Physical and Chemical Factors Affecting The Distribution of Freshwater Snails in Four Lakes of New Croton/Muscoot Reservoir Watershed, Westchester County, NY

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A dissertation submitted to the Graduate Faculty in Biology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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This manuscript has been read and accepted for the
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THE CITY UNIVERSITY OF NEW YORK

Abstract:

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Advisor: **Dr. Joseph W. Rachlin**

ABSTRACT

In a model study four lakes were examined to determine if benthic macroinvertebrates in the littoral zone were affected by physicochemical factors and shoreline development. The central hypothesis was that there would be correlations between the physicochemical factors in the lakes, levels of development around the lakes and the populations of benthic organisms. The study was conducted from April through October 2009 and 2010. Diversity and EPT indices were calculated to quantify taxa. Physicochemical variables measured included: temperature, pH, DO, mean nitrate and phosphate concentrations, total hardness, calcium, total dissolved solids (TDS), conductivity (ECS) and coliform testing. Sediment analysis and loss on ignition studies were done to assess percent composition, percent organic matter and percent carbonates in littoral sediments. Data characterizing shoreline development was collected from appropriate town, county and state resources, including: phosphorous loading, number of structures, number of storm drains, percent developed land and run-off into the lakes. Multivariate and correlation analyses were used to explore the data and to identify significant relationships between the benthic fauna and the abiotic variables. Results showed that freshwater benthic macroinvertebrates had significant correlations to physicochemical and development factors, including: ambient temperatures, hardness, DO, ECS, TDS, pH, percent silt, mean nitrate concentrations, coliforms, phosphorous loading, percent developed land, storm drains and the number of structures. The results of this study illustrate how anthropogenic inputs associated with development affect benthic macroinvertebrates in the littoral zone of suburban lakes.

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Special thanks to my dad, Thomas F. Cloherty, my first biology teacher. He always encouraged my scientific interests and challenged me to think critically and analytically about the world around me. He taught me to enjoy the pursuit of knowledge, but he warned me about taking a bite of the apple…and I’m still eating this apple… **:O)**
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Introduction:

There is remarkable diversity among freshwater gastropods in New York State with more than sixty species distributed among ten families and thirty-two genera (Jokinen 1992). Freshwater gastropods are ubiquitous. They often play an important role in aquatic ecosystems as detritivores. Gastropods feed on decaying plant matter, carrion and microbial biofilms. Their ability to break down organic matter drives the dynamic process of nutrient cycling in freshwater communities. They are also an integral component of food webs, as they are prey for waterfowl, fish, reptiles and other invertebrates. The preferred habitats of snails include both lotic and lentic waters. Due to physiological variation among freshwater snails, they vary in their tolerance for the chemical composition of their watery habitats. Dissolved minerals, organic matter, pH and oxygen levels all fluctuate and vary seasonally even in lentic, still water habitats. While many species of aquatic mollusks have preferred chemical characteristics of their habitats, some are ubiquitous and extremely tolerant of euryoecious conditions. For example, some Planorbidae snails will inhabit waters with calcium levels as various as 4.9 ppm to 89 ppm (Jokinen 1992).

Figure 1: Planorbidae snails – On left: *Helisoma sp*. Juvenile. On right: *Gyraulus deflectus* adult.

Some species of snails are more particular in their physicochemical requirements. These more sensitive species have potential as useful biomonitoring organisms, especially the oxygen sensitive Prosobranchs, the subclass consisting of gilled snails. Because the Prosobranchs are dependent on the concentrations of dissolved oxygen in the water, the productivity of the aquatic plant life is important. Lakes with low water quality often have reduced dissolved oxygen concentrations due to reduced productivity (Wetzel 2001). The presence of particularly sensitive species in an aquatic habitat is often indicative of higher oxygen levels and thus a specific set of environmental conditions within that community. Changes in the oxygen levels in an aquatic ecosystem can occur naturally, for example, seasonal turnover, or artificially, due to human activity in and around aquatic habitats. Even without testing for oxygen and other water chemistry, changes to baseline parameters such as dissolved oxygen levels can often be signaled by the decline of populations of these sensitive gastropods.

Gastropods in the subclass Pulmonata breathe using a lung, bringing their own air supplies, in the form of bubbles tucked under the lip of their mantle, when they venture below the surface. In this study, a common aquatic snail found at most of the research sites in the preliminary faunal survey belong to the family Physidae, which is in the subclass Pulmonata. Their mode of respiration allows them to capitalize on low oxygen habitats that are off limits to their gilled Prosobranch cousins.

Figure 2: The pulmonate snail, *Physa heterostropha* (Say 1817). In the photo on the right, the aperture is on the lefthand side of the shell, typical of Physidae snails.

Since many aquatic snails are herbivorous or omnivorous, the presence of plants, both submerged and littoral zone epiphytes, are important to the distributions of the organisms. Plants provide not only food, but a microhabitat suitable for laying eggs, as well as hiding from predators. Recent studies of benthic macroinvertebrates from the Hudson River indicate that benthic invertebrate distributions are often a spatial function of local plant populations (Strayer and Malcolm 2007). Studies have suggested that increasing aquatic plant diversity directly increases microhabitats for benthic macroinvertebrates (Vermonden et al. 2009). In fact, some studies recommended removing macrophytes or allowing eutrophication to destroy aquatic plant populations in order to control snail populations, especially in tropical regions where snails harbor parasites that infect humans through the water supply

(Daldorph et al. 1991). Aquatic plants are also known to sequester contaminants, such as metals and other pollutants, which can then enter the food chain through herbivorous benthic macroinvertebrates and accumulate in larger predators. Recent studies have indicated that the metals do affect the distributions of the organisms that ingest the contaminated plants (Johnson et al. 2007 cited in Johnson et al. 2010).

Apart from very early studies done in the nineteenth century by various natural historians, previous studies of New York's freshwater gastropods included surveys completed throughout the state in the early twentieth century with the last two major surveys being completed by W.N. Harman in the 1960s and E. Jokinen in the late 1980s. The latter work was published as a state survey and dichotomous key in 1992 (Jokinen 1992). In addition, more recent studies of the Hudson River and the Great Lakes have provided more details on mollusk distributions and associated plant life (Strayer and Malcolm 2007).

Given the pace of development in southeastern New York State, especially in the metropolitan area, a new study of aquatic habitats now is both necessary and timely. The pace of development in once bucolic, upstate communities has been rapid and substantial, as new housing developments have spread northward into what was once wilderness or farmland; in the recent past, much of this development centered along waterfront properties in the New Croton/Muscoot Reservoir watershed region. In the early nineties, with increased environmental awareness among ordinary citizens, the environmental impact of such development began to be examined more closely. Monitoring the quality of drinking water in the New York City reservoir system and its associated watershed became a priority. Since benthic fauna can be indicative of water quality (Rosenberg and Resh 1993), recent studies of the reservoirs have included biomonitoring of benthic macroinvertebrates (Blaine et al. 2006). Wetlands ordinances were reviewed or new ones developed and implemented to deal with increasing concerns for the health and quality of the water supply, for the city as well as for local communities. Nevertheless, the character of rural towns in the New Croton/Muscoot Reservoir Watershed region has changed dramatically in the last twenty-five years.

This study was conducted in the Town of Lewisboro in northeastern Westchester County. Older, census based reports have shown that the local resident human population increased rapidly. From 1980 to 1990 Lewisboro’s population increased by approximately 50%, with nearly 2,000 additional homes built (Martin 2004). Numerous housing developments and condominiums were constructed, since then. The last census report in 2000 indicated 4,218 households in the town. Similar rapid development occurred in other nearby towns in the New Croton/Muscoot Reservoir Watershed.

The study lakes were located in the Town of Lewisboro, a vacation destination for New York City dwellers since the late 1800s. The lakefront cottages that were once seasonal vacation rentals or weekend homes have been winterized and enlarged to become year round residences. Often this development occurred with little understanding of the impact of more human activity on and near the lakes, especially regarding such environmentally significant aspects of year round habitation as proximity of septic fields to waterways.

Recreational use of the lakes has increased substantially with fishing, boating, swimming and the use of jet-skis becoming increasingly popular with year round residents. In addition, some of land adjacent to the lakes is a golf course, which saw much more use by local residents as the population climbed. As with any new housing development, more roads were constructed to access these new homes. Nitrates are the result of run-off from sewage and drainages, while phosphorous can accumulate naturally as anoxic conditions develop or can result from runoff flowing into the lakes from fertilizers used on adjacent land (Baccini 1985; Martin 2004). Waters adjacent to golf courses could be higher in these nutrients due to extensive fertilization of their turf.

While Lewisboro retained some of its traditional dirt roads, most of these new roads are paved. Their construction involved installation of appropriate drainage grates and conduits. Year round use of the roads also means that roads are salted in the winter. In addition, the usual petroleum based run-off from tar, car exhaust and fluids also is added to the drainage. All of this drainage and run-off filters into the watershed, as well.

Many local towns have residents committed to preserving the rural character of the towns, although some would argue that thorough suburbanization is complete. Lewisboro, NY has an active group of citizens dedicated to an open space initiative that focuses on ecological conservation throughout the region. In addition, there are a number of private associations comprised of residents of the lakefront properties.

Figure 3: Regional map of the New Croton/Muscoot Reservoir Watershed. (©2010 Delorme (www.delorme.com) Topo North America 9.0®)

These groups determine recreational use, management of aquatic plants and access to the lakes. One group, particularly relevant to this study, is the Three Lakes Council. The Three Lakes Council has been instrumental in assisting me with the development of this project, providing previous environmental reports from the DEC, private environmental consultants and students from local and state universities. The Three Lakes Council also assisted in securing permission to access the lakes on both public and private lands. Assistance in securing access to the fourth lake was through the generosity of a lakeside resident. Recently, Lewisboro instituted a Town Lakes' Committee to manage concerns about the town's seven lakes. Ecological reports generated by professional environmental consultants were used to mandate septic management for residents immediately adjacent to the lakes.

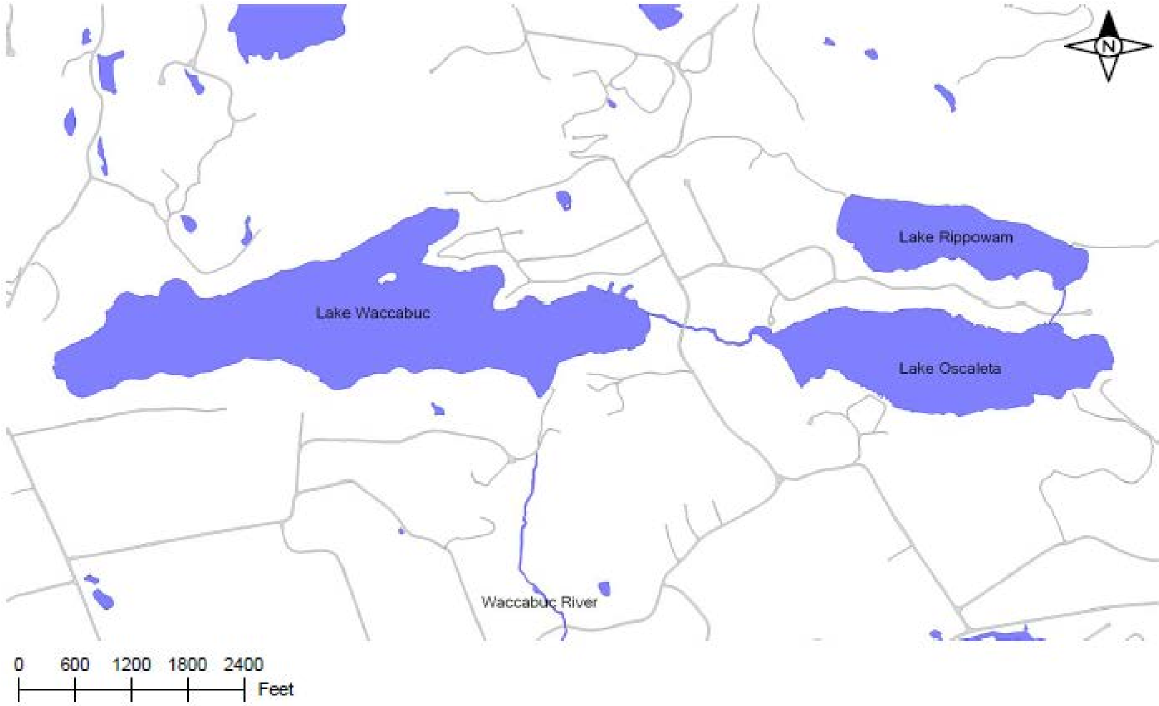


Figure 4: The Three Lakes: Waccabuc, Rippowam and Oscaleta in Lewisboro, NY. Map Courtesy of Janet Andersen and Lou Feeney

The lakes in this study varied in their dimensions and their hydrological classes. More on the hydrological characteristics of the lakes themselves will be described, below.

This study of benthic macroinvertebrates required a faunal survey as well as a survey of abiotic variables in the four lakes. The details of the methods are given, below. While there were a number of recent studies of the lakes, none focused on the benthic fauna and none examined the mollusks in the lakes. This project provides updated ecological information on conditions of these habitats and the benthic fauna that live there. Physical and chemical factors were measured and analyzed in relation to the species distributions in the four lakes. Much of the area adjacent to the lakes is subject to increased human activities and development. During the course of this study from 2008-2010, residents decided to take various actions to control plant populations in the lakes from hand pulling invasive species in 2008 and 2009 to chemical SONAR (fluoridone) treatment in 2010. Therefore this assessment of physical and chemical factors affecting benthic macroinvertebrates as well as water quality is both useful and timely.

The final results of this study will be made available to the Three Lakes Council, the local association concerned with the health, management and conservation of the three interconnected lakes in Waccabuc, as well as the Kitchawan residents' lake association. These data will be useful to the residents, as they develop future policies regarding management of aquatic plants, recreational activities, land use on adjacent properties and will assist in assessing ecological impacts of developments in the area. In addition, the Town of Lewisboro Lakes' Committee and planning board will find the information useful in deliberating on development and zoning policies.

Study Sites

The study sites are located on four lakes in Westchester County, NY. All of the lakes were formed in the last glacial period, after the retreat of the Wisconsin ice sheets. The lakes in northern Westchester County are contiguous with a large network of streams and wetlands which sit on one of the largest aquifers in the region and comprise the New Croton/Muscoot Reservoir Watershed, which supplies drinking water to the City of New York. One of the lakes in this study, Kitchawan, drains into the Eastern half of the adjacent Cross River Watershed. The NYS Stormwater Report in 2009 stated that the Cross River Watershed is an "impaired" watershed, due to high levels of mercury contamination (Town of Lewisboro 2009a).

The three contiguous lakes, Waccabuc, Oscaleta and Rippowam, comprise a 2,200 acre watershed within the larger New Croton/Muscoot Reservoir Watershed. These lakes are commonly referred to as the "Three Lakes." This watershed consists of wetlands and interconnected channels and lakes, with residential communities intermixed with forested areas and adjacent fields (Martin 2004). Table 1 shows hydrological characteristics of the lakes. The largest of the lakes is Lake Waccabuc, which has a surface area of 53 hectares and an average depth of 7.1 meters. Lake Oscaleta is the second largest with a surface area of 26 hectares and an average depth of 5.9 meters. Lake Rippowam is the smallest with a surface area of approximately 14 hectares and an average depth of 4.1 meters (Martin 2004). Lake Kitchawan has a surface area of 43 hectares, but an average depth of only 1.7 meters (Arrigo 2009).

Table 1: Table of lakes' relative sizes and adjacent development. The presence of aerator is indicated with an X. Hydrological classes were assigned by the NYS DEC. Class A = high transparency, suitable for recreational swimming and boating. Class B = low transparency, suitable for recreational swimming and boating (From Lewisboro Town Lakes' Committee Report February, 2009).

Lake	Surface Area (ha)	Max Depth (m)	Avg Depth (m)	Human Population/ha	P (kg/yr) Septic Run-off	Hydrologic Class	Aerator
Kitchawan	43	4.3	1.7	7.4	94	B	X
Oscaleta	26	10.8	5.9	6.5	35	B	-
Rippowam	14	6.1	4.1	8.2	29	B	-
Waccabuc	53	14.2	7.1	11.1	144	A	X

Waccabuc, Oscaleta and Rippowam are interconnected by natural and manmade channels. Many of these channels were made in the late 1800s to allow recreational boaters to pass from one lake into another (Koehl 1981). This was a popular activity of vacationers staying at the hotel which once stood on the shores of Lake Waccabuc in the 1890s (Koehl 1981). Today, the lakes have varying levels of development. Rippowam has the least development. Oscaleta has moderate development and is used recreationally for non-power boating and swimming. Waccabuc is heavily developed with more than 90 homes directly on the lake (Gehrum et al. 2000), with frequent power boat and jet-ski activity and a golf course adjacent to the lake. Each of the homes uses septic tanks to manage sewage, although previous environmental reports noted that the soil types around the lake were not suitable for effective septic system processing and drainage (Gehrum et al. 2000). In addition, there are at least 50 municipal storm drains that empty into Lake Waccabuc (Martin 2004). The lakes are part of a New York State program (CSLAP) Citizen Statewide Lake Assessment Program, where lakeside residents participate in monitoring the water quality of their local lakes. Data on these three lakes is therefore more comprehensive. The water quality in Lake Waccabuc is listed as Class A with greater "transparency" of the water, making it suitable for swimming and other recreational uses (Department of Environmental Conservation [DEC] 2008). Interestingly, the DEC report on Waccabuc is self-contradictory with a description of it as a Class B lake embedded in the report. The potability of the water apparently distinguishes Class A from Class B, so that Lake Waccabuc is most likely Class B, although the Town Lakes' Committee report lists Waccabuc as Class A due to its water chemistry (Martin 2004). Lakes Oscaleta and Rippowam are considered only Class B lakes, because they are less transparent and appear to have problems with excessive run-off and possibly higher pathogen counts. This difference in the classification of the lakes is interesting, because all three lakes are interconnected by wide channels.

According to reports on the lakes written by professional environmental consultants, Oscaleta and Rippowam are more eutrophic than Waccabuc, which is considered mesotrophic/eutrophic (Martin 2004; Arrigo 2009). Eutrophic lakes tend to have higher nutrient loads from run-off and thus more plant productivity, while mesotrophic lakes have a lower nutrient load from run-off, since surrounding soils in their hydrological basins are poor (Wetzel 2001). The DEC also indicated in its report that metals, organic pollutants and bacteria are a concern for lakes Rippowam and Oscaleta (DEC 2008).

The fourth study site, Lake Kitchawan, is a lake located on the opposite side of the Town of Lewisboro and partly in the Town of Pound Ridge, NY. Kitchawan has somewhat less development than Waccabuc, but similarly relies on septic tanks for sewage management. The highly eutrophic condition of the lake is a concern for many of the lakeside residents. In 2009, residents sought permits for the application of fluoridone herbicide, also known as SONAR treatment to control the aquatic plants. SONAR treatment was applied during the summer of 2010.

Kitchawan has a different drainage in the Lower Hudson Basin, making it a “control lake” in the New York City water supply watershed, monitoring of its phosphorous and management of its condition are under the jurisdiction of the New York City Department of Environmental Protection (DEC 2008).

Ecological stress on the lake was considered to be largely the result of septic issues and run-off. Pathogens were also reported to be a concern in Lake Kitchawan (DEC 2008). Coliform testing was incorporated into the study to examine this issue, further.

Figure 5: Eutrophication in Lake Kitchawan (July 2009). Plant growth in the littoral zone extends >5m into lake.

Kitchawan was the site of the preliminary faunal surveys completed in the 2008 season. In the fall of 2008, Lake Kitchawan was fitted with an aerator to filter the water in an attempt to improve water quality by increasing dissolved oxygen.

In the 1970s, Lake Waccabuc was fitted with a hypolimnion aerator by the Union Carbide Corporation which also produced an environmental report on the effect of the aerator on the lake's water quality (Fast et al. 1975). In 2001, the aerators in Lake Waccabuc were refitted, however, they had technical problems and ceased to operate in 2004 (Martin 2004).

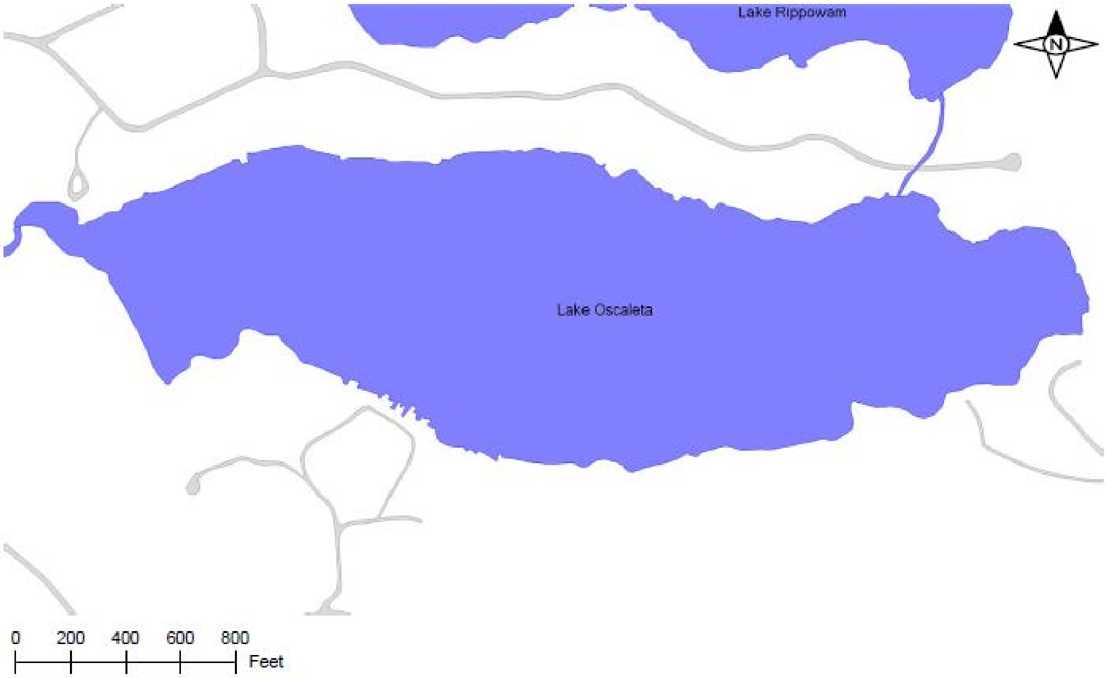


Figure 6: Lake Oscaleta

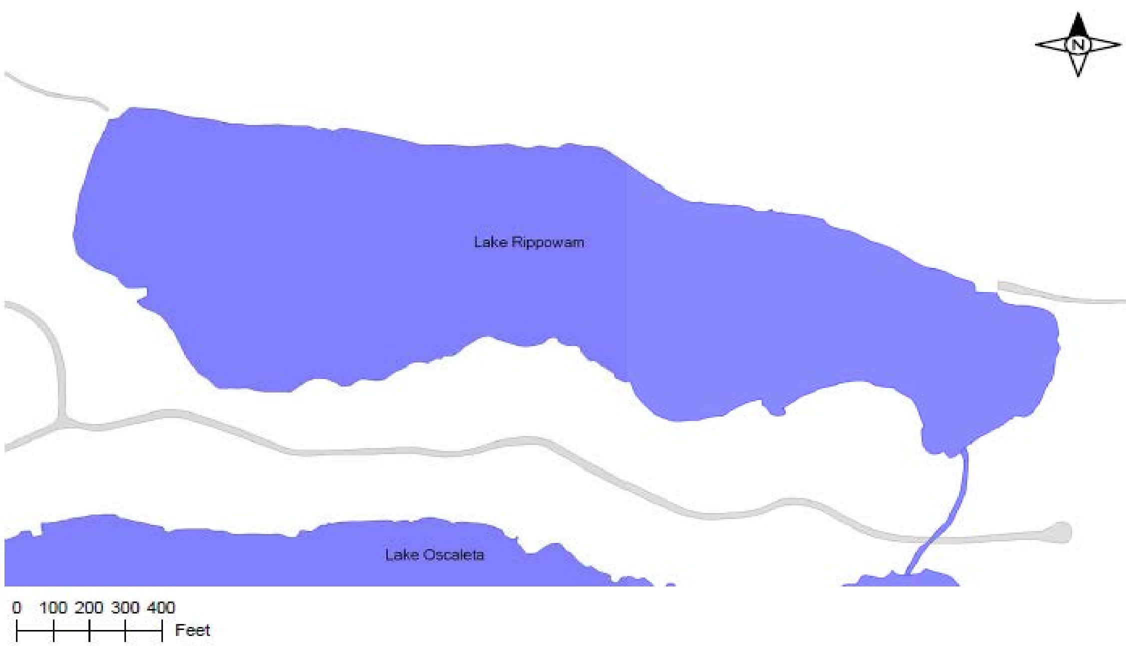


Figure 7: Lake Rippowam, above.

Figure 8: Lake Waccabuc, above. Maps Courtesy of Janet Andersen and Lou Feeney.

<u>Objectives:</u>

The following objectives outline how the study proceeded:

- Faunal Survey and Gastropod Identification
- Plant Survey and Identification
- Measurement of Physicochemical Variables
- Univariate and Multivariate Analysis of data

Using univariate techniques, the snail populations were analyzed to determine the most populous, the rarest, as well as the general population dynamics over the course of the season from April to October. The physical and chemical data were analyzed to determine if there were any associations or correlations between them. Typically, dissolved oxygen fluctuated seasonally and other chemical parameters were expected to vary based on seasons and human use of the waterways and adjacent land.

Dissolved oxygen levels are useful indicators of the health of lakes, because anoxic conditions tend to arise if organic contaminants foul water causing bacteria to multiply and use up the oxygen in their metabolic activities (Martin 2004). This makes conditions poor for animals that depend on dissolved oxygen, like gilled snails and other benthic organisms.

Traditional statistical methods and single factor analyses were performed using JMP 8.0 to assess the data for distributions, normality and univariate relationships (JMP 8.0, SAS Institute, Inc. Cary, NC 2010). Multivariate analyses were used to analyze the relationships between the snails, plants, benthic fauna and the abiotic factors in the lakes' microhabitats. Cluster analysis, Principal Components Analysis (PCA), Canonical Correspondence Analysis (CCA) and other multivariate methods were used to glean as much information as possible from the data. These data visualization techniques were among the most useful forms of analysis, because of the large number of variables that can potentially influence the ecology of these organisms.

Preliminary Study 2008:

From April to October 2008, a preliminary faunal survey was conducted to identify the freshwater snail families present at the study sites. Initially, access was only available to Lake Kitchawan. Sampling was done at four sites along the shore of a resident's two acre lakefront property. In addition, the outflow site was identified, but permission to access that site was not granted.

In August of 2008, Three Lakes Council granted access to numerous sites on Lake Waccabuc, Lake Rippowam and Lake Oscaleta. On Lake Rippowam, access was granted that borders both the lake and the outflow channel that flows through a large cement drainage pipe into Lake Oscaleta. Early sampling was done on the outflow channel, but permission was obtained later to sample the following spring and summer on the lakefront. On Lake Oscaleta, access was available to sites on a beach with a sandy substrate, a boat launch and a marsh area, as well as the use of boats, thanks to the Three Lakes Council. Permission was secured to access the lakes in late August of 2008, so preliminary data was only collected from September to October for the Three Lakes sites. Permission was granted to resume sampling on all lakes for both 2009 and 2010 from April through October.

Methods for Preliminary Study 2008:

The methodology for the preliminary study consisted of a faunal survey to determine if a substantial enough diversity of gastropods existed in the lakes to merit any further study. Using a , 500 micrometer mesh Surber net, benthic samples were taken along the lake littoral <40cm depth. Three replicates at each sample site were collected from littoral sites on Lake Kitchawan. Samples collected with the Surber net were placed in glass jars with 75% ethanol and 0.01% Rose Bengal solution to stain tissues. Samples were analyzed and identified at LaMER (Laboratory for Marine and Estuarine Research) at Lehman College using an Olympus stereomicroscope, hand lenses and dissecting kit. Each family of organisms was separated and stored in glass vials containing 75% ethanol. Sites were visited in one or two week intervals from April to October of 2008. Temperature, cloud cover and vegetation at individual sample sites were noted at each visit. The preliminary study at Lakes Waccabuc, Oscaleta and Rippowam was conducted with the same protocol, but for a shorter sampling period, from September to October, for reasons described above.

Data from the 2008 Preliminary Study:

Results from the preliminary faunal survey on Lake Kitchawan showed that mollusks from two different classes occur in the lakes. Class Bivalvia had one populous representative, Family Sphaeriidae, better known as pea clams. From Class Gastropoda, snails from five freshwater snail families were found, including: Physidae, Planorbidae, Lymnaeidae, Hydrobiidae and Ancylidae – the limpets. In addition, the family Succineidae – a terrestrial snail - appeared in samples. The species, *Succinea campestris,* has been known to demonstrate amphibious habits, seasonally extending its range into the littoral zone (confirmed by D. Strayer, 2009 in visit to his lab). Total mollusks by family found in sampling of Lake Kitchawan are in Table 2, below.

Table 2: Results of 2008 faunal survey at Lake Kitchawan, showing mollusk families found in the lake

Physidae	Lymnaeidae	Succineidae	Hydrobiidae	Planorbidae	Ancylidae	Bivalvia
215	3	2	327	489	144	917

When possible specimens were identified to species, however, this was only possible for some families. Those identifications to species level were confirmed in visits to the freshwater mollusk collections at the AMNH and the Peabody Museum at Yale University, as well as in consultations with experts at the Cary Institute in Millbrook, New York.

Figure 9: Above left, *Succinea campestris*, a terrestrial gastropod with amphibious habits (Actual size ~3mm). Above right, *Fossaria sp.* a Lymnaeidae snail (actual size ~5mm).

Among the different gastropods found in Lake Kitchawan were more than eight different genera and several species. The preliminary data for Lakes Waccabuc, Oscaleta and Rippowam covers only the last two months of the season, for reasons explained above. Despite the fact that the lakes exist in an entirely separate drainage basin from Lake Kitchawan, similar mollusk families were found to exist at all four lakes. Table 3 shows the total gastropod fauna from the three contiguous lakes.

Table 3: 2008 Faunal survey totals for Waccabuc, Oscaleta and Rippowam.

Lake	Physid	Hydrobiid	Planorbidae	Lymnaeidae	Sphaeriidae	Ancylidae
Oscaleta	11	10	14	0	7	3
Waccabuc	15	2	4	0	1	0
Inflow-W	1	0	1	0	3	0
Outflow-W	0	0	2	0	13	0
Rippowam	0	1	0	0	8	0
Totals	27	13	21	0	32	3

Although the 2008 sampling season was truncated, the preliminary faunal survey showed a fair amount of biodiversity existed among mollusks in Lakes Waccabuc, Oscaleta and Rippowam, meriting further study.

Figure 10: *Pisidium sp.,* photographed at the Yale Peabody Museum Invertebrate Zoology Department. These clams are approximately 3-5mm in width.

Additional Observations from the 2008 Preliminary Study:

The aquatic plants were another important addition to the dataset. From simple observation, different aquatic plants were noted in sampling the littoral in Lake Kitchawan. Large common water lilies were present including *Nymphaea odorata* with white flowers, as well as the yellow flowered water lilies, *Nuphar luteum*. Planorbidae snails were found in this area. The macrophyte, *Pontederia cordata,* with purple flowers was the predominant macrophyte. *Pontederia*, also known as Pickerel weed, appeared most often in areas with deeper water and more sunlight. Wetlands adjacent to the lakes were characterized by dense growth of *Phragmites* reeds from the edge of the water out several meters along lake shore. In the littoral zone, *Carex* sp*.,* sedges, *Scirpus* sp. - bulrushes - and corkscrew rush grew in a dense carpet. Snails from the family Hydrobiidae were very common. *Lythrum* sp., purple loosestrife, another invasive, also occurred in this area.

The plant data were examined to determine if the kinds of plants significantly affected the distribution of snails and other benthic macroinvertebrates. While these plants were more readily identifiable, other aquatic plants were also present, such as: *Elodea canadensis*, *Lemna minor* or Duckweed, *Myriophyllum spicatum* or milfoil, *Vallisnera americana* and *Typha latifolia*, cat tails. Invasive plants such as European milfoil and Brazilian *Elodea* also occurred in the lakes. There were also numerous surface growing algae and filamentous algae. Unfortunately, large amounts of heavy growth of blue-green algae appeared at the lakes in midsummer, especially heavy in Lake Kitchawan. Aquatic macrophytes were identified and noted along with the fauna for each benthic sample. Analysis of the flora of the lakes may give some indication of any trends in habitat preferences and host plants for the various species of snails and may be a clue as to what comprises a microhabitat, especially when families like Hydrobiidae are heavily concentrated in areas with distinct flora.

The Three Lakes Council and the Lake Kitchawan Association were both deeply concerned with the problem of eutrophication. Both maintained active programs for the management of aquatic plants to maintain recreational swimming and boating in the lakes. They carefully watched for invasive species. A visit to the Three Lake's Council website featured a warning about Brazilian *Elodea*, which was found in Lake Waccabuc in 2009. The invasive plant is sold in pet shops and it is suspected to have been dumped into the lake by a careless resident emptying an aquarium (see www.threelakescouncil.org).

In the 2009-2010 field studies, the plants at each sample site were identified and recorded. Each of the lakes had various plant communities that appeared to change from lilies and reeds to sedges and rush. Still others were dominated by *Pontederia*, *Lemna* or *Elodea*. The changing plant community along the shores varied by substrate and light availability – among other factors. The varieties of substrate within the lakes led to the addition of a sediment analysis and a loss on ignition protocol to the study to characterize and to quantify soil types. These varied from sand to pebble and glacial till to thick organic muck in the various inflow, outflow channels and littoral areas.

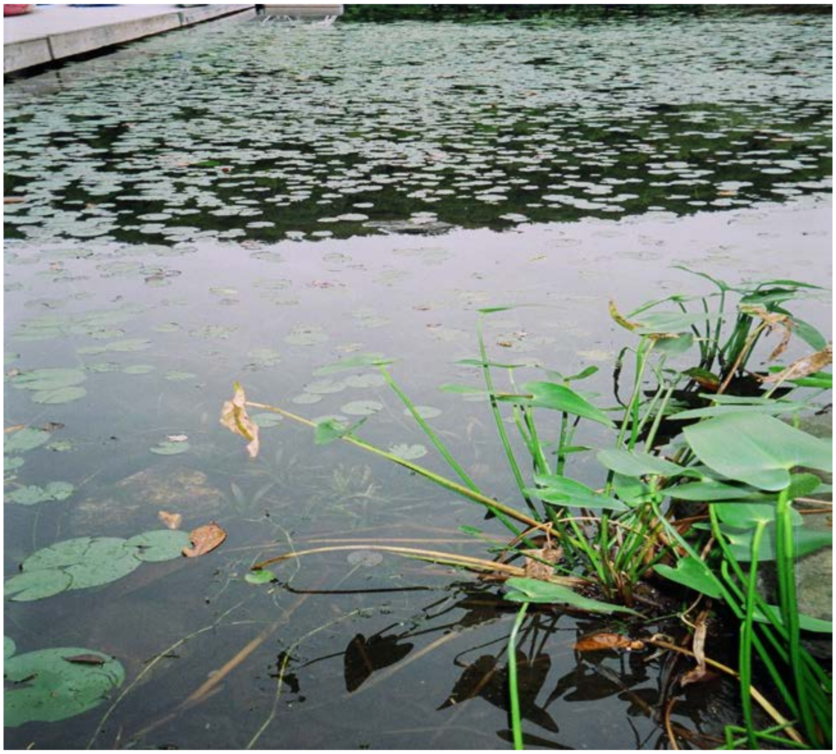


Figure 11: Plants at Lake Oscaleta 2009, *Nuphar, Pontederia, Myriophyllum* and *Vallisneria* are visible at the water's edge.

Results of the 2008 Preliminary Study:

The data from the preliminary study in 2008 indicated a distinct difference between the Lake Kitchawan fauna and the fauna in the other three lakes.

Figure 12 shows a cluster analysis of the 2008 data for the months of September and October, when data was collected for all the lakes in the study. The data clustered neatly into the months of September and October, with the exception of Lake Waccabuc for which the two months appear clustered together in the outflow site (P08O and I08S). Lake Kitchawan's fauna also fell outside the central Three Lakes' cluster, indicating a distinct difference from the other lakes for both September and October 2008.

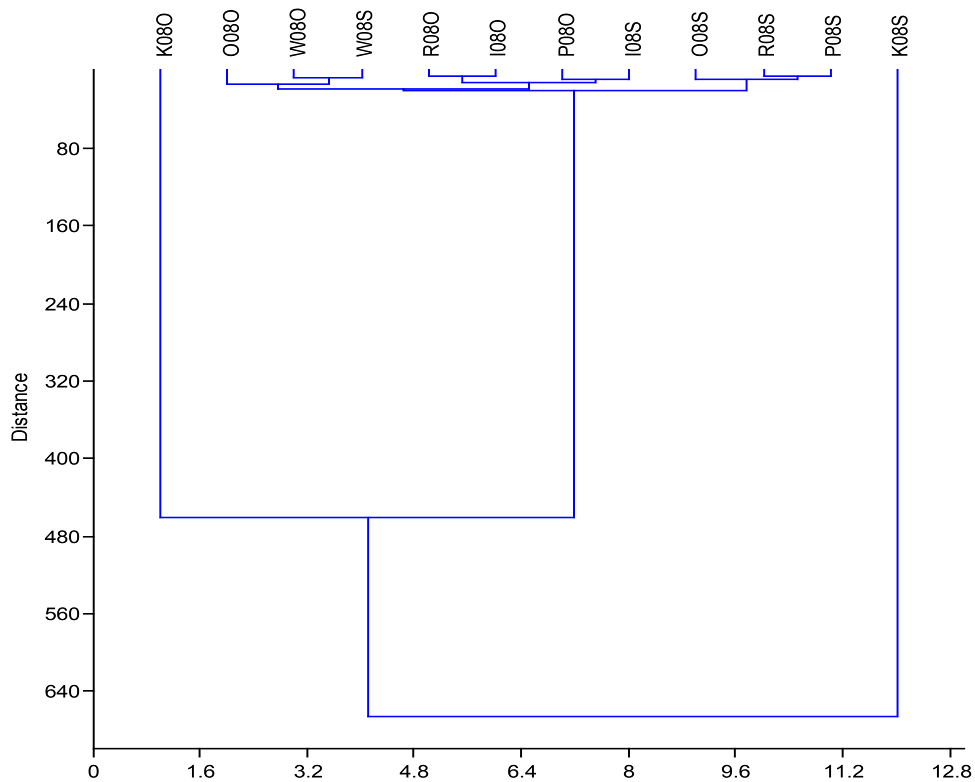


Figure 12: Cluster analysis of 2008 data, similarity, Euclidean distance. W08S= Waccabuc September, W08O= Waccabuc October; R08S= Rippowam September, R08O=Rippowam October; O08S=Oscaleta September, O08O=Oscaleta October; P08S= PerchBay September, P08O=Perch Bay October; I08S=Inflow September, I08O=Inflow October; K08S=Kitchawan September, K08O=Kitchawan October.

Field Studies 2009-2010 Goals and Hypotheses:

The goal of this project was to analyze the interrelationships between physicochemical factors and development factors and the distribution of aquatic snail species to determine which environmental factors, if any, influence the distribution, habitat and ecology of the freshwater snails in four suburban lakes subject to varying levels of residential development and human activity.

Many other organisms inhabit the lakes. Due to the nature of benthic sampling with Surber nets, a large number of non-molluscan benthic fauna are retained in the collection process. These organisms can be used for a further study of the coexistence of non-gastropod/non-molluscan organisms to determine if there are diverse species assemblages that occur together in significant patterns of association. Three hypotheses have been developed for this multivariate study:

Hypothesis I: Are there correlations between the physicochemical variables of the lakes and the composition and distribution of gastropod populations?

H-0: There are no interrelationships between the physicochemical parameters of the lakes and the composition and distribution of gastropod populations.

H-alt: There are interrelationships between the physicochemical parameters of the lakes and the composition and distribution of gastropod populations.

Hypothesis II: Snail species appear to be associated with distinct species of plants, is this indicative of a species' preference for particular plants as hosts for feeding and egg laying?

H-0: Snails have no association/preference as to which aquatic plants they feed or live on.

H-alt: Snails have distinct associations with particular aquatic plants as hosts for food and life cycle requirements.

Hypothesis III: Based on the preliminary faunal survey, are there particular species assemblages of benthic organisms that favor similar microhabitats as particular gastropods and thus are frequently found in association with those snails?

H-0: There are no associations between species assemblages of non-molluskan benthic fauna and mollusks.

H-alt: There are associations between species assemblages of non-molluskan benthic fauna and mollusks.

Methods for Field Studies 2009-2010:

Data was collected on both the biotic and abiotic factors potentially affecting snails in the study areas. Sampling was done from April-October 2009 and from April-October 2010, with sites sampled approximately twice a month. Sampling sites along the littoral were delineated for each lake. A six sided die was used to determine where samples would be collected from at each visit. Since many benthic macroinvertebrates were more active in the warmer part of the day, sampling was done between 9am and 2pm. Weather conditions were recorded at each visit. Sampling was done regardless of the weather. The snails were sampled using the same method as the preliminary study with 500 micrometer mesh Surber net, with three replicates at each sample site per visit. The benthic samples were taken at sample sites in access points along the shores of each lake at depths not exceeding 40cm. The samples were preserved in 75% ethanol with 0.01% Rose Bengal solution to stain tissues. The samples were analyzed at LaMER at Lehman College using surgical pans, microforceps and microscopy to sort, identify and record benthic macroinvertebrates present in each sample. Dichotomous keys were used to identify organisms (Edmundson 1954; Pennak 1978; Jokinen 1992; Ogden 1976; Crow 2000). Assistance was sought to ensure proper identification of species from experts and museum collections. Digital photos of plants and algae were taken to help identify habitat and host plants. When necessary, samples of foliage and flowers were taken.

At every sampling date, a water sample from each lake was tested for coliform bacteria, using Coliscan Easygel® water monitoring test kits from Forestry Suppliers. Two milliliters of water samples were gently mixed with the kit's Easygel® plating mixture and poured onto plates. Once the gel hardened, plates were incubated at 25 degrees Celsius for 48 hours. The plates were then observed under a microscope and results recorded in colony forming units per square centimeter (cfu/). The growth medium in the gels contained indicators that showed dark pink colonies in the presence of *Citrobacter, Klebsiella* and *Enterobacter* species. A blue-green color colony appeared for *Escherichia coli*. Other bacteria, such as *Proteus* sp. or *Salmonella* sp. appeared as white colonies.

The presence of coliforms is indicative of a typical problem of urban and suburban ecology, although rural agricultural environments can also supply coliforms in run-off. The proximity of old, leaky septic fields is a difficult subject to broach with local residents, but the effects may be measurable and significant, as such run-off influences nutrient loading, plant growth and alters the natural microbial fauna in the lakes. Not to mention, drinking water in the vicinity of the lakes comes from wells in this municipality, wells that are often situated quite close to septic fields. The amount of rainfall can affect the coliform parameter, as old septic systems tend to have more problems with filtration in periods of heavy rain. It was therefore useful to collect and record local weather and rainfall data during, and immediately preceding the sampling periods. These data were collected from the National Oceanic and Atmospheric Administration (NOAA)'s online weather archives (NOAA 2010).

Physicochemical factors can strongly influence the presence of snail species in waterways, with some species having distinct preferences for softer water (Jokinen 1992; Schiebler and Ciocco 2010). Physicochemical variables measured in this study are listed in Table 4, below. Physical parameters were measured using a Hannah probe. Parameters measured by the probe included: air temperature, water temperature, total dissolved solids (TDS), conductivity (ECS) in microSiemens (μS) per square centimeter and one chemical indicator on the probe – pH. Conductivity (ECS) is indicative of run-off from adjacent roads and paved driveways in the developments around the lakes (Martin 2004). Conductivity can also be indicative of salt levels and many freshwater snails do not inhabit high salinity environments (Jokinen 1992; Schiebler and Ciocco 2010). Gastropods have a range of pH preferences and dissolved oxygen tolerances (Jokinen 1992).

Chemical analyses were done using LaMotte and Hach Surface Water test kits. Dissolved oxygen was tested with the classic Winkler titration and appears in data tables in milligrams per liter (mg L^{-1}). Since snails cannot construct their shells without adequate levels of calcium and magnesium, both total hardness and calcium were measured (ppm). During 2009, the test kits (both Hach and LaMotte) were unable to detect the levels of nitrates and phosphates in this study, due to lack of sensitivity. However, nitrates and phosphorous were measured periodically by Three Lakes Council volunteers who collected samples and had them processed at a professional lab, Upstate Freshwater Institute, Syracuse, NY (proprietary protocol, NY Laboratory ID No. 11462/EPA Laboratory Code NY 01276). Data on nitrates and phosphorous concentrations was provided by Janet Andersen. Average values are presented in Table 10. Data for Kitchawan was drawn from data published in the town lakes' reports in 2009.

Anoxic conditions are attributed to phosphorous release from iron oxide in lake sediments, but this usually occurs seasonally in the summer depending on when dissolved oxygen levels fall (Wetzel 2001). More pertinent to this study, littoral zone aquatic plants are believed to retain phosphorous in the sediments, thereby limiting the bioavailability of phosphorous in shallow areas of lakes (Wetzel 1990a cited in Wetzel 2001). Numerous aquatic macrophytes can help to control phosphorous levels, but nitrates can increase phytoplankton blooms. Later as phytoplankton die off after nitrates are consumed, the decaying plant life can lead to a rise in phosphorous levels due to anoxic conditions from the respiration of bacterial decomposers (Wetzel 2001; Genkai-Kato and Carpenter 2005).

Table 4: Physicochemical Factors Measured in this Study

Physicochemical Variables Measured
Total Hardness
Total Calcium
Conductivity
Acidity/Alkalinity (pH)
Turbidity
Dissolved
Fecal Coliform
Temperature
Total Dissolved Solids
Nitrates
Phosphorous

Turbidity, measured using a Secchi disk, was recorded at the time of benthic sampling. Turbidity or transparency is associated with the productivity level of plankton in a lake (Wetzel 2001). Diminished transparency can be indicative of phytoplankton blooms and tied to influx of nitrates or other fertilizers. It can also be indicative of increased sediment loading due to shoreline erosion resulting from construction and/or heavy rains washing non-stabilized banks into the waterways.

Sites were noticeably different in their substrates. Therefore, it seemed prudent to identify the composition of the sediments from which the benthic samples came. Sediment samples were taken from each lake and from the inflow and outflow of Waccabuc, because they had noticeably different substrates from the main Cove Road site. The samples were taken within the sampling area to a depth of no more than 2cm, in keeping with the usual parameters of the benthic samples in this study, for consistency. A literature search indicated that most sediment analyses used five USDA standard testing sieve categories: fine gravel (#10), coarse sand (#35), fine sand (#60), very fine sand (#230) and silt. Standard protocols for sediment analysis and loss-on-ignition studies were used in analyzing aquatic sediments (Hieri et al. 2001; Coral Reef Assessment and Monitoring Program [CRAMP] 2009; Luoto 2010). The protocol was repeated twice and the average values appear in the results, Table 12.

Following the University of Hawaii protocol, sediment samples of approximately 500 grams were taken from each research site (CRAMP 2009). Samples were weighed into 60-120g subsamples and labeled A, B, C and D. Samples A and B were used to determine sediment composition. Samples were filtered using wash bottles filled with distilled water, #114 weight filter paper, plastic funnels and glass one-arm flasks with hose, the liquid vacuumed off and each sieve product separated out. Filtered sediments were dried for three weeks and then massed three days in a row, until a consistent mass was attained. Percent composition for each category of sediment was then determined. Results are shown below in Table 11.

The loss-on-ignition (LOI) protocol determined the percent organic matter and percent carbonate in the samples (CRAMP 2009). Crucibles, tongs, drying oven, muffle furnace, dessicator, Drierite, heat proof gloves, mortar and pestle, and a balance were required for these steps of the protocol. Sediment samples C and D (weighing between 60-120g) were dried for three weeks. After three weeks, samples were crushed with a mortar and pestle to break up large pieces of organic matter. Empty heat resistant crucibles were massed and recorded. The crushed sediment samples were placed in heat resistant crucibles and massed again. The crucibles were placed in a drying oven at C ten hours. They were then cooled in a dessicator containing ~4cm of Drierite™, overnight. The samples were then placed in a muffle furnace and heated to C. When the furnace reached C, the samples were timed for twelve hours. After twelve hours, they were then returned to the desiccator to cool overnight. The following day, samples were massed again. Samples were then placed into the muffle furnace and heated to C. Upon reaching C, the samples were heated for two hours. Afterwards, they returned to the desiccators to cool. When cool enough to sit on the balance, samples were massed a final time. Recorded masses were used to determine the percent organic matter and percent carbonates in each sample (CRAMP 2009).

Methods for Statistical Analyses:

The following methods were used to extract as much information from the data as possible. Diversity indices are numerous, so choosing one for this study was not easy. Reading studies of benthic macroinvertebrates and water quality assessments led to the choice of Margalef's R. Studies have shown that Brillouin's and Margalef's Diversity Indices are better for exploring correlations with abiotic data (Gray and Delaney 2008). Other studies suggested that Margarlef's R was a good compromise between the presence/absence taxa based diversity indices and the abundance based indices (Gray and Delaney 2008). Taxa (S) and abundances (n) were used to calculate $R = (S-1)/(\ln(n))$ (Hammer et al. 2001). Margarlef's R – a measure of alpha diversity - was calculated for each lake for 2009 and 2010, and for both years of the study combined (Table 7). Beta diversity and gamma diversity were also calculated for each lake to quantify non-molluskan taxa (Table 8).

Single factor analysis (one-way ANOVA) was used to assess the environmental variables of the lakes to determine which physicochemical factors were significantly different between the four lakes: from lake size, overall depth, water temperature, pH, conductivity, total dissolved solids, percent organic matter, percent carbonates, percent fines (sediment analysis results), dissolved oxygen, turbidity, total hardness and total calcium. As explained earlier, nitrates and phosphorous were not collected for each sampling date after the kits proved unable to detect the concentrations. Data for nitrates and phosporous were available later, and analysis was performed using the means.

All meristic data was square root (x + 0.5) transformed prior to analyzing the data to avoid the problem of zeros (Sokal and Rolf 1987; Van Den Brink and Ter Braak 1999). Physicochemical and development variables were log transformed in the case of continuous variables and arcsine transformed in the case of percentage data as is customary (Sokal and Rolf 1987). The data transformations did not entirely normalize all of the data, however. Therefore nonparametric methods were used for further data analysis.

Cluster analysis was used to assess basic relationships between species and sample sites, to determine trends in species distributions. Ordination techniques were used to more closely examine the relationships between physicochemical parameters, molluskan fauna and macrophytes. Past 2.04 was used to perform the initial ordinations with Principal Components Analysis (PCA) and Correspondence Analysis (CA). Taxa were analyzed in sample space to explore species distributions by site. PCA was then used to examine the physicochemical parameters and the taxa to determine which factors were most prominent, based on eigenvalues, in causing species distributions.

Due to the multivariate nature of this study, Cluster Analysis and Principal Components Analysis (PCA) were used in exploratory data analysis. Because of the non-linearity of the taxa data, Correspondence Analysis (CA) was used to explore data relating species distributions of snails to sampling sites. Canonical Correspondence Analysis (CCA) was deemed the best for relating environmental variables, including physicochemical, development and sediment composition, and benthic taxa, both macrophytes and invertebrates. Canonical Correspondence Analysis (CCA) was performed using PAST 2.04. Environmental variables found to have the most influence on distributions of snails and other benthic macroinvertebrates in CCA were singled out and explored further. Canonical Correspondence Analysis was used to relate environmental variables to data on benthic fauna. CCA provides eigenvalues which can be used to interpret interrelationships between environmental factors and the fauna (Hammer et al. 2001; Luoto 2010). The percentages given for each output indicate the amount that each axis accounts for the distribution of factors in the triplots shown. CCA is a particularly illuminating type of multivariate analysis using multiple regression to assess the environmental variables and their relationships to taxa and sampling sites (Ter Braak 1986 cited in Simaika and Samways 2010). The only drawback is that it relies on a linear distribution of the data (McCune and Grace 2002) which was evident in the environmental data, but not in the taxa data. The problem of linearity led to the use of Nonmetric Multidimensional Scaling (NMDS) to visualize the data from one more multivariate perspective. NMDS takes the data and ranks them, plotting them according to the best associations possible in a model iterated a number of times. In PAST 2.04, eleven iterations are performed and the one with the least stress is selected (Hammer et al. 2001). The NMDS output is a plot of the best associations. A Shepard plot is produced as a side output to verify the linearity of the NMDS plot. If the Shepard plot has a high stress value or shows up as a non-linear cloud, then the NMDS is useless. A linear cloud of points, reflecting a real and nonrandom pattern in the data, is the goal (McCune and Grace 2002).

Discriminant analysis (DA) was performed using JMP 8.0. Discriminant analysis was useful for further exploring the data, because it has the capacity to analyze data by ordinating multiple matrices at once (Pielou 1984). DA is the best form of multivariate analysis for making sharp distinctions between groups. By using only those components from PCA that had significant eigenvalues, Discriminant Analysis gave a clearer picture of the distinctions between each parameter (axes) and taxa (points).

Past 2.04 has excellent multivariate capabilities, but runs correlation analyses in a separate function. JMP 8.0 has a more generic multivariate analysis platform, but it allows you to choose from a number of non-parametric correlation analyses in the same operation. After analysis of the environmental and macroinvertebrate data using JMP 8.0's multivariate analysis platform, Spearman's ρ correlations were performed to discover any significant correlations between the taxa and the physicochemical variables. The results are reported, below.

Results of the 2009-2010 Study:

The 2009 and 2010 field seasons ran from April through October. Samples were collected approximately twice a month. Physicochemical parameters were measured at each trip into the field. Samples were taken using the Surber net in the manner described in the methods section above and stored in 75% ethanol with 0.01% Rose Bengal to stain tissues. The samples were processed at LaMER lab according to the protocol outlined above. The mollusk fauna in the lakes was fairly diverse, including six species of Planorbidae in five different genera, at least one species of Physidae, two species of Hydrobiidae and possibly two Lymnaeidae genera: *Fossaria* and *Stagnicola*. Two species of Ancylidae, the limpets, were present, though it was difficult to distinguish *Ferrissia rivularis* and *Ferrissia parallela*. *F. parallela* was the more likely limpet, based on its habitat requirements (Jokinen 1992). Due to the fragility of the limpet shells, they often broke during identification. Two possible genera of pea clams, *Sphaeriidium* and *Pisidium,* were present in the bivalve family Corbiculoidea. Because of the taxonomic expertise required to discern the different species of pea clams, these were identified only to family and no further. A few Unionidae mussels were identified. The outflow to Lake Waccabuc harbored the only population of *Margaritifera margaritifera*, freshwater pearl mussels, found in this study. Table 5 shows the mollusk taxa found in the lakes.

Table 5: Molluskan fauna in the four lakes: Families occur in the far left column. Genus and species (where such identification was possible) occur in the column second from left. The abbreviations stand for: K=Kitchawan, O=Oscaleta, R=Rippowam, W=Waccabuc.

Molluscan Taxa		K	O	R	W
Planorbidae					
	Gyraulus parvus	315	216	50	175
	Gyraulus deflectus	94	145	7	11
	Helisoma trivolvis	167	2	9	9
	Micromenetus dilatatus	13	0	0	1
	Planorbis sp.	13	5	0	19
	Promenetus exacuous	31	7	0	6
Physidae					
	Physa sp.	403	206	27	333
Hydrobiidae					
	Amnicola grana	342	90	5	23
	Amnicola limosa	242	123	157	117
Lymnaeidae					
	Stagnicola elodes	35	1	1	1
	Fossaria rustica	4	0	0	0
Succineidae					
	Succinea campestris	27	1	0	2
Ancylidae					
	Ferrissia sp.	103	24	10	11
Corbiculoidea					
	Sphaerium or Pisidium	1405	279	96	214
Unionidae					
	Margaritifera sp.	0	0	0	5

Species Richness

Species richness, the number of species in a sample unit (s.u.), was calculated. The resulting average species richness for each lake is reported in Table 6, below.

Table 6: Species richness at each lake.

Lake	**Average Species Richness (species/s.u.)**
Kitchawan	66.9
Waccabuc	21.4
Oscaleta	30.7
Rippowam	28.2

Species richness at Lake Kitchawan was the greatest of the four lakes more than triple that of Waccabuc and more than double that of Oscaleta or Rippowam. It is hypothesized that the lake's shallow depth, production and heavy eutrophication contribute to this biodiversity.

Diversity Indices

Alpha diversity, measured with Margarlef's R diversity index, was calculated for taxa found at each lake. Margalef's R is calculated as (S-1)/ln(n). S is the number of taxa and n is the abundance of each taxa (Hammer et al. 2001). The results are reported in Table 7, below.

Table 7: Alpha diversity was calculated for taxa found at each lake and for the study years combined.

Lake	2009	2010	Combined
Kitchawan	22.13	27.11	44.77
Oscaleta	23.08	13.44	32.31
Waccabuc	22.31	14.89	33.42
Rippowam	11.69	20.19	28.98

The alpha diversity present at the lakes varied widely. In 2009, the greatest diversity was found at Lake Oscaleta, with Kitchwan nearly matched with Waccabuc for biodiversity. Rippowam was the pauper of the group, with R = 11.69. In 2010, Kitchawan had the highest diversity index and Oscaleta the lowest. In the combined calculation, the diversity in Lake Waccabuc, which is contiguous with Oscaleta via a large channel, was very close to that of Oscaleta. Rippowam showed the second highest diversity in 2010. The reasons for this variation are not clear. In the combined calculations of Margalef's R, Kitchawan clearly had the highest biodiversity of the lakes. The 2009-2010 combined alpha diversity values were used in the multivariate and correlation analyses described below.

Beta (β) diversity and gamma (γ) diversity indices were then calculated between the Three Lakes and compared to those of Kitchawan using Whittaker's equations for beta and gamma diversities. Beta diversity was calculated: $\beta = (Sc/S) - 1$. Where Sc= number of species in a composite sample and S = the average species richness per sampling unit (Whittaker 1972 cited in McCune and Grace 2002). Beta diversity is defined many ways in the literature, but one of the more general and therefore basic definitions is found on page 28 of McCune and Grace's book Analysis of Biological Communities: "Beta diversity measures compositional heterogeneity without reference to a particular gradient (p28 McCune and Grace 2002)." Basically, while most biologists are interested in focusing on one or two species in their sampling, the reality is that sampling picks up many other species. These 'other' species comprise beta diversity and the degree of variation within and between samples can be quantified and studied.

The recent return to examining beta diversity in the literature of community ecology reflects the more holistic view of ecosystems and their interactions.

Gamma diversity was calculated: $\gamma = \beta * \alpha$, which is beta diversity times alpha diversity (Whittaker 1972 cited in McCune and Grace 2002).

Table 8: Beta and gamma diversities calculated for Lake Kitchawan and the Three Lakes (Waccabuc, Oscaleta and Rippowam.)

Lakes	Beta Diversity	Gamma Diversity
Kitchawan	11	492.4
Oscaleta	11.6	374.7
Rippowam	11.4	330.3
Waccabuc	11	367.6

In community ecology, beta diversity helps explain the rest of the biodiversity outside the target study group. Gamma diversity is a function of the diversity in individual habitats and the variation between them (McCune and Grace 2002). Interestingly, the beta diversity did not vary as much as the gamma diversity. This is explained by the fact that gamma diversity tends to reflect the alpha diversity, generally. The beta diversity values above indicate that the various benthic taxa were similar among all four lakes.

Single factor analyses were performed to determine data distributions of the physicochemical parameters that were significantly different among the lakes, such as dissolved oxygen (DO), pH, hardness, conductivity (ECS), total dissolved solids (TDS) and coliforms. Univariate statistics and data distributions were analyzed using JMP 8.0.

Table 9: Means and Standard Error for: water temperature (^{o} C), DO (mg L^{-1}), total hardness/Ca2^{+}(mg L^{-1}), ECS in microSiemens per square centimeter (μS/), TDS (mg L^{-1}), coliforms in colony forming units per square centimeter (cfu/).

Site	Water Temp	DO	Total Hardness	Calcium	pH	ECS	TDS	Coli-forms
K	23 ± 0.7	3.9 ± 0.4	146 ± 3.5	108 ± 3.1	6.5 ± 0.04	361± 4.8	181± 4.1	324± 38.8
O	20 ± 0.5	3.3 ± 0.8	94 ± 3.9	63 ± 2.4	5.9 ± 0.06	183± 10.9	93± 5.4	165± 18.7
R	20 ± 0.5	4.7 ± 0.8	84 ± 3.3	50 ± 1.5	6.7 ± 0.04	207± 5.1	104± 2.5	261± 27.3
W	21 ± 0.6	4.3 ± 0.9	115 ± 14.3	84 ± 7.3	6.8 ± 0.04	341± 17.3	170± 8.6	392± 40.1

Overall, Lake Kitchawan had the highest water temperature, which is not surprising considering that it is the shallowest of the four lakes. The contours of its shores and its width also expose more of

Kitchawan's surface area to solar radiation. Waccabuc, Oscaleta and Rippowam are longer, narrower lakes, surrounded by more trees. Thus their waters are shaded for a longer portion of the day. Lake Kitchawan also had the highest total hardness and calcium concentrations, 146 mg L^{-1} and 108 mg L^{-1}, respectively. Waccabuc had the second highest calcium concentration and Rippowam had the lowest calcium of the four lakes. It is interesting to note that Rippowam had the lowest numbers of snails. Since snails require calcium to build their shells, Rippowam's lower calcium content could make it a less suitable habitat for snails. It is noted in the literature, however, that gastropods, in general, have a fairly wide tolerance for calcium concentrations (Jokinen 1992; Dillon 2010). Even within species, field studies have shown populations widely varied in their needs for calcium conditions (Jokinen 1992). A comprehensive study of lakes in Finland in the 1970s found gastropod distributions and higher calcium concentrations correlated in oligotrophic lakes (Aho et al. 1981). The authors suggest that oligotrophic lakes' lack of nutrients makes naturally occurring calcium levels much more important to gastropods, whereas more eutrophic conditions provide alternate sources of calcium and other nutrients (Aho et al. 1981).

Dissolved oxygen (DO) was highest in Rippowam and lowest in Oscaleta, an interesting difference between these two interconnected lakes. Dissolved oxygen concentrations in the lakes showed seasonal highs during the spring and fall turnover periods, consistent with normal limnological conditions in the temperate zone. Average DO levels were lowest in Lake Oscaleta at 3.3 mg L^{-1} and 3.9 mg L^{-1} in Lake Kitchawan. Levels of eutrophication and the vigorous growth of aquatic plants during the height of summer led to reduced oxygen levels, at times, near anoxic conditions. The lakes' reports from previous years state that anoxic conditions did occur seasonally at greater depths (Martin 2004; Arrigo 2009). Since this study focused on the littoral zone, dissolved oxygen, in this zone, was never completely depleted in any of the four lakes.

Rainfall is often associated with high coliform counts due to effluent release into waterways (Couillette and Noble 2008). Rainfall (inches per month) and coliforms were analysed by date using the multifactorial ANOVA function in JMP 8.0. The results showed positive correlations between rainfall and coliforms for all four lakes, but only Oscaleta had a significant p-value of 0.029, directly relating rainfall and its coliform counts for each date.

As described in the methods section, the detection of nitrates and phosphorous was not possible with the test kits. Data was collected from alternate sources. The levels of nitrates and phosphorous found in the lakes were not highly variable, although similarities in the levels of both nitrates and phosphorous levels appear to match the relative size of the lakes, closely (Table 10). The two smaller lakes had nitrate levels 0.012 mg L^{-1} in Oscaleta and 0.016 mg L^{-1} for Rippowam. The higher levels of nitrates in Rippowam may be reflecting the problems with septic drainage on properties near the sampling sites. The phosphorous levels were very close at 0.021mg L^{-1} for Oscaleta and 0.023mg L^{-1} for Rippowam. Lakes Kitchawan and Waccabuc have nitrate levels that are comparable to one another at 0.022mg L^{-1} and 0.023mg L^{-1}, respectively. The mean phosphorous levels were also fairly close 0.034mg L^{-1} in Waccabuc and 0.037mg L^{-1} in Kitchawan.

Table 10: Mean nitrate and phosphorous concentrations in the Three Lakes from 2007-2009. Three Lakes' data provided by J. Andersen of Three Lakes Council. *Kitchawan data from 2007 ONLY, from Cedar Eden report (Martin 2004).

Lake	Mean	SE(±)	Mean P	SE(±)
Oscaleta	0.012	0.002	0.021	0.002
Rippowam	0.016	0.008	0.023	0.002
Waccabuc	0.022	0.007	0.034	0.004
Kitchawan*	0.023	0.008	0.037	0.002

The variance between the nitrate levels for all the lakes was miniscule at 0.00002 mg L^{-1}, while the variance for phosphorous was 0.00006 mg L^{-1}. The mean nitrate level for all the lakes was 0.018mg L^{-1} and the mean phosphorous level for all the lakes was 0.028mg L^{-1}. Standard errors are reported above in Table 10. The levels of phosphorous in Lakes Oscaleta and Rippowam were low enough to class these lakes as meso-eutrophic, since the threshold for true eutrophic conditions is 0.030 mg L^{-1} of phosphorous (Wetzel 2001). With phosphorous levels in excess of 0.030 mg L^{-1}, both Kitchawan and Waccabuc were definitely eutrophic lakes according to the standard interpretation of phosphorous levels (Wetzel 2001), see Table 11.

Table 11: Standard interpretations of nitrate and phosphorous concentrations (p273 Wetzel, 2001).

Lake Classification	Nitrates Range (mg m^{-3})	Phosphorous Range (mg m^{-3})
Oligotrophic	307-1630	3.0-17.7
Mesotrophic	361-1387	10.9-95.6
Eutrophic	393-6100	16.0-386.0

Because of the derived nature of the phosphorous and nitrate data dating from 2007-2009, no further univariate analysis of the benthic macroinvertebrate population was done in relation to these two variables. Without regular monthly measurements during the study period (2009-2010), a more subtle analysis of nitrate and phosphorous chemistry and the population dynamics of benthic macroinvertebrates was not possible.

Lake Kitchawan also had the highest total dissolved solids (TDS) at 181 mg L^{-1} and Waccabuc had the second highest TDS at 170 mg L^{-1}. Total dissolved solids are indicative of total ions (both anions and cations) present in the water (Wetzel 2001). Significantly higher TDS is often associated with higher populations of gastropods. TDS is often measured along with conductivity and the two could be viewed as closely associated in their relevance to habitat preferences of gastropods, although it is not clear why snails prefer higher concentrations of ions. There is no categorical explanation of the role of TDS in gastropod ecology, although it has been associated with water salinity and the levels of physiologically critical metals such as potassium and sodium (Wetzel 2001). It is possible that TDS is simply reflective of the role of ions in nutrient cycling and overall production in lakes, making a higher TDS a better habitat for benthic macroinvertebrates, generally.

Oscaleta was also lower in conductivity (ECS). Conductivity is a curious variable that appears over and over again in the literature on gastropod ecology. Unfortunately, there is nothing definitive about it. Most field studies have indicated that gastropods prefer higher conductivity and are associated with habitats with high conductivity (Jokinen 1992; Schiebler and Ciocco 2010). There is a minority of dissenting views on the significance of conductivity, however, including some finding negative correlations between benthic populations and ECS (Varnosfaderany et al. 2010). A few recent papers note the ongoing debate about conductivity, although most gastropod researchers appear to consider ECS an essential variable to measure (Maltchik et al. 2010).

Acidity tends to lower biodiversity in the benthos in lake environments, with snails being more susceptible to lower pH because of their calcareous shells (Rosenberg and Resh 1993). The acidity of the lakes varied with mild fluctuations seasonally. Oscaleta had the lowest average pH (5.9) of all the lakes and Waccabuc had the highest (6.8).

Using one way ANOVA in JMP 8.0 with α= 0.05, the only variables that varied significantly between the lakes were pH (p=0.004), ECS (p=0.0001), TDS (p=0.0001), Hardness (p=0.0002) and $^{+}$ (p=0.0001). These ANOVA results (in Appendix B Table 4) are only descriptive of differences between the lakes for these factors. They do not address the interactions of the biota with these physicochemical factors.

Lake Kitchawan had the most mollusks overall in this study (Figure 13). The most ubiquitous mollusks were the bivalves, especially the Corbiculoidea. Among gastropods, however, snails from the family Physidae were the most common among all the lakes. Distinguishing between Physidae snails is difficult, but *Physa heterostropha* (Say, 1817), the Pewter snail, and *Physa gyrina* (Say, 1821), the Tadpole snail, were both found. The tiny Hydrobiidae snail, *Amnicola grana* (Say, 1822), the Squat Dusky snail, was nearly as numerous. Overall, in Lake Kitchawan the most abundant species was *Physa gyrina* at 27.8% of all gastropods found in the study. The Corbiculoidea, however, were most numerous comprising 49% of all mollusks sampled. The bulk of the Corbiculoidea were pea clams from the family Sphaeriidae with some from the family Pisidiae evident. As mentioned earlier, the amphibious terrestrial snail *Succinea campestris* (Say, 1818), the Crinkled Amber snail, took to the water in Lake Kitchawan, but consistently made its appearance only in the autumn. The snail that had the least occurrence in the entire study was *Micromenetus dilatatus*, (Gould, 1841), the Bugle Sprite, with thirteen found in Lake Kitchawan and one in Lake Waccabuc.

In Lakes Waccabuc, Oscaleta and Rippowam, the distributions were quite different. The most abundant species in Lake Oscaleta was *Gyraulus parvus* (Say, 1817), the Ash Gyro, comprising 27% of the snails found in the lake. The Corbiculoidea were 25.3% of the population of mollusks in Lake Oscaleta. The most abundant gastropod at Lake Rippowam was *Amnicola limosa* (Say, 1817), the Mud Amnicola, being 59% of the gastropod population. The Corbiculoidea comprised just 26% of the mollusks in Lake Rippowam.

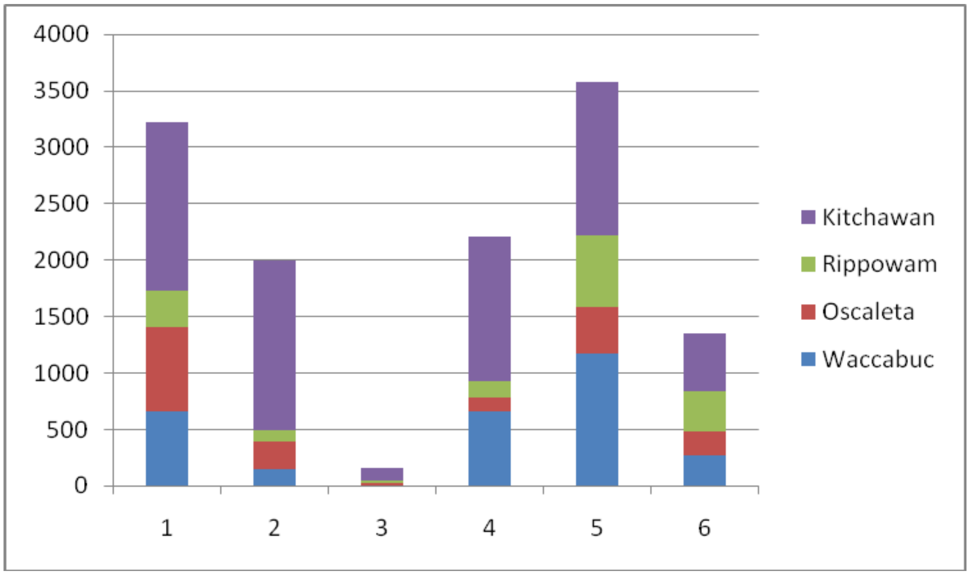
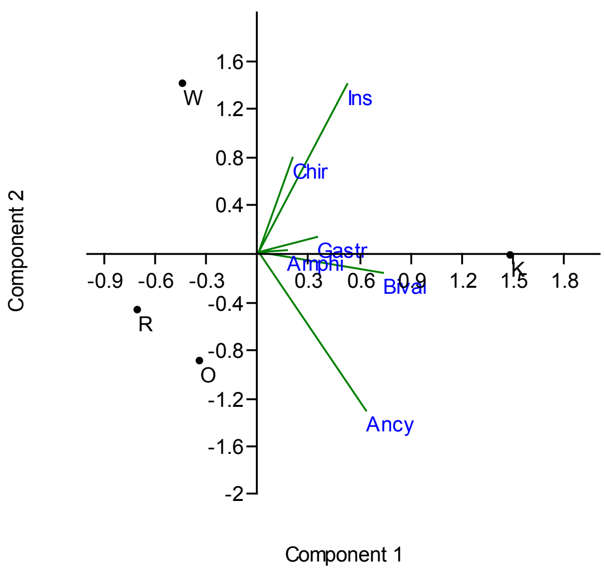


Figure 13: The histogram shows relative benthic macroinvertebrate totals for each lake. 1=Gastropods, 2=Bivalves, 3=Ancylidae, 4=Insects, 5=Chironomids, 6=Amphipods

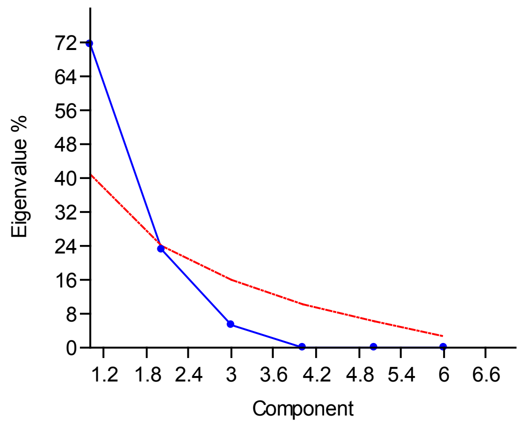
Results of the Multivariate Analyses:



PC	Eigenvalue	%Variance
1Amphi	0.712	71.72
2Gastr	0.228	23.00
3Bival	0.052	5.282

Figure 14: Principal Components Analysis

Figure 14: Above, PCA of means of major taxa in lakes. Key: Ins=Insects, Chir=Chironomids, Gastr=Gastropods, Amphi=Amphipods, Bival=Bivalves, Ancy=Ancylidae. Below, the broken stick scree plot showing the components.



The bulk of the fauna was found in Lake Kitchawan, as shown in the PCA in Figure 14. Correspondence Analysis (CA) was used to ordinate the physicochemical variables and the benthic taxa. The scatterplot of the taxa by lake in the CA scatterplot, Figure 15, was more informative than the PCA in Figure 14. This could be due to the nature of the data, which was not perfectly linear – a prerequisite for PCA.

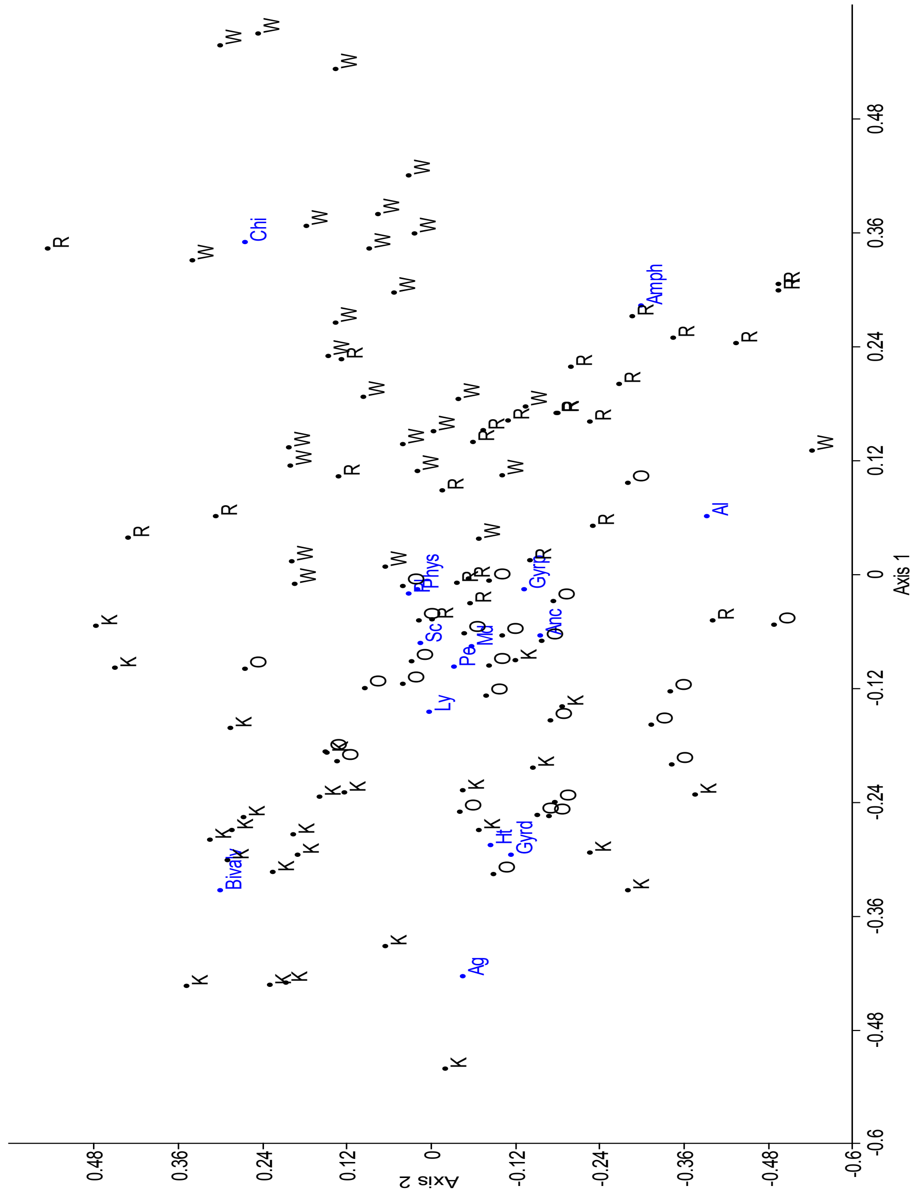


Figure 15: Correspondence Analysis Taxa by Site [K=Kitchawan, W=Waccabuc, R=Rippowam, O=Oscaleta] eigenvalues are shown below.

Axis	Taxon	Eigenvalue	% of total
1Phys	Physidae	0.0654918	23.341
2Gyrp	*G. parvus*	0.0495249	17.65
3Gyrd	*G. deflectus*	0.0397013	14.149
4Pla	*Planorbis*	0.0287383	10.242
5Pe	*P. exacuous*	0.0246367	8.7804
6Ht	*Helisoma trivolvis*	0.020191	7.196
7Al	*Amnicola limosa*	0.0142837	5.0907
8Ag	*Amnicola grana*	0.0120259	4.286
9Sc	*Succinea campestris*	0.00877442	3.1272

The bulk of the ordination fell distinctly into two sides with Waccabuc on the right and Kitchawan on the left. Lakes Oscaleta and Rippowam fell in the center with more moderate abundances for all species. The two larger lakes were probably polarized in this scatterplot by the abundance of bivalves (totaling 1405) in Lake Kitchawan, pulling it to the left.

The physicochemical parameters measured were compared between the lakes to determine significant differences. Of the nine variables tested using ANOVA, only six were actually significantly different between the lakes: pH ($p=0.004$), ECS ($p=0.0001$), TDS ($p=0.0001$), total hardness ($p=0.0135$), calcium ($p=0.0001$) and Secchi depth ($p=0.0001$). See Appendix B – Table 4.

The Canonical Correspondence Analysis (CCA) of the physicochemical variables is shown in Figure 16, along with the corresponding eigenvalues for the ten physicochemical variables.

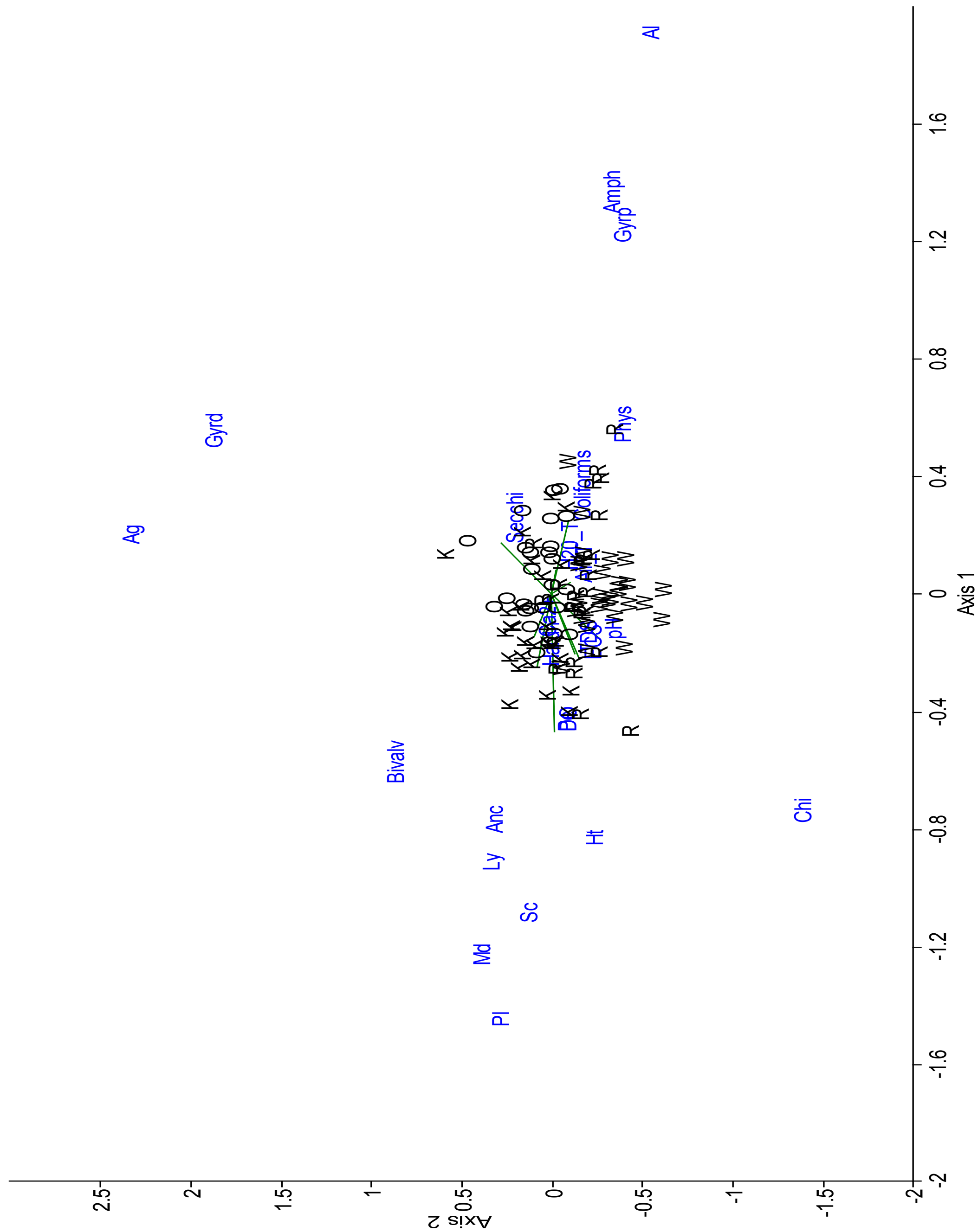


Figure 16: Canonical Correspondence Analysis triplot of taxa, site and physicochemical variables.

Axis	**Eigenvalue**	**%Correlation**
1Air Temp	0.016	28.97
2H20 Temp	0.013	24.56
3pH	0.013	24.14
4ECS	0.006	11.34
5TDS	0.003	5.74
6DO	0.001	3.01
7Hardness	0.0007	1.28

The CCA triplot in Figure 16 shows Kitchawan and Waccabuc in the upper quadrants of the CCA triplot, while Rippowam and Oscaleta appear in the mid to upper quadrants, although not exclusively. Waccabuc had some extraordinarily high coliform counts, especially in 2010, which appear on the plot closely associated with it. Kitchawan and Waccabuc are both more closely associated with the bulk of the fauna, than either Oscaleta or Rippowam. This reflects the actual field observations, as well.

Because of the tight clustering of the factors on the CCA above, Principal Components Analysis was used to visualize the relationships between the physicochemical variables and the taxa in each lake. The resulting scatterplot was also very tightly clustered indicating the similarities between the lakes were fairly strong. Another strategy was needed to elucidate more subtle relationships between the variables and the taxa. The PCA was not entirely useless, however, by eliminating the eigen scale values on the axes a more dramatic picture was visualized by the same PCA scatterplot. The resulting plot is shown below in Figure 17. The eigenvalues and percent correlations given below the plot indicate that ambient temperatures had a strong effect on the distribution in this PCA plot.

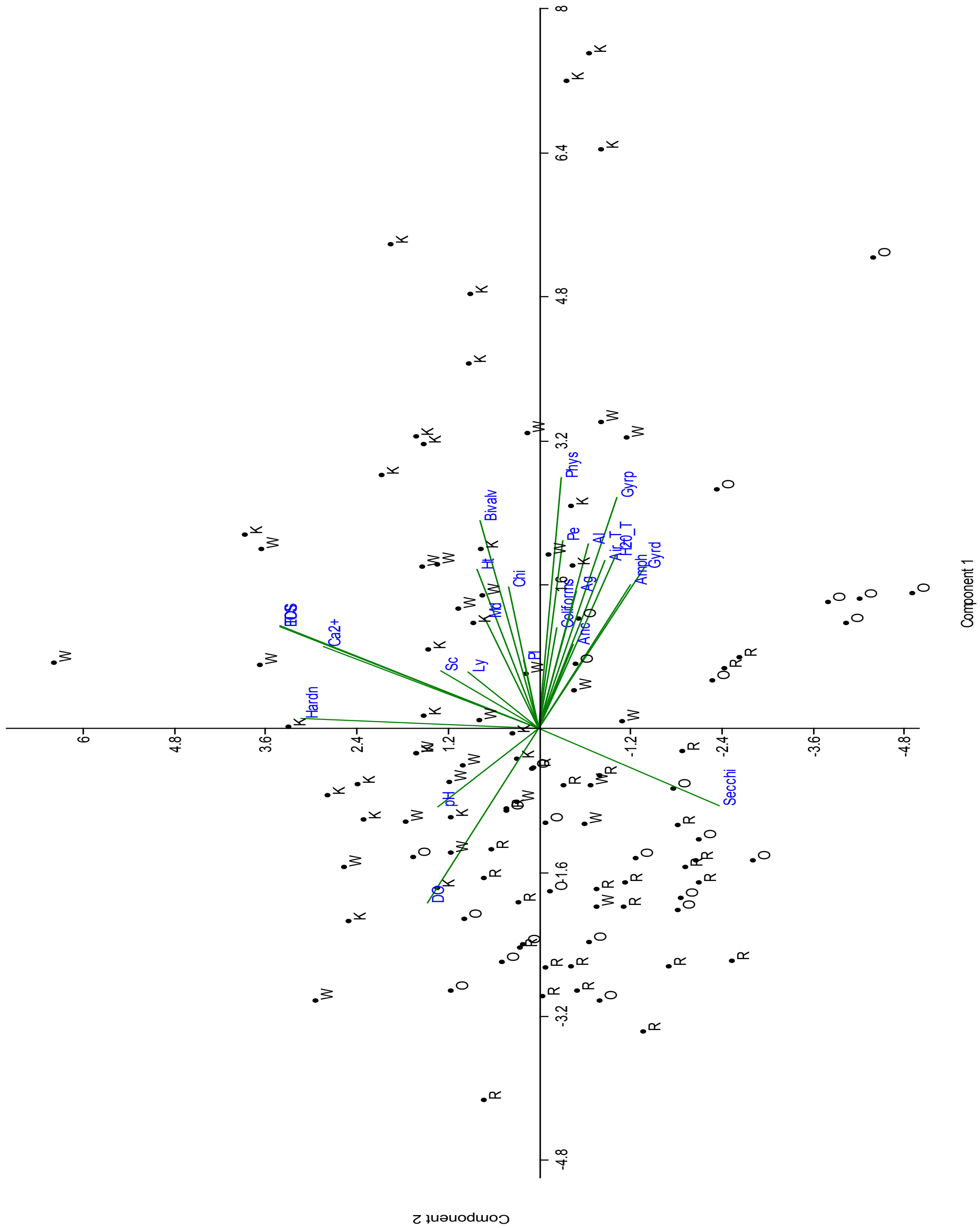
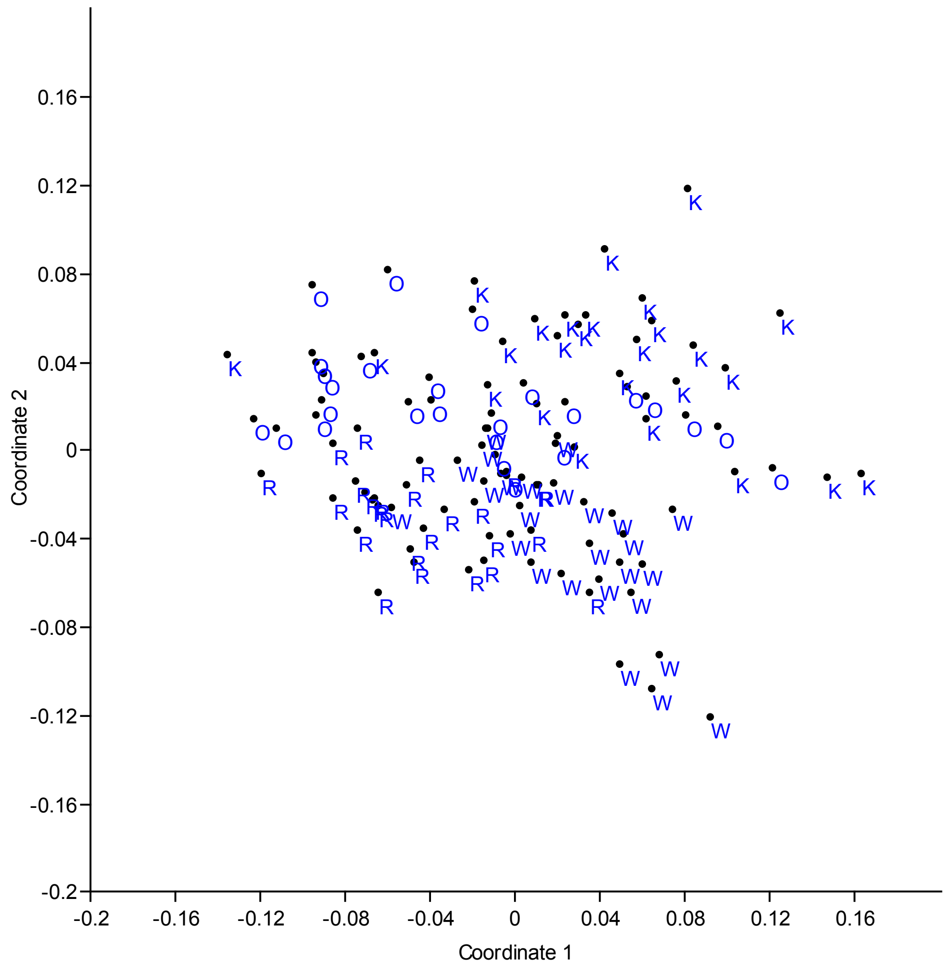


Figure 17: PCA biplot physicochemical variables and taxa by lakes (eigen scale removed).

Component	**Eigenvalue**	**%Correlation**
1AirT	5.50596	22.024
2WaterT	3.54881	14.195
3pH	2.15971	8.6388
4ECS	1.84467	7.3787
5TDS	1.45824	5.8329
6DO	1.30642	5.2257

In Figure 17, the significant sites and taxa were plotted together in environmental space. The physicochemical variables comprised the components in the eigenvalues reported above. The Three Lakes clustered together towards the middle, especially Waccabuc and Oscaleta which had a tendency to hover along the component 1 axis. Clearly, Kitchawan dominated the right side of the plot, although Waccabuc shared some of the distribution. Since the bulk of the organisms were found in the two largest lakes, this is not surprising. Interestingly, the Planorbidae and Physidae snails dominated the fauna found in Kitchawan and Waccabuc, this was indicated in the polarity of the taxa on the PCA in Figure 17. Lakes Oscaleta and Rippowam, which fall on the left side of the axes, showed fewer associations with the significant physicochemical parameters measured in the single factor analyses.

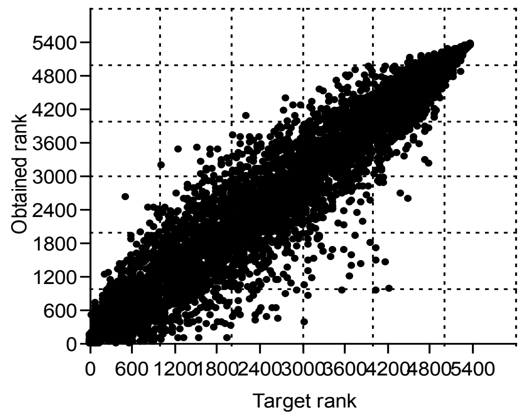
Non-Metric Multi-Dimensional Scaling (NMDS) was used to plot the lake sites based on taxa, using the Bray-Curtis distance measure. In Figure 18, below, Oscaleta and Rippowam aligned on the left, separated from Waccabuc and Kitchawan on the right.



Axis 1 = 0.66 Axis 2 = 0.13 Stress = 0.207

Figure 18: The NMDS of taxa by lake showing only the clustering of the lakes based on species space.

The resulting NMDS, shown above, is interesting for two reasons. It displays the sites in species space and the distribution is quite different from the earlier PCA scatterplots. The two largest lakes, Kitchawan and Waccabuc, cluster together further along the coordinate 1 axis, while the smaller lakes, Rippowam and Oscaleta, are clustered to the left. Because these data were drawn from all sampling dates, however, the model shows an occasional point of one of the larger lakes scattered in among the two smaller lakes.



Stress = 0.207

Figure 19: The Shepard plot of the NMDS shown above. Note the strong linear relationship.

The NMDS ranks and resamples the data for all the taxa at each site and plots them in the best model of the distribution, using the Bray-Curtis distance measure. A Shepard plot that reflects well distributed data should appear in a linear fashion (Hammer et al 2001), as seen above.

Analysis of the Diversity Indices

Since the ultimate goal of many freshwater ecology studies is to assess the health of the aquatic ecosystem, the physicochemical variables must be interpreted in light of the biota. There are myriad ways of doing this, but one common method is to use the diversity indices to interpret the environmental variables. Recently, numerous studies have tested diversity indices for their efficacy in describing the communities being studied. The diversity indices are calculated and then run against environmental variables in single factor analyses or in correlation analyses to determine significance (Heatherly et al. 2005; Gray and Delaney 2008; Wesolek et al. 2010). Another method used more recently, employed cluster analyses and similarity measures to distinguish between sites using the diversity indices in the study along with the environmental variables (Gray and Delaney 2008).

In this study, Margalef's R for each of the lakes and the means of the physicochemical variables for the lakes were included in a matrix that was subjected to K-means clustering. The output shows an expected dichotomy between the three contiguous lakes and Lake Kitchawan.

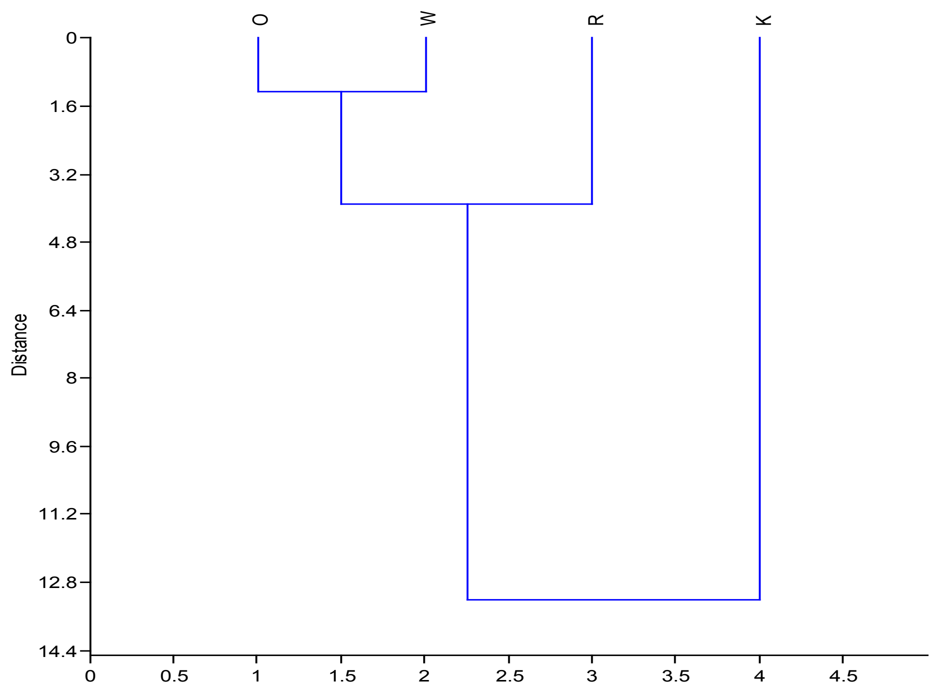


Figure 20: A K-Means Clustering of diversity measured using Margalef's R and the means of the physicochemical variables.

Because they are interconnected by channels, Waccabuc, Oscaleta and Rippowam were expected to be somewhat similar. The K-means clustering showed an interesting partition, however, as Oscaleta and Waccabuc were grouped together, apart from Rippowam. Kitchawan remained in an "outgroup" position in this clustering. The analysis was done using the combined Margalef's R, which included both 2009 and 2010 data. Kitchawan's R = 44.77 was by far the highest. Even though Waccabuc's sheer size seemed to make it more like Kitchawan, in fact, its diversity was comparable to Oscaleta's, 33.42 and 32.31, respectively. Rippowam had the lowest combined R, at 28.98. While its physicochemical conditions were similar to its sister lakes, the low diversity is seen in the clustering algorithm where Rippowam appears set apart from Oscaleta and Waccabuc.

Spearman's ρ Correlation Results

After the multivariate analysis of the data in JMP 8.0, Spearman's ρ Correlations were calculated to assess any significant correlations between the taxa and physicochemical variables. The Spearman's ρ and the p-values are given in the Appendix A in Table 1. Physidae and Planorbidae snails showed significant positive correlations to ambient temperatures, both air and water. *Gyraulus deflectus* and the bivalves showed significant negative correlations to pH. Surprisingly, only *Micromenetus dilatatus* showed significant positive response to conductivity and total dissolved solids. Dissolved oxygen correlated negatively with most of the Planorbidae and *Amnicola limosa*, but not *Amnicola grana*, among the Hydrobiidae. This outcome was strange considering these Hydrobiidae species are the only representatives of the gilled snails found in this study.

Based on the literature, the bivalves are known to be associated with higher dissolved oxygen levels (Vaughn et al. 2001; Geist and Auerswald 2007; Dillon 2010). They appeared negatively correlated in this study. This could be related to the low oxygen saturation levels in the lakes overall. None of the snails appeared to be correlated to calcium concentration in any of the lakes. However, the Planorbidae snails showed an affinity for total water hardness. Total hardness is a measure of both calcium and magnesium, a measure of divalent cations. Since the Planorbidae snails are among the largest species found in this study, their need for more minerals to construct their shells may play a role in this correlation. The tiny Sharp Sprite snail*, Promenetus exacuous*, showed a negative correlation with Secchi depth. In Oscaleta, the Hydrobiidae snails showed a positive correlation with Secchi depth, turbidity.

Two non-molluskan taxa tested in the Spearman's ρ correlations were Chironomidae, the midge larvae, and amphipods. Chironomids and amphipods had correlations with ambient temperatures, dissolved oxygen and hardness.

Sediments

Sediments from each lake were analyzed for percent composition using standard brass sieves in the manner described above in the methods section. Visibly, the sediments differed slightly at each lake.

All four lakes had layers of organic matter over rocky or sandy substrates, which was to be expected from lakes formed in the glacial period. The amount of organic material varied and was quantified by the loss-on-ignition studies. The results of the sediment analysis showed the lakes differed in basic sediment composition. While rocks and rubble underlay parts of Rippowam and Oscaleta's organic layer, Kitchawan had a sandy sediment underneath a heavy layer of plant and organic material that was thickly matted from eutrophication. Table 12 shows the results of the sediment analysis.

Table 12: Indicating percent sediment using standard brass sieves sized: #10 (fine gravel), #35 (coarse sand), #60 (fine sand), #120 (very fine sand), #220 (silt).

Lake	Fine Gravel	Coarse Sand	Fine Sand	Very Fine Sand	Silt
Kitchawan	44.5	15.7	14.3	20.3	4.97
Oscaleta	25.1	44.3	17.1	11.8	1.95
Rippowam	14.7	46.2	22.4	13.1	2.19
Waccabuc	62.6	18.3	5.2	10.8	3.08

The loss-on-ignition analysis showed that the percent organic matter was greatest at Lake Waccabuc and lowest at Lake Rippowam. The area where the Waccabuc sample was collected, a boat launch on Cove Road, was heavily disturbed by boat traffic which ground up much of the plant material in the cove. This probably slightly inflated the amount of organic matter measured in the analysis. Rippowam was sampled at a relatively placid, residential site, but the underlying substrate was rocks and rubble at that site. Percent carbonates were also highest at Lake Waccabuc. Interestingly, carbonates were lowest at Lake Kitchawan. This was possibly the result of the way the sample was taken. To get some of the lower sediment, a hole was pierced through the dense mat of plant material to gather some of the sand below it. This reduced the overall amount of organic, and hence carbon material, in the sample, so sampling error played a role in the results shown in Table 13.

Table 13: Results of loss-on-ignition study to determine percent organic matter and percent carbonates for each lake. Waccabuc* indicates that the sediment analysis here is from samples taken at the Cove Road site.

Lake	Percent Organic Matter	Percent Carbonates
Kitchawan	12.32	1.15
Oscaleta	18.70	8.60
Rippowam	5.24	2.07
Waccabuc*	62.87	23.00

Certain mollusks were found to be associated with sediment types in the lakes, as well. Sediment type was related to macrophyte distribution in the canonical plot shown in Figure 21. Lakes Kitchawan, Oscaleta and Waccabuc stand apart from Rippowam in terms of sediment composition and in the mollusk fauna that they support. This is not to say that Hydrobiidae did not occur in Rippowam. In fact, they did, however, the rockier substrate does set it apart in terms of the fauna it supports. Also the Sphaeriidae, pea clams, appear to occur in the finer sediments and were found in greater numbers in the lakes with higher percentage of fine sediments, Kitchawan, Oscaleta and Waccabuc. The only bivalves that appeared to prefer the rockiest substrates were the *Margaritifera margaritifera* mussels found exclusively in the outflow to Lake Waccabuc at Perch Bay.

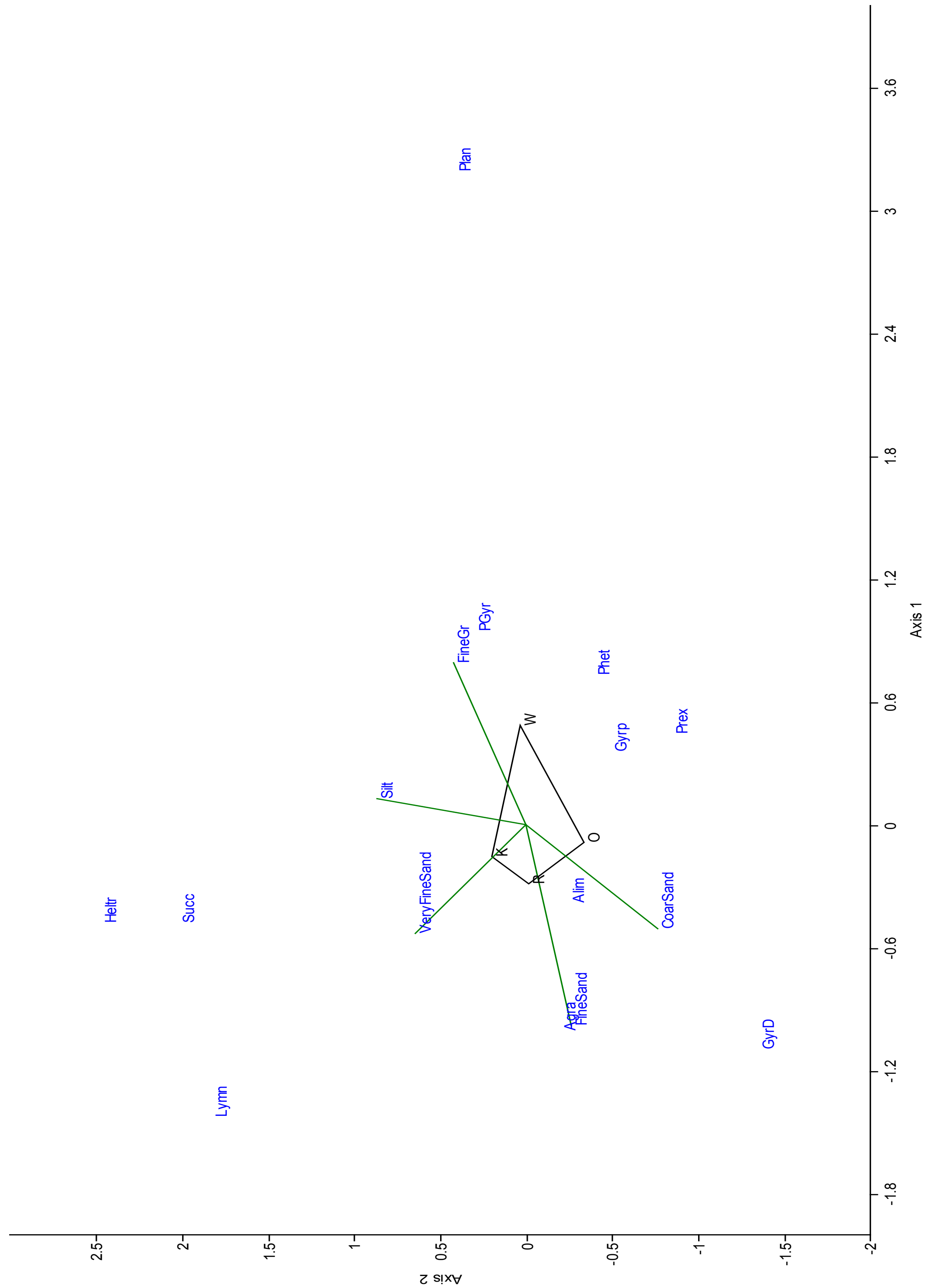


Figure 21: CCA canonical triplot of sediment composition and gastropods by lake.

Component	Eigenvalue	%Correlation
1 Fine Gravel	0.080	57.4
2 Coarse Sand	0.041	29.7
3 Fine Sand	0.017	12.8

The association of freshwater mollusks with particular sediment types has been studied for quite some time. Sediment preferences vary not only by species, but by life cycle stage, as well (Harman 1972). The CCA in figure 21, above, ordinates the gastropod taxa and sediment composition data for the lakes. The resulting triplot did not show any significant correlations in the permutation tests, but taxa such as *Helisoma* and *Succinea* are ordinated closer to silt and the Lymnaeidae are ordinated closer to very fine sand, reflecting associations that were found in subsequent correlation analyses.

Since sediments types can affect the kinds of benthic macroinvertebrates present, correlation analysis was run to see the effect of substrate on mollusks and other important taxa. The data set examined included the following environmental variables: mean nitrates, mean phosphorous, percent organic matter in sediments, percent carbonates in sediments and relative amounts of fine gravel, coarse sand, fine sand, very fine sand and silt. These variables were run against the taxa in the lakes, independently. Ephemeroptera, Plecoptera, Trichoptera (also known as EPT fauna) were all run separately, because they are fauna commonly used to characterize water quality (Rosenberg and Resh, 1993; Wetzel 2001). The benthic fauna included in these analyses included the gastropods, bivalves, ancylids, non-EPT insects (beetles, true bugs, etc.). Chironomids were also excluded from this group and run separately due their important role in benthic ecology. Odonate fauna were included in a separate analysis with EPT fauna, utilizing a fairly new type of index called an EPTO index (Simaika and Samways, 2010).

Spearman's ρ correlations showed sediment factors did significantly affect the mollusks, but varied by species. The Spearman's ρ and p-values are found in the Appendix A in Table 1. Physidae had a strong negative correlation with coarse sand. Lymnaeidae had a strong positive correlation with fine sand. *Helisoma trivolvis* and *Succinea campestris* both had strong positive correlations to silt. *Planorbis* sp. had a negative correlation with fine sand. Ancylidae, the limpets, had no correlations to the sediment characteristics tested.

Non-EPT insects and Chironomids had a positive correlation to silt. Plecoptera also had a positive correlation to silt, possibly because the texture of the substrate affects the growth of aquatic plants on which they feed. Most mayfly larvae feed on filamentous algae which were not observed growing in the sandy areas of the lakes. To better quantify the impact of each sediment type and the percent organic matter and percent carbonates on the success of these organisms, would require controlled laboratory experiments. Because of the multivariate nature of this field study, only correlations can be assessed.

To examine the distribution of benthic fauna among the lakes, canonical correspondence analysis was used to plot the taxa and sediment data by the lakes to explore relationships.

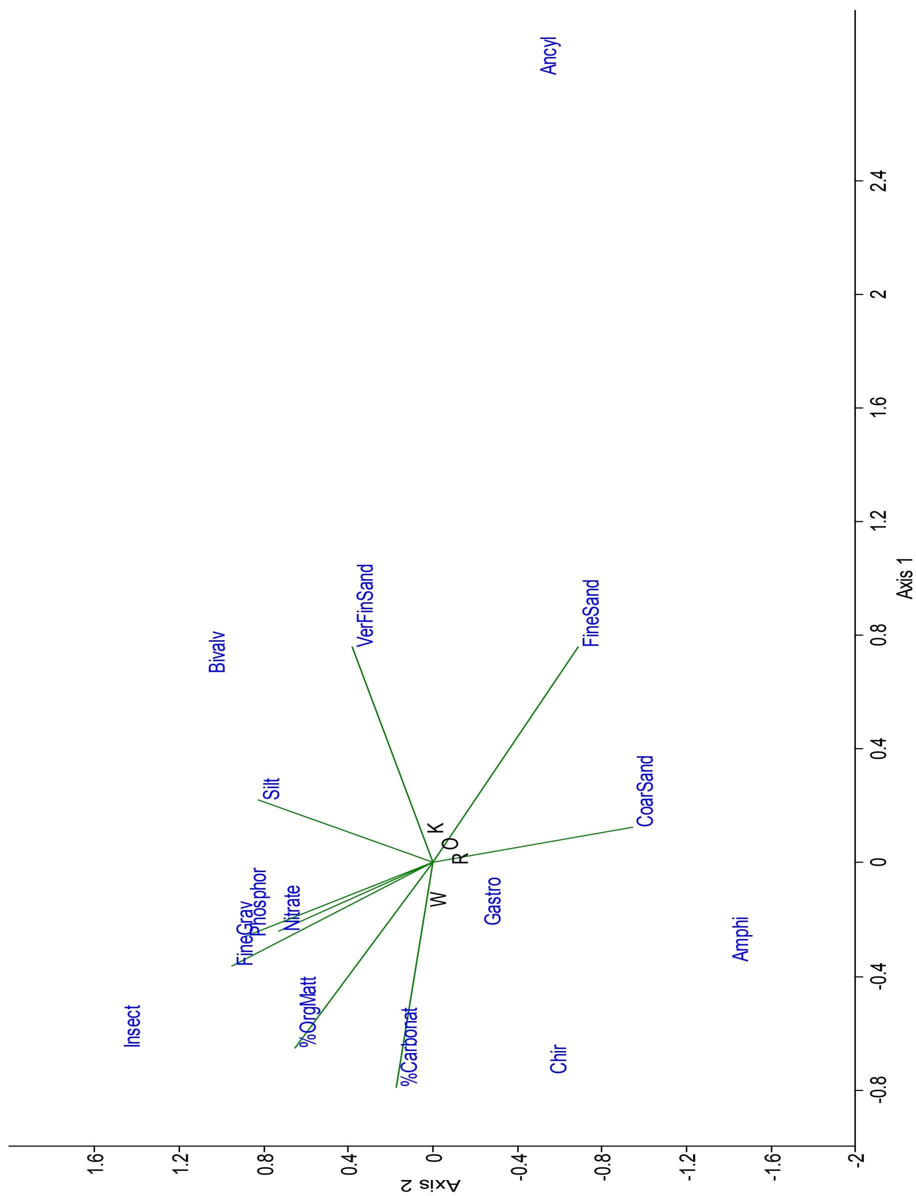


Figure 22: CCA triplot of the sediments, taxa and lakes. K=Kitchawan, O=Oscaleta, W=Waccabuc, R=Rippowam. The eigenvalues and percent variation for the CCA are given below.

Axis	Eigenvalue	%Variation	Permutation Test:	Eigenval	p-value
1%Org	0.0095575	74.29	1	0.009558	0.4455
2%C	0.0022325	17.35	2	0.002233	0.505
3FGrav	0.0010748	8.354	3	0.001075	0.5446

Most of the organisms were quite polarized on the triplot in Figure 22, with bivalves nearer to silt and fine sand and farther from coarse sand. Gastropods were situated closer to percent carbonates and percent organic matter in the ordination. Percent organic matter was on the left side of the plot, closest to Waccabuc, which had the greatest percentage of organic matter of all the lakes. From the percent variation given with the eigenvalue report, one can see that the first environmental variable on the axes was percent organic matter, which had the greatest effect on the distribution in the CCA triplot, Figure 22. The second axis was percent carbonate, which had some effect on the distribution. The other variables in the plot were: fine gravel, coarse sand, fine sand, very fine sand and silt. All of these data were percentages, so all of them were arcsine transformed prior to analysis. While the plot ordinates the data nicely, the permutation test showed that none of the variables were significantly affecting taxa distribution.

Aquatic Plants

The macrophyte plant populations varied at each lake. No lake had all the plants listed. Several of the more common aquatic plants of the northeast were present at each lake. Even among the ubiquitous plants, however, distributions were different. Macrophyte distributions varied by: sediment type, organic matter, and shading from terrestrial canopy among other factors. This is consistent with the literature on freshwater aquatic macrophytes (Harman 1972; Sheldon 1990; Della Bella et al. 2008; Zealand and Jeffries 2009). The results of the plant survey are shown in Table 14, below.

Table 14: Presence (1)/absence(0) data on aquatic plants found at study sites. Note that Lake Waccabuc is the Cove Road site on the northeastern side of the lake. The Inflow, is Waccabuc's inflow, on the western side of the lake and the Outflow is Waccabuc's outflow stream on the southern side of the lake at Perch Bay.

Plant	Kitchawan	Oscaleta	Rippowam	Waccabuc	Inflow	Outflow
Carex sp.	1	0	0	0	0	0
Filamentous Algae	1	1	1	1	0	1
Elodea canadensis	1	1	1	1	0	0
Lemna minor	1	1	1	1	0	0
Myriophyllum spicatum	1	1	1	0	1	0
Nymphea odorata	1	1	1	1	0	1
Nuphar lutea	1	1	0	0	0	0
Phragmites australis	1	1	1	1	0	0
Pontedaria cordata	1	1	0	0	0	0
Potamotegon sp.	1	0	0	0	0	0
Symplocarpus foetidus	0	0	0	0	1	0
Typha latifolia	1	1	0	1	0	0
Vallisneria americana	1	1	0	0	0	0

Most of the flora found in the lakes was very similar, not unexpected considering that three of the lakes are interconnected. Semi-aquatic plants along the lakes included: *Typha latifolia, Phragmites australis, Symplocarpus foetidus* and amphibious *Potamogeton* sp. Submerged aquatics included: *Carex* sp., *Elodea canadensis, Lemna minor, Myriophyllum spicata, Nuphar lutea, Nymphea adorata, Pontederia cordata* and *Vallisneria americana*.

Below is a parsimony analysis (Figure 23) of the binary presence/absence data in Table 14. The three interconnected lakes are all clustered together, with Waccabuc's inflow and outflow sites included in the analysis. Kitchawan stands apart. Even with similar taxa present, this distinction is clear. While the parsimony analysis shows Kitchawan distinctly set apart from the other three lakes, Rippowam and Waccabuc's inflow and outflow have fewer plant taxa and are clustered together in this analysis.

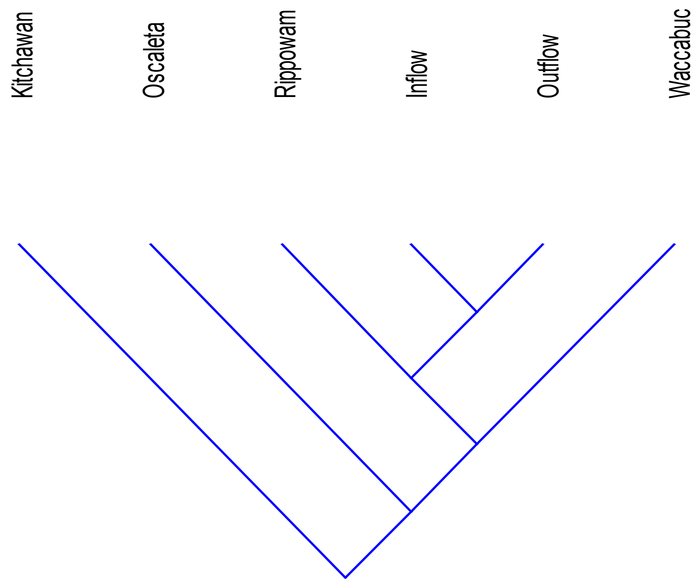


Figure 23: A parsimony analysis of the macrophytes presence-absence data from Table 14 shows Kitchawan set apart from the other lakes. Rippowam and Waccabuc's inflow and outflow group together, reflecting a dearth of species.

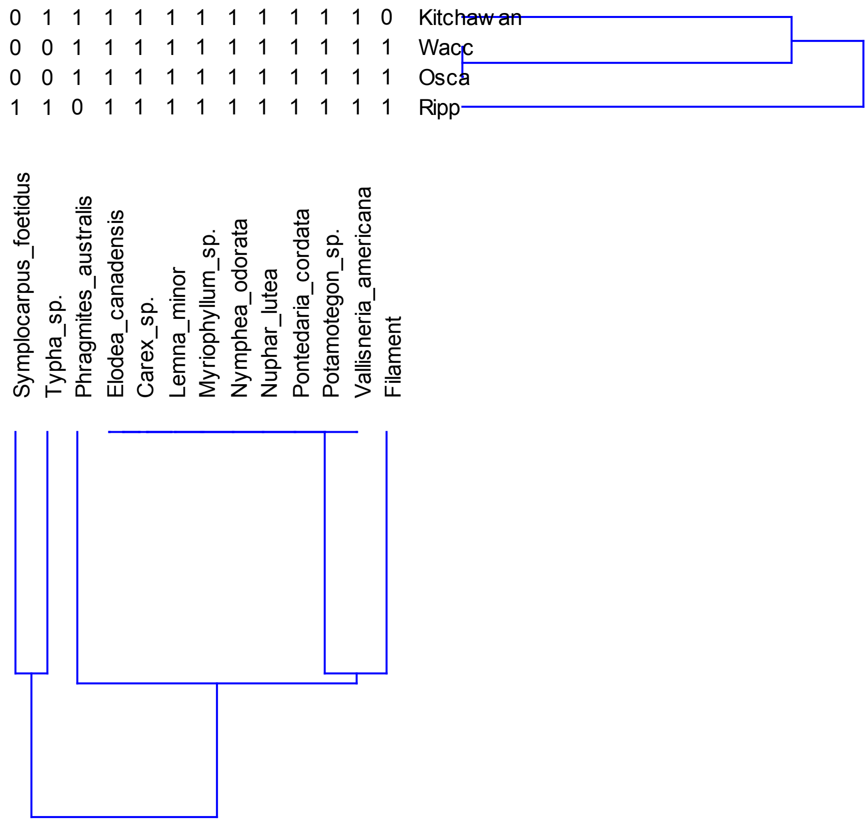


Figure 24: Biplot Cluster Analysis of plants by site, with the Inflow and Outflow data now combined with Waccabuc. The biplot now shows Oscaleta and Waccabuc having more in common, with Rippowam separate, reflecting its low plant diversity.

Most of the plant families in the floral survey were common to all the lakes to some degree. The cluster analysis of the presence/absence data on the aquatic plants shows Oscaleta and Waccabuc are most similar in the kinds of plants present. This is not surprising considering their sediments are similarly high in organic matter, favoring the growth of larger aquatic macrophytes. Kitchawan clusters with them, similar in plant diversity. Lake Rippowam, which sits at the foot of a very high ridge, has a rockier shoreline than the other lakes. The other lakes also all have contiguous wetlands, but Rippowam does not. Both the inflow site and the outflow site at Waccabuc were included here to act as “outgroups.” The inflow site was very sandy and the outflow site had a rocky, pebbly substrate. Both are singled out clearly in the cluster analysis. Correlations between specific macrophytes and mollusks were found in several studies (Sheldon 1990; Bronmark 1987; Zealand and Jeffries 2009).

Further analysis of the plants and the physicochemical variables is shown below in the section on development, where the numbers of plant taxa per lake were incorporated into a larger matrix of development and environmental variables to study their combined effects on the benthic fauna. See the section on *Development and Benthic Macroinvertebrates*, below.

Other Benthic Macroinvertebrates

In addition to the macroinvertebrates, a few vertebrates were found during sampling. A variety of amphibians appeared in the Surber nets, mostly tadpoles and pollywogs. Whenever possible, vertebrates were fished out of the nets and returned to their habitats. A few samples over the years managed to capture fish larvae, from tiny trout larvae to the Tesselated Darter, *Etheostoma olmstedii*.

The primary focus of this research study is the ecology of gastropod mollusks in the littoral benthos of four lakes. Many other benthic macroinvertebrates were captured in the sampling process. Their presence adds a multifaceted dimension to the study, as these other groups have many different kinds of life cycles and physiological requirements, though they also live in the benthos. The other benthic organisms occurring in the lakes included many invertebrate families and reflected strong biodiversity in the four lakes. Other benthic macroinvertebrates consisted of varieties of Annelida, including Oligochaeta and Hirudinea (leeches). Crustaceae were represented by crayfish, amphipods, ostracods, copepods and isopods. Porifera (sponges) and Cnideria (hydra) were also found in large numbers, mostly in the Waccabuc outflow site. Insects were ubiquitous and included ecologically important groups such as the Diptera, including the Chironomidae (midges). Other important insect orders included: Odonata (dragon and damsel flies), Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), Megaloptera (alderflies), Coleoptera (many aquatic beetles), and various Hemiptera (crawling water bugs, etc.). Presence/absence data for benthic organisms in the lakes are found in Table 15. The most numerous of all these were the Chironomidae, the midge larvae. Running close behind them were their predators, the Amphipoda.

Table 15: Presence/Absence table of benthic macroinvertebrates (non-molluscan). Genus and species (where such identification was possible) occur in the column second from left. The abbreviations stand for: K=Kitchawan, O=Oscaleta, R=Rippowam, W=Waccabuc, I-W=Inflow Waccabuc, O-W=Outflow Waccabuc.

Benthic Invertebrate Fauna (non-molluskan)		K	O	R	W	I-W	O-W
Diptera	*Chironomidae*	1	1	1	1	1	1
Ephemeroptera		1	1	1	1	1	1
Plecoptera		1	1	1	1	1	1
Odonata		1	1	1	1	1	1
Coleoptera	*Haliplidae*	1	1	1	1	0	0
	Gyrinidae	1	1	0	1	0	0
Megaloptera		1	1	0	1	0	0
Hemiptera	*Belostomatidae*	1	1	0	1	0	0
	Naucoridae	1	1	0	1	0	0
	Notonectidae	1	0	0	1	0	0
Ostracoda		1	1	1	1	0	0
Amphipoda		1	1	1	1	1	1
Copepoda		1	1	1	1	1	1
Decapoda	*Orconectes sp.*	0	0	0	0	0	1
Isopoda	*Assellus*	1	1	0	1	1	1

Principal components analysis (PCA) of the major groups comprising the benthic macroinvertebrate fauna in this study was performed on each lake each year, measuring correlations between lake-year and total numbers of snails, bivalves, limpets, insects, midges and amphipods. The sampling season for all four lakes was April to October for 2009 and 2010. Only the data from September and October were used from 2008, since sampling was done on all four lakes only for those two months. The benthic macroinvertebrates present in the largest numbers were used in this PCA: gastropods, bivalves, limpets (ancylids), insects (not Chironomidae), midges (Chironomidae) and amphipods.

The insects were a very diverse group including many insect families such as: Hemipterans, true bugs; and larvae from the following groups: Odonata, dragonflies and damselflies; Ephemeroptera, the mayflies; Trichoptera, the caddisflies, and Plecoptera, the stoneflies. These latter two were found predominantly in the late spring. Other larger hemipterans, like water striders, water scorpions and giant water bugs were found. Diverse Coleoptera, such as predaceous diving beetles, Dytisidae; crawling water beetles, the Haliplidae; and the whirligig beetles, Gyrinidae, were found in all of the lakes in varying numbers. The tiny midge larvae in the family Chironomidae are ecologically important and viewed as potential biomonitoring organisms (Heatherly et al. 2005; Luoto 2010). These were the only Dipterans that were singled out for this analysis.

Table 16: Benthic macroinvertebrate totals for each lake-year. W08= Waccabuc 2008, O08= Oscaleta 2008, R08=Rippowam 2008, K08= Kitchawan 2008, the W09= Waccabuc 2009, O09=Oscaleta 2009, R09=Rippowam 2009, W09=Waccabuc 2009 and W10= Waccabuc 2010, O10=Oscaleta 2010, R10=Rippowam 2010 and K10=Kitchawan 2010.

Lake	Gastropods	Bivalves	Ancylids	Insects	Midges	Amphipods
W08	4	12	0	92	128	12
O08	29	13	3	12	28	4
R08	2	13	0	1	17	0
K08	63	342	92	806	639	317
W09	277	101	5	508	905	149
O09	156	121	5	19	124	75
R09	34	45	8	30	354	75
K09	397	406	4	309	330	18
W10	375	37	0	58	142	105
O10	570	115	15	89	257	134
R10	282	33	11	121	263	286
K10	1035	759	14	164	393	176

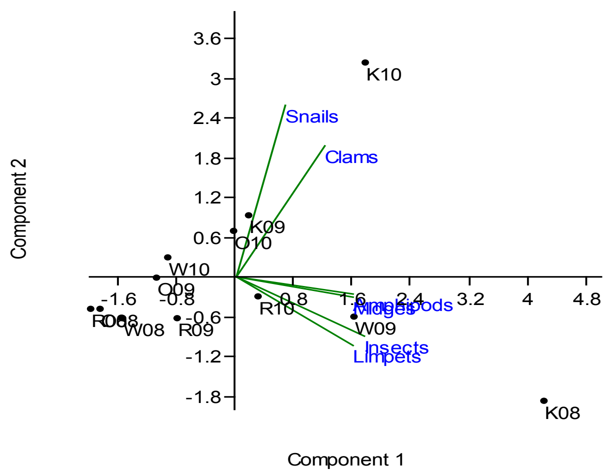
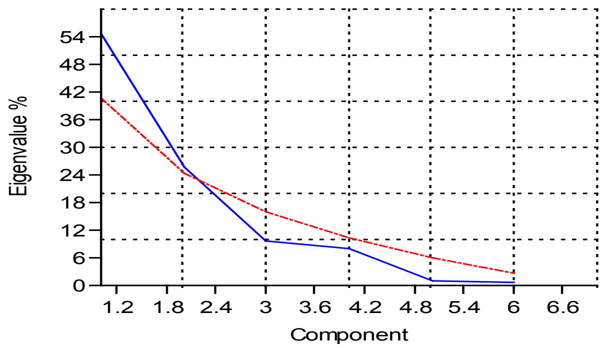


Figure 25: PCA biplot of lake-year by benthic macroinvertebrates. Eigenvalues are shown, below.

Components	**Eigenvalue**	**%Variance**
1 Gastropods	3.27	54.6
2 Bivalves	1.54	25.7
3 Ancylids	0.584	9.73
4 Insects	0.478	7.98
5 Chironomids	0.066	1.10
6 Amphipods	0.046	0.76

Figure 26: Below, Scree Plot – Broken Stick showing the components of the variation in the above PCA.



In figure 25, gastropods accounted for 54.6% of the variance among the lakes, bivalves 25.7% and the limpets 9.7%. Overall, molluskan fauna accounted for 90% of the variation between the four lakes over the course of the study. Other benthic macroinvertebrates accounted for a mere 10% of the variation. In the PCA, Lake Kitchawan stands apart from the others for all three years of the study. Of the Three Lakes, Waccabuc – especially in 2009 - stands apart from the others. Oscaleta in 2010 appears to be more similar to Kitchawan. While comparable to Oscaleta in size, Rippowam appears to have some factors in common with Waccabuc. Rippowam's mean pH of 6.7 was much closer to Waccabuc's mean of 6.8 than to Oscaleta's of 5.9. Rippowam had a mean dissolved oxygen level that was fairly moderate 4.7 ppm and Waccabuc had a mean dissolved oxygen of 4.3 ppm. Oscaleta's mean dissolved oxygen was 3.3 ppm. Considering the temperature and the low salinity of the lake environment, dissolved oxygen levels were fairly low in the lakes. The oxygen saturation was roughly 53% in Rippowam, 48% in Waccabuc and only 43% and 37% in Kitchawan and Oscaleta, respectively. Relative levels of eutrophication could be reflected in these oxygen saturation levels. These physicochemical differences are mentioned here, but their significance will explained in more detail, later in the discussion. In terms of benthic macroinvertbrates, the Chironomid midges and the amphipods were ubiquitous and therefore did little to distinguish between the lakes in the plot in Figure 25, above.

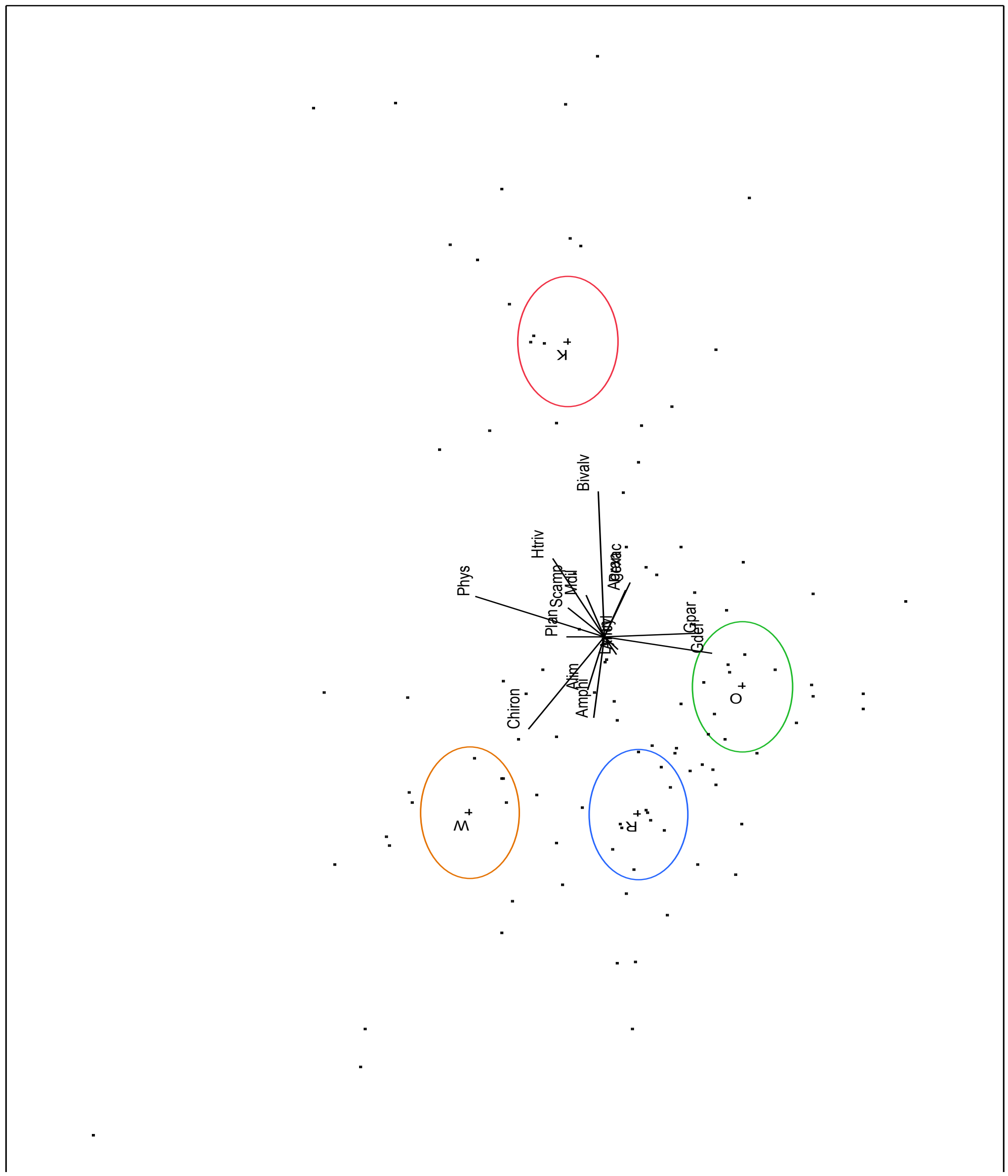


Figure 27: A canonical plot (Discriminant Analysis output) showing the distinct groupings of lakes and taxa (JMP 8.0). Ellipses represent 95% confidence intervals. Eigenvalues are below:

Eigenvalue	Percent	Cum Percent	Canonical Corr
2.73535827	61.486065	61.486065	0.85573831
1.25657488	28.2456034	89.7316684	0.74622417
0.45681189	10.2683316	100	0.55997284

Test	Value	Approx. F	NumDF	DenDF	Prob>F
Wilks' Lambda	0.08143564	7.55210201	45	256.264684	3.5226e-27

Figure 27 shows the canonical plot from discriminant analysis showing the three contiguous lakes grouped more closely together, but Kitchawan stands apart from the other two. Since Lake Kitchawan is in a separate drainage, the greater distance between it and the other three lakes is not surprising. Kitchawan had a distinctly more diverse benthic community; with all the taxa found individually in the other three lakes present in Lake Kitchawan together.

EPT/EPTO Metrics

The insect taxa found in this study were numerous and diverse, though fairly typical for the northeastern United States. While many insect taxa are interesting simply aesthetically, there are three that are significant for biomonitoring of freshwater systems, globally. The mayflies, Ephemeroptera (E); the stone flies, Plecoptera (P); and the caddisflies, Trichoptera (T), are typically used as indicator organisms to assess water quality (Wetzel 2001). Typically, the numbers of each family present are integrated into some sort of biotic index known as the EPT index. The indices are comprised of either percent species richness or percent of total benthic fauna – or in rare cases, the actual, raw numbers of those populations are used to describe water quality. Since mayflies, stoneflies and caddisflies demand fairly high oxygen levels, their presence is directly tied to water quality. As anoxic conditions develop – even in normal seasonal changes in the lakes – the levels of these organisms fluctuate with the chemistry (Callanan et al. 2008). Particularly fouled surface waters are without any EPT fauna, at all. The numbers of these taxa are often used to monitor surface waters that are in recovery from previously polluted conditions (Gray and Delaney 2008; Purcell et al. 2009; Perez-Quintero 2010). Recent studies from Illinois to Ireland to China, all have utilized some sort of EPT index and new regulations on water quality in the United States and the European Union have led to numerous studies of EPT indices to determine which ones are the best practice for biomonitoring (Heatherly et al. 2005; Callanan et al. 2008; Gabriels et al. 2010; Wesolek et al. 2010). A few studies comparing the application of EPT indices here in the US have made it clear that the context is as important as the metric. Specifically, the location of the study in the United States and the degree of anthropogenic disturbance at study sites will have a strong impact on the utility of particular EPT metrics (Heatherly et al. 2005; Wesolek et al. 2010; King and Baker 2010). Benthic researchers would do well to use multiple metrics and to use only those that have been successfully modified for their region (Wesolek et al. 2010).

Another metric used in biomonitoring is the EOT index, comprised of the percent Ephemeroptera, Odonata and Trichoptera in the water body. EOT is used less frequently, but can be found in some studies (Wesolek et al. 2010).

In the current study, some EPT fauna were found in all four lakes, although their numbers were very low in Oscaleta.

Table 17: EPT and EOT fauna by lake. Their corresponding metric appears in the columns on the right.

Lake	Ephemeroptera	Plecoptera	Trichoptera	%EPT	%EOT
Kitchawan	53	57	11	2.7	1.6
Oscaleta	14	0	9	0.9	1.6
Rippowam	19	7	48	3.9	0.1
Waccabuc	62	17	962	13.4	0.7

To analyze the distributions of the EPT assemblages in the four lakes, canonical correspondence analysis was done. The triplot in Figure 28, below, indicates a few interesting patterns. The EPT fauna seem to align themselves more with temperature range than oxygen levels, which is less typical of EPT fauna and more typical of Chironomids. The Trichoptera appear strongly associated with Waccabuc on the right side of the triplot in Figure 28, which accurately reflects their large numbers at the outflow site on Lake Waccabuc. Plecoptera were most numerous at Lake Kitchawan and appear nearest to Kitchawan on the left side of the triplot. In the correlation analysis, the results of which appear below in Appendix A Table 1, only the Ephemeroptera appear to have a positive correlation with water temperature. In the triplot, the Ephemeroptera sit neatly between axis one, air temperature, and axis two, water temperature, reflecting their association with ambient temperatures. The Ephemeroptera also had a significant correlation with the coliforms, which could explain the polarity seen in the CCA triplot, below.

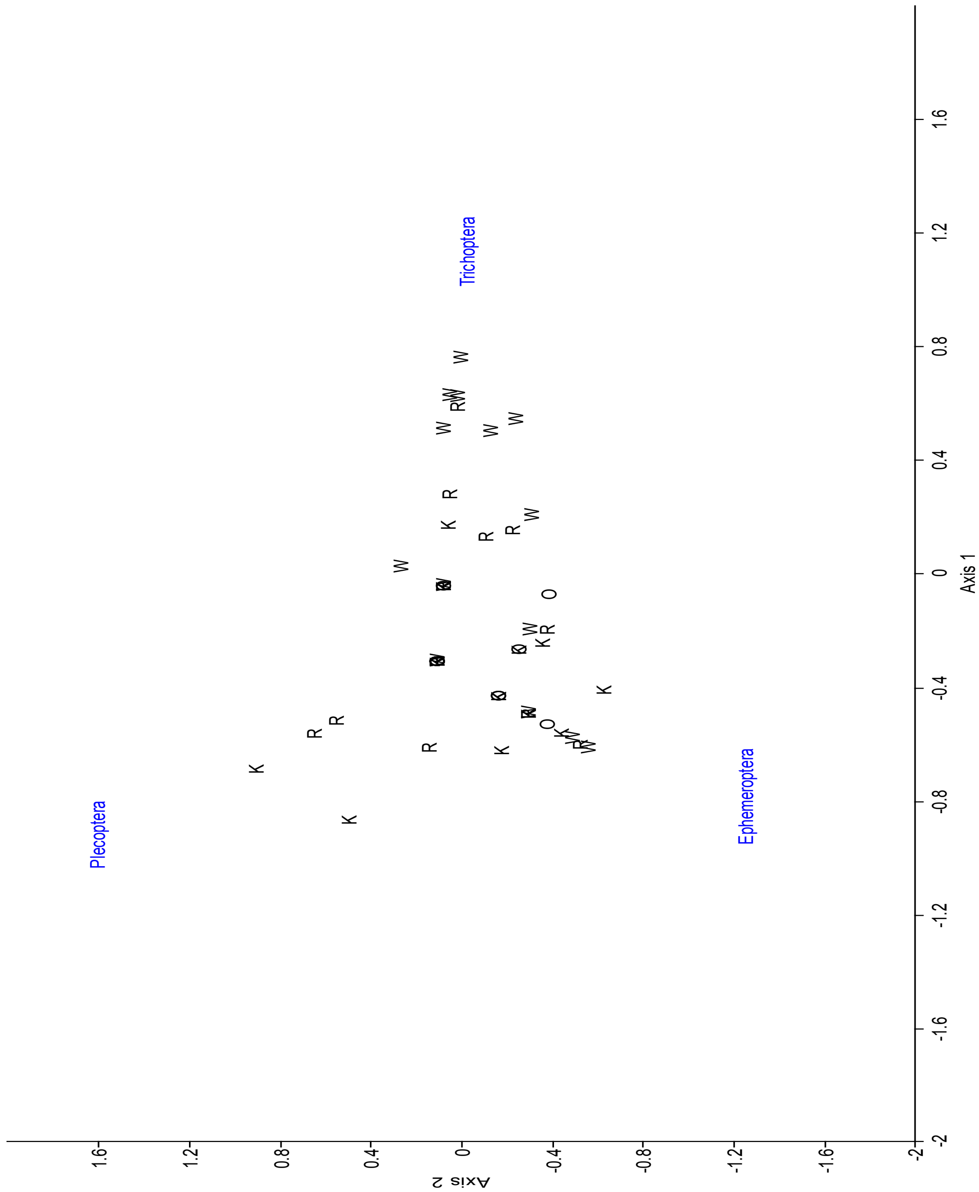


Figure 28: CCA triplot of the four lakes by EPT fauna and physicochemical parameters.

Axis	**Eigenvalue**	**% Var**
1	0.075	79.3
2	0.019	20.7

The bulk of the distribution is centered along the two axes. However, axis 1 divides the lake sites into an east-west distribution. Lakes Kitchawan and Waccabuc dominate the extremes of the distribution, while Oscaleta and Rippowam are central, though not exclusively. None of the lakes are ordinated significantly with any of the physicochemical variables like hardness, calcium, conductivity, total dissolved solids, dissolved oxygen and pH. This signifies that no one variable can account for all of the ordination. Plecoptera and Ephemeroptera also appear to be more closely associated with the Kitchawan side of the distribution. Trichoptera are more allied to the Waccabuc side along axis one. Since Oscaleta and Rippowam had the fewest EPT fauna, the distribution in figure 28 is clearly less informative about those two lakes.

Chironomid midge larvae are commonly taken in benthic sampling. They can appear in large numbers and are a critical part of the food chain as prey for fish, crayfish and amphipods among other benthic organisms. The percent Chironomids in the overall benthic fauna is sometimes calculated as a metric in freshwater ecological studies (Reynolds 1987; Heatherly et al. 2005; Luoto 2010).

Table 18: Chironomid population per lake and percent chironomids in overall lake fauna.

Lake	Chironomid Population	Percent Chironomids
Kitchawan	331	7.5%
Oscaleta	136	5.6%
Rippowam	351	18.8%
Waccabuc	1092	14.1%

Development and Benthic Macroinvertebrates

The combined effects of all of the physicochemical, sediment and development variables on benthic macroinvertebrates are reported, here. The variables included: nitrates, phosphates, percent organic matter, percent carbonates and the sediment classes (fine gravel, coarse sand, fine sand, very fine sand and silt). The development variables consisted of those listed in Table 19, below.

Table 19: Data on development and effect of development on the four lakes. NB: Run-off into the lakes is calculated in acre-feet/year. (Data from Martin, 2004.)

Lake	P Input (kg/yr)	Structures	Storm Drains	%Developed Land	Run-off into lake
Waccabuc	544	235	53	26	1597
Oscaleta	117	68	10	5.4	2058
Rippowam	42	46	4	6.8	507
Kitchawan	131	127	42	20	1204

Prior to the multivariate analyses, the development variables were square root transformed (if count data) and arcsine transformed (percent data) and run through a series of single factor analyses using bivariate fit tests in JMP 8.0 where the F-statistic was considered significant if the $p<0.05$ (Wu and Legg 2007). Following a technique found in the literature on species richness, the diversity index (Margalef's R) and %EPT, %EOT and % Chironomids were also run through these analyses against the taxa (Wu and Legg 2007; Gray and Delaney 2008).

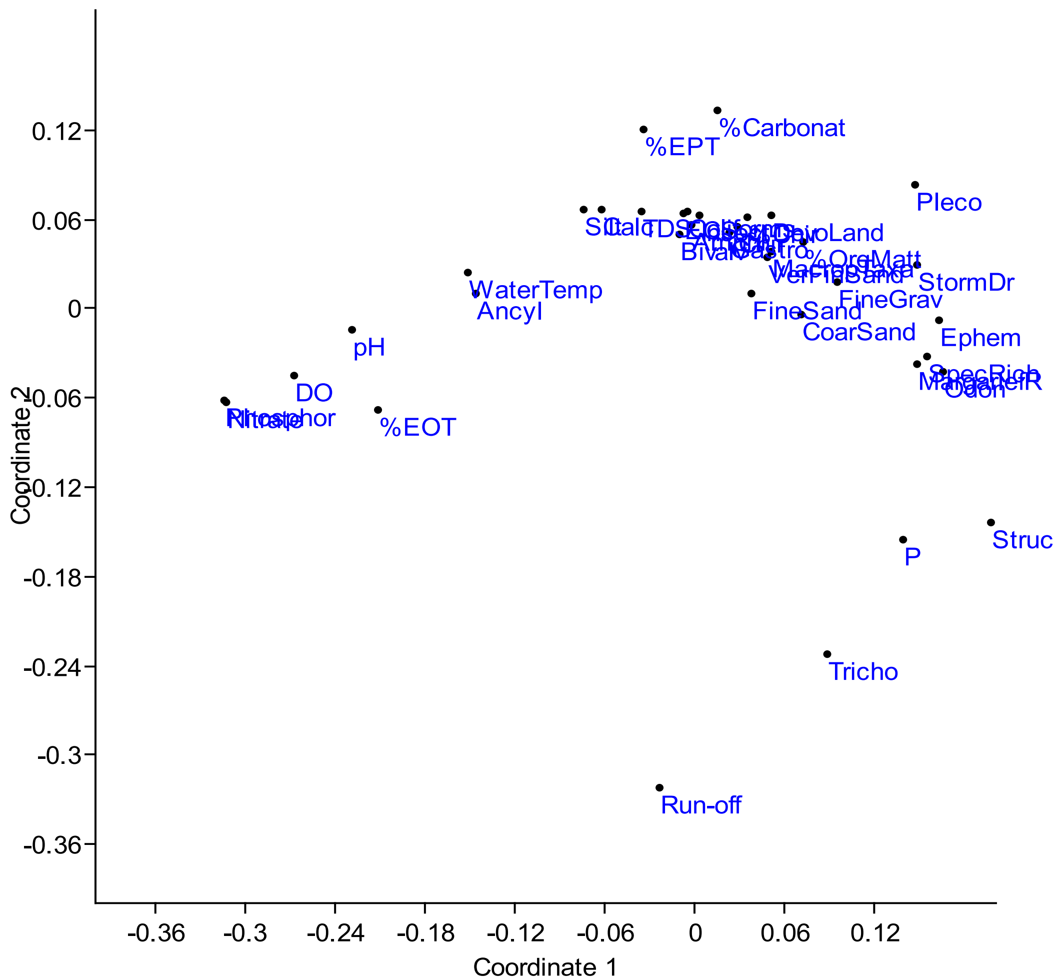
When the benthic taxa were run through the single factor analyses, phosphorous loading was found to be negatively correlated to amphipods, gastropods, bivalves, ancylids, insects – including Chironomids, Ephemeroptera, Odonates and Plecoptera, although not significantly. Stormwater run-off was found to be negatively correlated to amphipods, ancylids, Chironomids and Plecoptera, although here again, not significantly. Only the macrophyte taxa showed a significant p-value (0.037), against storm water run-off. The Ephemeroptera had significant results for the number of storm drains with a p-value = 0.046 and the percent of developed land with a p-value = 0.0003. See Appendix B Table 5.

The gastropod genera and/or species identified in this study were run through the single factor analysis against the development data, as well. The count data was square root transformed for normality. Somewhat surprisingly, *Physa gyrina* had a significant response to the number of structures ($p=0.030$) and the number of storm drains ($p=0.003$). The Lymnaeid snails had a significant response to annual phosphorous loading with a p-value of 0.049. To determine if this was an artifact of the nonlinear data, Spearman's rho non-parametric correlation tests were run. Again, *Physa gyrina*'s significant response to structures and storm drains appeared, with a significant negative correlation. Similarly, the Lymnaeidae also showed their significant negative correlation to phosphorous loading.

When the species diversity indices were run against the development variables, there was no significant response. The only significant negative response against sediment data was Margalef's R against coarse sand. Understandably, benthic macroinvertebrates do not like to live in coarse sand.

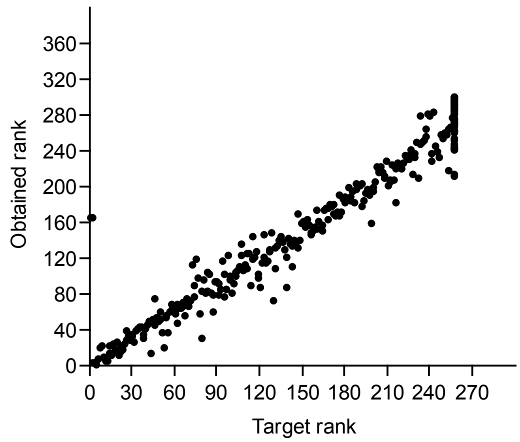
The development and sediment variables were run through two types of multivariate analysis, along with the data on the mean numbers of plant taxa for each lake and means for each benthic macroinvertebrate taxon. An essential precept in multivariate analysis is that the process of ordination is useful method for displaying samples so that similar ones are closer together and different ones are farther apart (Gauch 1982). This is important to remember, especially as the numbers of variables under analysis increase.

Multivariate analysis combining the development, physicochemical, sediment and taxa data was done using Nonmetric Multidimensional Scaling (NMDS) to ordinate samples.



Axis 1 = 0.050 Axis 2 = 0.043 Stress = 0.118

Figure 29: The NMDS above is 2D model of sediment, development and taxa data, using Bray-Curtis distance measure and 11 iterations.

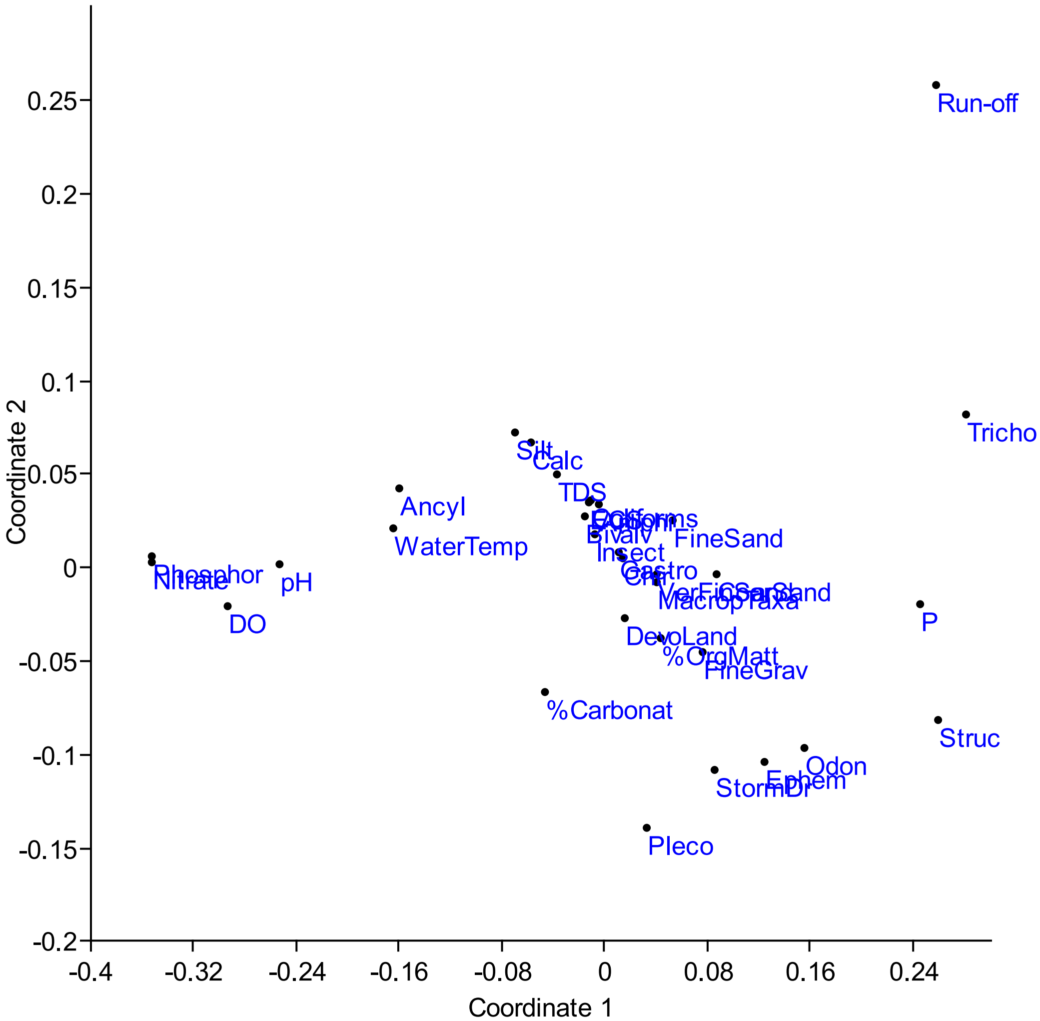


Stress = 0.118

Figure 30: Shepard Plot for the NMDS of the sediment, development and taxa.

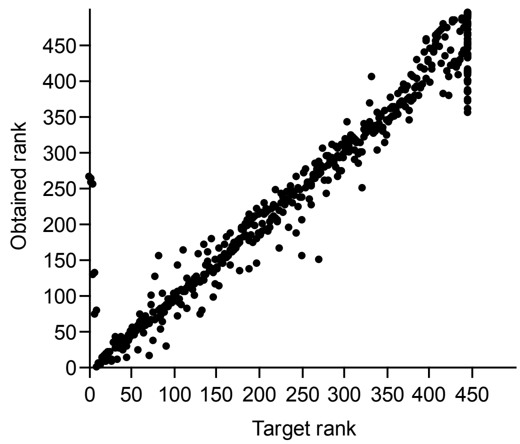
The NMDS ordinated the variables in low dimensional space and an interesting pattern emerged. The horseshoe pattern in the NMDS could be indicative of autocorrelation occurring between the means for nitrate and phosphorous and stormwater run-off. The EPT taxa fell to the outer edge of the plot with Plecoptera closest to percent carbonates in the upper portion of the plot. Ephemeroptera and Odonata were centered along the far right, with some important development variables: storm drains, number of structures and phosphorous loading. The Trichoptera appeared in the lower right stranded between the other development variables and the strong pull of run-off. The only development variable closest to axis one was mean phosphorous content. In Figures 29 and 30 the linearity of the Shepard plots is important in verifying the usefulness of the NMDS output (McCune and Grace 2002). The linearity of the Shepard plot and the low stress value of the NMDS indicate the nonrandom nature of the data, making these outputs good models of the interrelationships between these variables.

The next NMDS, shown in Figure 31, also used Bray-Curtis distance measure and 11 iterations to model physicochemical, sediment, development and taxa data. The stress on the axes was 0.122. The values are shown, below.



Axis 1 = 0.061 Axis 2 = 0.026 Stress = 0.122

Figure 31: NMDS of physicochemical, sediment, development and benthic taxa using Bray-Curtis distance measure.

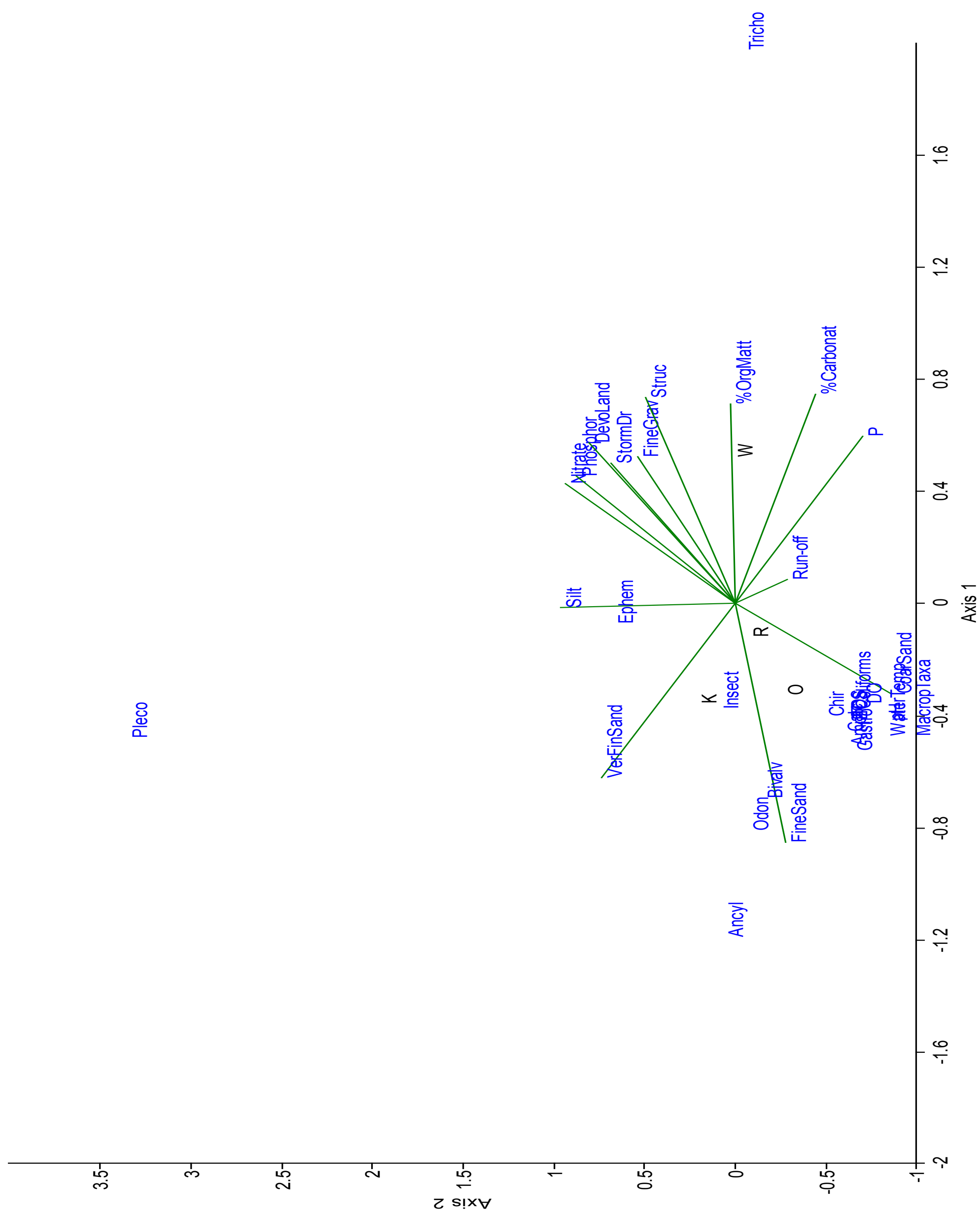


Stress = 0.122

Figure 32: Shepard Plot of NMDS physicochemical, sediment, development and benthic taxa.

Once again, the Trichoptera appear strongly polarized to the right along with mean phosphorous concentrations, storm water run-off and number of structures. Most of the other benthic macroinvertebrates appear centralized in this model, indicative of their fairly neutral response to most of the physicochemical variables. This matches their responses in single factor analyses, where only one or two variables were significant to specific taxa, but none were uniformly significant. In Figure 31, the EPT fauna appear closely associated with the data point for numbers of storm drains and structures, factors associated primarily with Waccabuc. The gastropods and bivalves appear closer to calcium, conductivity (ECS) and total dissolved solids (TDS). Chironomids, coliforms and amphipods also appear to cluster near each other, reflecting a feeding relationship described in other studies (Luoto 2010). From these NMDS models, the pattern of species interrelationships that was slowly forming from earlier separate analyses is now merging into a more cohesive picture of the benthos.

In CCA, the axes are combinations of the environmental variables acting as the independent variables and the taxa are the dependent variables.



Axis	Eigenvalue	% Var
	0.17272	84.68
2P	0.030101	14.76
3%Org	0.0011362	0.557

Figure 33: The CCA Scale 1 triplot shown above shows the relationships between physicochemical and development factors, as well as macrophyte and benthic faunal taxa.

In the triplot shown in Figure 33, Oscaleta is close to both Rippowam and Kitchawan. These lakes appear to be situated fairly neutrally between the nitrate and phosphorous axes, while Waccabuc with its heavy phosphorous loading, high organic matter and higher percent carbonates is pulled strongly along the first axis. The first two axes explain the bulk of the triplot. 84.68% of the distribution is explained by axis one, mean nitrate concentration. 14.76% of the distribution is explained by axis one, mean phosphorous concentration. Kitchawan is situated closer to axis one, indicative of its higher nitrate levels, as well. The development variables, such as number of storm drains, developed land, number of structures, are also more similar for Waccabuc and Kitchawan, relating them both in the lower half of the triplot in Figure 33. In terms of benthic macroinvertebrate distributions, Trichoptera appear at the extreme right, as polarized towards Waccabuc as possible. This is not unexpected, since Waccabuc had the greatest number of Trichoptera in the study. The bivalves, odonates, gastropods, chironomids, insects and ancylids appear to pull strongly to the left towards the phosphorous axis (two). The macrophyte taxa appear to be associated more strongly with axis two, phosphorous, as well.

Using scaling two in CCA allows you to relate taxa to environmental variables (Hammer et al. 2001). The technique scales back the distances on the variables. The taxa fall within the plot and are more centralized. In Figure 34 below, Scaling Two is used in the CCA triplot to further explore relationships between the taxa, environmental and developmental variables. The taxa vectors are noticeably contracted to lie within the environmental and developmental vectors.

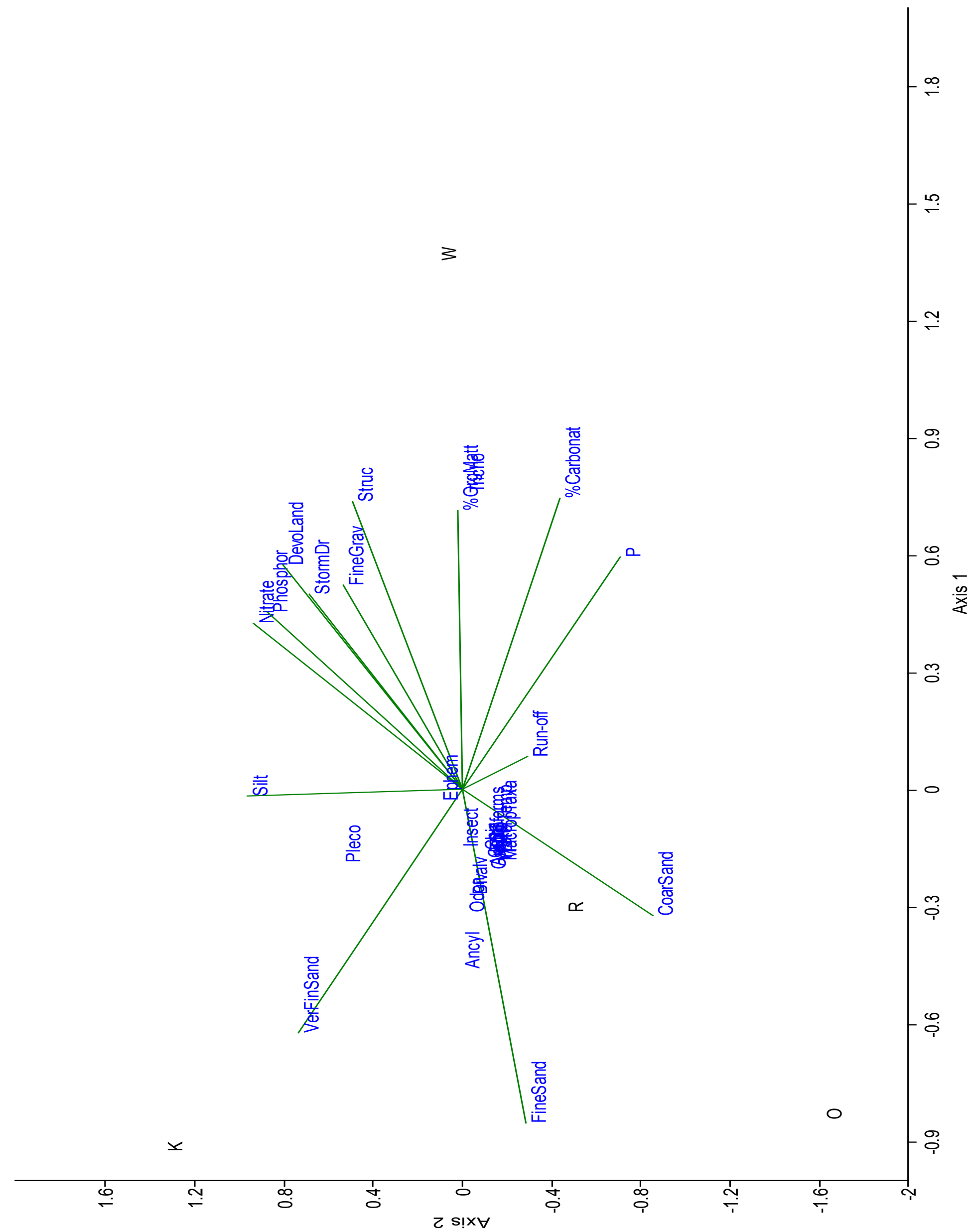
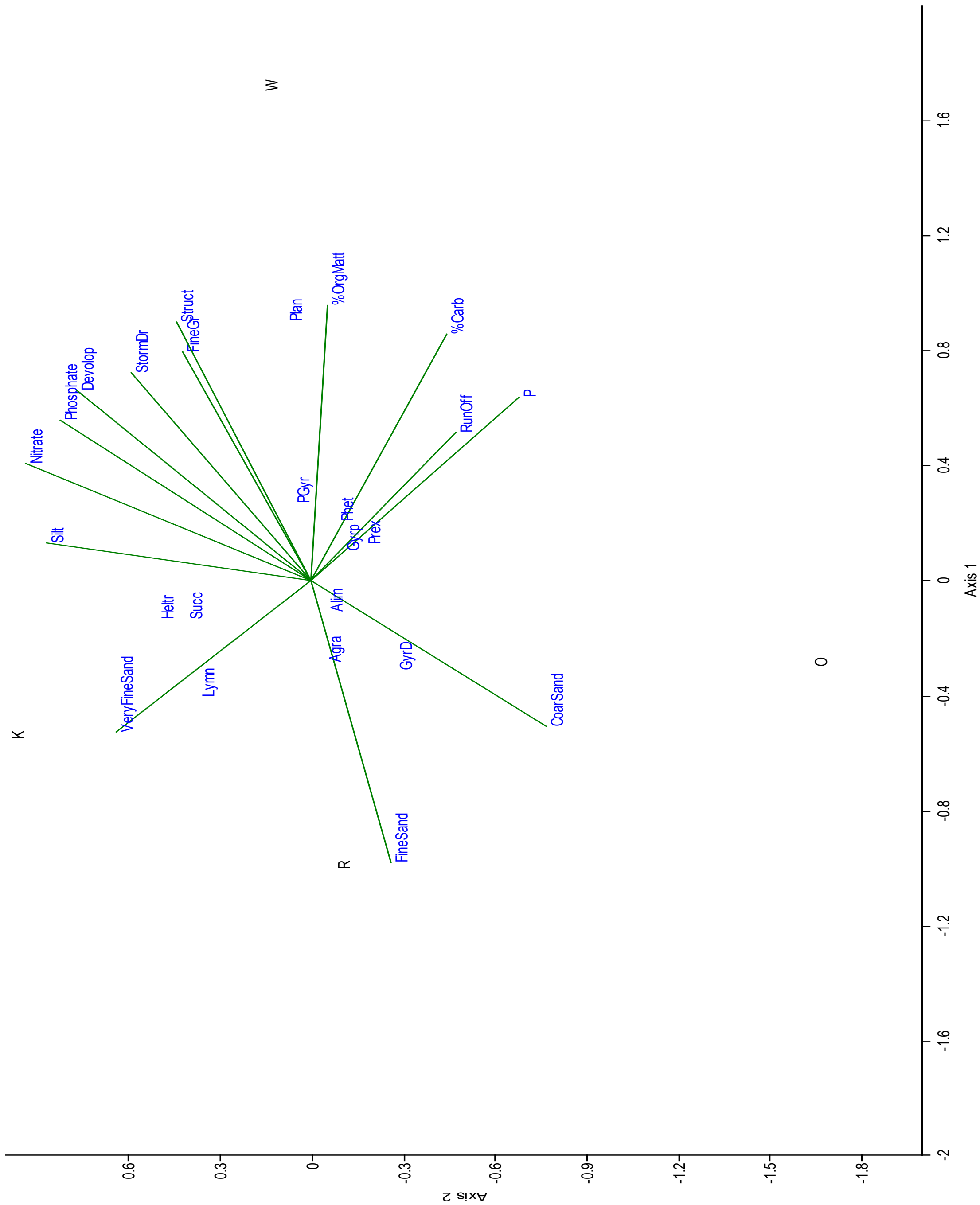


Figure 34: Above, CCA triplot in Scale 2 showing the relationships between physicochemical, development and benthic taxa. Scale 2 is used to find relationships among the taxa (Legendre, 1998 cited in Hammer, 2001).

The CCA triplot using Scaling Two, in Figure 34, above, shows some expected effects from the sediment data and development variables on the distributions of the taxa. Note that the eigenvalues are the same for Scaling Two plots. The first, most notable observation is that Oscaleta sits very high up on axis two. Left of the center, not far from Oscaleta, is Rippowam, which has similarities to Oscaleta in levels of development and number of storm drains. Kitchawan is located low on axis two, showing a strong relationship to the phosphorous and also relating to Waccabuc, which has similar values for mean phosphorous. In fact, all the environmental variables and development variables that are similar for these two lakes appear in the lower half of the plot between them: percent silt, mean nitrates, mean phosphorous, numbers of storm drains, numbers of structures and percent development. Unique to Waccabuc are the strongly related vectors percent organic matter and percent carbonates. The Trichoptera are actually superimposed on the former. The rest of the benthic macroinvertebrate taxa, the Ephemeroptera, gastropods, odonates, insects, bivalves and ancylids appear to be more centrally located and relatively neutral between the lakes. The amphipods and chironomids appear to be superimposed directly on top of one another. This association makes sense in light of the ecological relationship between predator and prey established in the earlier discussion of Chironomidae, above. The storm water run-off which was highest in Oscaleta at 2058 acre-feet per year appears to rest between Oscaleta and Waccabuc. Waccabuc had the second highest amount of run-off at 1597 acre-feet per year.

The same physicochemical, sediment and development data were then run through a second CCA using the mean numbers of each gastropod taxa found in the lakes in Figure 35.



Axis	Eigenvalue	%Var
1 Nitr	0.080493	57.47
2 P	0.041593	29.7
3 %Org	0.017972	12.83

Figure 35: CCA triplot of the environmental and development variables plotted against snail taxa only using Scaling 2.

In the CCA triplot (Figure 35) relating the gastropod taxa to the environmental and development variables, the lakes are distributed along the axes in a manner slightly different from the previous analysis. Kitchawan appears closest to axis two, strongly relating to the phosphorous concentration, while Waccabuc relates more strongly to axis one, nitrate concentration. The two lakes have similar values in this regard, so their polarity must be explained by other variables. The same development variables are still strongly affecting both of the two larger lakes: percent developed land, storm drains, number of structures and phosphate loading per year along with the sediment variables percent organic matter and percent carbonates. It is important to note that in this particular CCA triplot, the axes account for a very different ratio of the distances. Here, only 57.47% of axis one is explained by mean nitrates concentration. More of this distribution, 29.7%, is accounted for by axis two, the mean phosphorous concentration. 12.83% of the triplot is accounted for by the percent organic matter. It is interesting to note that the vector for percent organic matter is stretched directly towards Waccabuc. Silt and very fine sand appear closely related to Kitchawan, associated with *Helisoma, Succinea and Lymnea* snail taxa. Rippowam was related closely with fine sand sediments and the Hydrobiidae snails in the genus *Amnicola*. Once again, Oscaleta appears polarized vertically in Figure 35 reflecting less reliance on axis two and only moderate pull from axis one, however, run-off is still strongly situated between Oscaleta and Waccabuc. The CCA ordination in Figure 35 shows more plainly the implications of the impact of storm water run-off, which is affecting the kinds of species assemblages of snails found in lakes Oscaleta and Waccabuc.

Discussion:

Mollusks

Hypothesis I: Are there correlations between the physicochemical variables of the lakes and the composition and distribution of gastropod populations?

In response to hypothesis one, the relationship between the distributions of mollusk species and the significant physicochemical, sediment and development data was demonstrated in this study answering the question proposed in the first hypothesis. Gastropods, bivalves and limpets show correlations with such factors as conductivity, total dissolved solids, pH, dissolved oxygen, hardness, turbidity and temperature. They also show affinities for particular types of sediment, especially fine sand and silt. Physidae and Lymnaeidae snails also showed sensitivity to anthropogenic disturbances to their aquatic habitats, especially phosphorous loading, the number of structures and the numbers of storm drains present. These two lakes could be contributing to the phosphorous loading, indirectly or directly. Further investigation is needed.

The literature shows several recent studies indicating that snails occur in microhabitats defined by local physicochemical characteristics including pH, conductivity and water hardness – specifically calcium content (Aho et al. 1978b; Aho et al. 1981; Jokinen 1987; Vermonden et al. 2009; Schiebler and Ciocco 2010). There have been dissenting views on the role of physicochemical variables in past studies, however (Brown 1982).

In this study, when the physicochemical variables are incorporated into the analysis, the PCA analyses consistently group Kitchawan and Waccabuc apart from Oscaleta and Rippowam. The relatively smaller size of the latter two lakes is no doubt the first characteristic to strike the observer, as are the similarities in the nitrate and phosphorous concentrations in Waccabuc and Kitchawan versus Oscaleta and Rippowam. However, the significant physicochemical variables tested in this study are even more interesting. Conductivity, total dissolved solids, pH, dissolved oxygen, hardness and calcium were found to be significant in the distributions of particular snail species or families. As mentioned earlier, conductivity (ECS) has been the subject of much debate in the ecology of snails. Some researchers have found significant, strong associations between relatively high conductivity levels and the presence of snails (Jokinen 1992; Schiebler and Ciocco 2010), while others have found a negative correlation between snails and ECS (Varnosfaderany et al. 2010; Maltchik et al. 2010). The jury is still out on the field observations, but the matter could be settled with certainty with controlled laboratory experiments. Likewise, total dissolved solids (TDS) have been consistently attributed to preferred snail habitats (Jokinen 1992). Conductivity and total dissolved solids have been associated with alkalinity and overall water hardness (Wetzel 2001; Zealand and Jeffries 2009; Dillon 2010). TDS and alkalinity are also associated with salinity (Wetzel 2001). Studies in saline wetlands of Argentina, while investigating a very unique habitat, did find that some snails and many limpets had strong preferences for softer, even more acidic waters (Schiebler and Ciocco 2010).

In this study, snails from the family Planorbidae: *Gyraulus, Promenetus, Planorbis* and snails in the family Physidae appear to be more closely related to Oscaleta and Waccabuc than any of the other snail families, as seen in figure 35. This is important to note because these families of pulmonate snails are highly tolerant of anthropogenic pollutants, variable conductivity levels and low oxygen habitats. More sensitive gilled snails, such as the Hydrobiidae, are not as closely associated with those two lakes. More importantly, Oscaleta and Waccabuc absorb the most storm water run-off of all the lakes in this study. While earlier hierarchical and ordination techniques gave some hint of the relationship between the snails and their preferred habitats, the distinction between the gilled and pulmonate snails did not appear until the anthropogenic factors were incorporated. Storm water run-off flowing into Oscaleta and Waccabuc at thousands of acre-feet per year are bringing with them higher levels of total dissolved solids that increase conductivity. As explained earlier, conductivity is often associated with monovalent cations, i.e. salinity. Run-off also brings with it nitrates from septic fields and fertilizers, as well as the high levels of phosphorous loading. Combined, these contribute to increasing eutrophication of the lakes and lowering of water quality.

For snails of the northeastern US, the physiological need to build calcareous shells is probably the most important reason for their preference for hard waters, but the tolerance levels for softer waters varies greatly, even within species (Jokinen 1992). The greatest numbers of mollusks in this study appeared in Lake Kitchawan, which had the highest average ECS and TDS measurements of all the lakes. From analyzing the four lakes in this study, *Micromenetus* had significant associations with ECS. *Micromenetus* and the pea clams were associated with higher TDS. *Physa gyrina* and *Gyraulus parvus* were correlated with higher total hardness levels.

Kitchawan also had a mean pH of 6.49. It was not the most alkaline lake – that was Waccabuc, nor the most acidic – which was Oscaleta. Kitchawan did have the hardest water and the most available calcium in all of the lakes, which would certainly make a better habitat for mollusks. Waccabuc's water had fairly high calcium content and hardness, but mollusk shells from the Cove Road site were battered and pitted, even with live organisms still inside. At first, this was attributed to the adjacent boat launch and foot traffic, but Oscaleta's boat launch and beach was also adjacent to the sampling site and the shells from Oscaleta were very high quality with no signs of such decay. To reduce the difference to the effect of pH is not possible, because the mollusks from the more acidic environment (Oscaleta) had healthier shells. The paradoxical difference in the shells is something to scrutinize further. Perhaps other chemical interactions are involved. Also Waccabuc's boat launch caters to motor boats, while Oscaleta's launch is only for canoes and kayaks.

Nearly all previous studies that included sediment analysis and Secchi depth as part of their environmental analysis have noted that certain species prefer more productive littoral areas of the lakeshore to deeper waters. This is especially true of *Helisoma, Amnicola* and *Gyraulus* (Harman 1972). Only Physidae snails appeared to have a negative correlation with Secchi depth, but this could be reflective of a preference for specific levels of productivity in the lake, not depth per se. *Physa gyrina* appeared to be one of the most abundant snails in this study of the littoral zones of these four lakes. The large numbers of pea clams found in the littoral - especially in Kitchawan, the shallowest lake - were consistent with the findings of other studies, where pea clams were associated with shallow areas and fairly tolerant of some dessication (Maltchik et al. 2010). Studies of pond snails across England indicated that snails tend to be much more limited by spatial features of their habitats, perhaps because they do not migrate or move around as readily as other benthic macroinvertebrates (Zealand and Jeffries 2009).

The association of freshwater mollusks with particular sediment types has been studied for quite some time. Sediment preferences vary not only by species, but by life cycle stage, as well. *Helisoma trivolvis* preferred the substrate of aquatic macrophytes when juveniles, but are associated with organic matter and sediments high in silt when adults (Harman 1972). Likewise, *Gyraulus parvus* and *Amnicola limosa* preferred substrates high in organic matter (Harman 1972; Cui et al. 2008). *Helisoma trivolvis* showed a positive correlation with silt, and *Promenetus exacuous* a positive correlation with organic matter, in this study.

Lake Waccabuc had various sites with different substrates at each site. The Cove Road site on the northeastern shore of the lake had very high organic matter in the sediment; it had 71% of the mollusk population in Waccabuc. At the inflow site, the most abundant gastropods were Hydrobiidae snails, but pea clams were the most abundant mollusk. Perch Bay, Waccabuc's outflow, had the fewest mollusks, although interesting biodiversity. The Planorbidae snails were the most prevalent mollusk there, but the mollusks were outnumbered by a huge population of caddisfly larvae with totals of 289 in 2009, and 432 in 2010. Perch Bay was also notable for the presence of two large mussel specimens more than eight centimeters in length. These were identified as Unionidae, *Margaritifera margaritfera,* freshwater pearl mussels (Pecharsky et al. 1990). This was a very exciting discovery in the fall of 2009, as they had not been detected in the 2008 sampling. They were discovered during the collection of sediment for the sediment analysis in November 2009. Additional specimens were collected during routine sampling in the spring and summer of the 2010 season. The presence of these freshwater pearl mussels usually indicates good water quality, because of the physiological demands of these organisms (Geist and Auerswald 2007; Dillon 2010). Likewise, the large numbers of caddisfly larvae are also indicative of good water quality according to most benthic macroinvertebrate surveys (Rosenberg and Resh 1993).

High organic matter in the sediments was also congruent with high fecal coliform counts. This is probably an artifact of the fact that the two largest lakes, Kitchawan and Waccabuc, had the highest coliform counts, but they also had the most residential development and potential septic run-off seasonally. Nevertheless, associations between the coliform counts and some snails were evident, as well. *Amnicola limosa* had a positive correlation to coliforms in Lake Rippowam. Positive associations between coliforms and certain snails were found in other studies (Giovanelli et al. 2005; Cui et al. 2008). Studies that focused on water bodies heavily contaminated with sewage effluent, often reported that only certain species of snails – usually from the very tolerant family Physidae – were plentiful in areas with high coliform counts (Cui et al. 2008; Varnosfaderany et al. 2010). Anoxic conditions resulting from nitrate influx, algal blooms and subsequent bacterial population explosions make such habitats inhospitable to the gilled snails and the more sensitive pulmonate species. The finding that *Amnicola limosa* positively correlated with coliforms was therefore unexpected, for this study.

Aquatic Plants

<u>Hypothesis II:</u> Snail species appear to be associated with distinct species of plants, is this indicative of a species' preference for particular plants as hosts for feeding and egg laying?

While the second hypothesis was refuted in this study, the role of both submerged and epiphytic plants in the spatial distributions of aquatic mollusks cannot be understated. In lake littoral ecosystems, plants serve many ecological functions: as the basis for the food chain – both living and dead aquatic plants are an integral part of nutrient cycling. They are habitat for benthic or amphibious organisms. Another essential role for macrophytes in the littoral zone is stabilizing sediments. This is an important role, since the distribution of benthic organisms depends on substrate sediments (Harman 1972; Pringle et al. 1999). Previous studies of benthic macroinvertebrates in a variety of aquatic habitats have noted the association between the benthic fauna and specific aquatic plants (Harman 1972; Brown 1982; Sheldon 1990; Bronmark 1990; Strayer and Malcolm 2007; Luoto 2010). Even laboratory studies have confirmed that patchiness in aquatic plant distributions observed in streams is reflected in the distributions of mollusk populations (Kawata and Agawa 1999). Parsimony analysis can be used to illustrate the distributions of macrophyte taxa among sampling sites (Rachlin et al. 2008), articulating patchiness of the plant populations.

Most of the plant families in the floral survey were common to all the lakes to some degree. The cluster analysis of the presence/absence data on the aquatic plants shows Oscaleta and Waccabuc are most similar in the kinds of plants present. This is not surprising considering their sediments are similarly high in organic matter, favoring the growth of larger aquatic macrophytes. Kitchawan clusters with them, similar in plant diversity. Lake Rippowam, which sits at the foot of a very high ridge, has a rockier shoreline than the other lakes. The other lakes also all have contiguous wetlands, but Rippowam does not. Both the inflow site and the outflow site at Waccabuc were included here to act as “outgroups.” The inflow site was very sandy and the outflow site had a rocky, pebbly substrate. Both are singled out clearly in the cluster analysis. Correlations between specific macrophytes and mollusks were found in several other studies (Sheldon 1990; Bronmark 1987; Zealand and Jeffries 2009).

While there are studies noting radular scars on the leaves of aquatic macrophytes, there is some debate over whether or not snails are actually feeding on the leaves themselves or on the biofilms (Sheldon 1990; Bronmark 1990). Because there is physical evidence of snail radular scars on the leaves and there are stomach content analyses indicating a mixture of biofilm and macrophytes in common species of snails (Dillon 2010), there is enough evidence to warrant further investigation of the possible association between the levels of calcium in the leaves of these macrophytes and the snails’ feeding preferences. Any future field studies incorporating the subject of feeding preferences and the nutrients found in the plants would probably do well to include stomach content analysis in the procedure, since snail feeding preferences have a history of being a somewhat acrimonious subject in the literature on snails and aquatic macrophytes (Brown 1982; Sheldon 1990; Bronmark 1990).

In the context of freshwater gastropod fauna, a review of the literature shows many previous studies indicating differences in the kinds of plants preferred by different species. In his book, The Ecology of Freshwater Mollusks, Robert T. Dillon, Jr. cites a 1970 study by Clampitt, where two species of Physidae snails were collected and subject to stomach contents analyses (Dillon 2010, p 67). These showed that the snails ate both living and dead plant material – preferring *Carex* to other available plants such as *Myriophyllum* or *Ceratophyllum*. The Physidae also ate other benthic organisms, such as chironomids, diatoms, ostracods and amphipods (Clampitt 1970 cited in Dillon 2010). In a Minnesota based study, Physidae were found to prefer *Potamogeton* to every other aquatic plant offered (Sheldon 1987). *Ceratophyllum* was not eaten and the author attributed this to the sharp needlelike leaves of the plant (Sheldon 1987 cited in Dillon 2010). *Elodea, Lemna* and *Potamogeton* were the preferred foods of Lymnaeidae snails (Bovberg 1965, 1968, 1975; Calow 1970; all cited in Dillon, 2010). Planorbidae were found to favor *Lemna* and *Potamogeton* in studies conducted in the 1980s (Sterry et al. 1983; Thomas et al. 1986 cited in Dillon, 2010). Note that these aquatic plant preferences do not imply that all of these snails are herbivores. As mentioned earlier, Physidae are known omnivores. Planorbidae are also known to eat other benthic organisms, as well as the eggs of other snails and such varied foods as diatoms and bacteria (Dillon 2010). Many snails, like their fellow benthic organisms the oligochaetes, ingest the bacterial and/or algal biofilms coating the leaves of submerged macrophytes. Some studies indicate that these biofilms are also more prolific during periods of higher temperatures, increasing food availability (Reynolds 1987). Studies on the feeding preferences of freshwater snails indicate that the snails prefer to eat the epiphytes growing on the macrophytes, not the large plants themselves (Sheldon 1987, 1990). The algae coating the submerged surfaces of the macrophytes are easier for snails to ingest and less likely to have anti-feedant compounds in the leaves (Sheldon 1990).

From field observations in this study, *Helisoma* were eminent opportunists - seen eating *Nuphar* and *Pontederia* in the spring and summer and eating *Acer*, i.e., dead maple leaves in the fall. *Helisoma trivolvis* from Lake Kitchawan were also seen to devour the eggs of *Physa gyrina* laid on the glass walls of their habitat set up in the laboratory. *Helisoma* sp. have a reputation for being rather aggressive snails, especially towards other mollusks in competition for food (Dillon 2010). *Amnicola limosa* and *Succinea campestris* were found attached to *Nuphar* leaves, although without stomach content analysis it would be impossible to say if the snails were eating the biofilm on the underside of the leaves or the leaves themselves. Because of the diminutive size of these types of snails, in the future, a DNA "shotgun" method might be best for rapid identification of stomach contents.

As important as plants are to the food web, macrophyte distributions also appear to determine the spatial distributions of different mollusk species only generally. The second hypothesis could not be resolved in this study, because the macrophyte taxa appeared similar in all four lakes and had no correlations to physicochemical, sediment and development data. All benthic animals depend on the microhabitats created by aquatic macrophytes, even if they are not actually eating the plants. The varied morphology of aquatic plants helps to stratify the environment in which these organisms live (Harman, 1972; Sheldon, 1987, 1990). There are mollusks that tend to occupy more superficial habitats, such as *Helisoma trivolvis* and *Succinea campestris* which is actually a terrestrial gastropod that lives a semi-aquatic lifestyle at the edge of the lakes. These tend to be found on larger macrophytes. Field observations during this study found both *Helisoma trivolvis* and *S. campestris* present on *Pontederia, Nymphea* and *Nuphar* species. There are those that travel between the surface and the submerged plants, like many of the Physidae. *Physa gyrina* is capable of acrobatic feats when moving through the water column. *P. gyrina* collected from Lake Kitchawan were seen using mucus strands and air bubbles in their mantle lip to regulate their buoyancy and to facilitate rapid vertical movements when observed in tall 30cm glass jars in the lab. Not all snails move so rapidly through the littoral zone. There are more sedentary, benthic taxa, like limpets which cling to submerged plants. And then there are the bivalves and gilled snails, actually living in or on the bottom sediments, such as: *Amnicola* sp., *Pisidium* sp., *Margaritifera* sp., and other benthic organisms.

New York State's DEC report on lakes in the Lower Hudson Basin, published in 2008, indicated that the cause of Lake Kitchawan's severe eutrophication was algal blooms from run-off and the proximity of possibly inadequately maintained septic fields (DEC 2008). The Town Lake Committee's minutes from 2009 debated a new policy of pumping of septic fields annually instead of every five years for those residences adjacent to the lake (Town of Lewisboro 2009c). The lake's dwindling water supply is also a factor in causing the eutrophication of the lakes (DEC 2008). While the inflow has not been measured, to my knowledge, field observations this summer showed that water levels at Lake Kitchawan were more strongly affected by the drought in the summer of 2010 than the other three lakes in this study. At the start of the 2010 field season, the Lake Kitchawan representative from the Town of Lewisboro's Lakes' Committee notified me that the lake would undergo SONAR treatment with the herbicide fluoridone. Viewing the data from 2009 and 2010 in Lake Kitchawan, it is interesting to note that the number of species present was not affected by the application of SONAR (fluoridone). Instead, the benthic fauna appeared to occur in the usual numbers both seasons. Unfortunately, plant growth appeared equally unaffected by the treatment. The level of eutrophication appeared the same at midsummer with heavy growth of large macrophytes extending more than five meters out into the lake. The 2010 drought also caused water levels to fall dramatically, which led terrestrial colonists and semi aquatics, such as pokeweed and *Phragmites,* to thoroughly encroach on the first three meters of what had been the littoral zone in 2009.

The levels of development along the lakes varied widely, mostly a function of length of available shoreline and population. Of the four lakes, Rippowam is both the smallest and has the least development due to the very tall ridge over the north side of the lake which has limited development to the south side of the lake (Arrigo 2009). Both Oscaleta and Waccabuc receive more recreational users than Rippowam or Kitchawan. They have privately managed beaches and boat launches.

The critical factors of residential development that impact on the lakes are the proximity of septic fields and the number of storm drains. The two largest lakes, Waccabuc and Kitchawan, have more development and thus higher populations. From 2000 census data, Waccabuc has 588 people in 235 houses and Kitchawan 318 in 127 houses (Arrigo 2009). These houses are expected to have about two and half baths per home (Arrigo 2009). Such information helps to approximate annual phosphorous influx into the lake system based on run-off and the quality of adjacent land for septic filtration. Unfortunately, residential development on both Waccabuc and Kitchawan are situated on land considered 90% 'septic limited' (Arrigo 2009). This means that phosphorous influx into Lake Waccabuc could be as high as 544 kilograms per year and in Lake Kitchawan, 131 kilograms per year (Martin 2004). Both nitrogen and phosphorous were found to be in moderate concentrations. They appeared to be negligible in their direct effects on benthic organisms, but they could be causing greater eutrophication and thus indirectly affecting benthic life. This hypothesis would require further study and a more in-depth investigation of the macrophyte and algal populations and controlled studies of the herbivory habits among the benthic macroinvertebrates.

Stormwater run-off is a major concern in the watershed region, especially for those drainages associated with New York City's reservoir system, like Lake Kitchawan. Westchester County recently published The Croton Plan, a watershed protection plan that outlined the hydrologically significant land use adjacent to city water supplies and provided a framework for environmentally informed, future development in towns associated with water supplies, including Lewisboro (Westchester County Department of Planning [WCDP] 2009). The study noted that since there are more than one hundred acres of land that can be potentially subject to residential development, the town has an obligation to take into consideration the implications of storm water run-off in implementing future planning policies (WCDP 2009).

Sediment composition has been related to mollusk species distributions in a number of studies (Harman 1972; Pringle et al. 1999; Greenwood and Thorp 2001; Kent and Selzer 2008). Sediments are important to benthic ecology as a substrate for plant and animal growth, for regulating dissolved gases through microbial respiration and for nutrient cycling. Large aquatic macrophytes tend to favor sediments rich in organic matter (Lacoul and Freedman 2006). *Phragmites, Nuphar, Nymphea, Pontederia* and other macrophytes are found in Lake Kitchawan and the Cove Road site at Waccabuc, where sediments were rich in organic matter. Sandier and rockier substrates, such as the inflow and outflow sites at Lake Waccabuc had fewer macrophytes, although filamentous algae and other smaller submerged macrophytes, such as *Myriophyllum* were present in field observations. Benthic macroinvertebrates utilize the sediments as habitat, shelter and as a food source. A review of the literature showed many studies focused on the substrate preferences of mollusks.

From field observation, mollusks had distinct preferences for specific types of sediments. While *Helisoma, Physa* and *Stagnicola* species tended to prefer more superficial regions of the littoral zone, other snails, such as those in the genus *Amnicola*, were more often found in thick organic muds. Among the Bivalves, *Sphaerium* and *Pisidium* tended to prefer the muddy, organic layer, while *Margaritifera* were found exclusively in the rocky, pebble strewn outflow site from Lake Waccabuc. The sediment analysis showed significant differences between the sediment composition in the four lakes, although the macrophytes were fairly similar.

Benthic Fauna

Hypothesis III: Based on the preliminary faunal survey, are there particular species assemblages of benthic organisms that favor similar microhabitats as particular gastropods and thus are frequently found in association with those snails?

In support of the third hypothesis, there are correlations between mollusks and other benthic macroinvertebrates. These can be seen in the distributions of caddisfly larvae and *Amnicola* in the coarser sediments of the outflow region of Lake Waccabuc. Whereas, the waters of Kitchawan, heavily laden with organic matter, compose a unique nutrient rich habitat that support greater numbers of pea clams in association with larger populations of Physidae, a known pollution tolerant snail family. Odonates and Ancylidae had a strong positive correlation. Amphipods were strongly correlated with Hydrobiidae snails and the Planorbidae snail, *Promenetus exacuous*. Amphipods and *Amnicola limosa* both had a high affinity for dissolved oxygen, as well, showing a strong correlation.

Among the other benthic macroinvertebrates, certain associations are explained simply by food web dynamics. As discussed earlier, Chironomidae are known to prefer cooler temperatures (Reynolds 1987). The Chironomidae are also known to prefer rich organic sediments, which increases their numbers along with the population of their predators such as amphipods. Interestingly, like the midge larvae, the amphipods in this study displayed correlations with water temperature. Since both organisms breed in fairly large numbers, further experiments would be needed to determine whether it is the temperature or the increased food supply leading to the increase in amphipods.

Chironomids are considered tolerant of a wide variety of aquatic conditions, only some genera are sensitive (Reynolds 1987; Heatherly et al. 2005; Luoto 2010). The numbers found in the four lakes in this study are not atypical, but little more information can be drawn from their abundance in the lakes without further analysis of the samples taken. To draw any water quality conclusions from them, expert identification of the genera and species of Chironomidae would be needed. Another interesting study could be to examine the populations of sensitive versus tolerant midge larvae species.

As mentioned earlier, oxygen levels are fairly similar between Rippowam and Waccabuc, as opposed to Oscaleta and Kitchawan. While pH did not show as significant for the Chironomids, further study might examine the fact that Kitchawan and Oscaleta both have low percent Chironomids and both have fairly low pH, 6.4 and 5.9, respectively. The four lakes could be a natural laboratory to observe Chironomid habitat preferences. Since previous studies have shown that Chironomid larvae thrive at cooler temperatures, it is interesting to note that Rippowam, Oscaleta and Waccabuc are cooler lakes with water temperatures for all three averaging to 20.6 degrees Celsius. Lake Kitchawan is substantially warmer at 22.9 degrees Celsius, on average.

Depth was also found to be significant to the distribution of the larvae in other studies of Chironomidae (Reynolds 1987; Luoto 2010). Since Secchi transparency can be taken as a surrogate for production to some degree, the positive response of Chironomids to greater Secchi depths could be related to their feeding habits. Chironomids are known to do well in anoxic conditions, thriving on algal blooms and bacterial growth (Reynolds 1987). The only other benthic invertebrates that seem to like these conditions are the amphipods that eat Chironomids.

Among the EPT taxa, only the Ephemeroptera showed positive correlations to air and water temperatures in Spearman's ρ correlations. The mayflies also had a negative correlation to dissolved oxygen. Strangely, both the caddisflies and the mayflies had positive correlations to coliforms. The Plecoptera had a negative correlation to Secchi depth, turbidity.

As explained earlier, nitrate and phosphorous concentrations were not significant for the mollusks in this study, except for *Helisoma trivolvis*. The insects were divided into those taxa with less ecological significance to benthic ecology (true bugs, beetles, etc.) and those taxa which are used typically in assessing water quality: the Chironomids, Ephemeroptera, Plecoptera and Trichoptera. Spearman's ρ correlations showed the Plecoptera with a positive correlation with mean nitrate concentrations, which could be tied to their food source. Plants do well with increased nitrates, so the grazers, like these larvae, might also do well in higher nitrate conditions. Strangely, the Ephemeroptera showed a positive correlation to the percent developed land. There were more mayfly larvae found in Kitchawan and

Waccabuc, the two lakes with the most development around them. Chironomids also showed a positive correlation with nitrates, and the possible reasons for that were discussed above. Ephemeroptera and Trichoptera showed positive correlations with coliforms. Trichoptera are known to feed on microorganisms. Coliforms and the herbivorous Ephemeroptera may be correlated due to the rich organic sediments in which aquatic macrophytes grow.

Non-EPT Insecta, Chironomidae and Plecoptera all had significant responses to nitrates. Unfortunately, due to the nature of the data collected (annual means) there is no way to track seasonal fluctuations accurately. While the associations between nitrates and food have been discussed for the Chironomidae and the Plecoptera, interpreting the meaning of the significant response to nitrate concentrations for the general insects is difficult for two reasons. First, there are many diverse taxa included in this dataset including: whirligig beetles, diving beetles, true water bugs, crawling water beetles, water striders, mosquito larvae, dipteran larvae, water scorpions, alderflies and fishflies – to name just a few! To begin to explain an affinity for nitrate concentrations in such a vast array of species is not possible without much more data and perhaps many controlled experiments. As stated earlier, the multivariate nature of this study precludes the kind of traditional quantitative analysis of the data. Qualitative ecological relationships can be elucidated, but more specific, quantitative relationships cannot be assessed.

As discussed earlier, midge larvae tend to prefer periods of algal blooms and bacterial growth. Nitrate infusions into aquatic habitats, whether from fertilizers or from septic run-off, will cause algal blooms and bacterial growth. The positive response of Chironomidae to nitrate concentration is no surprise. Ephemeroptera and Plecoptera are two important taxa in water quality assessment and biomonitoring. These animals are known to be fairly sensitive to pollutants (Callanan et al. 2008; Purcell et al. 2009). Their affinity for nitrates, here, is a little surprising. It is possible that algal blooms caused by nitrate influxes also increase food supplies for mayfly and stonefly larvae. This might explain the positive response to nitrates and the significant p-values seen in the analysis. Further field and laboratory based studies would be needed to determine the exact concentrations of nitrates in which these animals flourish and what the threshold may be for their tolerance of various nitrate concentrations.

Because of the qualitative nature of this multivariate study, these results show relationships between the species distributions and the physicochemical and biotic variables. Further experimental studies in a controlled setting would be required to directly quantify the actual preferences in mollusks for such variables as preferred sediment composition, preferred water chemistry, food, physical factors, etc.

The water quality of Lake Waccabuc's outflow made ideal conditions for caddisflies, as well as freshwater pearl mussels, indicating that it is very good. Pearl mussels have very stringent water quality requirements (Geist and Auerswald 2007). While caddisflies and mayflies far outnumbered stoneflies, the presence of stoneflies was important. Stoneflies are noted for being particularly vulnerable to anoxic conditions, which can be indicative of even slight changes in water quality. Stonefly populations often mirror seasonal fluctuations in oxygen levels in the temperate zone (Callanan et al. 2008). Because of seasonal turnover in lakes, these metrics are being evaluated to determine when they are best applied. Some studies state that EPT indices should only be used in the spring, because the EPT fauna declines in the summer giving indications of environmental decline, when the figures are really just picking up on normal seasonal fluctuations (Callanan et al. 2008; Purcell et al. 2009). There are dissenting views, however, that do not see any reason to restrict the timing of collection for EPT indices. These authors state that there are enough taxa present from each group that seasonal fluctuations should not interfere with the efficacy of an index (Sporka et al. 2006 cited in Gabriels et al. 2010). Some studies recommend using the EPT metrics in conjunction with other metrics to improve results, such as percent Amphipoda or by feeding categories: percent collector, percent scraper, etc. (Purcell et al. 2009).

As mentioned above, some studies recommend including Odonate fauna in the EPT index (Wesolek et al. 2009; Simaika and Samways 2010). Others have suggested using only Odonate fauna as biomonitoring organisms, stating that benthic macroinvertebrate fauna are not as sensitive and thus not effective predictors of water quality (Simaika and Samways 2010). Yet another study recommended the inclusion of Chironomidae larvae into the EPT index to assess water quality in highly polluted water bodies. Since midge larvae are known to be very pollution tolerant, they balance the sensitivity of the EPT fauna in the index. In highly polluted situations, as in the Irish study cited above, EPT fauna were nearly absent, making an index solely based on EPT fauna useless for biomonitoring polluted rivers (Gray and Delaney 2008).

Another important element of the insect population was the family Chironomidae, the midge larvae. These tiny wormlike organisms are found in most water bodies, but some families can be useful for determining water quality. Most Chironomidae are not as sensitive to oxygen fluctuations as stoneflies, but they do appear more sensitive to temperature. Ecological studies observing Chironomidae in natural habitats have been backed up by laboratory based experimental studies, showing that Chironomidae prefer very specific, cooler temperatures for growth (Reynolds 1987). Shallow lakes heat up faster, increasing temperature, reducing dissolved oxygen and making a less favorable environment for midge larvae. Water depth has been positively correlated to midge distributions in lakes in Finland (Luoto 2010). Chironomidae have been found to be strongly associated with amphipods that prey on them (March et al. 2002). EPT indices are often used when studying these other benthic organisms, especially since insects like mayflies often flourish in the same habitats (March et al. 2002). In the present study, the amphipods did have a similar affinity for water temperature and dissolved oxygen as the mayflies. While co-occurrence between the two has been observed in the field, a controlled laboratory study would be needed to confirm positive correlations between populations of amphipods and these insects. Freshwater amphipods are well known for being in direct competition with snails for food (March et al. 2002; Heatherly et al. 2005). Snails are notorious for being voracious and many snails are omnivorous, as are the amphipods. The degree of interaction or obstruction of feeding between snails and amphipods is not well documented, experimentally. A study contrasting their grazing efficiency would be an interesting laboratory-based experiment to demonstrate which of the two are more efficient feeders, although amphipod researchers write with exasperation of snails eating their study animals out of house and home (or niche), anyway. Aquatic snails in Puerto Rican lowland habitats decimated amphipod populations, while in highland habitats - lacking snails - the amphipods were very successful organisms (March et al. 2002).

Finally, the idea of using the gastropod fauna as potential biomonitoring organisms must be addressed. Many studies have been done examining the use of mollusks as potential biomonitoring organisms (Mouthon 1993; Rosenberg and Resh 1993; Mouthon 1999; Vaughn et al. 2001; Coeurdassier et al. 2005; Geist and Auerswald 2007; Perez-Quintero 2010; Schiebler and Ciocco 2010). While some sensitive species may serve as the proverbial “canary in the coal mine” for specific ecosystems, it is clear that the localized and very specific nature of freshwater mollusk environmental sensitivities make it difficult to generalize. Many gastropod researchers have noticed the wide variability in tolerance within species over vast ranges, so that in specific microhabitats a species may be more susceptible to environmental changes than that same species in another context (Jokinen 1992; Perez-Quintero 2010; Strayer and Dudgeon 2010). Mollusks can be useful biomonitoring organisms, but they should be used in diversity indices combined with other metrics to ensure an accurate picture of the entire benthos (Purcell et al 2009; Perez-Quintero 2010). Even so, freshwater mollusks are in decline globally and their demise is an early warning about the condition of our limited global freshwater resources (Strayer and Dudgeon 2010). Therefore it is important to retain the mollusks as bioindicators in any study of freshwater habitats.

To return to the study at hand, the benthic fauna is quite diverse in the littoral zone of these four lakes. The lakes are fairly healthy, although no doubt undergoing eutrophication due to some anthropogenic causes. The residents around the lakes appear very cognizant of the need for conservation and are diligently working to ensure the health of the lakes. Future studies would do well to expand into the deeper areas of the lakes to explore the benthos, there. This study just scratches the surface of the intricate ecological interactions at the littoral zone. There is no doubt that many more dynamic interactions are waiting to be explored at greater depths.

<u>Conclusions and Recommendations:</u>

Extending a study such as this, could be the basis for a biomonitoring program, using the benthic macroinvertebrates as indicators of water quality. There are community wide efforts to improve the health of the lakes, limit phosphorous loading and control storm water run-off. Public education efforts on water quality issues increased each year in the Town of Lewisboro, even as this study was being conducted. This effort, combined with the citizen science efforts of CSLAP, run under the auspices of the DEC, will no doubt help to improve the condition of the lakes.

Monitoring efforts by local residents are ongoing and lakeside residents appear to be eager to engage in conservation projects and to study the aquatic life in their lakes. This means that a biomonitoring program using benthic organisms can easily be implemented with just a little training. The interest and commitment of the residents are already evident.

The dynamics of populations of very sensitive organisms can reflect changes in nearby land use and development or the effects of recreational use of the waterways. Knowing how such changes will affect the nearby aquatic habitats can assist communities and local planning boards in determining how to use land and adjacent water resources.

A further application of the ecological study described above involves the now inevitable problem of global warming. The continuation of this study through periodic monitoring (every three to five years) might be advised in light of global warming. Benthic macroinvertebrates are integral to the dynamics of lake ecosystems having ecological interactions at many levels, engaging in such broad ranging roles as nutrient recyclers to prey/predator species to parasitic hosts. This last role has historically been of concern only in tropical regions. However, the role of mollusks as hosts and transmitters of parasites to humans is one of increasing concern in the arena of public health. Global warming has exacerbated the problem in the tropics, where snails facilitate the transmission of helminth and schistosome parasites that can infect both humans and animals (Johnson et al. 2010). In fact, one North American snail that has become an invasive in New Zealand has naturalized very well and is now a principal host for a liver fluke that infects sheep (Jokinen 1992). Very often parasitic infections can be zoonotic, infecting humans and the animals that they interact with whether they are pets, livestock or in fisheries. Nutrient loading has been shown to exacerbate this problem, by increasing the parasite loads harbored in host snails (Johnson et al. 2007 cited in Johnson et al. 2010). Since the pace of global warming is increasing, it may be prudent to maintain ecological monitoring of benthic macroinvertebrates in freshwater habitats, with a weather eye to species that could act as potential reservoirs or hosts to parasites or other pathogens. The unexpected, yet rapid, spread of West Nile Virus across the US in just a few short years is a good example of the speed with which a non-native pathogen naturalized in a native host can become a public health concern for both humans and animals (Johnson et al. 2010).

This study of benthic macroinvertebrates of the four lakes in Westchester County provides information on the interrelationships between species assemblages and physicochemical variables. Because of the changing nature of climatic conditions, a long term study of the benthic macroinvertebrate populations would be informative for local conservation efforts as well as for global monitoring of climate change. A similar study conducted over a ten year period in France showed significant changes in benthic macroinvertebrate assemblages over a ten year period of rising temperatures, including record high, summer temperatures in 2003 (Mouthon and Daufresne 2006). Climate change is clearly upon us, and future extreme weather events cannot be ruled out as possibly affecting the ecology of the lakes.

Continuing to study benthic macroinvertebrates to assess, less global and more local effects of continued development, plant management and anthropogenic pollution would provide additional understanding of the suburban ecology of the lakes. The multivariate analyses illustrate the nature of the complexity of the lakes' ecological interactions. Ideally, long term studies (several years) could be undertaken to better understand the effects of anthropogenic pollution on the benthos.

In the future, it is possible that a predictive model could be developed to explore possible future changes in the ecology when associated environmental factors change by applying remote sensing and GIS. The ecology of the snails could be modeled using ArcGIS with geospatial analysis applications to create a multidimensional view of the data. Layers can be added for the data on the snail distributions, the physical and chemical parameters, as well as for the distribution of aquatic plants. Then the data on species distributions together with the measured physical and chemical factors can be used to identify patterns in species distributions and abiotic factors. Eventually, the data on invertebrate community assemblages of non-molluskan fauna can be added, so that they can be viewed alongside the freshwater snail communities and the abiotic factors to search for patterns in species assemblages. This portion of the analysis can be used to identify microhabitats within the larger environment of the littoral of each lake. The entire model can then be used in a predictive manner to better manage the lakes.

Appendix A
Table 1 - Spearman's ρ Correlation Results:

Lake	Variable	By Variable	Spearman ρ	Prob>|ρ|
Kitchawan	Air Temperature	Physa gyrina	0.559	0.002
		Gyraulus parvus	0.545	0.003
		Promenetus exacuous	0.619	0.000
		Helisoma trivolvis	0.459	0.018
		Amnicola limosa	0.585	0.001
		Chironomidae	0.529	0.005
		Amphipoda	0.576	0.002
	Water Temperature	Physa gyrina	0.615	0.000
		Gyraulus parvus	0.417	0.033
		Promenetus exacuous	0.677	0.000
		Amnicola limosa	0.499	0.009
		Chironomidae	0.522	0.006
		Amphipoda	0.472	0.014
	pH	Gyraulus deflectus	-0.483	0.012
		Bivalvia	-0.414	0.035
	ECS	Micromenetus dilatatus	0.472	0.014
	TDS	Micromenetus dilatatus	0.399	0.043
		Bivalvia	-0.375	0.059
	DO	Physa gyrina	-0.546	0.003
		Gyraulus parvus	-0.524	0.005
		Gyraulus deflectus	-0.472	0.014
		Helisoma trivolvis	-0.462	0.017
		Amnicola limosa	-0.668	0.000
		Amnicola grana	-0.362	0.069
		Bivalvia	-0.481	0.012
		Chironomidae	-0.559	0.002
		Amphipoda	-0.739	0.000
	Hardness	Physa gyrina	-0.455	0.019
		Gyraulus parvus	-0.439	0.024
	Secchi	Promenetus exacuous	-0.606	0.001
Oscaleta	Air Temperature	Physa gyrina	0.644	0.000
		Gyraulus parvus	0.414	0.035
		Gyraulus deflectus	0.648	0.000
		Promenetus exacuous	-0.481	0.012
		Bivalvia	0.521	0.006
	Water Temperature	Physa gyrina	0.635	0.000
		Promenetus exacuous	0.449	0.021
		Amnicola grana	0.512	0.007
		Bivalvia	0.519	0.006
		Chironomidae	0.715	0.000
		Amphipoda	0.479	0.013

	Dissolved Oxygen	Physa gyrina	-0.403	0.040
Oscaleta	Dissolved Oxygen	Gyraulus parvus	-0.392	0.047
		Gyraulus deflectus	-0.567	0.002
		Amnicola limosa	-0.608	0.000
		Bivalvia	-0.436	0.025
		Chironomidae	-0.489	0.011
		Amphipoda	-0.460	0.017
	Hardness	Amnicola limosa	-0.417	0.033
		Chironomidae	-0.442	0.023
		Amphipoda	-0.417	0.033
	Calcium	Gyraulus deflectus	-0.409	0.037
	Secchi	Promenetus exacuous	0.390	0.048
		Amnicola limosa	0.543	0.004
		Amnicola grana	0.559	0.002
		Amphipoda	0.514	0.007
Rippowam	Air Temperature	Bivalvia	0.542	0.004
		Chironomidae	0.497	0.009
	Water Temperature	Bivalvia	0.455	0.019
	pH	Gyraulus deflectus	-0.410	0.037
		Amnicola limosa	-0.392	0.047
		Ancylidae	0.398	0.043
	Dissolved Oxygen	Amnicola limosa	-0.421	0.031
		Amphipoda	-0.608	0.000
	Hardness	Gyraulus parvus	-0.458	0.018
		Amphipoda	-0.437	0.025
	Coliforms	Physa gyrina	0.491	0.010
		Amnicola limosa	0.617	0.000
Waccabuc	Air Temperature	Physa gyrina	0.396	0.045
		Chironomidae	0.389	0.048
		Amphipoda	0.440	0.024
	Water Temperature	Physa gyrina	0.436	0.025
		Chironomidae	0.424	0.030
		Amphipoda	0.474	0.014
	Dissolved Oxygen	Physa gyrina	-0.391	0.048
		Gyraulus parvus	-0.482	0.012
	Hardness	Physa gyrina	-0.399	0.043
		Helisoma trivolvis	-0.439	0.024
All Lakes	Physa gyrina	Fine Gravel	1	0
	Physa gyrina	Number of structures	1	0
	Physa gyrina	Number storm drains	1	0
	Physa heterostropha	Coarse Sand	-1	0
	Helisoma trivolvis	Nitrates	1	0
	Helisoma trivolvis	Silt	1	0
	Succinea campestris	Silt	1	0
	Lymneaidae.	Percent carbonates	-1	0
	Lymnaeidae	Very Fine Sand	1	0
	Lymnaeidae	Phosphorous Loading	-1	0

	Planorbis sp.	Fine Sand	-1	0
	Planorbis sp.	Number of structures	1	0
	Planorbis sp.	Storm Drains	1	0
	Promenetus exacuous	Percent organic matter	1	0
	Insecta	Nitrates	1	0
	Insecta	Silt	1	0
All Lakes	Chironomidae	Nitrates	1	0
	Chironomidae	Silt	1	0
	Ephemeroptera	%Developed Land	1	0
	Secchi Depth	Plecoptera	-0.383	0.003
	Coliforms	Ephemeroptera	0.303	0.023
	Coliforms	Trichoptera	0.297	0.025
	Dissolved Oxygen	Ephemeroptera	-0.348	0.008
	Water Temperature	Ephemeroptera	0.317	0.017
	Air Temperature	Ephemeroptera	0.294	0.027

Appendix B – Table 1: Number of Taxa Per Month for 2009-2010

Lake	April	May	June	July	August	September	October
Kitchawan ‘09	13	6	10	9	19	12	13
Oscaleta ‘09	10	3	9	12	12	7	6
Rippowam‘09	6	8	6	7	3	7	7
Waccabuc ‘09	9	8	8	13	6	11	10
Kitchawan ‘10	13	10	15	11	11	14	12
Oscaleta ‘10	7	12	13	10	12	8	11
Rippowam ‘10	11	7	12	4	11	10	13
Waccabuc ‘10	7	9	10	7	9	5	9

Appendix B - Table 2: Summary of Data for Diversity Index Calculations for 2009-2010

Lake	Taxa 2009	Abundance 2010	Taxa 2010	Abundance 2010	Combined 2009-10 Taxa	Combined 2009-10 Abundance	Margalef’s R Combined 2009-2010
Kitchawan	156	1102	190	1067	344	2169	44.7
Oscaleta	137	362	89	696	226	1058	32.3
Rippowam	72	434	130	594	201	1028	28.9
Waccabuc	132	355	82	230	214	585	33.4

Appendix B – Table 3: Composite Sample Data and Average Species Richness for Each Lake (Beta Diversity = Total number of species /Avg number species per sampling unit, McCune and Grace, p38)

Lake	Total number of species	Avg species/s.u.	Beta Diversity
Kitchawan	168	14	11.0
Oscaleta	138.8	11	11.6
Rippowam	112	9.3	11.04
Waccabuc	121	10.1	10.98

*Average number of species per sample unit

Appendix B – Table 4: One-way ANOVA on Differences in Physicochemical Variables Between Lakes α=0.05

Variable	F	DF	p-value
pH	4.77	3	0.004
ECS	29.10	3	0.0001
TDS	24.40	3	0.0001
Total Hardness	7.02	3	0.0002
$^{+}$	9.68	3	0.0001

Appendix B – Table 5: One-way ANOVA Taxa by Physicochemical Variables α=0.05

Variables	F	DF	p-value
Ephemeropt/PLoading	142.90	3	0.006
Ephemertopt/Storm Dr	20.09	3	0.046
Ephemeropt/%DevLand	3240.10	3	0.0003
Macrophyte/Run-off	25.21	3	0.037
Physagyr/Structures	31.34	3	0.030
Lymnaeids/P_Loading	18.79	3	0.049

Appendix C – Tables of Taxa

Table 1	**Other Benthic Taxa**				
Taxa	Common Name	Kitchawan	Waccabuc	Oscaleta	Rippowam
Amphipoda		206	238	208	345
Hirudinae	Leeches	9	5	9	13
Annelidae	Worms (var.)	22	29	22	23
Chironomidae	Midge Flies	724	1111	397	607
Coleoptera	Aquatic Beetles	68	30	11	7
Copepoda		71	182	108	42
Hemiptera/Megaloptera	Other Insects	298	48	30	29
Ephemeroptera	Mayflies	53	62	14	19
Isopoda		90	20	8	65
Odonata	Dragon/Damselflies	74	26	39	17
Ostracoda		53	327	113	131
Plecoptera	Stoneflies	57	17	0	7
Ranidae	Frogs	19	4	1	0
Trichoptera	Caddisflies	11	1030	9	48
TOTAL		1755	3129	969	1353

Appendix C - Table 2

Molluscan Taxa		Common Name
Planorbidae		
	Gyraulus parvus	Ash Gyro
	Gyraulus deflectus	Flexed Gyro
	Helisoma trivolvis	Marsh Rams-Horn
	Micromenetus dilatatus	Bugle Sprite
	Planorbis sp.	Rams-Horn
	Promenetus exacuous	Sharp Sprite
Physidae		
	Physa sp.	Tadpole or Pewter Physa
Hydrobiidae		
	Amnicola grana	Squat Dusky Snail
	Amnicola limosa	Mud Amnicola
Lymneaidae		
	Stagnicola elodes.	Marsh Pond Snail
	Fossaria rustica	Country Fossaria
Succineaidae		
	Succinea campestris	Crinkled Amber Snail
Ancylidae		
	Ferrissia sp.	Cloche or Oblong Ancylid
Corbiculoidiae		
	Sphaerium or Pisidium	Pea Clams
Unionidae	*Margaritifera sp.*	Pearl Musssels

Appendix C Table 3 Raw Data

Lake	Jar#	Date	Month	Physa gyrir	Physa hete	G parvus	G deflectus	Planorbis
Waccabuc	1	4/14/2009	April	1	0	0	0	0
Waccabuc	2	4/14/2009	April	0	0	0	0	0
Waccabuc	1	4/29/2009	April	2	0	0	0	0
Waccabuc	2	4/29/2009	April	0	0	0	0	0
Waccabuc	3	4/29/2009	April	1	0	0	0	0
Waccabuc	1	5/13/2009	May	1	0	0	0	0
Waccabuc	2	5/13/2009	May	0	0	1	0	0
Waccabuc	3	5/13/2009	May	3	0	0	0	0
Waccabuc	1	6/1/2009	June	0	0	0	0	0
Waccabuc	2	6/1/2009	June	9	0	0	0	0
Waccabuc	3	6/1/2009	June	4	0	2	0	0
Waccabuc	1	6/16/2009	June	1	0	1	0	0
Waccabuc	2	6/16/2009	June	2	0	0	0	0
Waccabuc	3	6/16/2009	June	7	0	1	0	0
Waccabuc	1	7/10/2009	July	2	0	4	0	0
Waccabuc	2	7/10/2009	July	7	0	0	3	0
Waccabuc	3	7/10/2009	July	7	0	0	0	60
Waccabuc	1	7/22/2009	July	0	0	1	0	0
Waccabuc	2	7/22/2009	July	11	0	1	0	0
Waccabuc	3	7/22/2009	July	0	0	1	0	0
Waccabuc	1	8/10/2009	August	2	0	0	0	0
Waccabuc	2	8/10/2009	August	6	0	0	0	0
Waccabuc	3	8/10/2009	August	18	0	0	0	0
Waccabuc	1	8/24/2009	August	4	0	1	0	0
Waccabuc	2	8/24/2009	August	1	0	2	0	0
Waccabuc	3	8/24/2009	August	2	0	3	0	0
Waccabuc	1	9/12/2009	September	3	0	0	0	0
Waccabuc	2	9/12/2009	September	3	0	0	2	0
Waccabuc	3	9/12/2009	September	1	0	0	0	0
Waccabuc	1	9/22/2009	September	6	0	0	0	0
Waccabuc	2	9/22/2009	September	9	0	5	0	0
Waccabuc	3	9/22/2009	September	9	0	4	0	0
Waccabuc	1	10/6/2009	October	4	0	3	0	0
Waccabuc	2	10/6/2009	October	1	0	0	0	0
Waccabuc	3	10/6/2009	October	13	0	4	0	1
Waccabuc	1	#########	October	4	0	0	0	0
Waccabuc	2	#########	October	3	0	2	0	0
Waccabuc	3	#########	October	5	0	1	2	0
Rippowam	1	4/14/2009	April	0	0	0	0	0
Rippowam	2	4/14/2009	April	0	0	0	0	0
Rippowam	1	4/29/2009	April	0	0	0	0	0
Rippowam	2	4/29/2009	April	0	0	0	0	0
Rippowam	3	4/29/2009	April	0	1	0	0	0
Rippowam	1	5/13/2009	May	0	0	0	0	0
Rippowam	2	5/13/2009	May	0	0	1	0	0
Rippowam	3	5/13/2009	May	0	0	0	0	0

Rippowam	1	6/1/2009	June	0	0	0	0	0
Rippowam	2	6/1/2009	June	0	0	0	0	0
Rippowam	3	6/1/2009	June	0	0	0	0	0
Rippowam	1	6/16/2009	June	0	0	0	0	0
Rippowam	2	6/16/2009	June	0	0	3	0	0
Rippowam	3	6/16/2009	June	0	0	0	0	0
Rippowam	1	7/10/2009	July	0	0	0	0	0
Rippowam	2	7/10/2009	July	0	0	0	0	0
Rippowam	3	7/10/2009	July	0	0	0	0	0
Rippowam	1	7/27/2009	July	0	0	0	0	0
Rippowam	2	7/27/2009	July	0	0	0	0	0
Rippowam	3	7/27/2009	July	0	0	1	0	0
Rippowam	1	8/10/2009	August	0	0	0	0	0
Rippowam	2	8/10/2009	August	0	0	0	0	0
Rippowam	3	8/10/2009	August	0	0	0	0	0
Rippowam	1	8/24/2009	August	0	0	0	0	0
Rippowam	2	8/24/2009	August	0	0	0	0	0
Rippowam	3	8/24/2009	August	0	0	0	0	0
Rippowam	1	9/12/2009	September	0	0	0	0	0
Rippowam	2	9/12/2009	September	0	0	0	0	0
Rippowam	3	9/12/2009	September	0	0	0	0	0
Rippowam	1	9/22/2009	September	0	0	0	0	0
Rippowam	2	9/22/2009	September	0	0	0	0	0
Rippowam	3	9/22/2009	September	0	0	0	0	0
Rippowam	1	10/6/2009	October	0	0	0	0	0
Rippowam	2	10/6/2009	October	0	0	0	0	0
Rippowam	3	10/6/2009	October	0	0	0	0	0
Rippowam	1	#########	October	0	0	0	0	0
Rippowam	2	#########	October	0	0	0	0	0
Rippowam	3	#########	October	1	0	0	0	0
Oscaleta	1	4/14/2009	April	4	0	0	0	0
Oscaleta	2	4/14/2009	April	0	0	0	0	0
Oscaleta	1	4/29/2009	April	0	0	0	0	0
Oscaleta	2	4/29/2009	April	0	0	2	0	0
Oscaleta	3	4/29/2009	April	3	0	0	0	0
Oscaleta	1	5/13/2009	May	0	0	0	0	0
Oscaleta	2	5/13/2009	May	0	0	0	0	0
Oscaleta	3	5/13/2009	May	0	0	0	0	0
Oscaleta	1	6/1/2009	June	0	0	1	0	0
Oscaleta	2	6/1/2009	June	0	0	0	0	0
Oscaleta	3	6/1/2009	June	0	0	0	0	0
Oscaleta	1	6/16/2009	June	0	2	2	0	0
Oscaleta	2	6/16/2009	June	1	0	0	0	0
Oscaleta	3	6/16/2009	June	0	0	3	0	0
Oscaleta	1	7/10/2009	July	0	6	0	4	0
Oscaleta	2	7/10/2009	July	10	0	11	1	0
Oscaleta	3	7/10/2009	July	4	0	6	0	0

Oscaleta	1	7/27/2009	July	0	0	4	0	0
Oscaleta	2	7/27/2009	July	1	0	0	0	0
Oscaleta	3	7/27/2009	July	4	0	5	0	0
Oscaleta	1	8/10/2009	August	3	0	2	0	1
Oscaleta	2	8/10/2009	August	2	0	0	3	0
Oscaleta	3	8/10/2009	August	0	0	0	0	0
Oscaleta	1	8/24/2009	August	3	0	0	8	0
Oscaleta	2	8/24/2009	August	0	0	0	0	0
Oscaleta	3	8/24/2009	August	3	0	0	1	0
Oscaleta	1	9/12/2009	September	0	0	0	0	0
Oscaleta	2	9/12/2009	September	0	0	2	0	0
Oscaleta	3	9/12/2009	September	0	0	0	0	0
Oscaleta	1	9/22/2009	September	0	0	0	0	0
Oscaleta	2	9/22/2009	September	1	0	10	3	0
Oscaleta	3	9/22/2009	September	0	0	0	0	0
Oscaleta	1	10/6/2009	October	0	0	2	0	0
Oscaleta	2	10/6/2009	October	0	0	0	0	0
Oscaleta	3	10/6/2009	October	0	0	1	0	0
Oscaleta	1	#########	October	1	0	1	0	0
Oscaleta	2	#########	October	1	0	3	0	0
Oscaleta	3	#########	October	1	0	0	0	0
Kitchawan	1	4/27/2009	April	0	0	2	0	0
Kitchawan	2	4/27/2009	April	0	0	0	1	0
Kitchawan	3	4/27/2009	April	2	0	0	0	0
Kitchawan	1	5/13/2009	May	3	0	0	0	0
Kitchawan	2	5/13/2009	May	0	0	0	0	0
Kitchawan	3	5/13/2009	May	3	0	0	0	0
Kitchawan	1	6/1/2009	June	9	0	0	0	0
Kitchawan	2	6/1/2009	June	0	0	0	0	0
Kitchawan	3	6/1/2009	June	12	0	5	0	0
Kitchawan	1	6/16/2009	June	0	0	1	0	0
Kitchawan	2	6/16/2009	June	1	0	0	1	0
Kitchawan	3	6/16/2009	June	5	0	3	0	0
Kitchawan	1	7/10/2009	July	0	0	0	0	0
Kitchawan	2	7/10/2009	July	0	0	2	0	0
Kitchawan	3	7/10/2009	July	9	0	0	0	0
Kitchawan	1	7/27/2009	July	11	0	1	0	0
Kitchawan	2	7/27/2009	July	0	0	1	0	0
Kitchawan	3	7/27/2009	July	4	0	0	0	1
Kitchawan	1	8/10/2009	August	2	0	1	0	0
Kitchawan	2	8/10/2009	August	3	0	2	1	0
Kitchawan	3	8/10/2009	August	6	0	0	2	0
Kitchawan	1	8/24/2009	August	9	0	0	0	0
Kitchawan	2	8/24/2009	August	3	0	0	0	0
Kitchawan	3	8/24/2009	August	4	0	4	0	0
Kitchawan	1	9/12/2009	September	1	0	2	0	0
Kitchawan	2	9/12/2009	September	2	0	0	0	0

Kitchawan	3	9/12/2009	September	1	1	2	0	0
Kitchawan	1	9/22/2009	September	2	0	1	0	0
Kitchawan	2	9/22/2009	September	1	0	0	0	0
Kitchawan	3	9/22/2009	September	0	0	4	0	0
Kitchawan	1	10/6/2009	October	1	0	0	0	0
Kitchawan	2	10/6/2009	October	13	0	5	0	0
Kitchawan	3	10/6/2009	October	0	0	0	13	0
Kitchawan	1	#########	October	0	0	0	0	0
Kitchawan	2	#########	October	0	0	0	0	0
Kitchawan	3	#########	October	1	0	0	0	0
Waccabuc	1	4/15/2010	April	0	0	0	0	0
Waccabuc	2	4/15/2010	April	1	1	0	0	0
Waccabuc	3	4/15/2010	April	2	0	3	0	1
Waccabuc	1	4/28/2010	April	6	0	5	0	0
Waccabuc	2	4/28/2010	April	2	0	1	0	0
Waccabuc	3	4/28/2010	April	1	0	0	0	0
Waccabuc	1	5/6/2010	May	1	0	0	0	0
Waccabuc	2	5/6/2010	May	6	0	0	0	0
Waccabuc	3	5/6/2010	May	0	0	2	0	0
Waccabuc	1	5/24/2010	May	2	0	6	0	0
Waccabuc	2	5/24/2010	May	3	0	4	0	0
Waccabuc	3	5/24/2010	May	0	0	2	0	0
Waccabuc	1	6/4/2010	June	0	6	1	0	0
Waccabuc	2	6/4/2010	June	0	32	9	0	0
Waccabuc	3	6/4/2010	June	0	12	4	0	0
Waccabuc	1	6/21/2010	June	0	4	0	0	0
Waccabuc	2	6/21/2010	June	0	14	6	0	0
Waccabuc	3	6/21/2010	June	0	12	3	0	0
Waccabuc	1	7/9/2010	July	0	7	3	0	0
Waccabuc	2	7/9/2010	July	0	2	3	0	0
Waccabuc	3	7/9/2010	July	0	0	1	0	0
Waccabuc	1	7/20/2010	July	0	39	19	1	1
Waccabuc	2	7/20/2010	July	0	2	0	0	0
Waccabuc	3	7/20/2010	July	0	18	2	1	0
Waccabuc	1	8/5/2010	August	6	0	1	0	0
Waccabuc	2	8/5/2010	August	0	9	5	0	0
Waccabuc	3	8/5/2010	August	4	0	8	0	0
Waccabuc	1	8/18/2010	August	0	1	0	0	0
Waccabuc	2	8/18/2010	August	0	0	1	0	0
Waccabuc	3	8/18/2010	August	0	1	0	0	0
Waccabuc	1	9/7/2010	September	8	0	1	1	0
Waccabuc	2	9/7/2010	September	6	0	2	1	0
Waccabuc	3	9/7/2010	September	0	0	2	0	0
Waccabuc	1	9/20/2010	September	5	0	0	0	0
Waccabuc	2	9/20/2010	September	4	0	0	0	0
Waccabuc	3	9/20/2010	September	0	0	0	0	0
Waccabuc	1	10/4/2010	October	3	0	13	0	0

Waccabuc	2	10/4/2010	October	4	0	4	1	1
Waccabuc	3	10/4/2010	October	0	0	0	0	0
Rippowam	1	4/15/2010	April	0	0	1	1	0
Rippowam	2	4/15/2010	April	0	0	0	0	0
Rippowam	3	4/15/2010	April	0	0	0	0	0
Rippowam	1	4/28/2010	April	0	0	0	1	0
Rippowam	2	4/28/2010	April	0	0	0	0	0
Rippowam	3	4/28/2010	April	0	0	0	0	0
Rippowam	1	5/6/2010	May	0	0	0	0	0
Rippowam	2	5/6/2010	May	0	0	0	0	0
Rippowam	3	5/6/2010	May	0	0	0	0	0
Rippowam	1	5/24/2010	May	0	0	0	12	0
Rippowam	2	5/24/2010	May	0	3	0	2	0
Rippowam	3	5/24/2010	May	0	1	0	1	0
Rippowam	1	6/4/2010	June	0	6	0	12	0
Rippowam	2	6/4/2010	June	0	9	0	6	0
Rippowam	3	6/4/2010	June	0	1	0	0	0
Rippowam	1	6/21/2010	June	0	2	7	1	0
Rippowam	2	6/21/2010	June	0	1	0	0	0
Rippowam	3	6/21/2020	June	0	0	1	0	0
Rippowam	1	7/9/2010	July	0	0	0	0	0
Rippowam	2	7/9/2010	July	0	0	0	0	0
Rippowam	3	7/9/2010	July	0	0	0	0	0
Rippowam	1	7/20/2010	July	0	0	0	0	0
Rippowam	2	7/20/2010	July	0	0	0	0	0
Rippowam	3	7/20/2010	July	0	0	0	0	0
Rippowam	1	8/5/2010	August	0	0	2	2	0
Rippowam	2	8/5/2010	August	0	0	0	0	0
Rippowam	3	8/5/2010	August	0	2	0	0	0
Rippowam	1	8/18/2010	August	0	0	0	0	0
Rippowam	2	8/18/2010	August	0	0	0	1	0
Rippowam	3	8/18/2010	August	0	0	0	0	0
Rippowam	1	9/7/2010	September	2	0	0	0	0
Rippowam	2	9/7/2010	September	0	0	0	0	0
Rippowam	3	9/7/2010	September	0	0	0	0	0
Rippowam	1	9/20/2010	September	0	0	1	0	0
Rippowam	2	9/20/2010	September	0	0	1	0	0
Rippowam	3	9/20/2010	September	0	0	0	0	0
Rippowam	1	10/4/2010	October	1	0	5	0	0
Rippowam	2	10/4/2010	October	0	0	0	0	0
Rippowam	3	10/4/2010	October	0	0	0	0	0
Oscaleta	1	4/15/2010	April	0	0	3	0	0
Oscaleta	2	4/15/2010	April	0	0	2	0	0
Oscaleta	3	4/15/2010	April	0	0	1	0	0
Oscaleta	1	4/28/2010	April	0	0	0	2	0
Oscaleta	2	4/28/2010	April	0	0	0	0	0
Oscaleta	3	4/28/2010	April	0	0	0	1	0

Oscaleta	1	5/6/2010	May	0	1	0	2	0
Oscaleta	2	5/6/2010	May	0	1	0	0	0
Oscaleta	3	5/6/2010	May	0	17	0	29	0
Oscaleta	1	5/24/2010	May	0	0	0	12	0
Oscaleta	2	5/24/2010	May	0	3	0	2	0
Oscaleta	3	5/24/2010	May	0	1	0	1	0
Oscaleta	2	6/4/2010	June	0	36	16	24	0
Oscaleta	3	6/4/2010	June	0	17	0	29	0
Oscaleta	1	6/4/2010	June	0	0	0	0	0
Oscaleta	1	6/21/2010	June	0	19	16	2	0
Oscaleta	2	6/21/2010	June	0	4	26	0	0
Oscaleta	3	6/21/2010	June	0	5	5	0	0
Oscaleta	1	7/9/2010	July	0	18	9	10	0
Oscaleta	2	7/9/2010	July	0	3	0	4	0
Oscaleta	3	7/9/2010	July	0	4	3	0	0
Oscaleta	1	7/20/2010	July	0	0	2	1	0
Oscaleta	2	7/20/2010	July	0	5	3	7	0
Oscaleta	3	7/20/2010	July	0	0	1	1	0
Oscaleta	1	8/5/2010	August	6	0	1	23	0
Oscaleta	2	8/5/2010	August	0	2	0	0	0
Oscaleta	3	8/5/2010	August	0	2	0	2	0
Oscaleta	1	8/18/2010	August	0	0	0	2	0
Oscaleta	2	8/18/2010	August	0	0	0	0	0
Oscaleta	3	8/18/2010	August	0	0	0	0	0
Oscaleta	1	9/7/2010	September	0	0	0	0	0
Oscaleta	2	9/7/2010	September	1	0	0	0	0
Oscaleta	3	9/7/2010	September	1	0	3	4	0
Oscaleta	1	9/20/2010	September	1	0	0	1	0
Oscaleta	2	9/20/2010	September	0	0	1	0	0
Oscaleta	3	9/20/2010	September	0	0	1	0	0
Oscaleta	1	10/4/2010	October	0	0	0	0	1
Oscaleta	2	10/4/2010	October	1	0	2	1	0
Oscaleta	3	10/4/2010	October	1	0	1	0	0
Kitchawan	1	4/15/2010	April	0	0	0	3	0
Kitchawan	2	4/15/2010	April	0	1	0	0	0
Kitchawan	3	4/15/2010	April	0	0	0	0	0
Kitchawan	1	4/28/2010	April	1	0	0	0	0
Kitchawan	2	4/28/2010	April	0	0	0	0	0
Kitchawan	3	4/28/2010	April	0	0	0	0	0
Kitchawan	1	5/6/2010	May	0	0	0	0	0
Kitchawan	2	5/6/2010	May	2	0	0	3	0
Kitchawan	3	5/6/2010	May	0	0	0	0	0
Kitchawan	1	5/24/2010	May	0	8	0	9	0
Kitchawan	2	5/24/2010	May	24	0	12	26	0
Kitchawan	3	5/24/2010	May	0	16	0	17	0
Kitchawan	1	6/4/2010	June	0	32	3	16	0
Kitchawan	2	6/4/2010	June	0	11	21	0	0

Kitchawan	3	6/4/2010	June	0	15	9	0	0
Kitchawan	1	6/21/2010	June	0	2	7	0	0
Kitchawan	2	6/21/2010	June	0	32	18	14	0
Kitchawan	3	6/21/2010	June	0	44	20	0	0
Kitchawan	1	7/9/2010	July	0	9	3	0	0
Kitchawan	2	7/9/2010	July	0	4	0	1	0
Kitchawan	3	7/9/2010	July	0	6	4	7	0
Kitchawan	1	7/20/2010	July	0	6	10	8	0
Kitchawan	2	7/20/2010	July	0	10	6	0	4
Kitchawan	3	7/20/2010	July	0	0	1	0	0
Kitchawan	1	8/5/2010	August	0	5	1	4	0
Kitchawan	2	8/5/2010	August	0	0	3	0	0
Kitchawan	3	8/5/2010	August	0	1	7	0	0
Kitchawan	1	8/18/2010	August	0	0	0	0	0
Kitchawan	2	8/18/2010	August	3	0	3	0	0
Kitchawan	3	8/18/2010	August	0	1	0	0	0
Kitchawan	1	9/7/2010	September	6	0	12	17	0
Kitchawan	2	9/7/2010	September	1	0	7	0	0
Kitchawan	3	9/7/2010	September	2	0	1	0	0
Kitchawan	1	9/20/2010	September	0	0	2	0	0
Kitchawan	2	9/20/2010	September	0	0	3	0	0
Kitchawan	3	9/20/2010	September	2	0	4	0	0
Kitchawan	1	10/4/2010	October	4	0	3	2	0
Kitchawan	2	10/4/2010	October	0	7	2	1	0
Kitchawan	3	10/4/2010	October	0	0	2	0	0

Lake	Jar#	Date	Month	P exacuous	Helisoma	A limosa	A grana	Succinea
Waccabuc	1	4/14/2009	April	0	0	0	1	0
Waccabuc	2	4/14/2009	April	0	0	1	0	0
Waccabuc	1	4/29/2009	April	0	0	0	0	0
Waccabuc	2	4/29/2009	April	0	0	0	0	0
Waccabuc	3	4/29/2009	April	0	0	1	0	0
Waccabuc	1	5/13/2009	May	0	0	0	0	0
Waccabuc	2	5/13/2009	May	0	0	0	0	0
Waccabuc	3	5/13/2009	May	0	0	0	0	0
Waccabuc	1	6/1/2009	June	0	1	0	0	0
Waccabuc	2	6/1/2009	June	0	0	0	0	0
Waccabuc	3	6/1/2009	June	0	1	0	0	0
Waccabuc	1	6/16/2009	June	0	0	0	0	0
Waccabuc	2	6/16/2009	June	0	0	0	0	0
Waccabuc	3	6/16/2009	June	0	0	0	1	0
Waccabuc	1	7/10/2009	July	0	2	0	0	0
Waccabuc	2	7/10/2009	July	0	0	2	0	0
Waccabuc	3	7/10/2009	July	0	0	0	0	0
Waccabuc	1	7/22/2009	July	0	0	0	0	0
Waccabuc	2	7/22/2009	July	0	0	0	0	0
Waccabuc	3	7/22/2009	July	0	0	0	0	0
Waccabuc	1	8/10/2009	August	0	0	0	0	0
Waccabuc	2	8/10/2009	August	0	0	3	0	0
Waccabuc	3	8/10/2009	August	0	1	4	0	0
Waccabuc	1	8/24/2009	August	0	1	0	2	0
Waccabuc	2	8/24/2009	August	0	0	0	0	0
Waccabuc	3	8/24/2009	August	0	0	4	0	0
Waccabuc	1	9/12/2009	September	0	0	4	0	0
Waccabuc	2	9/12/2009	September	0	0	10	0	0
Waccabuc	3	9/12/2009	September	0	0	1	0	0
Waccabuc	1	9/22/2009	September	0	0	1	0	0
Waccabuc	2	9/22/2009	September	0	1	4	0	0
Waccabuc	3	9/22/2009	September	0	0	4	0	0
Waccabuc	1	10/6/2009	October	0	0	2	0	0
Waccabuc	2	10/6/2009	October	0	0	1	0	0
Waccabuc	3	10/6/2009	October	0	0	1	0	0
Waccabuc	1	#########	October	0	0	0	0	0
Waccabuc	2	#########	October	0	0	8	0	0
Waccabuc	3	#########	October	0	0	2	0	1
Rippowam	1	4/14/2009	April	0	0	0	0	0
Rippowam	2	4/14/2009	April	0	0	0	0	0
Rippowam	1	4/29/2009	April	0	0	0	0	0
Rippowam	2	4/29/2009	April	0	0	0	0	0
Rippowam	3	4/29/2009	April	0	0	0	0	0
Rippowam	1	5/13/2009	May	0	0	0	1	0
Rippowam	2	5/13/2009	May	0	0	2	0	0
Rippowam	3	5/13/2009	May	0	0	0	0	0

Rippowam	1	6/1/2009	June	0	0	1	0	0
Rippowam	2	6/1/2009	June	0	0	0	0	0
Rippowam	3	6/1/2009	June	0	0	0	0	0
Rippowam	1	6/16/2009	June	0	0	2	0	0
Rippowam	2	6/16/2009	June	0	0	0	1	0
Rippowam	3	6/16/2009	June	0	0	0	0	0
Rippowam	1	7/10/2009	July	0	0	0	0	0
Rippowam	2	7/10/2009	July	0	0	0	0	0
Rippowam	3	7/10/2009	July	0	0	0	0	0
Rippowam	1	7/27/2009	July	0	0	0	0	1
Rippowam	2	7/27/2009	July	0	1	0	0	0
Rippowam	3	7/27/2009	July	0	0	0	0	0
Rippowam	1	8/10/2009	August	0	0	0	0	0
Rippowam	2	8/10/2009	August	0	0	0	0	0
Rippowam	3	8/10/2009	August	0	0	0	0	0
Rippowam	1	8/24/2009	August	0	0	0	0	0
Rippowam	2	8/24/2009	August	0	0	0	0	0
Rippowam	3	8/24/2009	August	0	0	0	0	0
Rippowam	1	9/12/2009	September	0	0	0	0	0
Rippowam	2	9/12/2009	September	0	0	0	0	0
Rippowam	3	9/12/2009	September	0	0	0	0	0
Rippowam	1	9/22/2009	September	0	0	0	0	0
Rippowam	2	9/22/2009	September	0	0	5	1	0
Rippowam	3	9/22/2009	September	0	0	0	0	0
Rippowam	1	10/6/2009	October	0	0	2	0	0
Rippowam	2	10/6/2009	October	0	0	9	0	0
Rippowam	3	10/6/2009	October	0	0	0	0	0
Rippowam	1	#########	October	0	0	2	2	0
Rippowam	2	#########	October	0	0	2	0	0
Rippowam	3	#########	October	0	0	1	0	0
Oscaleta	1	4/14/2009	April	0	0	0	0	0
Oscaleta	2	4/14/2009	April	0	0	0	0	0
Oscaleta	1	4/29/2009	April	0	0	0	0	0
Oscaleta	2	4/29/2009	April	0	0	0	0	0
Oscaleta	3	4/29/2009	April	0	0	0	0	0
Oscaleta	1	5/13/2009	May	0	0	0	0	0
Oscaleta	2	5/13/2009	May	0	0	0	0	0
Oscaleta	3	5/13/2009	May	0	0	0	0	0
Oscaleta	1	6/1/2009	June	0	0	0	0	0
Oscaleta	2	6/1/2009	June	0	0	0	3	0
Oscaleta	3	6/1/2009	June	0	0	0	0	0
Oscaleta	1	6/16/2009	June	0	0	0	0	0
Oscaleta	2	6/16/2009	June	0	0	0	0	0
Oscaleta	3	6/16/2009	June	0	0	0	0	0
Oscaleta	1	7/10/2009	July	0	0	0	0	0
Oscaleta	2	7/10/2009	July	0	0	0	0	0
Oscaleta	3	7/10/2009	July	0	0	0	4	0

Oscaleta	1	7/27/2009	July	0	0	0	0	0
Oscaleta	2	7/27/2009	July	0	0	0	0	0
Oscaleta	3	7/27/2009	July	0	0	0	0	0
Oscaleta	1	8/10/2009	August	0	0	0	0	0
Oscaleta	2	8/10/2009	August	0	0	2	3	0
Oscaleta	3	8/10/2009	August	0	0	0	0	0
Oscaleta	1	8/24/2009	August	0	0	0	0	0
Oscaleta	2	8/24/2009	August	0	0	0	3	0
Oscaleta	3	8/24/2009	August	1	0	0	0	0
Oscaleta	1	9/12/2009	September	0	0	0	0	0
Oscaleta	2	9/12/2009	September	0	0	0	0	0
Oscaleta	3	9/12/2009	September	0	0	0	0	0
Oscaleta	1	9/22/2009	September	0	0	0	0	0
Oscaleta	2	9/22/2009	September	0	0	0	0	0
Oscaleta	3	9/22/2009	September	0	0	1	4	0
Oscaleta	1	10/6/2009	October	0	0	0	0	0
Oscaleta	2	10/6/2009	October	0	0	0	2	0
Oscaleta	3	10/6/2009	October	0	0	0	0	0
Oscaleta	1	#########	October	0	0	0	0	0
Oscaleta	2	#########	October	0	0	4	0	0
Oscaleta	3	#########	October	0	0	0	0	0
Kitchawan	1	4/27/2009	April	1	0	0	0	0
Kitchawan	2	4/27/2009	April	0	2	0	0	0
Kitchawan	3	4/27/2009	April	1	0	0	0	2
Kitchawan	1	5/13/2009	May	0	0	0	0	0
Kitchawan	2	5/13/2009	May	0	0	0	0	0
Kitchawan	3	5/13/2009	May	0	0	0	0	0
Kitchawan	1	6/1/2009	June	0	0	0	1	0
Kitchawan	2	6/1/2009	June	2	1	0	0	0
Kitchawan	3	6/1/2009	June	0	1	0	4	0
Kitchawan	1	6/16/2009	June	0	0	0	0	0
Kitchawan	2	6/16/2009	June	0	1	1	0	0
Kitchawan	3	6/16/2009	June	0	0	0	0	0
Kitchawan	1	7/10/2009	July	0	1	0	0	0
Kitchawan	2	7/10/2009	July	0	0	0	0	0
Kitchawan	3	7/10/2009	July	0	1	0	0	1
Kitchawan	1	7/27/2009	July	0	1	1	0	0
Kitchawan	2	7/27/2009	July	0	1	0	0	7
Kitchawan	3	7/27/2009	July	1	2	0	0	0
Kitchawan	1	8/10/2009	August	0	0	0	0	0
Kitchawan	2	8/10/2009	August	1	2	0	0	0
Kitchawan	3	8/10/2009	August	3	2	9	74	0
Kitchawan	1	8/24/2009	August	0	1	0	0	0
Kitchawan	2	8/24/2009	August	1	0	0	0	0
Kitchawan	3	8/24/2009	August	0	0	1	3	0
Kitchawan	1	9/12/2009	September	0	0	0	0	0
Kitchawan	2	9/12/2009	September	0	1	0	0	0

Kitchawan	3	9/12/2009	September	1	0	0	0	0
Kitchawan	1	9/22/2009	September	0	0	0	1	0
Kitchawan	2	9/22/2009	September	1	0	0	0	0
Kitchawan	3	9/22/2009	September	0	1	1	6	0
Kitchawan	1	10/6/2009	October	0	2	0	0	1
Kitchawan	2	10/6/2009	October	9	1	47	0	0
Kitchawan	3	10/6/2009	October	0	2	4	53	0
Kitchawan	1	#########	October	0	0	0	0	0
Kitchawan	2	#########	October	0	2	0	0	1
Kitchawan	3	#########	October	0	0	0	3	0
Waccabuc	1	4/15/2010	April	0	0	0	0	0
Waccabuc	2	4/15/2010	April	0	0	1	0	0
Waccabuc	3	4/15/2010	April	0	0	2	0	0
Waccabuc	1	4/28/2010	April	0	0	0	0	0
Waccabuc	2	4/28/2010	April	0	0	0	0	0
Waccabuc	3	4/28/2010	April	0	0	7	0	0
Waccabuc	1	5/6/2010	May	0	0	0	0	0
Waccabuc	2	5/6/2010	May	0	2	0	0	0
Waccabuc	3	5/6/2010	May	0	0	2	0	0
Waccabuc	1	5/24/2010	May	0	0	8	0	0
Waccabuc	2	5/24/2010	May	0	0	1	0	0
Waccabuc	3	5/24/2010	May	1	0	1	0	0
Waccabuc	1	6/4/2010	June	0	1	5	0	0
Waccabuc	2	6/4/2010	June	1	0	5	0	0
Waccabuc	3	6/4/2010	June	1	2	3	0	0
Waccabuc	1	6/21/2010	June	0	0	0	0	0
Waccabuc	2	6/21/2010	June	0	0	0	2	0
Waccabuc	3	6/21/2010	June	5	1	3	0	0
Waccabuc	1	7/9/2010	July	0	0	0	0	0
Waccabuc	2	7/9/2010	July	0	0	1	0	0
Waccabuc	3	7/9/2010	July	0	0	0	0	0
Waccabuc	1	7/20/2010	July	0	2	2	10	0
Waccabuc	2	7/20/2010	July	0	0	0	1	0
Waccabuc	3	7/20/2010	July	0	0	1	4	0
Waccabuc	1	8/5/2010	August	0	1	1	0	0
Waccabuc	2	8/5/2010	August	0	0	1	0	0
Waccabuc	3	8/5/2010	August	0	0	0	0	0
Waccabuc	1	8/18/2010	August	0	0	0	0	0
Waccabuc	2	8/18/2010	August	0	0	0	0	0
Waccabuc	3	8/18/2010	August	0	0	0	0	0
Waccabuc	1	9/7/2010	September	0	3	4	0	0
Waccabuc	2	9/7/2010	September	0	0	2	0	1
Waccabuc	3	9/7/2010	September	0	0	8	0	0
Waccabuc	1	9/20/2010	September	0	0	0	0	0
Waccabuc	2	9/20/2010	September	0	0	1	0	0
Waccabuc	3	9/20/2010	September	0	0	1	0	0
Waccabuc	1	10/4/2010	October	0	3	15	0	0

Waccabuc	2	10/4/2010	October	1	0	5	0	0
Waccabuc	3	10/4/2010	October	0	0	2	0	0
Rippowam	1	4/15/2010	April	0	0	5	0	0
Rippowam	2	4/15/2010	April	0	0	0	0	0
Rippowam	3	4/15/2010	April	0	0	0	0	0
Rippowam	1	4/28/2010	April	0	0	0	1	0
Rippowam	2	4/28/2010	April	0	0	0	0	0
Rippowam	3	4/28/2010	April	0	0	1	0	0
Rippowam	1	5/6/2010	May	0	0	4	0	0
Rippowam	2	5/6/2010	May	0	0	4	0	0
Rippowam	3	5/6/2010	May	0	0	0	0	0
Rippowam	1	5/24/2010	May	0	0	42	6	0
Rippowam	2	5/24/2010	May	0	0	0	8	0
Rippowam	3	5/24/2010	May	0	0	1	0	0
Rippowam	1	6/4/2010	June	0	0	3	0	0
Rippowam	2	6/4/2010	June	0	0	2	0	0
Rippowam	3	6/4/2010	June	0	0	1	0	0
Rippowam	1	6/21/2010	June	3	0	0	1	0
Rippowam	2	6/21/2010	June	0	0	2	0	0
Rippowam	3	6/21/2020	June	0	0	0	0	0
Rippowam	1	7/9/2010	July	0	0	0	0	0
Rippowam	2	7/9/2010	July	0	0	0	0	0
Rippowam	3	7/9/2010	July	0	0	0	0	0
Rippowam	1	7/20/2010	July	0	0	0	0	0
Rippowam	2	7/20/2010	July	0	0	0	0	0
Rippowam	3	7/20/2010	July	0	0	0	0	0
Rippowam	1	8/5/2010	August	0	1	2	28	0
Rippowam	2	8/5/2010	August	0	0	0	0	0
Rippowam	3	8/5/2010	August	0	0	0	0	0
Rippowam	1	8/18/2010	August	0	0	5	0	0
Rippowam	2	8/18/2010	August	0	0	24	0	0
Rippowam	3	8/18/2010	August	0	0	0	0	0
Rippowam	1	9/7/2010	September	0	3	8	0	0
Rippowam	2	9/7/2010	September	0	0	2	0	0
Rippowam	3	9/7/2010	September	0	0	0	0	0
Rippowam	1	9/20/2010	September	0	0	11	1	0
Rippowam	2	9/20/2010	September	0	0	1	0	0
Rippowam	3	9/20/2010	September	0	1	0	0	0
Rippowam	1	10/4/2010	October	0	3	12	0	0
Rippowam	2	10/4/2010	October	0	0	0	0	0
Rippowam	3	10/4/2010	October	0	0	0	0	0
Oscaleta	1	4/15/2010	April	0	0	0	0	0
Oscaleta	2	4/15/2010	April	0	0	0	2	0
Oscaleta	3	4/15/2010	April	0	0	0	0	0
Oscaleta	1	4/28/2010	April	0	0	0	0	0
Oscaleta	2	4/28/2010	April	0	0	0	0	0
Oscaleta	3	4/28/2010	April	0	0	0	0	0

Oscaleta	1	5/6/2010	May	0	0	0	0	0
Oscaleta	2	5/6/2010	May	0	0	0	0	0
Oscaleta	3	5/6/2010	May	0	0	9	0	0
Oscaleta	1	5/24/2010	May	0	0	42	6	0
Oscaleta	2	5/24/2010	May	0	0	8	6	0
Oscaleta	3	5/24/2010	May	0	0	1	0	0
Oscaleta	2	6/4/2010	June	0	0	1	0	0
Oscaleta	3	6/4/2010	June	2	0	40	0	0
Oscaleta	1	6/4/2010	June	0	0	0	0	0
Oscaleta	1	6/21/2010	June	0	0	1	0	0
Oscaleta	2	6/21/2010	June	1	0	0	0	0
Oscaleta	3	6/21/2010	June	0	0	0	0	0
Oscaleta	1	7/9/2010	July	0	0	2	0	0
Oscaleta	2	7/9/2010	July	0	0	3	0	0
Oscaleta	3	7/9/2010	July	0	0	0	0	0
Oscaleta	1	7/20/2010	July	0	0	3	0	0
Oscaleta	2	7/20/2010	July	2	0	1	0	0
Oscaleta	3	7/20/2010	July	0	0	0	1	0
Oscaleta	1	8/5/2010	August	0	0	0	52	0
Oscaleta	2	8/5/2010	August	0	0	0	0	0
Oscaleta	3	8/5/2010	August	0	0	1	2	0
Oscaleta	1	8/18/2010	August	0	0	1	0	0
Oscaleta	2	8/18/2010	August	0	0	0	0	0
Oscaleta	3	8/18/2010	August	0	0	0	5	0
Oscaleta	1	9/7/2010	September	1	0	0	2	0
Oscaleta	2	9/7/2010	September	0	0	0	0	0
Oscaleta	3	9/7/2010	September	0	2	15	0	0
Oscaleta	1	9/20/2010	September	0	0	6	6	0
Oscaleta	2	9/20/2010	September	0	0	12	3	0
Oscaleta	3	9/20/2010	September	0	0	2	0	0
Oscaleta	1	10/4/2010	October	0	0	2	0	0
Oscaleta	2	10/4/2010	October	0	0	2	0	0
Oscaleta	3	10/4/2010	October	0	0	0	0	0
Kitchawan	1	4/15/2010	April	0	0	1	0	0
Kitchawan	2	4/15/2010	April	0	0	1	0	0
Kitchawan	3	4/15/2010	April	0	1	0	0	0
Kitchawan	1	4/28/2010	April	0	0	0	0	0
Kitchawan	2	4/28/2010	April	0	0	0	0	0
Kitchawan	3	4/28/2010	April	0	0	0	0	0
Kitchawan	1	5/6/2010	May	0	0	0	0	0
Kitchawan	2	5/6/2010	May	0	0	0	0	0
Kitchawan	3	5/6/2010	May	0	0	0	0	0
Kitchawan	1	5/24/2010	May	0	1	56	0	0
Kitchawan	2	5/24/2010	May	8	0	0	50	0
Kitchawan	3	5/24/2010	May	0	6	3	0	1
Kitchawan	1	6/4/2010	June	3	10	8	0	0
Kitchawan	2	6/4/2010	June	1	2	33	0	0

Kitchawan	3	6/4/2010	June	0	6	44	3	0
Kitchawan	1	6/21/2010	June	0	12	14	0	0
Kitchawan	2	6/21/2010	June	6	10	13	0	0
Kitchawan	3	6/21/2010	June	0	4	0	22	0
Kitchawan	1	7/9/2010	July	0	1	0	0	0
Kitchawan	2	7/9/2010	July	0	1	1	0	0
Kitchawan	3	7/9/2010	July	1	4	8	0	0
Kitchawan	1	7/20/2010	July	3	5	0	0	0
Kitchawan	2	7/20/2010	July	0	4	0	0	0
Kitchawan	3	7/20/2010	July	0	1	2	0	0
Kitchawan	1	8/5/2010	August	0	8	1	0	0
Kitchawan	2	8/5/2010	August	0	3	1	0	0
Kitchawan	3	8/5/2010	August	2	3	0	0	0
Kitchawan	1	8/18/2010	August	0	11	0	0	0
Kitchawan	2	8/18/2010	August	0	15	2	0	0
Kitchawan	3	8/18/2010	August	0	6	0	0	0
Kitchawan	1	9/7/2010	September	0	16	19	0	0
Kitchawan	2	9/7/2010	September	0	10	0	5	0
Kitchawan	3	9/7/2010	September	0	4	1	0	0
Kitchawan	1	9/20/2010	September	0	4	0	0	0
Kitchawan	2	9/20/2010	September	0	15	6	0	0
Kitchawan	3	9/20/2010	September	0	8	4	0	0
Kitchawan	1	10/4/2010	October	1	0	2	0	1
Kitchawan	2	10/4/2010	October	0	0	1	0	3
Kitchawan	3	10/4/2010	October	0	0	0	0	0

Lake	Jar#	Date	Month	Secchi	pH	ECS	TDS	Sky
Waccabuc	1	4/14/2009	April	45	7.1	425	213	8
Waccabuc	2	4/14/2009	April	45	7.1	425	213	8
Waccabuc	1	4/29/2009	April	5	7.22	292	150	3
Waccabuc	2	4/29/2009	April	5	7.22	292	150	3
Waccabuc	3	4/29/2009	April	5	7.22	292	150	3
Waccabuc	1	5/13/2009	May	60	7.22	169	85	1
Waccabuc	2	5/13/2009	May	60	7.22	169	85	1
Waccabuc	3	5/13/2009	May	60	7.22	169	85	1
Waccabuc	1	6/1/2009	June	10	7.22	402	202	0
Waccabuc	2	6/1/2009	June	10	7.22	402	202	0
Waccabuc	3	6/1/2009	June	10	7.22	402	202	0
Waccabuc	1	6/16/2009	June	25	7.22	375	188	8
Waccabuc	2	6/16/2009	June	25	7.22	375	188	8
Waccabuc	3	6/16/2009	June	25	7.22	375	188	8
Waccabuc	1	7/10/2009	July	60	6.37	357	176	1
Waccabuc	2	7/10/2009	July	60	6.37	357	176	1
Waccabuc	3	7/10/2009	July	60	6.37	357	176	1
Waccabuc	1	7/22/2009	July	60	6.62	203	100	1
Waccabuc	2	7/22/2009	July	60	6.62	203	100	1
Waccabuc	3	7/22/2009	July	60	6.62	203	100	1
Waccabuc	1	8/10/2009	August	60	6.07	766	384	1
Waccabuc	2	8/10/2009	August	60	6.07	766	384	1
Waccabuc	3	8/10/2009	August	60	6.07	766	384	1
Waccabuc	1	8/24/2009	August	45	7.22	247	124	2
Waccabuc	2	8/24/2009	August	45	7.22	247	124	2
Waccabuc	3	8/24/2009	August	45	7.22	247	124	2
Waccabuc	1	9/12/2009	September	7.5	7.25	726	363	8
Waccabuc	2	9/12/2009	September	7.5	7.25	726	363	8
Waccabuc	3	9/12/2009	September	7.5	7.25	726	363	8
Waccabuc	1	9/22/2009	September	11.5	6.12	532	267	8
Waccabuc	2	9/22/2009	September	11.5	6.12	532	267	8
Waccabuc	3	9/22/2009	September	11.5	6.12	532	267	8
Waccabuc	1	10/6/2009	October	1	6.89	642	321	0
Waccabuc	2	10/6/2009	October	1	6.89	642	321	0
Waccabuc	3	10/6/2009	October	1	6.89	642	321	0
Waccabuc	1	#########	October	6	6.91	396	197	0
Waccabuc	2	#########	October	6	6.91	396	197	0
Waccabuc	3	#########	October	6	6.91	396	197	0
Rippowam	1	4/14/2009	April	47.8	7.1	240	120	8
Rippowam	2	4/14/2009	April	47.8	7.12	240	120	8
Rippowam	1	4/29/2009	April	60	7.12	191	95	3
Rippowam	2	4/29/2009	April	60	7.5	191	95	3
Rippowam	3	4/29/2009	April	60	7.5	191	95	3
Rippowam	1	5/13/2009	May	60	7	209	105	1
Rippowam	2	5/13/2009	May	60	7	209	105	1
Rippowam	3	5/13/2009	May	60	7	209	105	1

Rippowam	1	6/1/2009	June	52.8	6.64	235	119	1
Rippowam	2	6/1/2009	June	52.8	6.64	235	119	1
Rippowam	3	6/1/2009	June	52.8	6.64	235	119	1
Rippowam	1	6/16/2009	June	60	6.75	189	94	8
Rippowam	2	6/16/2009	June	60	6.75	189	94	8
Rippowam	3	6/16/2009	June	60	6.75	189	94	8
Rippowam	1	7/10/2009	July	60	7.21	218	110	1
Rippowam	2	7/10/2009	July	60	7.21	218	110	1
Rippowam	3	7/10/2009	July	60	7.21	218	110	1
Rippowam	1	7/27/2009	July	60	6.87	313	156	1
Rippowam	2	7/27/2009	July	60	6.87	313	156	1
Rippowam	3	7/27/2009	July	60	6.87	313	156	1
Rippowam	1	8/10/2009	August	11	7.32	284	143	1
Rippowam	2	8/10/2009	August	11	7.32	284	143	1
Rippowam	3	8/10/2009	August	11	7.32	284	143	1
Rippowam	1	8/24/2009	August	60	7.4	203	101	2
Rippowam	2	8/24/2009	August	60	7.4	203	101	2
Rippowam	3	8/24/2009	August	60	7.4	203	101	2
Rippowam	1	9/12/2009	September	60	7.35	200	100	8
Rippowam	2	9/12/2009	September	60	7.35	200	100	8
Rippowam	3	9/12/2009	September	60	7.35	200	100	8
Rippowam	1	9/22/2009	September	14.9	7.53	302	150	8
Rippowam	2	9/22/2009	September	14.9	7.53	302	150	8
Rippowam	3	9/22/2009	September	14.9	7.53	302	150	8
Rippowam	1	10/6/2009	October	26	6.96	350	173	0
Rippowam	2	10/6/2009	October	26	6.96	350	173	0
Rippowam	3	10/6/2009	October	26	6.96	350	173	0
Rippowam	1	#########	October	49.8	7.1	197	98	0
Rippowam	2	#########	October	49.8	7.1	197	98	0
Rippowam	3	#########	October	49.8	7.1	197	98	0
Oscaleta	1	4/14/2009	April	12	6.68	274	138	8
Oscaleta	2	4/14/2009	April	12	6.68	274	138	8
Oscaleta	1	4/29/2009	April	34.8	7.09	352	180	3
Oscaleta	2	4/29/2009	April	34.8	7.09	352	180	3
Oscaleta	3	4/29/2009	April	34.8	7.09	352	180	3
Oscaleta	1	5/13/2009	May	20	6.96	163	81	1
Oscaleta	2	5/13/2009	May	20	6.96	163	81	1
Oscaleta	3	5/13/2009	May	20	6.96	163	81	1
Oscaleta	1	6/1/2009	June	42.2	6.62	598	289	0
Oscaleta	2	6/1/2009	June	42.2	6.62	598	289	0
Oscaleta	3	6/1/2009	June	42.2	6.62	598	289	0
Oscaleta	1	6/16/2009	June	30	7.31	158	77	8
Oscaleta	2	6/16/2009	June	30	7.31	158	77	8
Oscaleta	3	6/16/2009	June	30	7.31	158	77	8
Oscaleta	1	7/10/2009	July	60	7.07	237	143	1
Oscaleta	2	7/10/2009	July	60	7.07	237	143	1
Oscaleta	3	7/10/2009	July	60	7.07	237	143	1

Oscaleta	1	7/27/2009	July	18.5	6.86	226	112	1
Oscaleta	2	7/27/2009	July	18.5	6.86	226	112	1
Oscaleta	3	7/27/2009	July	18.5	6.86	226	112	1
Oscaleta	1	8/10/2009	August	60	6.61	264	133	1
Oscaleta	2	8/10/2009	August	60	6.61	264	133	1
Oscaleta	3	8/10/2009	August	60	6.61	264	133	1
Oscaleta	1	8/24/2009	August	60	7.31	281	170	2
Oscaleta	2	8/24/2009	August	60	7.31	281	170	2
Oscaleta	3	8/24/2009	August	60	7.31	281	170	2
Oscaleta	1	9/12/2009	September	60	6.73	366	182	8
Oscaleta	2	9/12/2009	September	60	6.73	366	182	8
Oscaleta	3	9/12/2009	September	60	6.73	366	182	8
Oscaleta	1	9/22/2009	September	40	6.66	168	82	8
Oscaleta	2	9/22/2009	September	40	6.66	168	82	8
Oscaleta	3	9/22/2009	September	40	6.66	168	82	8
Oscaleta	1	10/6/2009	October	60	6.68	204	97	0
Oscaleta	2	10/6/2009	October	60	6.68	204	97	0
Oscaleta	3	10/6/2009	October	60	6.68	204	97	0
Oscaleta	1	#########	October	60	6.78	233	116	0
Oscaleta	2	#########	October	60	6.78	233	116	0
Oscaleta	3	#########	October	60	6.78	233	116	0
Kitchawan	1	4/27/2009	April	19	7.32	370	162	0
Kitchawan	2	4/27/2009	April	19	7.32	370	162	0
Kitchawan	3	4/27/2009	April	19	7.32	370	162	0
Kitchawan	1	5/13/2009	May	43.5	7.25	409	180	1
Kitchawan	2	5/13/2009	May	43.5	7.25	409	180	1
Kitchawan	3	5/13/2009	May	43.5	7.25	409	180	1
Kitchawan	1	6/1/2009	June	12	6.97	355	124	0
Kitchawan	2	6/1/2009	June	12	6.97	355	124	0
Kitchawan	3	6/1/2009	June	12	6.97	355	124	0
Kitchawan	1	6/16/2009	June	27	7.22	342	120	8
Kitchawan	2	6/16/2009	June	27	7.22	342	120	8
Kitchawan	3	6/16/2009	June	27	7.22	342	120	8
Kitchawan	1	7/10/2009	July	40	7.2	334	112	8
Kitchawan	2	7/10/2009	July	40	7.2	334	112	8
Kitchawan	3	7/10/2009	July	40	7.2	334	112	8
Kitchawan	1	7/27/2009	July	11	6.36	305	99	1
Kitchawan	2	7/27/2009	July	11	6.36	305	99	1
Kitchawan	3	7/27/2009	July	11	6.36	305	99	1
Kitchawan	1	8/10/2009	August	10	6.5	318	170	4
Kitchawan	2	8/10/2009	August	10	6.5	318	170	4
Kitchawan	3	8/10/2009	August	10	6.5	318	170	4
Kitchawan	1	8/24/2009	August	60	6.12	307	100	1
Kitchawan	2	8/24/2009	August	60	6.12	307	100	1
Kitchawan	3	8/24/2009	August	60	6.12	307	100	1
Kitchawan	1	9/12/2009	September	32	6.39	299	110	2
Kitchawan	2	9/12/2009	September	32	6.39	299	110	2

Kitchawan	3	9/12/2009	September	32	6.39	299	110	2
Kitchawan	1	9/22/2009	September	13.8	6.27	331	138	8
Kitchawan	2	9/22/2009	September	13.8	6.27	331	138	8
Kitchawan	3	9/22/2009	September	13.8	6.27	331	138	8
Kitchawan	1	10/6/2009	October	23.6	6.06	311	110	8
Kitchawan	2	10/6/2009	October	23.6	6.06	311	110	8
Kitchawan	3	10/6/2009	October	23.6	6.06	311	110	8
Kitchawan	1	#########	October	17.4	6.14	353	180	0
Kitchawan	2	#########	October	17.4	6.14	353	180	0
Kitchawan	3	#########	October	17.4	6.14	353	180	0
Waccabuc	1	4/15/2010	April	24.5	6.42	247	124	0
Waccabuc	2	4/15/2010	April	24.5	6.42	247	124	0
Waccabuc	3	4/15/2010	April	24.5	6.42	247	124	0
Waccabuc	1	4/28/2010	April	60	6.05	339	168	7
Waccabuc	2	4/28/2010	April	60	6.05	339	168	7
Waccabuc	3	4/28/2010	April	60	6.05	339	168	7
Waccabuc	1	5/6/2010	May	120	7.21	160	80	8
Waccabuc	2	5/6/2010	May	120	7.21	160	80	8
Waccabuc	3	5/6/2010	May	120	7.21	160	80	8
Waccabuc	1	5/24/2010	May	2.5	7.75	459	230	7
Waccabuc	2	5/24/2010	May	2.5	7.75	459	230	7
Waccabuc	3	5/24/2010	May	2.5	7.75	459	230	7
Waccabuc	1	6/4/2010	June	29.8	6.53	410	196	2
Waccabuc	2	6/4/2010	June	29.8	6.53	410	196	2
Waccabuc	3	6/4/2010	June	29.8	6.53	410	196	2
Waccabuc	1	6/21/2010	June	12.5	6.96	287	143	1
Waccabuc	2	6/21/2010	June	12.5	6.96	287	143	1
Waccabuc	3	6/21/2010	June	12.5	6.96	287	143	1
Waccabuc	1	7/9/2010	July	14	6.23	462	231	7
Waccabuc	2	7/9/2010	July	14	6.23	462	231	7
Waccabuc	3	7/9/2010	July	14	6.23	462	231	7
Waccabuc	1	7/20/2010	July	105	6.97	332	166	4
Waccabuc	2	7/20/2010	July	105	6.97	332	166	4
Waccabuc	3	7/20/2010	July	105	6.97	332	166	4
Waccabuc	1	8/5/2010	August	13.4	6.97	395	198	7
Waccabuc	2	8/5/2010	August	13.4	6.97	395	198	7
Waccabuc	3	8/5/2010	August	13.4	6.97	395	198	7
Waccabuc	1	8/18/2010	August	9	6.97	342	172	8
Waccabuc	2	8/18/2010	August	9	6.97	342	172	8
Waccabuc	3	8/18/2010	August	9	6.97	342	172	8
Waccabuc	1	9/7/2010	September	34	6.96	351	176	1
Waccabuc	2	9/7/2010	September	34	6.96	351	176	1
Waccabuc	3	9/7/2010	September	34	6.96	351	176	1
Waccabuc	1	9/20/2010	September	16.5	6.97	427	213	0
Waccabuc	2	9/20/2010	September	16.5	6.97	427	213	0
Waccabuc	3	9/20/2010	September	16.5	6.97	427	213	0
Waccabuc	1	10/4/2010	October	120	6.98	228	115	8

Waccabuc	2	10/4/2010	October	120	6.98	228	115	8
Waccabuc	3	10/4/2010	October	120	6.98	228	115	8
Rippowam	1	4/15/2010	April	60	6.69	180	92	0
Rippowam	2	4/15/2010	April	60	6.69	180	92	0
Rippowam	3	4/15/2010	April	60	6.69	180	92	0
Rippowam	1	4/28/2010	April	60	6.61	189	96	7
Rippowam	2	4/28/2010	April	60	6.61	189	96	7
Rippowam	3	4/28/2010	April	60	6.61	189	96	7
Rippowam	1	5/6/2010	May	60	6.97	178	89	8
Rippowam	2	5/6/2010	May	60	6.97	178	89	8
Rippowam	3	5/6/2010	May	60	6.97	178	89	8
Rippowam	1	5/24/2010	May	60	6.86	178	89	8
Rippowam	2	5/24/2010	May	60	6.86	178	89	8
Rippowam	3	5/24/2010	May	60	6.86	178	89	8
Rippowam	1	6/4/2010	June	72	7.15	184	92	2
Rippowam	2	6/4/2010	June	72	7.15	184	92	2
Rippowam	3	6/4/2010	June	72	7.15	184	92	2
Rippowam	1	6/21/2010	June	32	7.03	195	98	1
Rippowam	2	6/21/2010	June	32	7.03	195	98	1
Rippowam	3	6/21/2020	June	32	7.03	195	98	1
Rippowam	1	7/9/2010	July	36	6.96	202	96	5
Rippowam	2	7/9/2010	July	36	6.96	202	96	5
Rippowam	3	7/9/2010	July	36	6.96	202	96	5
Rippowam	1	7/20/2010	July	16	6.04	195	96	4
Rippowam	2	7/20/2010	July	16	6.04	195	96	4
Rippowam	3	7/20/2010	July	16	6.04	195	96	4
Rippowam	1	8/5/2010	August	22.3	6.96	249	126	7
Rippowam	2	8/5/2010	August	22.3	6.96	249	126	7
Rippowam	3	8/5/2010	August	22.3	6.96	249	126	7
Rippowam	1	8/18/2010	August	13	6.44	263	133	8
Rippowam	2	8/18/2010	August	13	6.44	263	133	8
Rippowam	3	8/18/2010	August	13	6.44	263	133	8
Rippowam	1	9/7/2010	September	34	6.31	247	122	1
Rippowam	2	9/7/2010	September	34	6.31	247	122	1
Rippowam	3	9/7/2010	September	34	6.31	247	122	1
Rippowam	1	9/20/2010	September	28.6	6.39	223	113	0
Rippowam	2	9/20/2010	September	28.6	6.39	223	113	0
Rippowam	3	9/20/2010	September	28.6	6.39	223	113	0
Rippowam	1	10/4/2010	October	97	6.97	219	104	8
Rippowam	2	10/4/2010	October	97	6.97	219	104	8
Rippowam	3	10/4/2010	October	97	6.97	219	104	8
Oscaleta	1	4/15/2010	April	20.5	6.25	237	119	0
Oscaleta	2	4/15/2010	April	20.5	6.25	237	119	0
Oscaleta	3	4/15/2010	April	20.5	6.25	237	119	0
Oscaleta	1	4/28/2010	April	37.4	5.86	200	100	7
Oscaleta	2	4/28/2010	April	37.4	5.86	200	100	7
Oscaleta	3	4/28/2010	April	37.4	5.86	200	100	7

Oscaleta	1	5/6/2010	May	87.2	6.01	204	102	8
Oscaleta	2	5/6/2010	May	87.2	6.01	204	102	8
Oscaleta	3	5/6/2010	May	87.2	6.01	204	102	8
Oscaleta	1	5/24/2010	May	22	6.36	235	118	8
Oscaleta	2	5/24/2010	May	22	6.36	235	118	8
Oscaleta	3	5/24/2010	May	22	6.36	235	118	8
Oscaleta	2	6/4/2010	June	61	6.24	84	60	2
Oscaleta	3	6/4/2010	June	61	6.24	84	60	2
Oscaleta	1	6/4/2010	June	61	6.24	84	60	2
Oscaleta	1	6/21/2010	June	120	5.93	153	76	1
Oscaleta	2	6/21/2010	June	120	5.93	153	76	1
Oscaleta	3	6/21/2010	June	120	5.93	153	76	1
Oscaleta	1	7/9/2010	July	34	5.54	181	90	5
Oscaleta	2	7/9/2010	July	34	5.54	181	90	5
Oscaleta	3	7/9/2010	July	34	5.54	181	90	5
Oscaleta	1	7/20/2010	July	107.3	5.35	186	92	4
Oscaleta	2	7/20/2010	July	107.3	5.35	186	92	4
Oscaleta	3	7/20/2010	July	107.3	5.35	186	92	4
Oscaleta	1	8/5/2010	August	117	5.79	185	93	7
Oscaleta	2	8/5/2010	August	117	5.79	185	93	7
Oscaleta	3	8/5/2010	August	117	5.79	185	93	7
Oscaleta	1	8/18/2010	August	120	5.77	171	85	8
Oscaleta	2	8/18/2010	August	120	5.77	171	85	8
Oscaleta	3	8/18/2010	August	120	5.77	171	85	8
Oscaleta	1	9/7/2010	September	88.4	5.52	211	104	1
Oscaleta	2	9/7/2010	September	88.4	5.52	211	104	1
Oscaleta	3	9/7/2010	September	88.4	5.52	211	104	1
Oscaleta	1	9/20/2010	September	54	5.52	176	88	0
Oscaleta	2	9/20/2010	September	54	5.52	176	88	0
Oscaleta	3	9/20/2010	September	54	5.52	176	88	0
Oscaleta	1	10/4/2010	October	120	6.97	164	82	8
Oscaleta	2	10/4/2010	October	120	6.97	164	82	8
Oscaleta	3	10/4/2010	October	120	6.97	164	82	8
Kitchawan	1	4/15/2010	April	28	6.11	303	151	0
Kitchawan	2	4/15/2010	April	28	6.11	303	151	0
Kitchawan	3	4/15/2010	April	28	6.11	303	151	0
Kitchawan	1	4/28/2010	April	15	6.57	326	162	7
Kitchawan	2	4/28/2010	April	15	6.57	326	162	7
Kitchawan	3	4/28/2010	April	15	6.57	326	162	7
Kitchawan	1	5/6/2010	May	19	6.61	352	174	8
Kitchawan	2	5/6/2010	May	19	6.61	352	174	8
Kitchawan	3	5/6/2010	May	19	6.61	352	174	8
Kitchawan	1	5/24/2010	May	40	6.48	304	152	7
Kitchawan	2	5/24/2010	May	40	6.48	304	152	7
Kitchawan	3	5/24/2010	May	40	6.48	304	152	7
Kitchawan	1	6/4/2010	June	3	6.04	289	144	2
Kitchawan	2	6/4/2010	June	3	6.04	289	144	2

Kitchawan	3	6/4/2010	June	3	6.04	289	144	2
Kitchawan	1	6/21/2010	June	11.2	6.96	318	161	1
Kitchawan	2	6/21/2010	June	11.2	6.96	318	161	1
Kitchawan	3	6/21/2010	June	11.2	6.96	318	161	1
Kitchawan	1	7/9/2010	July	18	6.35	400	199	5
Kitchawan	2	7/9/2010	July	18	6.35	400	199	5
Kitchawan	3	7/9/2010	July	18	6.35	400	199	5
Kitchawan	1	7/20/2010	July	6.9	6.97	412	205	4
Kitchawan	2	7/20/2010	July	6.9	6.97	412	205	4
Kitchawan	3	7/20/2010	July	6.9	6.97	412	205	4
Kitchawan	1	8/5/2010	August	13.4	6.97	414	208	5
Kitchawan	2	8/5/2010	August	13.4	6.97	414	208	5
Kitchawan	3	8/5/2010	August	13.4	6.97	414	208	5
Kitchawan	1	8/18/2010	August	10	6.25	372	198	8
Kitchawan	2	8/18/2010	August	10	6.25	372	198	8
Kitchawan	3	8/18/2010	August	10	6.25	372	198	8
Kitchawan	1	9/7/2010	September	60	6.24	416	207	1
Kitchawan	2	9/7/2010	September	60	6.24	416	207	1
Kitchawan	3	9/7/2010	September	60	6.24	416	207	1
Kitchawan	1	9/20/2010	September	45	6.4	407	204	0
Kitchawan	2	9/20/2010	September	45	6.4	407	204	0
Kitchawan	3	9/20/2010	September	45	6.4	407	204	0
Kitchawan	1	10/4/2010	October	44.5	6.35	383	191	8
Kitchawan	2	10/4/2010	October	44.5	6.35	383	191	8
Kitchawan	3	10/4/2010	October	44.5	6.35	383	191	8

Lake	Jar#	Date	Month	Air Temp	Water Tem	DO	Total Hardı	Calcium
Waccabuc	1	4/14/2009	April	9.8	8.7	33	181	83
Waccabuc	2	4/14/2009	April	9.8	8.7	33	181	83
Waccabuc	1	4/29/2009	April	13.8	23.2	12	284	50
Waccabuc	2	4/29/2009	April	13.8	23.2	12	284	50
Waccabuc	3	4/29/2009	April	13.8	23.2	12	284	50
Waccabuc	1	5/13/2009	May	18.8	20.6	26	138	50
Waccabuc	2	5/13/2009	May	18.8	20.6	26	138	50
Waccabuc	3	5/13/2009	May	18.8	20.6	26	138	50
Waccabuc	1	6/1/2009	June	22.2	23.3	22	112	60
Waccabuc	2	6/1/2009	June	22.2	23.3	22	112	60
Waccabuc	3	6/1/2009	June	22.2	23.3	22	112	60
Waccabuc	1	6/16/2009	June	20.1	20.5	23	100	64
Waccabuc	2	6/16/2009	June	20.1	20.5	23	100	64
Waccabuc	3	6/16/2009	June	20.1	20.5	23	100	64
Waccabuc	1	7/10/2009	July	27.2	28.8	29	102	52
Waccabuc	2	7/10/2009	July	27.2	28.8	29	102	52
Waccabuc	3	7/10/2009	July	27.2	28.8	29	102	52
Waccabuc	1	7/22/2009	July	24.6	24.8	15	120	72
Waccabuc	2	7/22/2009	July	24.6	24.8	15	120	72
Waccabuc	3	7/22/2009	July	24.6	24.8	15	120	72
Waccabuc	1	8/10/2009	August	24.7	24.2	5	120	48
Waccabuc	2	8/10/2009	August	24.7	24.2	5	120	48
Waccabuc	3	8/10/2009	August	24.7	24.2	5	120	48
Waccabuc	1	8/24/2009	August	23.7	25.1	4.9	118	68
Waccabuc	2	8/24/2009	August	23.7	25.1	4.9	118	68
Waccabuc	3	8/24/2009	August	23.7	25.1	4.9	118	68
Waccabuc	1	9/12/2009	September	18.5	18.7	14.8	726	363
Waccabuc	2	9/12/2009	September	18.5	18.7	14.8	726	363
Waccabuc	3	9/12/2009	September	18.5	18.7	14.8	726	363
Waccabuc	1	9/22/2009	September	21	19.5	7	100	43
Waccabuc	2	9/22/2009	September	21	19.5	7	100	43
Waccabuc	3	9/22/2009	September	21	19.5	7	100	43
Waccabuc	1	10/6/2009	October	11.6	10.8	5.8	104	62
Waccabuc	2	10/6/2009	October	11.6	10.8	5.8	104	62
Waccabuc	3	10/6/2009	October	11.6	10.8	5.8	104	62
Waccabuc	1	#########	October	8.6	7.1	10	148	72
Waccabuc	2	#########	October	8.6	7.1	10	148	72
Waccabuc	3	#########	October	8.6	7.1	10	148	72
Rippowam	1	4/14/2009	April	10.1	9	34	108	60
Rippowam	2	4/14/2009	April	10.1	9	34	108	60
Rippowam	1	4/29/2009	April	19.4	19.5	23	130	50
Rippowam	2	4/29/2009	April	19.4	19.5	23	130	50
Rippowam	3	4/29/2009	April	19.4	19.5	23	130	50
Rippowam	1	5/13/2009	May	16.5	17.3	24	120	75
Rippowam	2	5/13/2009	May	16.5	17.3	24	120	75
Rippowam	3	5/13/2009	May	16.5	17.3	24	120	75

Rippowam	1	6/1/2009	June	19.7	20.6	17	168	70
Rippowam	2	6/1/2009	June	19.7	20.6	17	168	70
Rippowam	3	6/1/2009	June	19.7	20.6	17	168	70
Rippowam	1	6/16/2009	June	18.5	19.8	20	74	42
Rippowam	2	6/16/2009	June	18.5	19.8	20	74	42
Rippowam	3	6/16/2009	June	18.5	19.8	20	74	42
Rippowam	1	7/10/2009	July	28.3	25.5	12	90	44
Rippowam	2	7/10/2009	July	28.3	25.5	12	90	44
Rippowam	3	7/10/2009	July	28.3	25.5	12	90	44
Rippowam	1	7/27/2009	July	23.9	24.2	19	102.5	60
Rippowam	2	7/27/2009	July	23.9	24.2	19	102.5	60
Rippowam	3	7/27/2009	July	23.9	24.2	19	102.5	60
Rippowam	1	8/10/2009	August	22.8	23.2	5	112	48
Rippowam	2	8/10/2009	August	22.8	23.2	5	112	48
Rippowam	3	8/10/2009	August	22.8	23.2	5	112	48
Rippowam	1	8/24/2009	August	23.2	22.3	5.7	106	54
Rippowam	2	8/24/2009	August	23.2	22.3	5.7	106	54
Rippowam	3	8/24/2009	August	23.2	22.3	5.7	106	54
Rippowam	1	9/12/2009	September	17.8	18	13.7	100	52
Rippowam	2	9/12/2009	September	17.8	18	13.7	100	52
Rippowam	3	9/12/2009	September	17.8	18	13.7	100	52
Rippowam	1	9/22/2009	September	20.2	19.9	7.8	78	78
Rippowam	2	9/22/2009	September	20.2	19.9	7.8	78	78
Rippowam	3	9/22/2009	September	20.2	19.9	7.8	78	78
Rippowam	1	10/6/2009	October	15.5	14.4	4.1	92	70
Rippowam	2	10/6/2009	October	15.5	14.4	4.1	92	70
Rippowam	3	10/6/2009	October	15.5	14.4	4.1	92	70
Rippowam	1	#########	October	10.4	9.7	7.5	132	78
Rippowam	2	#########	October	10.4	9.7	7.5	132	78
Rippowam	3	#########	October	10.4	9.7	7.5	132	78
Oscaleta	1	4/14/2009	April	16.4	8.6	25	116	58
Oscaleta	2	4/14/2009	April	16.4	8.6	25	116	58
Oscaleta	1	4/29/2009	April	19.3	21.5	30	120	55
Oscaleta	2	4/29/2009	April	19.3	21.5	30	120	55
Oscaleta	3	4/29/2009	April	19.3	21.5	30	120	55
Oscaleta	1	5/13/2009	May	17.7	16.6	16	95	60
Oscaleta	2	5/13/2009	May	17.7	16.6	16	95	60
Oscaleta	3	5/13/2009	May	17.7	16.6	16	95	60
Oscaleta	1	6/1/2009	June	17.2	17.9	14	128	44
Oscaleta	2	6/1/2009	June	17.2	17.9	14	128	44
Oscaleta	3	6/1/2009	June	17.2	17.9	14	128	44
Oscaleta	1	6/16/2009	June	17.7	19.6	16	90	33
Oscaleta	2	6/16/2009	June	17.7	19.6	16	90	33
Oscaleta	3	6/16/2009	June	17.7	19.6	16	90	33
Oscaleta	1	7/10/2009	July	26.6	27.7	9	162	62
Oscaleta	2	7/10/2009	July	26.6	27.7	9	162	62
Oscaleta	3	7/10/2009	July	26.6	27.7	9	162	62

Oscaleta	1	7/27/2009	July	22.6	23.9	16	102.5	65
Oscaleta	2	7/27/2009	July	22.6	23.9	16	102.5	65
Oscaleta	3	7/27/2009	July	22.6	23.9	16	102.5	65
Oscaleta	1	8/10/2009	August	23.7	24	2.5	134	90
Oscaleta	2	8/10/2009	August	23.7	24	2.5	134	90
Oscaleta	3	8/10/2009	August	23.7	24	2.5	134	90
Oscaleta	1	8/24/2009	August	23	25.3	5.6	132	72
Oscaleta	2	8/24/2009	August	23	25.3	5.6	132	72
Oscaleta	3	8/24/2009	August	23	25.3	5.6	132	72
Oscaleta	1	9/12/2009	September	19.1	19	11.3	118	60
Oscaleta	2	9/12/2009	September	19.1	19	11.3	118	60
Oscaleta	3	9/12/2009	September	19.1	19	11.3	118	60
Oscaleta	1	9/22/2009	September	19.9	19.6	3.5	42	42
Oscaleta	2	9/22/2009	September	19.9	19.6	3.5	42	42
Oscaleta	3	9/22/2009	September	19.9	19.6	3.5	42	42
Oscaleta	1	10/6/2009	October	19.5	16.4	4.5	124	80
Oscaleta	2	10/6/2009	October	19.5	16.4	4.5	124	80
Oscaleta	3	10/6/2009	October	19.5	16.4	4.5	124	80
Oscaleta	1	#########	October	9.5	8.8	4.8	147	108
Oscaleta	2	#########	October	9.5	8.8	4.8	147	108
Oscaleta	3	#########	October	9.5	8.8	4.8	147	108
Kitchawan	1	4/27/2009	April	21.5	26.8	20	162	137
Kitchawan	2	4/27/2009	April	21.5	26.8	20	162	137
Kitchawan	3	4/27/2009	April	21.5	26.8	20	162	137
Kitchawan	1	5/13/2009	May	19	23.8	16	180	112
Kitchawan	2	5/13/2009	May	19	23.8	16	180	112
Kitchawan	3	5/13/2009	May	19	23.8	16	180	112
Kitchawan	1	6/1/2009	June	19.8	24.2	10	124	84
Kitchawan	2	6/1/2009	June	19.8	24.2	10	124	84
Kitchawan	3	6/1/2009	June	19.8	24.2	10	124	84
Kitchawan	1	6/16/2009	June	18.8	21.6	11	120	88
Kitchawan	2	6/16/2009	June	18.8	21.6	11	120	88
Kitchawan	3	6/16/2009	June	18.8	21.6	11	120	88
Kitchawan	1	7/10/2009	July	22.2	26.1	5	112	86
Kitchawan	2	7/10/2009	July	22.2	26.1	5	112	86
Kitchawan	3	7/10/2009	July	22	26.1	5	112	86
Kitchawan	1	7/27/2009	July	24.1	27.3	8	99	72
Kitchawan	2	7/27/2009	July	24.1	27.3	8	99	72
Kitchawan	3	7/27/2009	July	24.1	27.3	8	99	72
Kitchawan	1	8/10/2009	August	25.5	29.2	4	170	128
Kitchawan	2	8/10/2009	August	25.5	29.2	4	170	128
Kitchawan	3	8/10/2009	August	25.5	29.2	4	170	128
Kitchawan	1	8/24/2009	August	25.4	27.8	3.8	100	82
Kitchawan	2	8/24/2009	August	25.4	27.8	3.8	100	82
Kitchawan	3	8/24/2009	August	25.4	27.8	3.8	100	82
Kitchawan	1	9/12/2009	September	19.3	19.3	9.2	110	62
Kitchawan	2	9/12/2009	September	19.3	19.3	9.2	110	62

Kitchawan	3	9/12/2009	September	19.3	19.3	9.2	110	62
Kitchawan	1	9/22/2009	September	19.5	20.1	5.6	138	120
Kitchawan	2	9/22/2009	September	19.5	20.1	5.6	138	120
Kitchawan	3	9/22/2009	September	19.5	20.1	5.6	138	120
Kitchawan	1	10/6/2009	October	14.2	15.5	7	110	46
Kitchawan	2	10/6/2009	October	14.2	15.5	7	110	46
Kitchawan	3	10/6/2009	October	14.2	15.5	7	110	46
Kitchawan	1	#########	October	11.2	11.5	4	180	110
Kitchawan	2	#########	October	11.2	11.5	4	180	110
Kitchawan	3	#########	October	11.2	11.5	4	180	110
Waccabuc	1	4/15/2010	April	14.2	13.1	4.8	83	54
Waccabuc	2	4/15/2010	April	14.2	13.1	4.8	83	54
Waccabuc	3	4/15/2010	April	14.2	13.1	4.8	83	54
Waccabuc	1	4/28/2010	April	8.4	9.4	6.05	156	84
Waccabuc	2	4/28/2010	April	8.4	9.4	6.05	156	84
Waccabuc	3	4/28/2010	April	8.4	9.4	6.05	156	84
Waccabuc	1	5/6/2010	May	17.2	17.5	7.8	99	60
Waccabuc	2	5/6/2010	May	17.2	17.5	7.8	99	60
Waccabuc	3	5/6/2010	May	17.2	17.5	7.8	99	60
Waccabuc	1	5/24/2010	May	23.1	22.3	6	200	180
Waccabuc	2	5/24/2010	May	23.1	22.3	6	200	180
Waccabuc	3	5/24/2010	May	23.1	22.3	6	200	180
Waccabuc	1	6/4/2010	June	23.7	25.1	4.5	60	46
Waccabuc	2	6/4/2010	June	23.7	25.1	4.5	60	46
Waccabuc	3	6/4/2010	June	23.7	25.1	4.5	60	46
Waccabuc	1	6/21/2010	June	33.2	29.1	3	106	46
Waccabuc	2	6/21/2010	June	33.2	29.1	3	106	46
Waccabuc	3	6/21/2010	June	33.2	29.1	3	106	46
Waccabuc	1	7/9/2010	July	26.7	27	1.2	150	112
Waccabuc	2	7/9/2010	July	26.7	27	1.2	150	112
Waccabuc	3	7/9/2010	July	26.7	27	1.2	150	112
Waccabuc	1	7/20/2010	July	26.2	27.1	2.5	180	152
Waccabuc	2	7/20/2010	July	26.2	27.1	2.5	180	152
Waccabuc	3	7/20/2010	July	26.2	27.1	2.5	180	152
Waccabuc	1	8/5/2010	August	27.8	27.1	2.3	72	60
Waccabuc	2	8/5/2010	August	27.8	27.1	2.3	72	60
Waccabuc	3	8/5/2010	August	27.8	27.1	2.3	72	60
Waccabuc	1	8/18/2010	August	23.2	22.5	3.9	110	80
Waccabuc	2	8/18/2010	August	23.2	22.5	3.9	110	80
Waccabuc	3	8/18/2010	August	23.2	22.5	3.9	110	80
Waccabuc	1	9/7/2010	September	23.6	21.5	4	100	80
Waccabuc	2	9/7/2010	September	23.6	21.5	4	100	80
Waccabuc	3	9/7/2010	September	23.6	21.5	4	100	80
Waccabuc	1	9/20/2010	September	21.3	20.2	6	60	58
Waccabuc	2	9/20/2010	September	21.3	20.2	6	60	58
Waccabuc	3	9/20/2010	September	21.3	20.2	6	60	58
Waccabuc	1	10/4/2010	October	11.7	15.1	5	118	86

Waccabuc	2	10/4/2010	October	11.7	15.1	5	118	86
Waccabuc	3	10/4/2010	October	11.7	15.1	5	118	86
Rippowam	1	4/15/2010	April	15.4	14.5	5.6	60	26
Rippowam	2	4/15/2010	April	15.4	14.5	5.6	60	26
Rippowam	3	4/15/2010	April	15.4	14.5	5.6	60	26
Rippowam	1	4/28/2010	April	9.1	11.2	7.4	80	42
Rippowam	2	4/28/2010	April	9.1	11.2	7.4	80	42
Rippowam	3	4/28/2010	April	9.1	11.2	7.4	80	42
Rippowam	1	5/6/2010	May	18.7	18.7	6.97	136	60
Rippowam	2	5/6/2010	May	18.7	18.7	6.97	136	60
Rippowam	3	5/6/2010	May	18.7	18.7	6.97	136	60
Rippowam	1	5/24/2010	May	20.4	19.5	2	100	60
Rippowam	2	5/24/2010	May	20.4	19.5	2	100	60
Rippowam	3	5/24/2010	May	20.4	19.5	2	100	60
Rippowam	1	6/4/2010	June	23.8	24.9	3	80	50
Rippowam	2	6/4/2010	June	23.8	24.9	3	80	50
Rippowam	3	6/4/2010	June	23.8	24.9	3	80	50
Rippowam	1	6/21/2010	June	22.3	25.8	4	62	44
Rippowam	2	6/21/2010	June	22.3	25.8	4	62	44
Rippowam	3	6/21/2020	June	22.3	25.8	4	62	44
Rippowam	1	7/9/2010	July	24.6	24.8	2	60	42
Rippowam	2	7/9/2010	July	24.6	24.8	2	60	42
Rippowam	3	7/9/2010	July	24.6	24.8	2	60	42
Rippowam	1	7/20/2010	July	22.2	24.9	3.8	60	40
Rippowam	2	7/20/2010	July	22.2	24.9	3.8	60	40
Rippowam	3	7/20/2010	July	22.2	24.9	3.8	60	40
Rippowam	1	8/5/2010	August	25.1	25.6	5	80	60
Rippowam	2	8/5/2010	August	25.1	25.6	5	80	60
Rippowam	3	8/5/2010	August	25.1	25.6	5	80	60
Rippowam	1	8/18/2010	August	20.9	21.5	3.8	142	80
Rippowam	2	8/18/2010	August	20.9	21.5	3.8	142	80
Rippowam	3	8/18/2010	August	20.9	21.5	3.8	142	80
Rippowam	1	9/7/2010	September	21.2	20.9	5.8	100	60
Rippowam	2	9/7/2010	September	21.2	20.9	5.8	100	60
Rippowam	3	9/7/2010	September	21.2	20.9	5.8	100	60
Rippowam	1	9/20/2010	September	17.2	18.3	7.2	50	44
Rippowam	2	9/20/2010	September	17.2	18.3	7.2	50	44
Rippowam	3	9/20/2010	September	17.2	18.3	7.2	50	44
Rippowam	1	10/4/2010	October	14.6	15.8	5	85	51
Rippowam	2	10/4/2010	October	14.6	15.8	5	85	51
Rippowam	3	10/4/2010	October	14.6	15.8	5	85	51
Oscaleta	1	4/15/2010	April	18.4	14.1	5.4	122	62
Oscaleta	2	4/15/2010	April	18.4	14.1	5.4	122	62
Oscaleta	3	4/15/2010	April	18.4	14.1	5.4	122	62
Oscaleta	1	4/28/2010	April	8.7	10.3	.	142	124
Oscaleta	2	4/28/2010	April	8.7	10.3	.	142	124
Oscaleta	3	4/28/2010	April	8.7	10.3	.	142	124

Oscaleta	1	5/6/2010	May	18.4	17.7	4	124	78
Oscaleta	2	5/6/2010	May	18.4	17.7	4	124	78
Oscaleta	3	5/6/2010	May	18.4	17.7	4	124	78
Oscaleta	1	5/24/2010	May	20.7	20.3	2	68	52
Oscaleta	2	5/24/2010	May	20.7	20.3	2	68	52
Oscaleta	3	5/24/2010	May	20.7	20.3	2	68	52
Oscaleta	2	6/4/2010	June	25.9	24.5	1.25	84	60
Oscaleta	3	6/4/2010	June	25.9	24.5	1.25	84	60
Oscaleta	1	6/4/2010	June	25.9	24.5	1.25	84	60
Oscaleta	1	6/21/2010	June	24.9	24.6	4	40	40
Oscaleta	2	6/21/2010	June	24.9	24.6	4	40	40
Oscaleta	3	6/21/2010	June	24.9	24.6	4	40	40
Oscaleta	1	7/9/2010	July	24.8	26.5	1.2	68	48
Oscaleta	2	7/9/2010	July	24.8	26.5	1.2	68	48
Oscaleta	3	7/9/2010	July	24.8	26.5	1.2	68	48
Oscaleta	1	7/20/2010	July	24.2	25.2	2.4	52	44
Oscaleta	2	7/20/2010	July	24.2	25.2	2.4	52	44
Oscaleta	3	7/20/2010	July	24.2	25.2	2.4	52	44
Oscaleta	1	8/5/2010	August	25.9	26.4	3	80	32
Oscaleta	2	8/5/2010	August	25.9	26.4	3	80	32
Oscaleta	3	8/5/2010	August	25.9	26.4	3	80	32
Oscaleta	1	8/18/2010	August	21.2	23.1	3.9	100	72
Oscaleta	2	8/18/2010	August	21.2	23.1	3.9	100	72
Oscaleta	3	8/18/2010	August	21.2	23.1	3.9	100	72
Oscaleta	1	9/7/2010	September	21.8	21.7	3	80	62
Oscaleta	2	9/7/2010	September	21.8	21.7	3	80	62
Oscaleta	3	9/7/2010	September	21.8	21.7	3	80	62
Oscaleta	1	9/20/2010	September	16.3	19.6	2.8	176	88
Oscaleta	2	9/20/2010	September	16.3	19.6	2.8	176	88
Oscaleta	3	9/20/2010	September	16.3	19.6	2.8	176	88
Oscaleta	1	10/4/2010	October	11.8	15	7.2	87	61
Oscaleta	2	10/4/2010	October	11.8	15	7.2	87	61
Oscaleta	3	10/4/2010	October	11.8	15	7.2	87	61
Kitchawan	1	4/15/2010	April	16.3	16.2	4.4	180	102
Kitchawan	2	4/15/2010	April	16.3	16.2	4.4	180	102
Kitchawan	3	4/15/2010	April	16.3	16.2	4.4	180	102
Kitchawan	1	4/28/2010	April	9.3	10.3	7.9	182	102
Kitchawan	2	4/28/2010	April	9.3	10.3	7.9	182	102
Kitchawan	3	4/28/2010	April	9.3	10.3	7.9	182	102
Kitchawan	1	5/6/2010	May	18	17.9	5	206	182
Kitchawan	2	5/6/2010	May	18	17.9	5	206	182
Kitchawan	3	5/6/2010	May	18	17.9	5	206	182
Kitchawan	1	5/24/2010	May	24.6	24.9	2.3	138	104
Kitchawan	2	5/24/2010	May	24.6	24.9	2.3	138	104
Kitchawan	3	5/24/2010	May	24.6	24.9	2.3	138	104
Kitchawan	1	6/4/2010	June	28.9	31.2	6.04	120	86
Kitchawan	2	6/4/2010	June	28.9	31.2	6.04	120	86

Kitchawan	3	6/4/2010	June	28.9	31.2	6.04	120	86
Kitchawan	1	6/21/2010	June	29.2	30.2	2	100	92
Kitchawan	2	6/21/2010	June	29.2	30.2	2	100	92
Kitchawan	3	6/21/2010	June	29.2	30.2	2	100	92
Kitchawan	1	7/9/2010	July	26.7	27.7	2.8	134	92
Kitchawan	2	7/9/2010	July	26.7	27.7	2.8	134	92
Kitchawan	3	7/9/2010	July	26.7	27.7	2.8	134	92
Kitchawan	1	7/20/2010	July	27.8	27.9	3	112	100
Kitchawan	2	7/20/2010	July	27.8	27.9	3	112	100
Kitchawan	3	7/20/2010	July	27.8	27.9	3	112	100
Kitchawan	1	8/5/2010	August	30.3	28.4	3.2	132	90
Kitchawan	2	8/5/2010	August	30.3	28.4	3.2	132	90
Kitchawan	3	8/5/2010	August	30.3	28.4	3.2	132	90
Kitchawan	1	8/18/2010	August	23.6	23.3	3.8	140	120
Kitchawan	2	8/18/2010	August	23.6	23.3	3.8	140	120
Kitchawan	3	8/18/2010	August	23.6	23.3	3.8	140	120
Kitchawan	1	9/7/2010	September	28.3	26.1	3.2	185	145
Kitchawan	2	9/7/2010	September	28.3	26.1	3.2	185	145
Kitchawan	3	9/7/2010	September	28.3	26.1	3.2	185	145
Kitchawan	1	9/20/2010	September	20.8	21.4	3	140	84
Kitchawan	2	9/20/2010	September	20.8	21.4	3	140	84
Kitchawan	3	9/20/2010	September	20.8	21.4	3	140	84
Kitchawan	1	10/4/2010	October	13.4	14.2	5	140	106
Kitchawan	2	10/4/2010	October	13.4	14.2	5	140	106
Kitchawan	3	10/4/2010	October	13.4	14.2	5	140	106

Lake	Jar#	Date	Month	Lymnaea st	Bivalves	Ancylidae	Midges	Amphipods
Waccabuc	1	4/14/2009	April	0	2	0	14	4
Waccabuc	2	4/14/2009	April	0	2	0	9	1
Waccabuc	1	4/29/2009	April	0	0	0	0	0
Waccabuc	2	4/29/2009	April	0	3	0	0	0
Waccabuc	3	4/29/2009	April	0	2	0	15	0
Waccabuc	1	5/13/2009	May	0	4	0	11	0
Waccabuc	2	5/13/2009	May	0	0	0	16	0
Waccabuc	3	5/13/2009	May	0	0	0	25	7
Waccabuc	1	6/1/2009	June	0	1	0	27	7
Waccabuc	2	6/1/2009	June	0	0	0	46	5
Waccabuc	3	6/1/2009	June	0	14	0	6	0
Waccabuc	1	6/16/2009	June	0	0	0	11	0
Waccabuc	2	6/16/2009	June	0	14	0	7	0
Waccabuc	3	6/16/2009	June	0	1	0	67	33
Waccabuc	1	7/10/2009	July	0	0	0	11	1
Waccabuc	2	7/10/2009	July	0	17	1	20	13
Waccabuc	3	7/10/2009	July	0	0	0	69	0
Waccabuc	1	7/22/2009	July	0	0	0	15	1
Waccabuc	2	7/22/2009	July	0	2	0	29	1
Waccabuc	3	7/22/2009	July	0	2	0	11	1
Waccabuc	1	8/10/2009	August	0	1	0	17	0
Waccabuc	2	8/10/2009	August	0	3	0	47	9
Waccabuc	3	8/10/2009	August	0	9	0	25	11
Waccabuc	1	8/24/2009	August	0	3	0	40	0
Waccabuc	2	8/24/2009	August	0	3	0	36	3
Waccabuc	3	8/24/2009	August	0	0	0	25	2
Waccabuc	1	9/12/2009	September	0	2	0	7	0
Waccabuc	2	9/12/2009	September	0	0	0	13	6
Waccabuc	3	9/12/2009	September	0	0	0	7	0
Waccabuc	1	9/22/2009	September	0	1	0	38	1
Waccabuc	2	9/22/2009	September	0	8	0	14	0
Waccabuc	3	9/22/2009	September	0	5	0	12	2
Waccabuc	1	10/6/2009	October	0	3	0	36	8
Waccabuc	2	10/6/2009	October	0	3	0	12	1
Waccabuc	3	10/6/2009	October	0	0	1	61	18
Waccabuc	1	#########	October	0	5	0	6	1
Waccabuc	2	#########	October	0	2	0	15	1
Waccabuc	3	#########	October	0	0	0	5	0
Rippowam	1	4/14/2009	April	0	0	0	3	0
Rippowam	2	4/14/2009	April	0	1	0	3	0
Rippowam	1	4/29/2009	April	0	0	0	0	0
Rippowam	2	4/29/2009	April	0	0	1	5	2
Rippowam	3	4/29/2009	April	0	1	0	0	0
Rippowam	1	5/13/2009	May	0	0	0	2	1
Rippowam	2	5/13/2009	May	0	0	0	9	7
Rippowam	3	5/13/2009	May	0	1	0	2	0

Rippowam	1	6/1/2009	June	0	0	0	0	0
Rippowam	2	6/1/2009	June	0	0	0	12	3
Rippowam	3	6/1/2009	June	0	0	0	0	3
Rippowam	1	6/16/2009	June	0	0	0	0	1
Rippowam	2	6/16/2009	June	0	0	0	9	2
Rippowam	3	6/16/2009	June	0	0	0	23	4
Rippowam	1	7/10/2009	July	0	2	1	3	4
Rippowam	2	7/10/2009	July	0	2	1	10	1
Rippowam	3	7/10/2009	July	0	3	0	12	1
Rippowam	1	7/27/2009	July	0	20	1	20	1
Rippowam	2	7/27/2009	July	0	0	0	0	0
Rippowam	3	7/27/2009	July	0	0	0	2	2
Rippowam	1	8/10/2009	August	0	1	0	15	0
Rippowam	2	8/10/2009	August	0	2	0	25	0
Rippowam	3	8/10/2009	August	0	4	0	70	0
Rippowam	1	8/24/2009	August	0	7	0	15	0
Rippowam	2	8/24/2009	August	0	0	0	13	0
Rippowam	3	8/24/2009	August	0	10	0	25	2
Rippowam	1	9/12/2009	September	0	4	0	0	0
Rippowam	2	9/12/2009	September	0	4	0	9	0
Rippowam	3	9/12/2009	September	0	4	0	14	0
Rippowam	1	9/22/2009	September	0	0	3	6	5
Rippowam	2	9/22/2009	September	0	0	0	0	0
Rippowam	3	9/22/2009	September	0	8	0	24	7
Rippowam	1	10/6/2009	October	0	0	0	1	0
Rippowam	2	10/6/2009	October	0	0	0	4	9
Rippowam	3	10/6/2009	October	0	4	0	12	3
Rippowam	1	#########	October	0	0	1	3	4
Rippowam	2	#########	October	0	0	0	4	0
Rippowam	3	#########	October	0	0	0	6	0
Oscaleta	1	4/14/2009	April	0	0	1	3	0
Oscaleta	2	4/14/2009	April	0	0	0	0	0
Oscaleta	1	4/29/2009	April	0	0	0	1	1
Oscaleta	2	4/29/2009	April	0	0	1	3	1
Oscaleta	3	4/29/2009	April	0	2	0	0	0
Oscaleta	1	5/13/2009	May	0	0	0	2	0
Oscaleta	2	5/13/2009	May	0	0	0	2	0
Oscaleta	3	5/13/2009	May	0	0	0	0	0
Oscaleta	1	6/1/2009	June	0	0	1	0	0
Oscaleta	2	6/1/2009	June	0	1	0	1	0
Oscaleta	3	6/1/2009	June	0	0	2	2	2
Oscaleta	1	6/16/2009	June	0	0	0	6	0
Oscaleta	2	6/16/2009	June	1	2	1	5	4
Oscaleta	3	6/16/2009	June	0	0	0	1	0
Oscaleta	1	7/10/2009	July	0	2	0	12	1
Oscaleta	2	7/10/2009	July	0	14	0	20	1
Oscaleta	3	7/10/2009	July	0	0	0	3	0

Oscaleta	1	7/27/2009	July	0	7	0	2	0
Oscaleta	2	7/27/2009	July	0	9	0	13	0
Oscaleta	3	7/27/2009	July	0	3	0	7	0
Oscaleta	1	8/10/2009	August	0	2	0	4	0
Oscaleta	2	8/10/2009	August	0	2	0	12	0
Oscaleta	3	8/10/2009	August	0	52	0	7	42
Oscaleta	1	8/24/2009	August	0	0	0	0	0
Oscaleta	2	8/24/2009	August	0	1	1	1	2
Oscaleta	3	8/24/2009	August	0	2	0	2	0
Oscaleta	1	9/12/2009	September	0	0	0	8	0
Oscaleta	2	9/12/2009	September	0	5	0	2	0
Oscaleta	3	9/12/2009	September	0	5	0	2	1
Oscaleta	1	9/22/2009	September	0	0	0	4	1
Oscaleta	2	9/22/2009	September	0	9	0	4	5
Oscaleta	3	9/22/2009	September	2	0	6	6	1
Oscaleta	1	10/6/2009	October	0	0	0	0	1
Oscaleta	2	10/6/2009	October	0	0	0	4	9
Oscaleta	3	10/6/2009	October	0	0	0	12	0
Oscaleta	1	#########	October	0	0	0	3	4
Oscaleta	2	#########	October	0	1	0	4	0
Oscaleta	3	#########	October	0	0	0	6	3
Kitchawan	1	4/27/2009	April	1	4	0	0	0
Kitchawan	2	4/27/2009	April	0	3	0	8	0
Kitchawan	3	4/27/2009	April	0	4	2	9	0
Kitchawan	1	5/13/2009	May	0	10	0	0	3
Kitchawan	2	5/13/2009	May	0	1	0	0	0
Kitchawan	3	5/13/2009	May	0	9	0	1	0
Kitchawan	1	6/1/2009	June	0	14	0	0	0
Kitchawan	2	6/1/2009	June	0	12	0	1	0
Kitchawan	3	6/1/2009	June	0	6	0	5	0
Kitchawan	1	6/16/2009	June	0	2	0	3	0
Kitchawan	2	6/16/2009	June	0	11	0	5	0
Kitchawan	3	6/16/2009	June	2	17	0	3	0
Kitchawan	1	7/10/2009	July	0	6	0	7	0
Kitchawan	2	7/10/2009	July	0	1	0	0	0
Kitchawan	3	7/10/2009	July	1	30	0	39	0
Kitchawan	1	7/27/2009	July	0	33	0	11	0
Kitchawan	2	7/27/2009	July	6	0	0	6	0
Kitchawan	3	7/27/2009	July	0	14	0	5	0
Kitchawan	1	8/10/2009	August	0	7	0	42	1
Kitchawan	2	8/10/2009	August	0	27	0	43	0
Kitchawan	3	8/10/2009	August	0	3	2	38	2
Kitchawan	1	8/24/2009	August	0	5	0	0	0
Kitchawan	2	8/24/2009	August	15	0	5	5	0
Kitchawan	3	8/24/2009	August	0	1	0	13	6
Kitchawan	1	9/12/2009	September	0	12	0	6	0
Kitchawan	2	9/12/2009	September	0	13	0	5	0

Kitchawan	3	9/12/2009	September	0	3	0	3	0
Kitchawan	1	9/22/2009	September	0	11	0	7	0
Kitchawan	2	9/22/2009	September	0	25	0	20	0
Kitchawan	3	9/22/2009	September	0	0	0	4	1
Kitchawan	1	10/6/2009	October	0	36	0	5	0
Kitchawan	2	10/6/2009	October	0	15	0	0	0
Kitchawan	3	10/6/2009	October	0	14	0	11	4
Kitchawan	1	#########	October	0	14	0	0	0
Kitchawan	2	#########	October	0	1	0	2	0
Kitchawan	3	#########	October	0	21	0	10	0
Waccabuc	1	4/15/2010	April	0	0	0	4	0
Waccabuc	2	4/15/2010	April	0	1	0	25	0
Waccabuc	3	4/15/2010	April	0	2	0	27	1
Waccabuc	1	4/28/2010	April	0	6	0	5	0
Waccabuc	2	4/28/2010	April	0	1	0	10	0
Waccabuc	3	4/28/2010	April	0	4	0	13	1
Waccabuc	1	5/6/2010	May	0	0	0	2	0
Waccabuc	2	5/6/2010	May	0	1	0	8	1
Waccabuc	3	5/6/2010	May	0	2	0	28	2
Waccabuc	1	5/24/2010	May	0	9	0	28	9
Waccabuc	2	5/24/2010	May	0	0	0	17	1
Waccabuc	3	5/24/2010	May	0	1	0	343	7
Waccabuc	1	6/4/2010	June	0	5	0	107	20
Waccabuc	2	6/4/2010	June	0	5	0	392	9
Waccabuc	3	6/4/2010	June	0	4	0	69	13
Waccabuc	1	6/21/2010	June	0	1	0	36	8
Waccabuc	2	6/21/2010	June	0	0	0	86	12
Waccabuc	3	6/21/2010	June	0	9	0	127	58
Waccabuc	1	7/9/2010	July	0	0	0	35	17
Waccabuc	2	7/9/2010	July	0	1	0	93	18
Waccabuc	3	7/9/2010	July	0	0	0	22	3
Waccabuc	1	7/20/2010	July	0	2	1	21	10
Waccabuc	2	7/20/2010	July	0	5	0	23	10
Waccabuc	3	7/20/2010	July	0	3	0	30	34
Waccabuc	1	8/5/2010	August	0	1	0	5	1
Waccabuc	2	8/5/2010	August	0	1	0	46	8
Waccabuc	3	8/5/2010	August	0	25	1	36	14
Waccabuc	1	8/18/2010	August	0	2	0	0	0
Waccabuc	2	8/18/2010	August	0	0	0	2	1
Waccabuc	3	8/18/2010	August	0	0	0	5	0
Waccabuc	1	9/7/2010	September	0	1	0	29	8
Waccabuc	2	9/7/2010	September	0	2	0	18	0
Waccabuc	3	9/7/2010	September	0	2	9	12	3
Waccabuc	1	9/20/2010	September	0	1	0	12	0
Waccabuc	2	9/20/2010	September	0	3	0	8	0
Waccabuc	3	9/20/2010	September	0	0	0	2	0
Waccabuc	1	10/4/2010	October	1	1	4	6	73

Waccabuc	2	10/4/2010	October	0	1	2	0	5
Waccabuc	3	10/4/2010	October	0	2	0	0	4
Rippowam	1	4/15/2010	April	0	0	0	0	5
Rippowam	2	4/15/2010	April	0	1	0	7	17
Rippowam	3	4/15/2010	April	0	0	0	3	0
Rippowam	1	4/28/2010	April	0	0	0	0	0
Rippowam	2	4/28/2010	April	0	0	2	1	2
Rippowam	3	4/28/2010	April	0	0	0	1	3
Rippowam	1	5/6/2010	May	0	0	0	1	3
Rippowam	2	5/6/2010	May	0	0	0	13	2
Rippowam	3	5/6/2010	May	0	0	0	0	0
Rippowam	1	5/24/2010	May	0	0	1	8	3
Rippowam	2	5/24/2010	May	6	0	2	10	26
Rippowam	3	5/24/2010	May	0	1	0	12	2
Rippowam	1	6/4/2010	June	0	0	0	28	12
Rippowam	2	6/4/2010	June	0	0	7	17	28
Rippowam	3	6/4/2010	June	0	0	0	10	20
Rippowam	1	6/21/2010	June	0	1	0	11	14
Rippowam	2	6/21/2010	June	0	0	0	8	9
Rippowam	3	6/21/2020	June	0	2	0	3	9
Rippowam	1	7/9/2010	July	0	0	0	6	9
Rippowam	2	7/9/2010	July	0	0	0	4	0
Rippowam	3	7/9/2010	July	0	0	0	1	0
Rippowam	1	7/20/2010	July	0	6	0	5	1
Rippowam	2	7/20/2010	July	0	0	0	0	5
Rippowam	3	7/20/2010	July	0	2	0	2	6
Rippowam	1	8/5/2010	August	0	1	1	2	4
Rippowam	2	8/5/2010	August	0	3	0	17	2
Rippowam	3	8/5/2010	August	0	2	1	10	5
Rippowam	1	8/18/2010	August	0	0	0	1	13
Rippowam	2	8/18/2010	August	0	0	0	15	3
Rippowam	3	8/18/2010	August	0	1	0	4	0
Rippowam	1	9/7/2010	September	0	1	0	10	1
Rippowam	2	9/7/2010	September	1	3	0	4	0
Rippowam	3	9/7/2010	September	0	1	0	8	0
Rippowam	1	9/20/2010	September	0	0	0	4	17
Rippowam	2	9/20/2010	September	0	0	0	8	3
Rippowam	3	9/20/2010	September	0	1	0	8	0
Rippowam	1	10/4/2010	October	0	1	0	4	73
Rippowam	2	10/4/2010	October	0	1	1	5	7
Rippowam	3	10/4/2010	October	0	0	0	10	5
Oscaleta	1	4/15/2010	April	0	1	0	1	0
Oscaleta	2	4/15/2010	April	0	0	0	0	0
Oscaleta	3	4/15/2010	April	0	4	0	7	0
Oscaleta	1	4/28/2010	April	0	4	0	7	0
Oscaleta	2	4/28/2010	April	0	0	0	1	2
Oscaleta	3	4/28/2010	April	0	2	2	0	1

Oscaleta	1	5/6/2010	May	0	1	0	4	0
Oscaleta	2	5/6/2010	May	0	1	0	4	0
Oscaleta	3	5/6/2010	May	0	0	0	28	0
Oscaleta	1	5/24/2010	May	0	0	1	8	3
Oscaleta	2	5/24/2010	May	0	2	26	1	10
Oscaleta	3	5/24/2010	May	0	1	0	2	12
Oscaleta	2	6/4/2010	June	0	36	1	29	0
Oscaleta	3	6/4/2010	June	0	1	6	29	0
Oscaleta	1	6/4/2010	June	0	0	0	0	0
Oscaleta	1	6/21/2010	June	0	0	1	9	5
Oscaleta	2	6/21/2010	June	0	1	0	8	1
Oscaleta	3	6/21/2010	June	0	0	0	6	0
Oscaleta	1	7/9/2010	July	0	0	0	10	33
Oscaleta	2	7/9/2010	July	0	1	0	0	0
Oscaleta	3	7/9/2010	July	0	0	0	8	0
Oscaleta	1	7/20/2010	July	0	5	0	6	12
Oscaleta	2	7/20/2010	July	0	4	0	16	4
Oscaleta	3	7/20/2010	July	0	1	0	9	10
Oscaleta	1	8/5/2010	August	0	0	0	17	37
Oscaleta	2	8/5/2010	August	0	3	0	2	2
Oscaleta	3	8/5/2010	August	0	10	1	9	6
Oscaleta	1	8/18/2010	August	0	3	0	0	0
Oscaleta	2	8/18/2010	August	0	0	0	0	0
Oscaleta	3	8/18/2010	August	0	5	0	21	3
Oscaleta	1	9/7/2010	September	0	8	0	3	0
Oscaleta	2	9/7/2010	September	0	3	0	2	1
Oscaleta	3	9/7/2010	September	0	0	0	4	0
Oscaleta	1	9/20/2010	September	0	0	1	6	7
Oscaleta	2	9/20/2010	September	0	6	0	1	3
Oscaleta	3	9/20/2010	September	0	3	0	1	0
Oscaleta	1	10/4/2010	October	0	0	0	0	0
Oscaleta	2	10/4/2010	October	0	0	2	0	0
Oscaleta	3	10/4/2010	October	0	4	0	1	0
Kitchawan	1	4/15/2010	April	0	7	0	5	1
Kitchawan	2	4/15/2010	April	0	11	0	0	0
Kitchawan	3	4/15/2010	April	0	12	0	29	0
Kitchawan	1	4/28/2010	April	0	12	0	29	0
Kitchawan	2	4/28/2010	April	0	17	0	2	2
Kitchawan	3	4/28/2010	April	0	13	0	5	0
Kitchawan	1	5/6/2010	May	0	8	0	2	0
Kitchawan	2	5/6/2010	May	0	7	0	3	0
Kitchawan	3	5/6/2010	May	0	7	0	3	0
Kitchawan	1	5/24/2010	May	0	25	1	25	9
Kitchawan	2	5/24/2010	May	0	56	0	45	0
Kitchawan	3	5/24/2010	May	0	47	0	36	0
Kitchawan	1	6/4/2010	June	0	33	0	29	8
Kitchawan	2	6/4/2010	June	0	11	0	11	0

Kitchawan	3	6/4/2010	June	1	28	0	7	11
Kitchawan	1	6/21/2010	June	0	9	0	10	16
Kitchawan	2	6/21/2010	June	0	55	0	7	21
Kitchawan	3	6/21/2010	June	0	90	0	23	12
Kitchawan	1	7/9/2010	July	2	5	0	3	0
Kitchawan	2	7/9/2010	July	0	5	0	8	0
Kitchawan	3	7/9/2010	July	0	4	0	0	7
Kitchawan	1	7/20/2010	July	3	5	1	10	8
Kitchawan	2	7/20/2010	July	0	23	0	7	10
Kitchawan	3	7/20/2010	July	0	3	0	1	0
Kitchawan	1	8/5/2010	August	0	101	0	47	7
Kitchawan	2	8/5/2010	August	0	1	0	3	0
Kitchawan	3	8/5/2010	August	0	5	0	0	0
Kitchawan	1	8/18/2010	August	0	22	0	9	13
Kitchawan	2	8/18/2010	August	0	22	4	15	0
Kitchawan	3	8/18/2010	August	0	21	0	9	0
Kitchawan	1	9/7/2010	September	0	1	3	12	4
Kitchawan	2	9/7/2010	September	0	4	2	8	0
Kitchawan	3	9/7/2010	September	0	14	0	1	3
Kitchawan	1	9/20/2010	September	0	1	0	0	0
Kitchawan	2	9/20/2010	September	0	4	2	1	7
Kitchawan	3	9/20/2010	September	0	2	0	1	11
Kitchawan	1	10/4/2010	October	2	39	0	5	0
Kitchawan	2	10/4/2010	October	23	20	0	7	0
Kitchawan	3	10/4/2010	October	0	20	0	0	0

Lake	Jar#	Date	Month	Coliforms
Waccabuc	1	4/14/2009	April	29.8
Waccabuc	2	4/14/2009	April	29.8
Waccabuc	1	4/29/2009	April	29.8
Waccabuc	2	4/29/2009	April	29.8
Waccabuc	3	4/29/2009	April	29.8
Waccabuc	1	5/13/2009	May	29.8
Waccabuc	2	5/13/2009	May	29.8
Waccabuc	3	5/13/2009	May	29.8
Waccabuc	1	6/1/2009	June	29.8
Waccabuc	2	6/1/2009	June	29.8
Waccabuc	3	6/1/2009	June	29.8
Waccabuc	1	6/16/2009	June	29.8
Waccabuc	2	6/16/2009	June	29.8
Waccabuc	3	6/16/2009	June	29.8
Waccabuc	1	7/10/2009	July	29.8
Waccabuc	2	7/10/2009	July	29.8
Waccabuc	3	7/10/2009	July	29.8
Waccabuc	1	7/22/2009	July	29.8
Waccabuc	2	7/22/2009	July	29.8
Waccabuc	3	7/22/2009	July	29.8
Waccabuc	1	8/10/2009	August	5
Waccabuc	2	8/10/2009	August	5
Waccabuc	3	8/10/2009	August	5
Waccabuc	1	8/24/2009	August	57
Waccabuc	2	8/24/2009	August	57
Waccabuc	3	8/24/2009	August	57
Waccabuc	1	9/12/2009	September	29.8
Waccabuc	2	9/12/2009	September	29.8
Waccabuc	3	9/12/2009	September	29.8
Waccabuc	1	9/22/2009	September	34
Waccabuc	2	9/22/2009	September	34
Waccabuc	3	9/22/2009	September	34
Waccabuc	1	10/6/2009	October	10
Waccabuc	2	10/6/2009	October	10
Waccabuc	3	10/6/2009	October	10
Waccabuc	1	#########	October	43
Waccabuc	2	#########	October	43
Waccabuc	3	#########	October	43
Rippowam	1	4/14/2009	April	36.9
Rippowam	2	4/14/2009	April	36.9
Rippowam	1	4/29/2009	April	36.9
Rippowam	2	4/29/2009	April	36.9
Rippowam	3	4/29/2009	April	36.9
Rippowam	1	5/13/2009	May	36.9
Rippowam	2	5/13/2009	May	36.9
Rippowam	3	5/13/2009	May	36.9

Rippowam	1	6/1/2009	June	36.9
Rippowam	2	6/1/2009	June	36.9
Rippowam	3	6/1/2009	June	36.9
Rippowam	1	6/16/2009	June	36.9
Rippowam	2	6/16/2009	June	36.9
Rippowam	3	6/16/2009	June	36.9
Rippowam	1	7/10/2009	July	36.9
Rippowam	2	7/10/2009	July	36.9
Rippowam	3	7/10/2009	July	36.9
Rippowam	1	7/27/2009	July	36.9
Rippowam	2	7/27/2009	July	36.9
Rippowam	3	7/27/2009	July	36.9
Rippowam	1	8/10/2009	August	16
Rippowam	2	8/10/2009	August	16
Rippowam	3	8/10/2009	August	16
Rippowam	1	8/24/2009	August	13
Rippowam	2	8/24/2009	August	13
Rippowam	3	8/24/2009	August	13
Rippowam	1	9/12/2009	September	36.9
Rippowam	2	9/12/2009	September	36.9
Rippowam	3	9/12/2009	September	36.9
Rippowam	1	9/22/2009	September	9
Rippowam	2	9/22/2009	September	9
Rippowam	3	9/22/2009	September	9
Rippowam	1	10/6/2009	October	4
Rippowam	2	10/6/2009	October	4
Rippowam	3	10/6/2009	October	4
Rippowam	1	#########	October	13
Rippowam	2	#########	October	13
Rippowam	3	#########	October	13
Oscaleta	1	4/14/2009	April	14.9
Oscaleta	2	4/14/2009	April	14.9
Oscaleta	1	4/29/2009	April	14.9
Oscaleta	2	4/29/2009	April	14.9
Oscaleta	3	4/29/2009	April	14.9
Oscaleta	1	5/13/2009	May	14.9
Oscaleta	2	5/13/2009	May	14.9
Oscaleta	3	5/13/2009	May	14.9
Oscaleta	1	6/1/2009	June	14.9
Oscaleta	2	6/1/2009	June	14.9
Oscaleta	3	6/1/2009	June	14.9
Oscaleta	1	6/16/2009	June	14.9
Oscaleta	2	6/16/2009	June	14.9
Oscaleta	3	6/16/2009	June	14.9
Oscaleta	1	7/10/2009	July	14.9
Oscaleta	2	7/10/2009	July	14.9
Oscaleta	3	7/10/2009	July	14.9

Oscaleta	1	7/27/2009	July	14.9
Oscaleta	2	7/27/2009	July	14.9
Oscaleta	3	7/27/2009	July	14.9
Oscaleta	1	8/10/2009	August	40
Oscaleta	2	8/10/2009	August	40
Oscaleta	3	8/10/2009	August	40
Oscaleta	1	8/24/2009	August	32
Oscaleta	2	8/24/2009	August	32
Oscaleta	3	8/24/2009	August	32
Oscaleta	1	9/12/2009	September	14.9
Oscaleta	2	9/12/2009	September	14.9
Oscaleta	3	9/12/2009	September	14.9
Oscaleta	1	9/22/2009	September	6
Oscaleta	2	9/22/2009	September	6
Oscaleta	3	9/22/2009	September	6
Oscaleta	1	10/6/2009	October	1
Oscaleta	2	10/6/2009	October	1
Oscaleta	3	10/6/2009	October	1
Oscaleta	1	#########	October	6
Oscaleta	2	#########	October	6
Oscaleta	3	#########	October	6
Kitchawan	1	4/27/2009	April	121
Kitchawan	2	4/27/2009	April	121
Kitchawan	3	4/27/2009	April	121
Kitchawan	1	5/13/2009	May	121
Kitchawan	2	5/13/2009	May	121
Kitchawan	3	5/13/2009	May	121
Kitchawan	1	6/1/2009	June	121
Kitchawan	2	6/1/2009	June	121
Kitchawan	3	6/1/2009	June	121
Kitchawan	1	6/16/2009	June	121
Kitchawan	2	6/16/2009	June	121
Kitchawan	3	6/16/2009	June	121
Kitchawan	1	7/10/2009	July	121
Kitchawan	2	7/10/2009	July	121
Kitchawan	3	7/10/2009	July	121
Kitchawan	1	7/27/2009	July	232
Kitchawan	2	7/27/2009	July	232
Kitchawan	3	7/27/2009	July	232
Kitchawan	1	8/10/2009	August	181
Kitchawan	2	8/10/2009	August	181
Kitchawan	3	8/10/2009	August	181
Kitchawan	1	8/24/2009	August	121
Kitchawan	2	8/24/2009	August	121
Kitchawan	3	8/24/2009	August	121
Kitchawan	1	9/12/2009	September	8
Kitchawan	2	9/12/2009	September	8

Kitchawan	3	9/12/2009	September	8
Kitchawan	1	9/22/2009	September	8
Kitchawan	2	9/22/2009	September	8
Kitchawan	3	9/22/2009	September	8
Kitchawan	1	10/6/2009	October	176
Kitchawan	2	10/6/2009	October	176
Kitchawan	3	10/6/2009	October	176
Kitchawan	1	#########	October	121
Kitchawan	2	#########	October	121
Kitchawan	3	#########	October	121
Waccabuc	1	4/15/2010	April	59
Waccabuc	2	4/15/2010	April	59
Waccabuc	3	4/15/2010	April	59
Waccabuc	1	4/28/2010	April	54
Waccabuc	2	4/28/2010	April	54
Waccabuc	3	4/28/2010	April	54
Waccabuc	1	5/6/2010	May	72
Waccabuc	2	5/6/2010	May	72
Waccabuc	3	5/6/2010	May	72
Waccabuc	1	5/24/2010	May	1100
Waccabuc	2	5/24/2010	May	1100
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Waccabuc	2	6/4/2010	June	973
Waccabuc	3	6/4/2010	June	973
Waccabuc	1	6/21/2010	June	306
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Waccabuc	3	6/21/2010	June	306
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Waccabuc	3	7/20/2010	July	8
Waccabuc	1	8/5/2010	August	69
Waccabuc	2	8/5/2010	August	69
Waccabuc	3	8/5/2010	August	69
Waccabuc	1	8/18/2010	August	22
Waccabuc	2	8/18/2010	August	22
Waccabuc	3	8/18/2010	August	22
Waccabuc	1	9/7/2010	September	1007
Waccabuc	2	9/7/2010	September	1007
Waccabuc	3	9/7/2010	September	1007
Waccabuc	1	9/20/2010	September	770
Waccabuc	2	9/20/2010	September	770
Waccabuc	3	9/20/2010	September	770
Waccabuc	1	10/4/2010	October	650

Waccabuc	2	10/4/2010	October	650
Waccabuc	3	10/4/2010	October	650
Rippowam	1	4/15/2010	April	18
Rippowam	2	4/15/2010	April	18
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Rippowam	2	4/28/2010	April	16
Rippowam	3	4/28/2010	April	16
Rippowam	1	5/6/2010	May	97
Rippowam	2	5/6/2010	May	97
Rippowam	3	5/6/2010	May	97
Rippowam	1	5/24/2010	May	830
Rippowam	2	5/24/2010	May	830
Rippowam	3	5/24/2010	May	830
Rippowam	1	6/4/2010	June	702
Rippowam	2	6/4/2010	June	702
Rippowam	3	6/4/2010	June	702
Rippowam	1	6/21/2010	June	256
Rippowam	2	6/21/2010	June	256
Rippowam	3	6/21/2020	June	256
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Rippowam	3	7/9/2010	July	2
Rippowam	1	7/20/2010	July	5
Rippowam	2	7/20/2010	July	5
Rippowam	3	7/20/2010	July	5
Rippowam	1	8/5/2010	August	0
Rippowam	2	8/5/2010	August	0
Rippowam	3	8/5/2010	August	0
Rippowam	1	8/18/2010	August	18
Rippowam	2	8/18/2010	August	18
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Rippowam	1	9/7/2010	September	350
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Rippowam	1	9/20/2010	September	510
Rippowam	2	9/20/2010	September	510
Rippowam	3	9/20/2010	September	510
Rippowam	1	10/4/2010	October	595
Rippowam	2	10/4/2010	October	595
Rippowam	3	10/4/2010	October	595
Oscaleta	1	4/15/2010	April	45
Oscaleta	2	4/15/2010	April	45
Oscaleta	3	4/15/2010	April	45
Oscaleta	1	4/28/2010	April	46
Oscaleta	2	4/28/2010	April	46
Oscaleta	3	4/28/2010	April	46

Oscaleta	1	5/6/2010	May	27
Oscaleta	2	5/6/2010	May	27
Oscaleta	3	5/6/2010	May	27
Oscaleta	1	5/24/2010	May	53
Oscaleta	2	5/24/2010	May	53
Oscaleta	3	5/24/2010	May	53
Oscaleta	2	6/4/2010	June	610
Oscaleta	3	6/4/2010	June	610
Oscaleta	1	6/4/2010	June	610
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Oscaleta	3	6/21/2010	June	220
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Oscaleta	1	8/18/2010	August	18
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Oscaleta	3	8/18/2010	August	18
Oscaleta	1	9/7/2010	September	162
Oscaleta	2	9/7/2010	September	162
Oscaleta	3	9/7/2010	September	162
Oscaleta	1	9/20/2010	September	490
Oscaleta	2	9/20/2010	September	490
Oscaleta	3	9/20/2010	September	490
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Oscaleta	2	10/4/2010	October	451
Oscaleta	3	10/4/2010	October	451
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Kitchawan	3	4/15/2010	April	9
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Kitchawan	1	5/6/2010	May	74
Kitchawan	2	5/6/2010	May	74
Kitchawan	3	5/6/2010	May	74
Kitchawan	1	5/24/2010	May	360
Kitchawan	2	5/24/2010	May	360
Kitchawan	3	5/24/2010	May	360
Kitchawan	1	6/4/2010	June	124
Kitchawan	2	6/4/2010	June	124

Kitchawan	3	6/4/2010	June	124
Kitchawan	1	6/21/2010	June	352
Kitchawan	2	6/21/2010	June	352
Kitchawan	3	6/21/2010	June	352
Kitchawan	1	7/9/2010	July	0
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Kitchawan	3	7/9/2010	July	0
Kitchawan	1	7/20/2010	July	4
Kitchawan	2	7/20/2010	July	4
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Kitchawan	2	8/18/2010	August	17
Kitchawan	3	8/18/2010	August	17
Kitchawan	1	9/7/2010	September	930
Kitchawan	2	9/7/2010	September	930
Kitchawan	3	9/7/2010	September	930
Kitchawan	1	9/20/2010	September	1190
Kitchawan	2	9/20/2010	September	1190
Kitchawan	3	9/20/2010	September	1190
Kitchawan	1	10/4/2010	October	1141
Kitchawan	2	10/4/2010	October	1141
Kitchawan	3	10/4/2010	October	1141

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