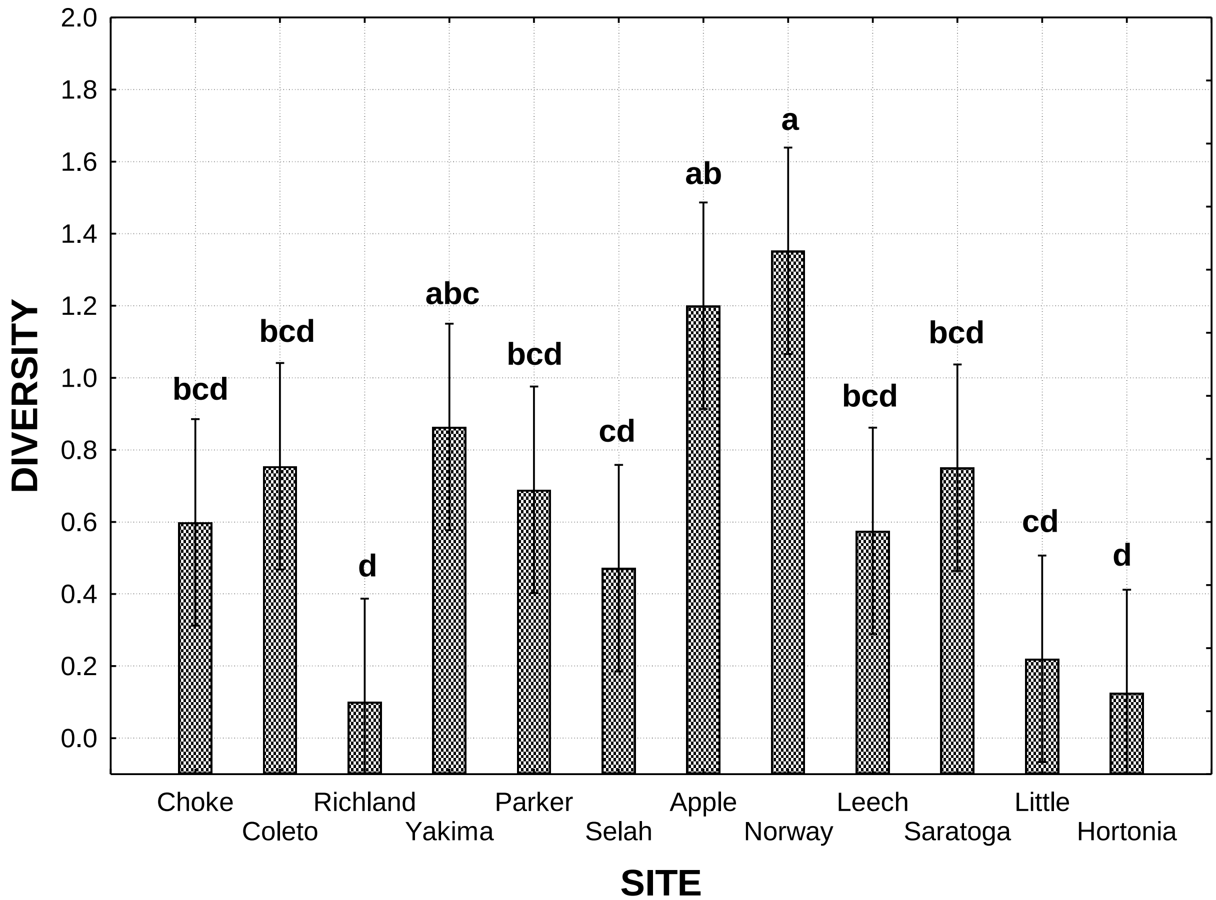

Figure 3.5. Mean herbivore diversity between sites (One-way ANOVA, df = 11, 24, F = 7.85, $P < 0.05$). Vertical bars denote 0.95 confidence intervals. Letters represent statistically different groups (Neuman-Keuls, $\alpha = 0.05$).

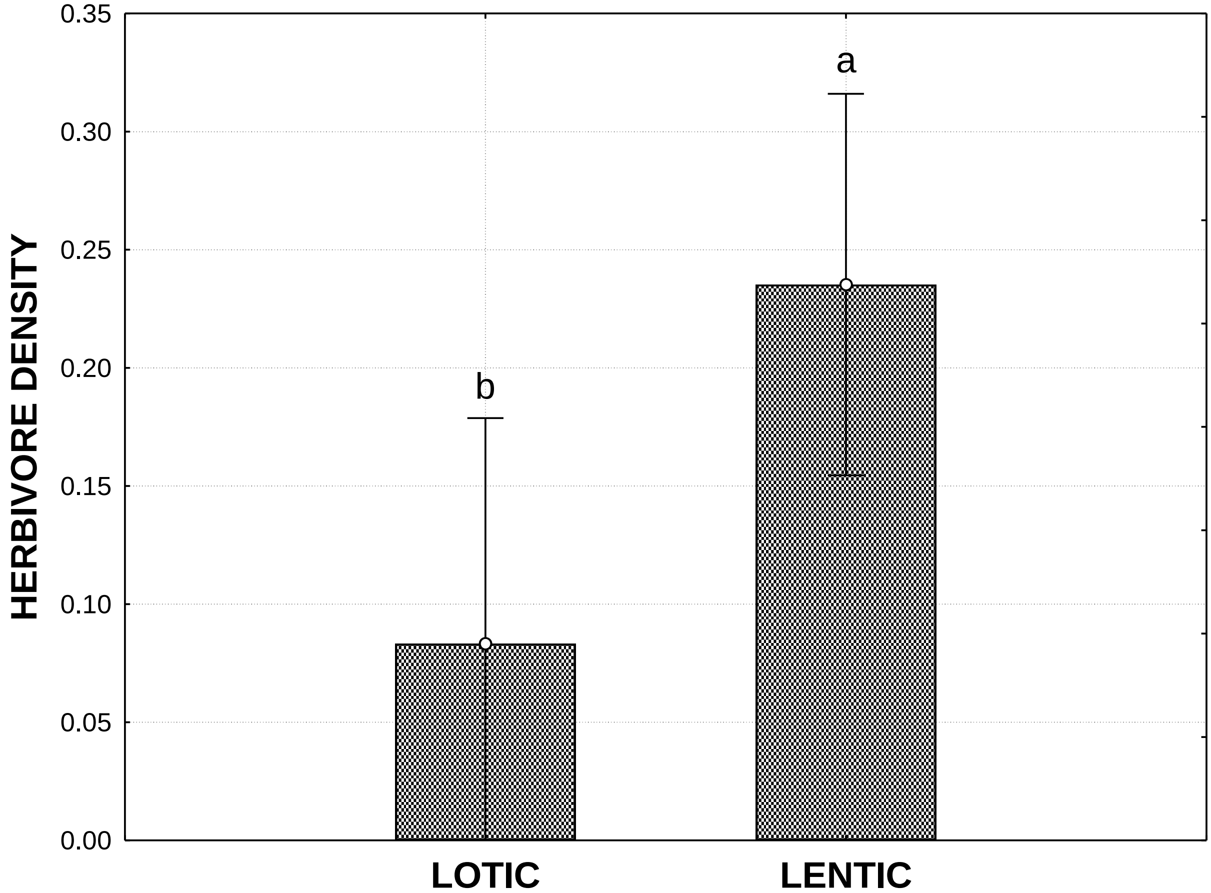

Figure 3.6. Mean herbivore relative abundance for lotic and lentic sites (One-way ANOVA, df = 1,34, $F = 6.10$, $P < 0.05$).

Table 3.1. Collection sites and dates.

Site	Lentic/Lotic	Collection Date	Coordinates
Richland Chambers, TX	Lentic	6-VII-2006	N32° 00' 16.0" W 96° 12'54.8"
Choke Canyon Reservoir, TX	Lentic	10-VII-2006	N 28 30'56.5" W 98° 18'50.3"
Coleto Creek Reservoir, TX	Lentic	11-VII-2006	N 28 43'14.1" W 97° 10"27.7"
Yakima River, WA	Lotic	24-VII-2006	N 46° 15'11.0" W 119° 28'40.9"
Parker Ponds, WA	Lentic	24-VII-2006	N 46° 30'52.4" W 120° 27'38.5"
Selah Ponds, WA	Lentic	25-VII-2006	N 46° 39'13.1" W 120° 29'45.7
Lake Wapagasset, WI	Lentic	18-VIII-2006	N 37 25'19.1" W 122 05'06"
Apple River, WI	Lotic	20-VIII-2006	N 45° 18'13.9" W 92° 21'47.5"
Leech Lake, MN	Lentic	23-VIII-2006	N 47° 06'07.6" W 94° 34'21.9"
Norway Lake, MN	Lotic	23-VIII-2006	N 46° 43'15.5" W 94° 24'01.7"
Saratoga Lake, NY	Lentic	29-VIII-2006	N 43° 03'13.1" W 73° 43' 11.0"
Lake Hortonia, VT	Lotic	30-VIII-2006	N 43° 44'44.6" W 73° 13'19.5"
Little Lake, VT	Lotic	30-VIII-2006	N 43° 25'18.5" W 73° 12'24.7"
San Marcos River, TX	Lotic	19-VIII-2008	N 29 53'18.1" W 097 56'01.7"

Table 3.2. *H. dubia*- associated insect herbivores.

Order: Family	Insect species	Life Stage	Washed or Hand-picked	Collection Site
Coleoptera: Curculionidae	*Bagous floridanus* Tanner	A	W	Richland Chambers Reservoir, TX
Diptera: Chironomidae	*Chironomus* sp.	L	W	Parker Ponds, WA
Diptera: Chironomidae	*Cricotopus* sp.	L	W	Leech Lake, MN
Diptera: Chironomidae	*Endochironomus* spp.*	L	W	Coleto Creek Reservoir, TX; Saratoga Lake, NY
Diptera: Chironomidae	*Glyptotendipes* sp.*	L	W, H	Choke Canyon Reservoir; Richland Chambers Reservoir, TX; Selah Pond, WA; Saratoga Lake, NY; Lake Wapagasset, WI
Diptera: Chironomidae	*Polypedilum* sp.*	L	W	Yakima River, WA; Apple River, WI; Norway Lake, MN; Saratoga Lake, NY
Diptera: Chironomidae	*Hydrellia* spp.	L, P	W	Selah Pond, WA; Leech Lake, MN; Saratoga Lake, NY; Norway Lake, MN; Apple River, WI
Homoptera: Aphididae	*Rhopalosiphum* sp. prob *nympheae*	A	W, H	*
Lepidoptera: Crambidae	*Acentria ephemerella* Olivier	L	W	Norway Lake, MN; Saratoga Lake, NY

Order: Family	Insect species	Life Stage	Washed or Hand-picked	Collection Site
Lepidoptera: Crambidae	*Paraponyx* spp.	L	W, H	Apple River, WI; Saratoga Lake, NY; San Marcos River, TX; Norway Lake, MN
Lepidoptera: Crambidae	*Oxyelophila callista* Forbes	L	W, H	San Marcos River, TX
Lepidoptera: Crambidae	*Synclita obliteralis* Walker	L	W	Apple River, WI; Selah Pond, WA; Parker Ponds, WA
Trichoptera: Leptoceridae	*Leptocerus americanus* Banks	L	W	Norway Lake, MN
Trichoptera: Leptoceridae	*Triaenodes injustus* Hagen	L	W	Norway Lake, MN; Selah Pond, WA
Trichoptera: Leptoceridae	*Nectopysche albida* Walker	L	W	Leech Lake, MN; Norway Lake, MN
Trichoptera: Leptoceridae	*Nectopysche diarina* Ross	L	W	Apple River, WI
Trichoptera: Leptoceridae	*Nectopysche minuta* Banks	L	W	Yakima River, WA
Trichoptera: Leptoceridae	*Nectopysche* sp.	L	W	Yakima River, WA
Trichoptera: Leptoceridae	*Oecetis cinerascens* Hagen*	L	W	Choke Canyon, TX; Coleto Creek, TX;

Order: Family	Insect species	Life Stage	Washed or Hand-picked	Collection Site
Trichoptera: Leptoceridae	*Oecetis eddlestoni* Ross*	L	W	Choke Canyon, TX; Coleto Creek, TX;
Trichoptera: Leptoceridae	*Oecetis* sp. 1*	L	W	Norway Lake, MN
Trichoptera: Leptoceridae	*Oecetis* sp. 2*	L	W	Norway Lake, MN
Trichoptera: Leptoceridae	*Oecetis* sp.*	L	W	Little Lake, VT; Saratoga Lake, NY
Trichoptera: Leptoceridae	*Ylodes* sp.	L	W	Lake Hortonia, VT

*These caddisfly larvae probably only occasionally feed on aquatic plant tissue.

Table 3.3. Herbivore taxa similarity between regions sampled, displayed as Chao-modified Jaccard's abundance-based index. T_{obs} refers to number of observed taxa in the sample.

First Region	Second Region	T_{obs} First Region	T_{obs} Second Region	Shared Taxa Observed	Chao-Jaccard-Raw Abundance-based Similarity Index
TX	WA	4	10	1	0.23
TX	MN/WI	4	11	0	0
TX	NY/ VT	4	6	1	0.035
WA	MN/WI	10	11	6	0.25
WA	NY/ VT	10	6	3	0.44
MN/WI	NY/ VT	11	6	4	0.36

APPENDIX A

SITE DESCRIPTIONS AND RESULTS

Site Descriptions

Lower Midwest (LMW)

In the LMW, three sites were visited and samples taken. Choke Canyon reservoir, Coleto Creek reservoir, and Richland Chambers reservoir were visited on 10 July 2006, 11 July 2006, and 6 July 2006, respectively.

Choke Canyon. Choke Canyon reservoir is a 25,000 acre impoundment located in Live Oak Co., TX. Used for both recreation and as water supply for the city of Corpus Christi, TX. Abundant aquatic vegetation provide habitat for fisheries, but also includes the introduced *Hydrilla verticillata*. Hydrilla was present at sample sites, but not included in the collection of plant material collected. Coordinates of the sample location are N 28° 30'56.5" W 098° 18'50.3".

Coleto Creek Reservoir. Coleto Creek reservoir is approximately 3,100 acres and was impounded in 1980. Located in the Guadalupe River Basin, Goliad Co., access to the water is marked by a road sign on US 59. *Heteranthera dubia* populations were sparse in the reservoir, and all three samples were taken from the area around the boat landing. The sample location (Fig. 5) coordinates are N 32° 00' 16.0" W 96° 12'54.8".

Richland Chambers Reservoir. Richland Chambers reservoir is a 41,000 acre impoundment located east-southeast of Corsicana, TX along US 287. Located on Richland and Chambers creeks, the reservoir is used for recreation (angling, etc.) as well as a water supply for the city of Corsicana. Sample coordinates are N 32° 00' 16.0" W 96° 12'54.8". Stands of hydrilla were present in the reservoir at time of sampling, but plant/ invertebrate specimens were taken from monotypic stands of *H. dubia.*

Northwest (NW)

Samples were taken from three sites in the NW. Parker Ponds, Yakima Co., Selah Pond, Yakima Co., and the Yakima River, Yakima Co. were visited on 24 July 2006, 25 July 2006, and 24 July 2006, respectively.

Parker Ponds. Parker ponds, in Yakima, WA, are previous gravel pits that are now filled with water and an abundance of aquatic plants. Samples were collected at N 46º 30’52.4” W 120º 27’38.5”.

Selah Pond. As with the Parker ponds, the Selah pond is a former gravel pit that is now used as a farm pond. Selah pond is located along Selah Rd., Yakima, Wa at the coordinates N 46° 39'13.1" W 120° 29'45.7”.

Yakima River. The collection site along the Yakima River (Fig. 9) was along SH-82 at the town of Benton City, WA. Samples were taken just upstream from a bridge and USGS data collection station. Coordinates of collection site are N 46° 15'11.0" W 119° 28'40.9".

Upper Midwest (UMW)

Samples were taken from three sites in the UMW, including at the Apple River, Norway Lake, and Leech Lake, Cass Co., MN on 20 August, 23 August, and 23 August, 2009, respectively.

Leech Lake. Leech Lake, MN is a 103,000 acre lake within the Chippewa National Forest used for boating and recreation, as well as angling. The sample location was along the shore near the boat ramp off SH-200/371. Coordinates are N 47° 06'07.6" W° 094 34'21.9".

Norway Lake. Norway Lake is an impoundment along the Pine River, MN. Plant and invertebrate samples were collected from near the outflow or Norway Lake near the junction of SH-371 and SR-1, in Pine River, MN. Coordinates of the sample location are N 46° 43'15.5" W

094° 24'01.7". *Heteranthera dubia* plants were in close proximity with several other species of aquatic plants, including *Myriophyllum* sp., and *Potamogeton* spp.

Apple River. The Apple River runs through Polk Co., WI, passing through the town of Amery. The sample location was in the town of Amery, off the SR-46. Sample coordinates are N 45 18'13.9" W 092 21'47.5".

Northeast (NE)

Samples were taken from three sites in the NE, including at Saratoga Lake, Little Lake, and Lake Hortonia on 29 August, 30 August, and 31 August, 2009, respectively.

Saratoga Lake. Saratoga Lake is located in New York, about 25 miles north of Albany, and southeast of Saratoga Springs. The lake is fed by Kaydeross Creek and empties into Fish Creek, which eventually feeds the Hudson River. The sample location was located at the public boat access point, off Route 9P, east of Saratoga Springs, NY. Coordinates are N 43° 03'13.1" W 073° 43' 11.0".

Lake Hortonia. Lake Hortonia is a reservoir in Hubbardton Co, VT formed along the Hubbardton River. Samples were collected from near the public boat ramp, off Lake Hortonia Rd. Coordinates are N 43° 44'44.6" W 073° 13'19.5".

Little Lake. Little Lake in Wells, Vermont Is an approximately 160 acre impounded wetland with an average depth of 5.5-6 ft, downstream of the glacial relict lake Lake Catherine. Samples were collected from the far end of the lake, near the dam/ overflow. Coordinates are N 43° 25'18.5" W 073° 12'24.7".

Site Results

LMW

Richland Chambers Reservoir.A total of 1,024 invertebrates were collected from *H. dubia* in Richland Chambers Reservoir, representing 23 taxa. Shannon's diversity index for Richland Chambers Reservoir is 1.71 and Shannon's evenness is 0.59.

The most abundant invertebrates were *Glyptotendipes* spp. (Diptera: Chironomidae) which made up 56.25 % of all invertebrates collected at the site with 576 specimens. This equates to an average density of 12 individuals/g plant biomass. The next most abundant organism was *Physa acuta* (Gastropoda: Physidae) which made up 8.49 % of all invertebrates collected from the Yakima River with 86 specimens, or an average density of 1 individual/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the shredders with a mean density of 14 invertebrates/g plant biomass, followed by predators (3 invertebrates/g plant biomass), collector-gatherers (2 invertebrates/ g plant biomass), and scrapers (1 invertebrates/g plant biomass). Collector-filterers were absent from collections.

For Richland Chambers Reservoir collections, there is no significant correlation between plant biomass and invertebrate numbers ($r = 0.18$).

Choke Canyon Reservoir.A total of 1,904 invertebrates were collected from *H. dubia* in Choke Canyon Reservoir, representing 20 taxa. Shannon's diversity index for Choke Canyon Reservoir is 1.95 and Shannon's evenness is 0.65.

The most abundant invertebrates were the Podocopods which made up 46.90 % of all invertebrates collected at the site with 893 specimens. This equates to an average density of 7 individuals/g plant biomass. The next most abundant organism was *Physa acuta* (Gastropoda:

Physidae) which made up 16.33 % of all invertebrates collected from the Yakima River with 311 specimens, or an average density of 3 individuals/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the collector-gatherers with a mean density of 10 invertebrates/g plant biomass, followed by scrapers (3 invertebrates/g plant biomass), shredders (2 invertebrates/ g plant biomass), predators (2 invertebrates/g plant biomass), and collector-filterers (3 invertebrates/10 g plant biomass).

For Choke Canyon Reservoir collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.046).

Coleto Creek Reservoir.A total of 818 invertebrates were collected from *H. dubia* in Choke Canyon Reservoir, representing 22 taxa. Shannon's diversity index for Coleto Creek Reservoir is 2.08 and Shannon's evenness is 0.60.

The most abundant invertebrates were *Physa acuta* (Gastropoda: Physidae) which made up 31.90 % of all invertebrates collected at the site with 261 specimens. This equates to an average density of 8 individuals/g plant biomass. The next most abundant organism was *Hyalella azteca* (Amphipoda: Hyalellidae) which made up 19.68 % of all invertebrates collected from the Yakima River with 161 specimens, or an average density of 3 individuals/g plant biomass. Two additional gastropod specimens of interest that were collected are the Old-world invasive *Melanoides tuberculata* and the rare *Cincinnatia integra*. A total of four snail species were associated with *H. dubia* in Coleto Creek Reservoir.

Analysis of functional feeding groups reveals that the most abundant group were the scrapers with a mean density of 10 invertebrates/g plant biomass, followed by collector-gatherers (5 invertebrates/g plant biomass), predators (4 invertebrates/ g plant biomass), collector-filterers (1 invertebrates/g plant biomass), and shredders (7 invertebrates/ 10 g plant biomass) (Fig. 19).

For Coleto Creek Reservoir collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.26).

NW

Yakima River.A total of 1,277 invertebrates were collected from *H. dubia* in the Yakima River, representing 26 taxa. Shannon's diversity index for the Yakima River site is 1.76 and Shannon's evenness is 0.54.

The most abundant invertebrates were *Tricorythodes* sp. (Trichoptera: Tricorythidae) which made up 56.3 % of all invertebrates collected at the site with 719 specimens. This equates to an average density of 17 individuals/g plant biomass. The next most abundant organism was *Physa acuta* (Gastropoda: Physidae) which made up 16.8 % of all invertebrates collected from the Yakima River with 216 specimens, or an average density of 6 individuals/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the collector-gatherers with a mean density of 18 invertebrates/g plant biomass, followed by scrapers (6 invertebrates/g plant biomass), shredders (4 invertebrates/ g plant biomass), collector-filterers (2 invertebrates/g plant biomass), and predators (2 invertebrates/g plant biomass).

For the Yakima River collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.15)

*Parker Ponds.*A total of 1,125 invertebrates were collected from *H. dubia* in Parker Ponds, representing 26 taxa. Shannon's diversity index for Richland Chambers Reservoir is 2.43 and Shannon's evenness is 0.75.

The most abundant invertebrates were *Rhopalosiphum* sp. (Homoptera: Aphidae) which made up 35.46 % of all invertebrates collected at the site with 399 specimens. This equates to an average density of 20 individuals/g plant biomass. The next most abundant organism was

Ferrissia parallela (Gastropoda: Ancylidae) which made up 16.18 % of all invertebrates collected from the Parker Ponds with 182 specimens, or an average density of 9 individuals/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the shredders with a mean density of 33.68 invertebrates/g plant biomass, followed by scrapers (19 invertebrates/g plant biomass), collector-gatherers (9.383 invertebrates/g plant biomass), collector-filterers (7 invertebrates/ g plant biomass), and predators (3 invertebrates/g plant biomass). The number of shredders is highly affected by the large population of aphids collected in the samples.

For the Parker Pond collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.034)

*Selah Pond.*A total of 349 invertebrates were collected from *H. dubia* in Selah Pond, representing 23 taxa. Shannon's diversity index for Selah Pond is 1.82 and Shannon's evenness is 0.58.

The most abundant invertebrates were *Hyalella azteca* (Amphipoda: Hyalellidae) which made up 24.92 % of all invertebrates collected at the site with 87 specimens. This equates to an average density of 2 individuals/g plant biomass. The next most abundant organism was *Coenagrion* sp. (Odonata: Coenagrionidae) which made up 17.19 % of all invertebrates collected from the Selah Pond with 60 specimens, or an average density of 2 individuals/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the predators with a mean density of 4 invertebrates/g plant biomass, followed by collector-gatherers (4 invertebrates/g plant biomass), shredders (2 invertebrates/ g plant biomass), scrapers (13 invertebrates/100 g plant biomass), and collector-filterers (30 invertebrates/100 g plant biomass).

For the Selah Pond collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.089).

UMW

Apple River. A total of 1935 invertebrates were collected from *H. dubia* in the Apple River, representing 35 taxa. Shannon's diversity index for the Apple River site is 2.28 and Shannon's evenness is 0.67.

The most abundant invertebrates were *Hyalella azteca* (Amphipoda: Hyalellidae) which made up 34.83 % of all invertebrates collected at the site with 674 specimens. This equates to an average density of 39 individuals/g plant biomass. The next most abundant organism were Oligochaetes which made up 13.54 % of all invertebrates collected from the Apple River with 262 specimens, or an average density of 18 individuals/g plant biomass. Total invertebrate density was 108 invertebrates/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the collector-gatherers with a mean density of 88 invertebrates/g plant biomass, followed by predators (13 invertebrates/g plant biomass), scrapers (8 invertebrates/ g plant biomass), shredders (5 invertebrates/g plant biomass), and collector-filterers (3 invertebrates/g plant biomass).

For the Apple River collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.089).

Leech Lake. A total of 927 invertebrates were collected from *H. dubia* in Leech Lake, representing 23 taxa. Shannon's diversity index for Leech Lake is 2.46 and Shannon's evenness is 0.78.

The most abundant invertebrates were the Oligochaetes which made up 17.47 % of all invertebrates collected at the site with 162 specimens. This equates to an average density of 8 individuals/g plant biomass. The next most abundant organism was *Ferrissia parallela* which made up 14.56 % of all invertebrates collected from the Leech Lake with 135 specimens, or an average density of 3 individuals/g plant biomass. Total invertebrate density was 31 invertebrates/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the collector-gatherers with a mean density of 15 invertebrates/g plant biomass, followed by scrapers (12 invertebrates/g plant biomass), shredders (6 invertebrates/ g plant biomass), predators (2 invertebrates/g plant biomass), and collector-filterers (39 invertebrates/100 g plant biomass). For this analysis it was unclear as to which functional group *Rheosmittia* sp. and *Stilocladius* sp. (Diptera: Chironomidae) belonged, and so were not assigned to any.

For the Leech Lake collections, there is no correlation between overall invertebrate density and plant biomass but there is a significant correlation between plant biomass and gastropod numbers ($r = 0.76$).

*Norway Lake.*A total of 3,878 invertebrates were collected from *H. dubia* in Norway Lake, representing 44 taxa. Shannon's diversity index for Norway Lake is 2.27 and Shannon's evenness is 0.63.

The most abundant invertebrates were *Amnicola limosa* (Gastropoda: Hydrobiidae) which made up 38.34 % of all invertebrates collected at the site with 1,487 specimens. This equates to an average density of 37 individuals/g plant biomass. The next most abundant organism were *Sida* sp. (Ctenopoda: Sididae) which made up 8.74 % of all invertebrates collected from the Norway Lake with 339 specimens, or an average density of 5 individuals/g plant biomass. Total invertebrate density was 80 invertebrates/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the scrapers with a mean density of 38 invertebrates/g plant biomass, followed by collector-gatherers (37 invertebrates/g plant biomass), predators (6 invertebrates/ g plant biomass), shredders (5 invertebrates/g plant biomass), and collector-filterers (.3 invertebrates/g plant biomass) (Fig. 27). It is unclear what functional group *Stilocladius* sp. belongs, and so was left out of the analysis, although 208 specimens were collected.

For the Norway Lake collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.034).

NE

*Saratoga Lake.*A total of 1,826 invertebrates were collected from *H. dubia* in Saratoga Lake, representing 39 taxa. Shannon's diversity index for Saratoga Lake is 1.79 and Shannon's evenness is 0.49.

The most abundant invertebrates were *Amnicola limosa* (Gastropoda: Hydrobiidae) which made up 38.34 % of all invertebrates collected at the site with 1,487 specimens. This equates to an average density of 36.63 individuals/g plant biomass. The next most abundant organism were *Dreissena polymorpha* (Bivalvia: Dreissenoidea) which made up 22.67 % of all invertebrates collected from the Saratoga Lake with 414 specimens, or an average density of 4.84 individuals/g plant biomass. Total invertebrate density was 32.85 invertebrates/g plant biomass. Analysis of functional feeding groups reveals that the most abundant group were the scrapers with a mean density of 61 invertebrates/g plant biomass, followed by collector-gatherers (33 invertebrates/g plant biomass), collector-filterers (33 invertebrates/ g plant biomass), shredders

(5 invertebrates/g plant biomass), and predators (4 invertebrates/g plant biomass). It is unclear what functional group *Stilocladius* sp. belongs, and so was left out of the analysis, although 208 specimens were collected.

For the Saratoga Lake collections, there is no significant correlation between plant biomass and invertebrate numbers (r = 0.0053).

*Lake Hortonia.*A total of 1,887 invertebrates were collected from *H. dubia* in Lake Hortonia, representing 30 taxa. Shannon's diversity index for Lake Hortonia is 2.16 and Shannon's evenness is 0.64.

The most abundant invertebrates were *Amnicola limosa* (Gastropoda: Hydrobiidae) which made up 26.50 % of all invertebrates collected at the site with 500 specimens. This equates to an average density of 41 individuals/g plant biomass. The next most abundant organism were Oligochaetes which made up 21.57 % of all invertebrates collected from the Lake Hortonia with 407 specimens, or an average density of 38 individuals/g plant biomass. Total invertebrate density was 75 invertebrates/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the collector-gatherers with a mean density of 60 invertebrates/g plant biomass, followed by scrapers (44 invertebrates/g plant biomass), collector-filterers (8 invertebrates/ g plant biomass), predators (7 invertebrates/g plant biomass), and shredders (6 invertebrates/g plant biomass). It is unclear what functional group *Stilocladius* sp. belongs, and so was left out of the analysis, although 62 specimens were collected.

For the Lake Hortonia collections, there is no significant correlation between plant biomass and invertebrate numbers (r = -0.10).

*Little Lake.*A total of 363 invertebrates were collected from *H. dubia* in Little Lake, representing 36 taxa. Shannon's diversity index for Little Lake is 2.85 and Shannon's evenness is 0.80.

The most abundant invertebrates were *Enallagma* sp. (Odonata: Coenagrionidae) which made up 14.88 % of all invertebrates collected at the site with 54 specimens. This equates to an average density of 8.58 individuals/g plant biomass. The next most abundant organism were Oligochaetes which made up 13.50 % of all invertebrates collected from Little Lake with 49 specimens, or an average density of 7 individuals/g plant biomass. Total invertebrate density was 57 invertebrates/g plant biomass.

Analysis of functional feeding groups reveals that the most abundant group were the predators with a mean density of 15 invertebrates/g plant biomass, followed by collector-gatherers (15 invertebrates/g plant biomass), scrapers (14 invertebrates/ g plant biomass), shredders (8 invertebrates/g plant biomass). Collector-filterers were absent from the samples taken at this site.

For the Little Lake collections, there is a significant correlation between plant biomass and invertebrate numbers ($r = 0.24$).

APPENDIX B

TAXA DENSITY (# SPECIMENS / kg PLANT MATERIAL) AT SITES

	Choke Canyon	Coleto Creek	Richland Chambers	Yakima RIver	Parker Ponds	Selah Ponds	Apple RIver	Norway Lake	Leech Lake	Saratoga Lake	Little Lake	Lake Hortonia
Ablabesmyia	8	67	0	246	134	143	79	244	231	64	558	134
Acentria	0	0	0	0	34	41	0	8	0	7	0	0
Acricotopus	0	0	207	0	0	0	0	0	0	0	0	0
Amnicola limosa	0	0	0	0	0	0	1588	10990	743	19930	1698	12257
Arachnida	0	111	29	33	133	43	13	565	475	535	91	770
Argia	0	0	0	0	0	0	0	0	0	0	212	0
Ariogomphus	0	0	0	0	0	0	0	0	0	0	30	0
Baetidae	29	78	5	66	0	167	3613	31	98	66	130	55
Bagous floridanus	0	0	100	0	0	0	0	0	0	0	0	0
Berosus	42	10	109	0	0	0	0	0	0	0	0	0
Bezzia	0	0	0	0	16	0	0	6	0	0	0	0
Biomphalaria obstructa	0	72	0	0	0	0	0	0	0	0	0	0
Caecidotea	0	0	0	0	629	0	0	0	0	21	59	0
Caenis	86	0	23	0	0	63	13	130	793	309	251	504
Cardiocladius	8	0	212	0	0	0	0	0	0	0	0	0
Ceriodaphnia	0	60	0	0	0	0	3489	252	12	7	179	503
Chironomus	0	0	0	0	3365	0	0	0	0	0	0	0
Cinncinatia integra	0	572	0	0	0	0	0	0	0	0	0	0
Coenagrionidae/ Enallagma	0	214	267	106	544	562	0	0	0	91	0	0
Constempellina	0	0	0	0	0	0	327	0	0	0	0	0
Copepoda	0	0	0	0	0	0	0	0	0	107	0	24
Corduliidae/ Libellulidae	0	0	0	0	0	0	0	12	0	59	118	43
Corynoneura	0	0	0	0	0	0	0	0	0	0	30	0
Cricotopus	0	0	0	0	0	0	0	0	1636	0	0	0
Cyrnellus fraternus	93	0	0	0	0	0	0	0	0	0	0	0
Cyzicus	0	336	0	0	0	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	16	0	0	0	0	0	0
Dicrotendipes	0	0	31	0	492	0	0	540	0	377	0	0
Dreissena polymorpha	0	0	0	0	0	0	0	0	0	9896	0	1907
Dubiraphia	0	0	0	0	0	0	0	12	6	7	212	0
Enallagma	250	0	0	0	0	0	1111	591	0	88	2574	373

	Choke Canyon	Coleto Creek	Richland Chambers	Yakima RIver	Parker Ponds	Selah Ponds	Apple RIver	Norway Lake	Leech Lake	Saratoga Lake	Little Lake	Lake Hortonia
Endochironomus	0	184	0	0	0	0	0	0	0	455	0	0
Epitheca	0	0	0	0	0	0	0	0	0	0	121	0
Eurycercus	0	0	0	0	0	0	0	0	0	0	71	0
Eurychiopsis lecontei	0	0	0	0	0	0	0	0	0	100	0	0
Ferrissia parallela	0	0	0	5	2676	0	25	25	1027	7	600	0
Fluminicola fuscus	0	0	0	23	0	9	0	0	0	0	0	0
Gammarus	0	0	0	0	0	0	0	0	0	95	0	0
Glyptotendipes	378	0	3589	0	0	3290	0	0	0	0	0	0
Goeldichironomus	0	0	0	0	0	0	0	0	0	0	251	0
Gyraulus deflectus	0	0	0	0	0	0	0	0	0	484	0	0
Gyraulus parvus	0	0	0	18	851	0	478	105	972	0	908	420
Gyrinus	0	0	0	0	0	0	405	0	0	0	0	0
Helisoma anceps	0	0	0	0	0	0	0	173	0	384	189	128
Helisoma campanulata	0	0	0	0	0	0	0	0	0	100	0	19
Heptageniidae	0	0	0	10	0	0	38	0	0	0	0	0
Hirudinea	0	0	7	0	54	135	104	49	11	105	30	12
Hyalella azteca	536	1043	328	40	1066	727	11767	1348	948	559	0	310
Hydrellia	0	0	0	0	0	1	13	0	0	0	0	0
Hydropsyche	0	0	0	0	0	0	610	0	0	0	0	0
Hydroptila	35	0	348	0	0	0	0	0	21	211	0	330
Labrudinia	0	0	0	0	0	49	0	0	0	0	0	0
Laccodytes	0	100	0	0	0	0	0	0	0	0	0	0
Leptocerus americanus	0	0	0	0	0	0	0	91	0	0	0	0
Lestes	0	0	0	0	0	0	0	0	0	0	59	0
Lipiniella	0	0	0	291	0	0	0	0	0	0	0	0
Lynceus	0	0	0	43	0	0	0	0	0	0	0	0
Melanoides tuberculata	0	20	0	0	0	0	0	0	0	0	0	0
Menetus opercularis	0	0	0	0	1617	0	0	0	0	0	0	0
Microspectra	0	0	0	0	0	0	0	2269	0	0	0	0
Nanocladius	0	0	0	0	0	0	1244	0	0	0	0	0
Nectopsyche albida	0	0	0	0	0	0	0	637	188	0	0	0
Nectopsyche diarina	0	0	0	0	0	0	191	0	0	0	0	0

	Choke Canyon	Coleto Creek	Richland Chambers	Yakima RIver	Parker Ponds	Selah Ponds	Apple RIver	Norway Lake	Leech Lake	Saratoga Lake	Little Lake	Lake Hortonia
Nectopsyche minuta	0	0	0	102	0	0	0	0	0	0	0	0
Nectopsyche tavara	0	0	0	10	0	0	0	0	0	0	0	0
Oecetis cinascerans	167	786	0	0	0	0	0	0	0	0	0	0
Oecetis eddlestoni	3	97	0	0	0	0	0	0	0	0	0	0
Oecetis sp.	0	0	0	0	0	0	0	130	0	21	214	0
Oligochaeta	3	10	52	5	706	53	7194	3964	2518	6713	2150	11297
Orthotrichia	90	9	0	5	0	18	0	202	6	540	735	1013
Oxyethira	0	0	0	0	0	0	0	320	0	823	364	1426
Parachironomus	24	0	436	10	0	0	0	18	0	0	0	0
Paraponyx	0	0	0	0	0	0	306	61	0	7	0	30
Paratanytarsus	0	0	0	47	2083	0	0	1043	118	0	0	1063
Pentaneura	0	0	0	0	0	0	624	0	0	0	0	0
Physa acuta	796	2304	442	1727	0	32	403	184	826	334	808	274
Physa gyrina	0	0	0	0	377	0	0	0	21	0	0	0
Pleuroxus	0	0	0	0	0	0	0	0	0	0	61	0
Podocopida	2220	0	39	13	0	128	0	0	0	0	30	0
Polypedilum	0	0	0	449	0	0	717	386	0	127	0	0
Procladius	0	0	0	0	0	0	0	0	0	0	191	0
Promenetus exacuous	0	0	0	0	0	0	0	0	0	0	30	0
Psectrocladius	0	0	0	0	0	0	0	18	0	0	0	0
Psychomyiidae	0	0	0	0	0	0	0	79	0	0	0	0
Rheosmittia	0	0	0	0	0	0	38	0	21	0	0	0
Rheotanytarsus	0	0	0	0	0	0	204	0	0	0	0	0
Rhopalosiphum	0	0	0	539	5946	0	183	62	52	62	1519	468
Sergentia	0	0	0	0	1204	0	0	0	0	0	191	0
Sida	42	208	78	0	312	0	0	1452	202	703	629	2679
Simulium	0	0	0	613	82	0	0	0	0	0	0	0
Stenelmis	1052	0	0	299	48	9	0	0	0	0	0	0
Stilocladius	10	0	0	0	0	0	0	1543	1060	0	0	1519
Synclita	0	0	0	0	49	164	51	0	0	0	0	0
Tanytarsus	0	0	0	0	0	9	0	0	0	0	0	419
Thienemanniola	0	0	0	91	0	0	0	0	0	152	0	0
Tramea	0	10	0	0	0	59	0	0	0	0	0	0

	Choke Canyon	Coleto Creek	Richland Chambers	Yakima RIver	Parker Ponds	Selah Ponds	Apple RIver	Norway Lake	Leech Lake	Saratoga Lake	Little Lake	Lake Hortonia
Triaenodes injusta	0	0	0	0	0	275	0	47	0	0	0	0
Tricorythodes	0	0	0	5109	238	0	688	0	0	0	0	0
Tropisternus	0	0	0	30	81	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	42	190	1394	142	0	143	91	737
Valvata tricarinata	0	0	0	0	0	0	0	0	0	268	0	121
Ylodes	0	0	0	0	0	0	0	0	0	0	0	6
Zavreliella	0	0	0	0	0	0	0	0	0	0	152	0

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