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Ecology of the Plankton of Lakes Wapalanne and Ocquittunk in Sussex County, New Jersey

Malgorzata Barbara Drazek-Falah

ABSTRACT

The diversity of planktonic organisms was studied for seven months in Lake Wapalanne and Lake Ocquittunk (Stokes State Forest), Sussex County, New Jersey. Relative abundance and species diversity were studied as well as water quality including parameters: temperature, pH, dissolved oxygen, conductivity and depth of lakes. The data of seasonal changes in abundance of organisms and water quality was compared between both lakes.

Three stations were set up along the straight line on Lake Wapalanne, buoyed by diatometers, which were used for diatom collection. There were also three stations located along the sides of Lake Ocquittunk arbitrary picked. Plankton samples from both lakes were collected using eighty micron plankton net which was dragged behind a row boat from one station to the next on Lake Wapalanne and collected from the sides of Lake Ocquittunk. Furthermore, water quality data were collected at each station of both lakes.

The results of my study support previous findings where species composition varied throughout the seasons specially, the abundance of cladocerans, dinoflagelates and volvocines occurred during the first period of the study (June), and copepods increased in relative abundance later in the year (August and September). Representatives of Monera, Protista, Rotifera, Cladocera, Copepoda, Ostracoda, Amphipoda, Decopoda and Insecta were found in both lakes, however their species evenness and diversity varies interchangeably throughout. When taking into consideration higher taxon data, I demonstrate that the similarities of organisms in both lakes are very high; around seventy

five percent with the 0.18 stress level suggesting that both sites are similar. Comparing water quality data, they are very alike in both sites.

MONTCLAIR STATE UNIVERSITY

ECOLOGY OF THE PLANKTON OF LAKES WAPALANNE AND OCQUITTUNK IN SUSSEX COUNTY, NEW JERSEY

by

MALGORZATA BARBARA DRA,ZEK-FALAH

A THESIS
Submitted in partial fulfillment of the requirements
For the degree of Master of Science in
The Department of Biology and Molecular Biology
In the Graduate Program of
Montclair State University
August 2005

College of Science and Mathematics

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INTRODUCTION

Purpose of My Research

The purpose of this study was to determine the hydrological and ecological character of the plankton of Lakes Wapalanne and Lake Ocquittunk in Sussex County, New Jersey and to compare the ecology of the two lakes. Water quality data and plankton samples were collected from late spring into fall and were analyzed to species level whenever possible.

Lakes have often been the subject of ecological study. It is important to consider the results of other investigators when making a study of a particular environment. Lakes Wapalanne and Ocquittunk are relatively small and shallow lakes in mostly wooded areas. The ecology of other lakes, similar in size and bathymetry has been studied in Georgia, Michigan and elsewhere. Lake Oglethorpe in Georgia (Porter et al. 1996) and Lakes Peter and Paul in Michigan (Pace and Funke 1991, Pace et al. 1998) found similar structural patterns in the plankton communities. They observed that these communities were dominated by cladocerans and copepods and supported by diverse autotrophic and heterotrophic bacteria and protists. Ciliates and rotifers provided important links between producers and the microcrustacean consumers. I expected to find similar plankton communities in the Sussex County lakes.

In addition to the analysis of the diversity of species, comparisons will be made at the level of higher taxa, such as Orders Amphipoda, Copepoda, Cladocera and in some cases Class Insecta, Phylum Rotifera, Kingdom Monera or Protista. To group species at

higher taxa is appropriate when those taxa represent characteristic functional groups in the food web.

Literature was examined to retrieve information on lakes that resemble Lakes Wapalanne and Ocquittunk, and have been studied with regard to food webs and trophic dynamics. Information from prior studies was compared with the results of this study.

Lake Wapalanne and Lake Ocquittunk History

The New Jersey School of Conservation (NJSOC) is located in Stokes State Forest, Sussex County New Jersey. The first settlers that occupied this land used it for small gardens. They grew different kinds of crops such as: maize, tobacco and pumpkins. In the early 1700s this land was known to be occupied by the English and Dutch. They used this land for farming. During eighteen hundred, this land was completely deforested. The wood was then used by the local people for private and domestic needs (Jasch 2005).

In 1907, the State of New Jersey purchased 5,432 acres of land. They named this land Stokes State Forest in honor of Governor Edward C. Stokes who donated five hundred acres to the state. The total area of the forest has since grown to 15, 482 acres, when 2,900 acres were purchased by the Green Acres Program (Jasch 2005), which was created in 1961 to meet New Jersey's growing recreation and conservation needs (NJDEP Green Acres Program 2005).

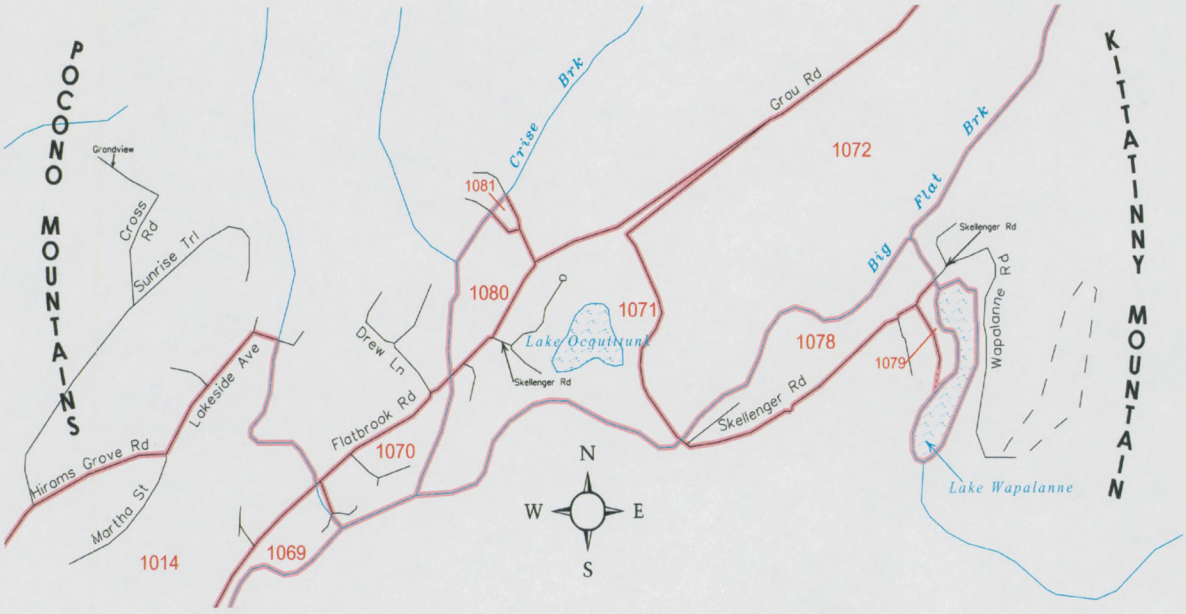
In the early 1930s, twenty two Civilian Conservation Corps (CCC) campuses were located at Stokes State Forest. The CCC was responsible for the construction of roads, shelter, cabins and trails throughout the forest. This provided many jobs to the

people during the Great Depression in the United States (Insight Online 2003, Klug et al. 2005).

Since 1972 the New Jersey School of Conservation (NJSOC) has been a part of the College of Science and Mathematics at Montclair State University (MSU) and is located 57 miles from the main campus (Insight Online 2003).

The NJSOC is the oldest and largest institute for environmental studies in the United States. The campus occupies 240-acres of land. Twelve acres of this land harbors Lake Wapalanne. Lake Wapalanne was built by CCC volunteers in 1935. The CCC achievements in Stokes State Forest also include the construction of local Lake Oquittunk (Insight Online 2003, Kight and Thomas 2004, Jasch 2005). Lake Wapalanne and Lake Oquittunk were the two primary sites, where my ecology of freshwater plankton study was performed.

Lake Wapalanne and Lake Oquittunk are surrounded by the Kittatinny Mountains with the Appalachian Trail on the East side, and by the Delaware River and the Pocono Mountains on the West side (NJSOC 2005).



NJSOC provides hands on experiences to about nine thousand students and one thousand teachers every year. There are currently fifty three environmental educational programs provided for students. This draws about one hundred elementary and secondary school students every year. The NJSOC also serves as a summer camp for teens. They are able to study all types of music such as jazz, blues, classical, rock and folk (Jash 2005). The NJSOC is a favorite place for astronomers. They can observe the rings of Saturn through the telescopes that are located in the observatory center (Jasch 2005, NJSOC 2005). Stokes State Forest has a great diversity of birds, this attracts many birders to this area in late August and early September (Jasch 2005).

Lake Wapalanne and Lake Oquittunk are also used by other large institutions such as Hofstra University and Rutgers University to conduct ecological studies (NJSOC 2005). Furthermore, Lake Oquittunk is a family camping area open to the public all year round. The lake is stocked annually by the Division of Fish, Game and Wildlife with trout. This allows everyone to come and enjoy the beauty of Stokes State Forest as well as have some fun fishing. Small boats: rowboats and canoes are permitted on the waters

of Lake Oquittunk (Jasch 2005, personal conversation with Harrigan 2005) however they were not used in this study.

Kinds of Fresh Water Lakes

Water is a mixture of hydrogen, deuterium, and tritium isotopes combined with isotopes of oxygen. The unique properties of water are high specific heat, nonlinear relation of density and viscosity to temperature (Malone 1997). These properties play an important role in the penetration, absorption, and distribution of light and heat, and in the density stratification in lakes. Furthermore, the water chemistry is closely related to geology and to the biology of aquatic habitats (Cole 1994, Essington 2005).

The biology of aquatic habitats consists of the study of aquatic species and populations. The organisms of the inland waters range from bacteria to mammals depending on a depth of a lake (Cole 1994). There are three very important regions in a lake. First from the top is the epilimnion region, also called the limnetic zone. It is a well lighted region where many organisms, including plants, find their support. This area has the greatest diversity, and the highest net annual production, compared to the deepest region of the lake, which is the hypolimnion zone in which net production is generally negative. This area is the coldest region because little, if any, light penetrates the water at these depths. In the hypolimnion zone the temperature remains relatively constant (Smith and Smith 2000, Pianka 1994). Due to the presence of carbonic acid (this deeper water is characterized by decay rather than by production of organic matter) there is a high concentration of hydrogen ion. This means that the pH level is low. In between the

epilimnion and the hypolinmion zone there may be a thermocline zone. It is a region of a lake where temperature changes drastically (Cole 1994, Pianka 1994, Ricklefs 2001).

Lake Wapalanne and Lake Oquittunk are classified as eutrophic lakes. The characteristics of an eutrophic lake consists of shallow, broad littoral zone, littoral plants abundant, water bloom common and a tendency to have an overturn of water throughout the seasons with high nutrient content and high productivity (Cole 1994, Pianka 1994, personal conversation with McCormick 2004). Both lakes are shallow and generally well mixed. The depth of Lake Wapallanne is one and half feet deep in the southern region and seven feet deep near the dam. The depth of Lake Oquittunk was not surveyed by me, but I was informed by Park Ranger Dan Harrigan (2005) that the average depth is roughly one meter and half. He also told me that there is a channel, where an old beach used to be located and the depth of the water in this area ranges between six to eight meters. The area of Lake Oquittunk is nine acres (personal conversation with Harrigan 2005) and area of Lake Wapalanne is twelve acres (Jasch 2005).

Plankton Community

The plankton community can be found concentrated in the epilimnion region of a lake. The plankton community consists of a mixed group of tiny plants and animals. These plants and animals can be found floating, drifting, or feely swimming in the water. The microflora is called phytoplankton and the microfouna make up the zooplankton group. The plankton is composed of bacteria, protozoans, tiny pigmented primary producers (phytoplankton) and minute animals. The species located at the epilimnion

zone play the role of herbivores, omnivores, carnivores, decomposers and detritivores (Cole 1994, Smith and Smith 2000).

The epilimnion is the region of a lake where my study took place. Because some parts of lakes were very shallow, my research touches upon the benthic community. The benthic community is the area associated with detrital material and its bacterial decomposers (Smith and Smith 2000).

The Food Web

The concept of the food web was first recognized by Charles Elton during the 1920's after he observed the feeding relationships between organisms. He argued that the organisms living in the same place not only have similar tolerances to physical factors in the environment, but also they interacted with one another in the feeding relationship called the food web. The feeding relationship where energy passes through the ecosystem is called a food chain. A food chain has many links: plants, herbivore, carnivore, and decomposers (bacteria) referred to as trophic levels (Smith and Smith 2000, Ricklefs 2001). The bacteria makes up fifty percent of the combined picoplankton (0.2-2 um) and nanoplakton (2-20um). They play an important role in a cycle of energy that passes through the ecosystem. These prokaryotes are grazed on by a host of small ciliates and flagellates (nanoplankters). Then the ciliates and flagellates become victims of larger ciliates and micro-zooplankters such as rotifers. The Cladocerans (e.g. *Daphnia sp.*) prey upon pico-planktons, nanoplanktons and microplankton, copepods feed on rotifers and the energy loop can be passed to the next level and then into the conventional food web. The microbial loop is completed when the ingested organisms are mineralized and

excreted as Nitrate and Phosphate containing carbon compounds. The Nitrate and Phosphate then serves as plant nutrients (Cole 1994, Smith and Smith 2000).

The food web of a lake is composed of a number of interacting communities. The benthic community is detritus-based, energized by dead organic matter from the surrounding terrestrial ecosystem supplemented by a "rain" of detritus from the epilimnion. The plankton community gets most of its energy from the sun through photosynthetic protists such as phytophagellats and diatoms. These communities are connected through vertically migrating insect larvae, crustacean and fish, and by the detrital "rain". In addition the larval stages of macrofauna such as snails, worms and crayfish (the mesoplankton) are temporary members of the plankton (personal conversation with McCormick 2004).

A variety of lakes in Georgia and Michigan that resemble Lakes Wapalanne and Ocquittunk have been studied with regard to food webs and trophic dynamics. In these lakes it has been found that predation by larger crustaceans, such as Daphnia pulex, and large insect larvae such as Chaoborus, may play a controlling role in top-down trophic cascades. (Cristiansen et al, 1996, Pace et al, 1998. Pace and Funke, 1991 and Porter et al, 1996).

The Fresh Water Biota and Habitats

The temperature of the inland waters in New Jersey is variable from 25°C or more in summer to 4 °C or less in deep water or frozen as ice at the surface in winter, with the pH around seven (Cole 1994, Ricklefs 2001). The fresh water is tolerant of this changing environment (Cole 1994). The common biotas found in fresh water are: Prokaryota

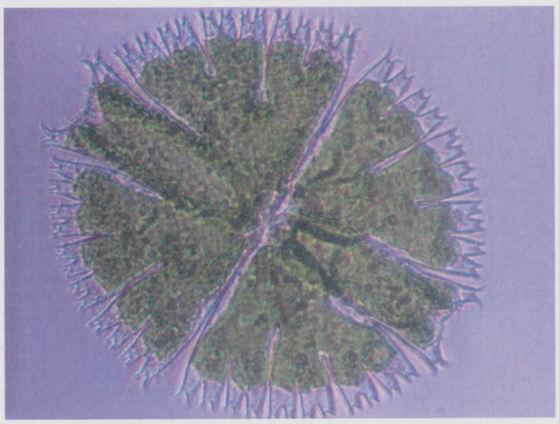
(Monera) for example bacteria that are decomposers, as well as the photosynthetic Cyanobacteria. Phytopflagelleate and diatoms are generally the dominant primary producers. Sponges and Cnidaria are common in some lakes and streams. Cladocera, Copepoda and Ostrocoda are small crustaceans that dominate the zooplankton. Amphipods, beetles and insect larvae also may be important consumer as part of the plankton (Cole 1994).

Kingdom Monera includes all organisms with prokaryotic cells (Archaebacteria and Eubacteria). Archaebacteria are very rare. They thrive in very harsh habitats like the deep sea and salt marshes. The Eubacteria is called the true bacteria and it consists of unicellular and colonial species. All these cells are prokaryotic which means that they do not have a nucleus (Countryman-Jones et al. 2003). There are three typical shapes of bacteria: bacillus (rodlike shape), spirillum (spiral) and coccus (spherical shape) (Countryman-Jones et al. 2003). Most bacteria are heterotrophs and this means that they obtain their nutrients from the surrounding environment. They do this by using decaying organic matter and dead organism and converting them to organic inorganic which are then used by plants (Cole 1994). They help to clean up the environment and are able to recycle chemicals that can be used again. They are parasitic heterotrophs that obtain nutrients from cells or tissues of a host. By taking nutrients they can cause disease to that organism. There is third kind of bacteria called autotrophs. These bacteria can produce organic nutrients themselves. There are two kinds of autotrophic bacteria: chemosynthetic (oxidize inorganic chemicals like sulfur or ammonia, and capture and release energy to synthesize organic nutrients) and photosynthetic (use light energy to synthesize their organic nutrients) (Freeman 2002, Countryman-Jones et al. 2003). Most

photosynthetic bacteria belong to the Cyanobacteria family and can live in freshwater, saltwater and terrestrial environment (Countryman-Jones et al. 2003). The cyanobacteria are slightly different from other bacteria because they do not have chloroplasts, the chlorophyll a is located on the thylakoid membranes. Their cell wall is much larger and they possess a spherical or cylindrical shape. Most appear to be blue-green in color but, can also be red, orange or yellow (Countryman-Jones et al. 2003).

The reproduction process in bacteria is asexual and mainly through binary fission. Some cyanobacteria can reproduce by fragmentation of their colonies. Sexual reproduction can occur and is called conjugation, which means that there is the transfer of genetic material (DNA) from one cell to another. After conjugation, bacterial cells separate and reproduction occurs by binary fission (Countryman-Jones et al. 2003).

The Protozoans, slime molds, algae, dinoflagellates, diatoms and euglenoids make up the **Protista Kingdom**. These groups of unicellular or colonial organisms exhibit animal-like, plant-like or fungus-like characteristics.



Desmidiaceae*: Micrasterias sp.* Magnification 400X

These organisms have Eukaryotic structure where cells have true nuclei and membrane-bound organelles such as a mitochondria, golgi bodies, and plastids. Protists are simple organisms, however their cellular organization is very complex even though we compare them to animals, plants or fungi. The animals, plants and fungi have cells, tissues, organs and organ systems to perform the life processes, where protists do all these functions within one cell (Freeman 2002, Countryman-Jones et al. 2003).

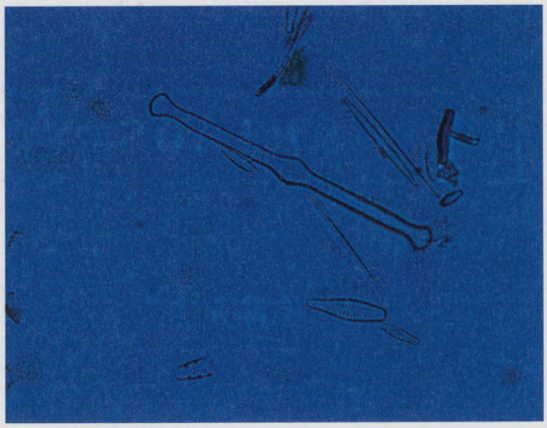
The Protozoan can survive in many different environments, due to well functioning organelles. Protozoans move by four different organelles: flagella, cilia, pseudopodia and undulating ridges (waving of plasma membrane). There is sexual and asexual reproduction and some species have both that they alternate between. The sexual reproduction occurs when two protozoan meet and exchange nuclear material (called conjugation). Another form of sexual reproduction is when two sex cells unite which is known fusion. In asexual reproduction the protozoa divide into two, and then break into a few parts. Next, it develops a bud and then a cell. An example of a protozoan is: *Arcella* sp. Paramecium (Jahn 1949, Freeman 2002, Countryman-Jones et al. 2003).

Slime molds are fungus-like Protists, which were previously classified as fungi. These organisms reproduce asexually by forming sporangia which produces spores (Jahn 1949, Countryman-Jones et al. 2003, Tero et al. 2005).

The study of Algae is called algology or phycology. Algae can be found in many different habitats including fresh water, salt water, and moist environments. Their size ranges from microscopic-unicellular to very large complex organisms (e.g. brown algae). Algae have a cellulose cell wall and chloroplasts, same as in plants. All algae have chlorophyll a and yellow and orange carotenoid pigments. Reproduction in algae can be

sexual or asexual. Algae can be found attached to rocks, floating in the water or appear as hard objects (Vymazal 1995, Countryman-Jones et al. 2003). There are three different kinds of algae: green, brown and red. Some scientists place them in the Protista kingdom while others have placed them in Plantae kingdom (Countryman-Jones et al. 2003). Dinoflagellates meaning "two flagella" are mostly marine, but some, such as *Ceratium hirundinella,* are found in fresh water. They contain chlorophyll a and c in their chloroplasts. Most of them have a cell wall, cellulose and as mentioned above two flagella. One flagellum is found around the equator of a cell wall and the other hangs free from the end of the cell. When conditions are favorable they can become very abundant and toxic. A condition called red tide is known to kill massive amounts of marine fish (Vymazal 1994, Silbergeld et al. 2000, Countryman-Jones et al. 2003).

Diatoms are unicellular and have a cell wall composed of hydrated silicon dioxide, a natural form of glass. The cell wall of a diatom consists of two frustules that fit together like a top and bottom of a shoe box. In the diatom's chloroplast chlorophyll a and c can be found. When a diatom dies the silica shell gets deposited on the bottom of the lake or sea. These deposits can be used commercially in production of abrasive cleaners, toothpaste, filters, and insulation. The 40% of primary production in the ocean is due to diatoms, but in fresh water the proportion of primary production due to diatoms is uncertain (Cox 1996, Countryman-Jones et al. 2003).



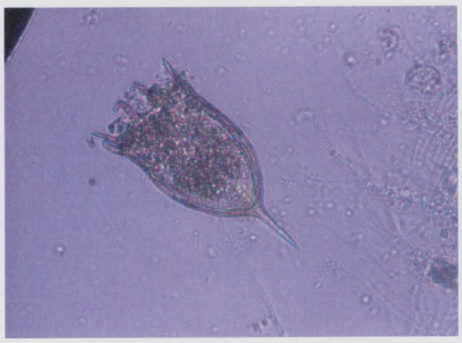
Diatoms: *Tabellaria fenestrata*
Gomphonema sp.

Magnification 400X

Euglenoids have both animal-like and plant-like characteristics but contain no cell wall. Their chloroplasts have chlorophyll a and b. Their movement is due to a flagellum. The Euglenoids have an eyespot which detects light intensity (Countryman-Jones et al. 2003). *Euglena sp.* is a common fresh water organism that is capable of heterotrophic as well as autotrophic production.

Phylum Rotifera is divided into two classes: Monogonta and Digononta. They are called cosmopolitan, which means that some rotifers can be found in the same type of habitat all around the world (Pennack, 1989). Most rotifers are found in fresh water and there are about 2500 species known to exist. They were first described by Leeuvenhoek in 1703. Rotifers are very small in size and their length ranges from 40μm to 2.5mm. They are found in many habitats: aquatic and semi-aquatic, limnetic and deep ends of lakes, ponds, damp soils, debris, and sand grains. Rotifers are wide spread and can be found from the Arctic to Antarctic to the tropics (Pennack, 1989, Cole 1994).

Rotifera: *Kellicottia longispina*
Dinoflagella*:* *Ceratum hirundinella*
Magnification 200X



Rotifera: *Keratella cochlearis*

Magnification 200X

Most Rotifers that are found are females. There are some species that have males but their life span is only few days. Some species of rotifers are free swimmers and others are sessile. The internal body of a Rotifer varies depending on the class it belongs to. However, they all have a brain, pharynx, esophagus, gastric gland, ovary, intestine, oviduct, stomach, bladder, and a pedal gland. The outer body of a typical rotifer is elongated and cylindrical of different shapes. They have three regions that can be seen a head, trunk and foot. The head includes the mouth, eyes, and corona-cilia which has dual function: locomotion and feeding. The body color of a rotifer range from green, brown, grayish, yellowish, pink to blue (Pennack, 1989). The animal moves through the water due to cilia. This is done by twisting on the longitudinal axis, through spiral movements of the whole body, by sudden jerks, leaps or by creeping (Cole 1994).

Most rotifers are omnivores and ingest all organic particles by sweeping them into their mouths by use of water current. Some species of rotifers are predators that detect their prey by biochemical stimuli or touch. They feed on other rotifers, small Metazoans,

Protozoans, and micrometazoas. Others feed on filamentous algal cells. Another group of rotifers feed on small Cladocerans and dead copepods (Pennak 1989).

Their digestive system varies from the one species to the next depending on their diet. However, the digestive system starts with the mouth which opens to pharynx which leads to the mastax cavity. Around the mastax cavity, there are salivary glands. Following the food pathway there is short then long esophagus and a thick walled ciliated stomach where digestion and absorption occur. On the anterior of stomach there is a bean-shaped gastric glands. After the stomach there is the intestine and the short cloaca (anus), which is opened to the outside and is usually located on the dorsal side of the foot (Pennak 1989, Cole 1994).

Most rotifers thrive in high oxygen level habitats, but some can withstand anaerobic conditions for short period of time (0.1-1.0 ppm). For example *Asplanchna*, *Polyarthra* and *Keratella* occur in the oxygen poor hypolimnion region of lakes in mid summer and winter. Under worst circumstances their ciliary movements help them with oxygen supply. Most rotifers are found in water with a pH of 7.0. If the pH is much above or below 7.0 there will definitely be a decrease in rotifers number (Cole 1994).

Rotifers keep their osmotic pressure constant due to a specialized system called the protonephridia. This system consists of four to fifty flame bulbs arranged along the tubes which are located on both sides of the body. These two tubules are connected to the excretory bladder from which a short duct goes to the cloaca. Extra water and some metabolic wastes are absorb by the flame bulbs and are excreted into the cavity of the ducts and then to the bladder (Pennak 1989).

There are muscle fibers that are present in rotifers: smooth and striated which are always arranged in bundles. These muscles are associated with movements of the spine and appendages. There are also visceral and cutaneovisceral muscles that help to move and hold the internal organs in place. Another internal arrangement in rotifers is a nonlinear nervous system. It consists of a brain that is located on the dorsal surface of the mastax and it leads to the esophagus. Some species of rotifers have nerve fibers associated with mastax, muscles, viscera and sensory regions. The most important sensory organs of rotifers are the cervical eyespots with red pigments. The number of eyespots varies due to life stage of the rotifer (immature have two additional eyespots) and species type. Another important sensory organ in rotifers is the antennae. The antennae can be small or medium in size and is located on the dorsal or posterior region depending on the species (Pennak 1989).

The developmental stage of plankton and littoral rotifers usually takes a few hours. The lifespan of a rotifer differs between the species, some live eight days others six weeks. Their abundance during the year can be monocyclic, dicyclic, polycyclic, acyclic or perennial. The abundance of rotifers varies from species to species, year to year and from one lake to the next.

A rotifer's life cycle goes through cyclomorphosis where their body size and shape change. An example is the *Keratella* sp. which has thirteen different forms and *Brachionus* sp. Their metamorphosis depends on the temperature of the water and food availability. Rotifers are food for other animals like protozoans, cylopoid copepods, cladocerans and small fish. There are a few species of Rotifers that are parasitic and have

been found inside of *Volvox* colonies. There are also groups of free living rotifers that live as commensals on many fresh water invertebrates like crustaceans and insects.

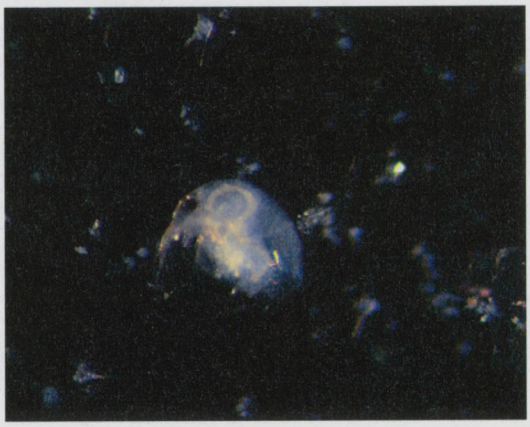
The abundance of rotifers is associated with food availability, space attachment, availability of protection and water chemistry. Some of the more abundant species are: *Keratella cochlearis, Keratella quadrate, Lellicotia longispina, Asplanchna* sp., *Brachonus* sp. *and Conochloides* sp.

Like the copepods and cladocerans, rotifers move vertically up and down based on a twenty four hour period. In the morning there is maximum abundance of rotifers at the surface of water and in the afternoon there is maximum number of rotifers in the deep part of the water.

In the past twenty years many studies have been done with rotifers. However, all of the studies were based on controlled treatments and certain condition of the laboratory. There are many studies that still need to be done and many questions waiting to be answer. Some of the questions posed by scientists are predation effects, bisexual reproduction, cannibalism and many others (Pennak 1989).

Cladocera is next group of organisms found in fresh water. They are also known as the water fleas. Members of this Order are between 0.2 to 3.0 mm long. Their body is not clearly segmented and in many species the thoracic and abdominal regions are covered by a secreted shell which has a bivalve appearance. In the lateral view the shell appears to be oval, circular, elongated or angular. In many species the posterior end has a spinule or spine. The head is a compact structure with large compound eye (important in orientation to light sources and light intensity). The first antennules are located on the ventral side of the head. The second antennae are very large in size and can be found near

the posterior margin of the head. Then in front of antennules, there is the beak known as rostrum. There are small mouthparts which are situated near the junction of the head and body. There are five or six leaf-like thoracic legs which contain some hairs. The true abdomen is reduced, but there is a large post abdomen at the posterior end of the body (Pennak 1989, Cole 1994).



Cladocera: *Bosmina longirostris* Magnification 100X

Through the year, the Cladocerans population consists mostly of females. The males are abundant mainly in the spring and autumn and in many species the males are rare or unknown (Pennak 1989, Cole 1994, Oda et al. 2005). Anatomically the males are different from the females. The males have smaller bodies, larger antennules and modified post abdomen. The males also have a hook on their first leg which is used to clasp the female during mating (Pennak 1989). The fresh water species possess a wide range of colors. The species at the top are usually light-colored and translucent, where at the benthic species are darker (light yellowish brown to reddish brown, grayish, or almost black). Cladocerans are very active and are always in motion. Their antennae are the

primary organs for locomotion. They move by "hopping". *Daphnia sp.* for example and some other genera move from place to place by swimming (Pennak 1989).

Most Cladocerans are filter feeders. They feed mostly on algae, Protozoa, bacteria and ingest organic detritus of all kinds. Some genera of cladocerans are predaceous such as: *Polyphemus* and *Leptodora.* Their preys are mostly rotifers (Pennak 1989). Although they have a complex muscular system, you can still distinguish a digestive system (esophagus, stomach, and tubular digestive tract, intestine). They do not have blood vessels. So blood enters the heart through two lateral ostia and leaves through an anterior opening. The exchange of oxygen and carbon dioxide takes place on the body surface. There is a nervous system that consists of a ventral double nerve cord, ganglia, paired nerves, and a brain. Gonads can be seen only in sexually mature species. The reproduction is parthenogenetic most of the year and only females are produced (Oda et al. 2005). The eggs undergo a single maturation and depending on the environmental conditions and species there are different numbers of eggs per clutch: between 2 to 40 (Pennak 1989). In the early spring there are only a few Cladocerans found in the pond or lakes. This population consists of females which survived the winter or have hatched from winter eggs (Oda et al. 2005).

As the temperature reaches 6 to 12°C, their reproduction begins and the offspring numbers can reach anywhere between 200 to 500 individuals per liter. However soon after, the population declines and is small during the summer months. In autumn there may or may not be a second population and in winter the population is very low (little or no reproduction). Because species differ from one another in their seasonal abundance, even single species may have different population densities in two adjacent bodies of

water that is why it is impossible to predict or formulate seasonal abundance. Furthermore, relative abundance and the specific time or maximum and minimum populations may vary considerably within a single species in the same lake from one year to the next (Pennak 1989).

In cladocerans, five percent of the population which appears in the lakes and ponds in the spring consists of males (Pennak 1989). Scientists do not have an explanation why this occurs, but it is thought that the low number of males is caused by a decrease in available food, water temperature, light intensity or hormones (Oda et al. 2005).

The life history of a cladoceran is divided into four periods: egg, juvenile, adolescent and adult. After the clutch of eggs is released into the brood chamber, segmentation begins. The whole process takes two days. During the juvenile stage there may be a doubling of size of the organism and an increase of volume which occurs within a few seconds or minutes (Pennak 1989). Recent laboratory work has shown that growth and reproduction of *Daphnia sp.* may be biochemically slowed or inhibited by dense populations of blue-green algae (Infante and Abella 1985).

One of the problems with reproduction in cladocerans is seasonal change, also known as cyclomorphosis. These changes usually occur in females during the late fall, winter, and early spring. The structure looks like a "helmet" which is fully developed in midsummer to late summer or early fall. What is unique about this structure is that the helmet disappears after development and goes back to the original state. In addition, there are changes that occur in the shape of the head, size of eye and length of the posterior

spine. These changes appear differently in each lake and it is though to be caused by differences in temperature, genetics or predation pressure (Coker 1939).

Most limnetic cladocerans undergo vertical migration during a twenty four hour period. They move upward at night and downward in the morning. Some species however migrate rapidly in an upward or downward cycle. There are also a few species that have opposite migratory movements. These vertical migrations are governed by the light intensity as well as size, age, species, temperature, food supply, water chemistry, water color, season of year and turbulence (Pennak 1989).

careful collection twenty five species can be harvested in a single day. The two most common inhabitants of ponds and pools are *Daphnia pulex* and *Daphnia magna.*

In limnetic situation it is unusual to find more than one species in a single genus at the same time, but when two species in the same genus do occur together, one is usually 20 or more times as abundant as the other. Most of them are found in wide range of pH ranging from 6.5 to 8.5 (Cole 1994).

Cladocera play an important role in the food chain. Studies have shown that 95% of the gut contents of some fish may be composed of Cladocera. With numbers this large, this makes Cladocera their primary food source. Hydra and insects have been known to prey on Cladocera as well. Their taxonomy is very complicated, due to seasonal and geographical variations and it is hard to classify them (Pennak 1989, Cole 1994).

Copepoda like the Cladocera, are universally distributed. They can be found in marine and fresh water habitats (Santer 1998, Raven and Johnson 1999). There are about 8,000 to 10,000 described species world wide.

Copepoda: *Eucyclops serrulatus*
Magnificatin 100X

Copepoda: *Limnocalanus macrurus*
Magnificatin 100X

The body length of the American species range from 0.3 to 3.2 mm, but a majority of Copepoda are less than 2.0 mm long. Most species are grayish or brownish in color. While species that live in high altitudes appear: bright orange, purple, or red. These bright colors make them more vulnerable and are often preyed on by fish. The American fresh water copepods are divided into two orders: Eucopepoda and Branchiura, and six suborders: Caligoida, Lernaeopodoida, Arguloida, Calanoida, Cyclopoida, and Harpacticoida. The first three suborders are parasitic and their morphology is different when compared to other suborders. The free swimming Copepoda body is segmented, elongated, cylindrical and divided into a head, thorax and abdomen. The head in composed of first and second antennae, mandibles, first and second maxillae (Pennak 1989).

The thoracic is connected to the head and composed of seven segments where swimming legs are connected (number of legs depends of species). The thorax seventh segment is fused with the abdomen and there are no appendages in that area. The sixth segment of Copepoda is so called urosome, this is where genitalia are located. The

abdomen consists of three to five segments. The last abdominal segment has two posteriorly directed caudal rami (exoskeleton outgrowths), which vary from species to species (Pennak 1989).

When talking about feeding, the harpacticoid mouth structure is slightly different from calanoids, harpacticoids feed on the bottom. Their mouth parts are adapted for raking seizing, and scraping food from bottom, whereas calanoids feed mostly by filtration. Their food consists mostly of unicellular plants and animals, small metazoans (crustaceans) as well as organic debris. Cannibalism of immature stages is very common. Their locomotion is based on coordinating movement of antennae and legs. The internal body is very difficult to study due to many complicated systems of muscles (Pennak 1989, Cole 1994).

The reproduction of Copepods varies because each species has different reproductive behavior (Santer 1998). Couple of examples would be: the *Eucyclops agilis*, which reproduce throughout the year where as the *Macrocyclops fuscus* reproduces only during the summer months, and the *Limnocalanus macrurus* produce only one generation. This reproductive behavior applies only for the Calanoid copepods because there is not enough information about the Harpacticoids. The Calainoids mate by the male clasping to the female and transferring sperm to a special ventral storage area of a female genital segment which serves as a seminal receptacle (Block et al. 3003). The fertilization does not occur until after the female and male have separated. Then the eggs will leave the female reproductive tract and enter the ventral storage area. This process can take few minutes or up to two months depending on the species. Fertilized egg is then carried by the female in one or two ovisacs. These ovisacs can hold anywhere five to

forty eggs. The female produce more eggs in the spring; however, the clutch size can vary with temperature or food conditions (Santer 1998, Zadereev et al. 2003). Copepods go through metamorphosis where there are six nauplius stages and five to seven copepodid stages before the last molt, which produces sexually mature adults (Neumann and Fennel 2005). There are more generations reproduced during summer and less in the winter (Santer 1998). Some cyclopoid copepods go into an inactive diapause on the bottom of a lake during cold months (Santer 1998, Zadereev et al. 2003). The parasitic copepods are the most bizarre of all fresh water animals. They are known as fish lice and can be found on the surface, fins, and gills of fish where they gain nourishments from their tissues. The only fresh water parasitic copepod leaving in the Unites States is the genus Argulus which consists of about fifteen species. The Argulus life stages are slightly different than other copepods where the nauplii stages are passed within the egg, but the first copepodid is a free-swimming plankter before it attaches to the fish. Because these species are not as abundant as some others they do not pose a threat to the fish. These adults are resistant to chemical solutions so they pose a risk of damaging hatcheries. In extreme cases there are no solutions for the infected ponds but to get rid of infected fish, clean the hatchery and start a new one (Pennak 1989). Free-living copepods play a huge role in a contribution to the aquatic food chain (Block et al. 3003). They appear on the intermediate trophic level between bacteria, algae, and protozoans, as well as small and large plankton predators-fish. However, they generally are not as important in a fresh water fish's diet as the Cladocera. They are important as intermediate host of parasites of the higher animals like tapeworms, carnivores, flukes, amphibians and birds (Pennak 1989, Cole 1994). Some species of plankton copepods show a vertical migration due to

the diel variation in light penetration. Consequently more of them are in the deeper part of a lake during the daylight hours (Santer 1998, Neumann and Fennel 2005).

The Ostracoda. Ostracods also known as Seed Shrimps can be found in a wide variety of habitats like standing or running waters, mud, sand, rubble, algal mats, debris, and rooted vegetation (Raven and Johnson 2001). Some species can be found in underground caves and others as commensals which were found in great densities on gills and articular membranes of crayfishes. Habitats that have lots of water movement usually do not support ostracods (Pennack 1989). They can thrive in water with a pH range of 4.0 to 8.0 however, some have been found in alkaline and acid conditions. Ostracods are the intermediate hosts of some tapeworms. There are about 300 species of Ostracods known in the United States. They are classified to four taxa: Myodocopa, Cladocopa, Platycopa and Podocopa. The Podocopa is the only one that has both marine and fresh water representatives (Pennack 1989, Raven and Johnson 2001). Because of their opaque bivalve shell they are difficult to study and therefore the identification involves dissection. The fresh water species of the American Ostracods can range from less then one mm to three mm in length. Their body displays colors from white, yellow, green, grey, red, brown and black. The light color Ostracods usually dwell in darker habitats where as the gray, green or brown are found among algae and rooted aquatics. The valve which consists of an inner and outer plate is connected to the anterior, posterior, and ventral margins. Between the two plates is a space that is occupied by a fold of skin. This fold of skin secretes the valve material. The valves are connected to the dorsal margin by an elastic band and held together by an adductor muscle. It is hard to distinguish between different parts of the body; however the head region is marked with

four pair of antennae. They have claw like bristles that are used for swimming, climbing and digging (five to seven segmented first antennae). The other appendages (four to six segmented second antennae) are used for locomotion, feeding, and in males it is used for clasping the female during copulation. In the thorax region there are three pairs of legs (Pennak 1989). The Ostracods moves due to movements of the first and second antennae and by the kicking of the caudal rami. Their food consists of bacteria, molds, algae, and fine detritus. Some of the larger Ostraocods have been observe feeding on living and dead animals. Ecologically they are considered to be omnivorous scavengers (Pennack 1989, Cole 1994).

The internal anatomy consists of a digestive tract, esophagus, secretory and absorptive midgut and a hindgut. The anus is located at the base of the caudal rami (Pennack 1989).

Respiration occurs through the body surface. In fresh water Ostracods there is no heart present in the internal anatomy. There are shell glands located between the shells and their functions are not yet known. They have an antennae gland that has an excretory function. The Ostraocod have a simple nervous system that contains a brain (ganglion), two esophageal connectives, a subesophageal ganglion and a ventral chin of two paired ganglia. At the base of the first antennae there are two to three eye spots with a small lens (Pennack 1989).

Reproduction in some male species is rare therefore reproduction in this species often occurs by parthenogenetic. The species where males are present reproduce through syngamic reproduction and there is another group that can reproduce both ways. The males and females have reproduction organs designed for copulation (Pennack 1989). A

very interesting fact is that the male sperm is the largest in size in all the animal kingdom. Animals reproduce in the summer and in most species there is only one generation per year. Most fresh water ostracods deposit their egg/eggs on rocks, twigs, debris or vegetation. The eggs are spherical and are usually white, yellow, orange, green or red. The hatching period for eggs is from few days to months. There are nine life stages for an animal where eight of them are molts and the ninth instar is an adult. Their life span is from few weeks to eight months (Pennack 1989).

Amphipods also called the fresh water shrimps. They are mainly marine organisms (Cole 1994, Raven and Johnson 1999). There are one hundred and fifty species of fresh water amphipods described in America and nine hundred species worldwide (Pennack 1989). They dwell mostly in unpolluted lakes, ponds, streams, brooks and springs. Most of the Amphipods species are five to twenty mm long. Their body consists of a cephalothorax (first thoracic segment fused with the head), seven thoracic segments, a six-segmented abdomen, and a small, terminal telson. Their eyes are usually well developed, and can be compound, circular, oval or elongated. Amphipods have two pairs of antennae that range from short to long. Each first antennae has a long flagellum, the second has a flagellum and a five-segmented peduncle. The mouth is relatively small, compactly arranged and hidden by the basal segments of the appendages of the first thoracic segment. They have seven pairs of legs that are very similar to the crayfish legs. The gills of amphipods have oval shape. The gills can be found on the second to sixth or seventh legs. There are six abdominal segments in every organism. Sexes can easily be distinguished because the males always have gnathopods. There is wide range of colors in amphipods; from light brown, greenish, bluish, purple, dark

brown, to reddish. There is not enough information known about the variety of color, but it is though to be due to their diet, temperature, or algae. In general, amphipods are more active at night than during the day (Pennack 1989, Raven and Johnson 1999). The water shrimps are voracious feeders. They consume all kinds of plant and animal matter rarely they attack and feed on living animals. Most common species breed between February and October, depending on water temperature (Cole 1994). They reproduce syngamicaly, which means that the male and female pair up for about one to seven days. After copulation the female releases her eggs. The number of released eggs depends of size and age of a female as well as the particular species. In general older females release larger numbers of eggs. The brood can be composed from one to fifty eggs (Pennack 1989). The fishes are the main predators of the Amphipods (Cole 1994), also birds, aquatic insects and amphibians. Amphipods support amazing population of algae, sessile protozoans and parasites (e.g. tapeworms) on the external body surfaces (Pennak 1989). Considering Taxonomy; of the three suborders of Order Amphipoda, only one, the Gammaroidae, is found in American fresh waters (Pennak 1989, Cole 1994).

The crayfish and shrimp are classified as Order **Decapoda.** The majority of organisms from this order are marine (Raven and Johnson 1999). In the United States there are about three hundred fifty species found in fresh water habitats. (Cole 1994). Crayfish (crawfish, crawdads) and crabs have cylindrical body with strong appendages. They have large, movable compound eyes. The length of their trunk ranges from ten to one hundred fifty mm (antennae not included). There are six abdominal segments, the head and thorax are fused together. They have nineteen pairs of homologous appendages used for a wide variety of functions. The last abdominal segment is a flat terminal telson

with a pair of flat biramous uropods. They have two kinds of antennae: first and second which are used as sensory organs (Pennak 1989, Cole 1994, Countryman-Jones et al. 2002). Mature crayfish are dimorphic which means that there is a difference in the appearance of the male and female (Freeman and Herron 2004). The male usually have larger chelae (claws) and a narrower abdomen. Their body color ranges from blackish to brown, red, orange, green or blue with some intermediate shades. The young are more likely to be brighter in color because the older ones usually have an accumulated coat of dirt debris, and algae. In *Palaemonetes paladosus*, the resemblance of the animal color to the background is incredible. This species can be found in four different colors ranging from white, red, yellow, or blue. They can adapt to their surroundings within twenty-four hours (Pennak 1989).

Their locomotion is due to pereipods which helps them either move or climb back and forth or side to side. They can also move through the water for short distances by abdominal contractions. The fresh water decapod: *Palaemonidae sp.* are distinct swimmers and can move continuously forward through the water (Pennak 1989). Crayfish feed on snails, small fish, aquatic insets, succulent aquatic vegetation and on sponge tissue. Ecologically they are considered scavengers (Pennak 1989, Cole 1994). The internal body is composed of short esophagus that is attached to the cardiac chamber of the stomach which is connected to a smaller pyloric chamber. These chambers are composed of ossicles which are used to grind food. The long intestine extends to the anus located on the ventral side of the telson (Raven and Johnson 2001). There are two glands associated with the digestive track and they are used for absorption and food storage. They have a pentagonal heart located in the dorsal portion of the cephalothorax. This

section receives and sends out the blood to the rest of the body. Their blood is almost colorless and it contains amoebocytes and dissolved hemocyanin. They have eighteen gills through which blood circulates along channels located in each gill. A crayfish does not drink, but the quantities of water are continuously diffusing the blood through the gill surfaces. Blood (minus its protein) is absorbed by the coelomic sac and after it is taken by the green gland apparatus. The two green glands are located on the anterior end of the cephalothorax. In fresh water animals some substances such as carbohydrates, salts and water are reabsorbed back into the blood, and the rest is released outside by the animal as diluted urine (Ricklefs 2001). The animal has a very simple nervous system which consists of a ventral nerve cord, chain of ganglia, two circumesophageal connectives and dorsal brain. The taste receptors are located in the mouth parts and antennae. The antennae serve as tactile and balance the organs. Each crayfish also has a pair of compound eyes and sinus glands (Pennak 1989).

Insects are classified as Class **Insecta** of the Phylum Arthropoda (Borror and White 1979). Insects are one of the most abundant animals on this planet. They account for more than half of the living organisms in our environment. Insects can be found in all types of habitats ranging from deserts to wetlands, lakes and streams (Cole 1994, Raven and Johnson 2001). They are relatively small in size and can range from less than a millimeter to about six inches (Peterson et al. 2005).

Insects are a valuable to both humans and the environment. They play important role in the pollination of flowers, trees, vegetables and field crops. Some insects are very important to us because they produce commercially valuable products such as silk, honey

and beeswax. They are a key factor in the food chain and are consumed by birds, fish and reptiles (Freeman and Herron 2004, Petersen and Dahllof 2005, Russell 2003

There is a great diversity of insect fauna in fresh water. Although the adults generally exposure to air for gas exchange, a number of aquatic laral forms are important members of the food webs of lakes and streams. Especially important are the larvae of certain Diptera (Chironomidae, Culicidae), Ephemeroptera (Ephemeridae, Baetidae). Some Hemiptera (Gerridae), the water striders and Coleoptera (Dytiscidae and Gyrinnidae) may be active predators. Ephemeropteran larvae are usually scrapers or filter feeders. Chironomids are scrapers, chewers, filter-feeders or predaceous swallowers (Wetzel 1975). *Chaoborus* larvae (Ord: Chaoboridae) are active predators on freshwater zooplankton. Chaoborus is a important consumer of cladocera and rotifers in lakes (Yab et all. 1991).

MATERIALS AND METHODS

I. Preparation For The Trip

Day before the trip

Every trip required preparation, and to ensure accuracy, all the equipment (net, funnel, electronic devices, secchi disk, forceps, cooler, notebook, pens, bottle with clean water, camera and rain coats) was gathered and checked. Refills of deionized water, filter paper, and paper towels were made when needed. Before every trip five jars, six vials and three petri dishes were labeled (place and date) and used for sample collections. The electronic device that was used, the Vernier water quality monitor TI83 Plus was checked and calibrated. It was important to do the calibration of TI83 Plus on the same day of the trip to ensure the proper measurements of the water quality.

II. On A Day Of Each Trip

II.1. Instrument preparation

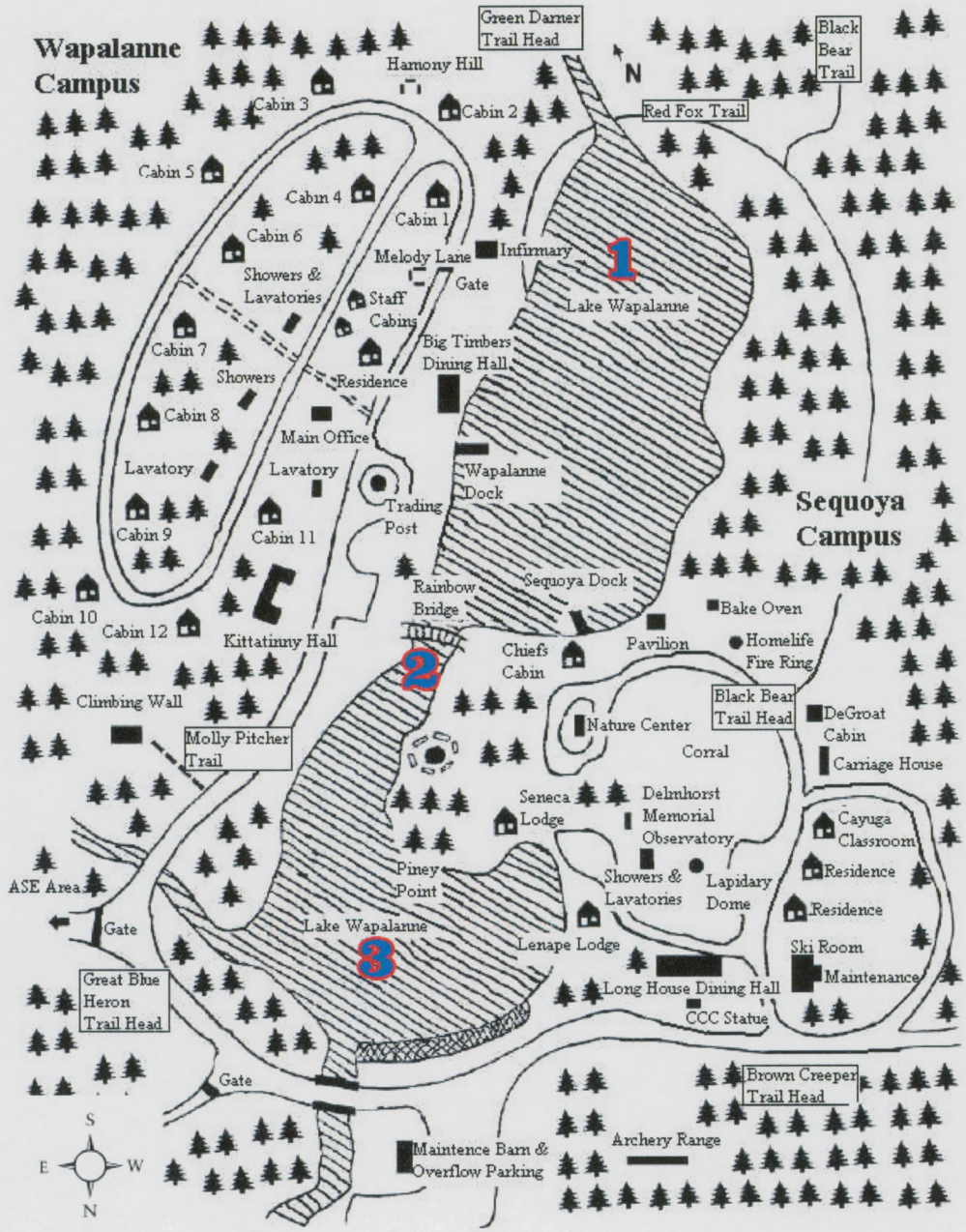
Once at the lake, the Vernier water quality monitor interfaced with a programmable TI83 Plus calculator was prepared for water quality measurements. First, the Dissolved Oxygen probe was filled with 1ml of DO Electrode Filling Solution and then attached to the channel located in the calculator. Next, the temperature probe, pH probe, and the Conductivity probe were placed into channels. Then the calculator was turned on to warm up for at least 10 minutes before measurements were taken, as recommended by the manual (Johnson et al. 2000). All the necessary equipment was placed in to the row boat.

II.2. Collection of plankton samples from Lake Wapalanne and Lake Ocquittunk

A row boat was used in this project as a source of transportation and to tow the plankton net from one sample site to another in transect, but only on Lake Wapalanne. Samples from Lake Ocquittunk were collected from the sides of the lake. Because row boat was used, extreme caution was taken at all times to avoid accidents and two people were needed at each time to gather samples: one person operated the boat and recorded the data, and the second person collected the samples, placed them into vials / jars and took measurements.

Plankton samples were taken from Lake Wapalanne by use of an 80 micron plankton-net, which was dragged behind the row boat. There were three sites on the lake each marked with floating diatom collectors that were anchored to the bottom of the lake. The upper site, A1, was in water about half meter deep. Just below the bridge was station A2 (about one meter deep) and in the deepest part of a lake, near the dam was station A3 (about eight meters). The plankton net was dragged behind the row boat near the surface of the water from station A1 to station A2. The plankton sample was collected at that station and marked as TI (Transect One) plankton sample. The second plankton sample TII was collected from station A2 to station A3 and marked TII.

Study Site Figure of Lake Wapalanne



Latitude: 41.22889 N **Longitude:** 74.75111 W

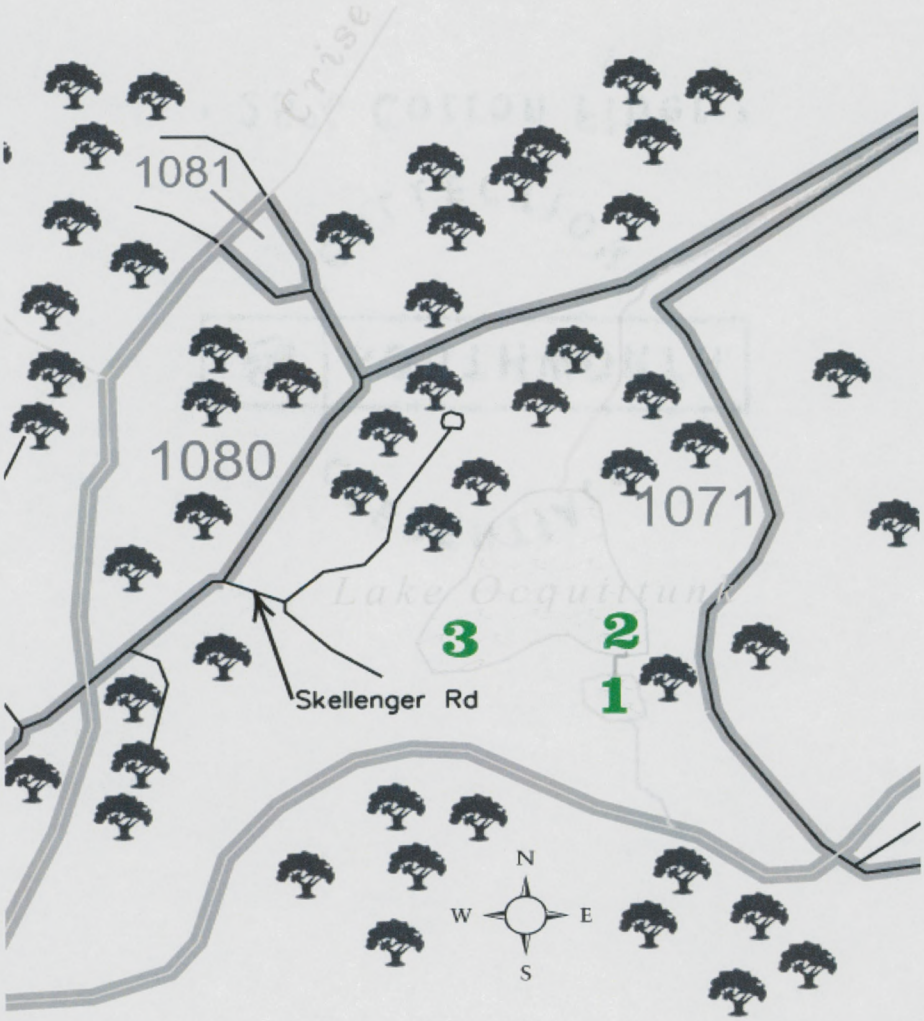
(NJSOC 2005).

Samples from Lake Ocquittunk were collected from three marked stations on the lake as well. However, there was a difference between the two methods of collections

because samples from Lake Ocquittunk were not collected in transect, but from the three stations located at three sides of the lake.

The first station was on the East-West side of Lake Ocquittunk and was marked as station B1. Station B2 was located by the overpass, and station B3 by the dam, located on the West-South side of the lake.

Study Site Figure of Lake Ocquittunk



Latitude: 41.22806 N **Longitude:** 74.76472

(Stone 2005).

These samples were gathered by throwing a plankton-net three times into the water, approximately five meters from the side of the lake (personal conversation with Dr. McCormick 2004). The depth of the lake at each station was about 1.5 meters. There were three plankton samples collected from Lake Ocquittunk.

After all the collections were completed, samples were placed in a cooler with ice and transported for further analysis in the lab. After live observation, samples were preserved with formaldehyde.

II.3. Water Quality

II.3.a. Sampling procedure. The collection of data always began at station A1 (located at southern part of Lake Wapalanne), then proceeded to A2 and A3 (near the dam). Same system was at Lake Ocquittunk, where starting station was B1 (located at south-east part of Lake Ocquittunk) and after B2 and B3 were visited. At Lake Wapalanne, diatometer traps were used as anchors to hold the boat in place at each station. Data were collected at each station of the lake and recorded in the notebook. The water quality monitor which was attached to the TI83 Plus calculator, was used to take measurements of temperature, pH, dissolved oxygen (DO) and conductivity (CO) of the water. The tested water of the lake was just below the surface to a maximum depth of about fifteen centimeters.

80 micron plankton net

TI-83 Vernier calculator

II.3.b. Temperature. The temperature probe was used to measure the temperature of the water. The probe tip was submerged to a depth of about 10 cm into the lake (always done on the shady side of the boat when a shadow was seen to avoid direct sunlight which could have altered the reading). The reading was recorded in degree Celsius when stabilized. The manual thermometer was used as well to double check recorded readings.

II.3.c. pH. pH probe was calibrated on the day when measurements were taken. It was calibrated using pH 4, pH 7 and pH 10 buffer solutions. Before recording each reading, the pH sensor tip was removed from the storage bottle, rinsed with the lake water and placed into the lake to a depth of 3-4 cm. To ensure accuracy, the readings were compared to the manually taken pH measurements. First, 5 drops of Wide Range Indicator and 2.5 ml of the water sample were mixed in a test tube. Next, the test tube was inserted into an Octet Comparator and the sample color was matched to a standard color (LaMotte Company 2004). The pH of the sample was recorded from the pH scale

that was located on an Octa-Slide viewer and it was then compared to the reading from the TI83 calculator.

II.3.d. Dissolved oxygen (DO). While DO data were taken, the probe tip had to be submerged in the water to a depth of 4-6 cm and stirred gently in one direction (clockwise or counterclockwise). When the reading stabilized it was recorded in the notebook. Occasionally during our trips, the readings from the TI83 were checked and compared to the LaMotte chemical test. This was done to ensure similarities in readings from the LaMotte test kit and the TI83 calculator.

II.3.e. Conductivity. The conductivity probe was calibrated before each session to a standard 500mg/l sodium chloride solution. Then the probe was filled with 1ml of an electrode filling solution. A conductivity probe with a box set to 0-2000 μS (2000μS = 1000 mg/L Total Dissolved Solid (TDS) (Johnson et al. 2000) was used to take measurements. The tip of the TDS probe was placed in the water. Once, the tip was completely covered, the reading was recorded after the value stabilized.

II.3.f. All the probes that were listed above used the DataMate program of the TI83 Plus calculator to take the readings. Then all the data that was recorded in the notebook was later placed onto the work sheet of the Excel program. After each station, all the probes were rinsed with distilled water and the DO and pH probes were placed into the storing solutions until needed at the next station.

II.3.g. The next collection required the use of the Nalgene funnel following the instructions for the Technical Services 1987 funnel manual. First, filter paper was placed inside the funnel. Then 150 ml of the water sample was filtered through using the manual pump with the recommended operating pressure of 10 psi (0.7 bars). It is important that

the pressure does not exceed 15 psi = 1.0 bar (Technical Services, 1987). After filtration the filter paper was placed in a labeled vial (place and date of collection) and saved in a bucket with ice. It was later brought to the lab for chlorophyll analysis.

II.4. After the trip

The samples, equipment and data were brought back to the lab. First, all the filter papers located in the vials were covered with 10 ml of 90% Acetone. This was made earlier from a mixture of 90 ml of acetone which was combined with 10 ml of deionized water to make 90% acetone. This was left for 48 hours as recommended in the Strickland and Parsons (1972) manual. After 48 hours, the samples for chlorophylls a, b, and c were determined by spectrophotometer. All the samples were placed in a refrigerator to be analyzed later. The plankton samples had to be viewed within two days, so that the plankton representatives were still intact. If the samples were not viewed within this time frame they would began to disintegrate and the data would be useless.

III. Lab Analysis

III.1. Analysis of plankton samples

Four drops from each sample were used in the analysis, which equals 0.12 ml of the sample. The sample was taken randomly from each vile by a one ml pipet. Next it was placed on a slide, covered with the cover slip and positioned under a Nikon or Leica CME microscope. The 10X objective was used to identify the organisms to the *Genus* and *species* and to find the abundance of each individual in each sample.

Once the observation was complete, various scientific journals and books were use to identify organisms from the lake. All the data were recorded in the notebook and later entered onto the spread sheet of the Excel program. Once completed the samples were preserved with 5% of a total volume of the sample with the Formaldehyde Solution. The Formaldehyde was used because it seemed to be the best preservative for tissue samples because it allows them to stay in the same condition indefinitely.

The data were organized and later used to compare and contrast Lake Wapalanne to Lake Ocquittunk. The data analyses were done by the PRIMER program. Through the Primer program I was able to calculate the similarities of species abundance between samples in both lakes. The presence and absence analysis helped me to determine appearance of species in my samples. Another analysis had to do with classification (cluster analysis) to find natural groupings of samples because generally samples within a group are more similar to each other, than samples in different groups. This analysis can be use when different sites or different times at the same site are sampled (Clarke and Warwick 1994), and that is what was done for this study. The multi-dimensional scaling (MDS) was also performed. The MDS analyses constructed a map also called configuration of the samples. If samples did not have species in common, the groups placed in the MDS plots would be shown as far distances apart and the calculated stress level would be high. The stress increases with reducing dimensionality and increasing quantity of data. The stress value < 0.2 gives a potentially useful two dimensional data (Clarke and Warwick

1994). Species richness and evenness was also calculated by Primer program and compared between both lakes.

III.2. Filter paper analysis

After 48 hours the filter paper solution was used for chlorophyll analysis. The Genesys™ 20 Spectrophotometer was used to take absorbance measurements that were needed to calculate chlorophyll a, b, and c in each sample. Cuvettes were marked and filled to the line with each sample. Then one blank cuvette (90% acetone only) was used to calibrate the machine to 0, this was done before each measurement to ensure proper readings. It was very important that the cuvettes were cleaned of all fingerprints and residues prior to insertion. This prevented interference with the displayed results. First, the spectrophotometer was turned on and warmed up for 30 minutes (Thermo Spectronic 2000). Then the mode/absorbance was selected and the value of the desired wavelength was set. Next, the blank cuvette was placed into the cell holder, covered with the sample door and set to zero absorbance. After calibrating, the blank was removed and one of the samples was placed in the cell holder for measurements. This took a few seconds for the value to stabilize on the LCD display. Once stable, the absorbance was recorded in the notebook. The wavelengths used for each sample were: 760nm, 665nm, 645nm, 630nm, 510nm, and 480nm, and each time the readings were taken from the highest one displayed. Samples and absorption data were entered into the equations of Strickland and Parsons (1972). Recorded readings were placed in the formula and chlorophyll a, b, and c amounts were calculated by the Excel program. After each use the instrument was wiped with a wet paper towel.

The formulae used were:

1. To calculate C for chlorophyll a, b and c I used the following equations:

C (chlorophyll a) = $11.6 \times E_{665} - 1.31 \times E_{645} - 0.14 \times E_{630}$

C (chlorophyll b) = $20.7 \times E_{645} - 4.34 \times E_{665} - 4.42 \times E_{630}$

C (chlorophyll c) = $55 \times E_{630} - 4.64 \times E_{665} - 16.3 \times E_{645}$

E = means extinction values, at wavelengths indicated by the subscripts, measured in ten centimeter cell after correcting for a blank, as explained above.

2. To calculate the concentration of pigments in water

C/V= Values for Chlorophylls in mg/m^3, where

C= absorbance reading at particular wavelength

V= volume of water filtered in liters (L), 0.15 L in our case

(Strickland and Parsons 1972).

RESULTS

I. Parameters Data.

I.1. Temperature Data.

Temperature readings were recorded over a six month period in Lake Wapalanne and compared with readings taken on Lake Ocquittunk (Figure 1). The results show slightly higher readings from Lake Ocquittunk. The higher readings indicate that temperature from Lake Wapalanne was taken early in the day each time samples were collected. The observed difference in temperature on August 8th (Figure 1) may be due to the two hours delay in recording the data between Lake Wapalanne and Lake Ocquittunk. The points that overlapped indicate the short time between recordings. The average temperature of Lake Wapalanne was 19.87^{o}C, and the average temperature of Lake Ocquittunk was 20.52 ^{o}C (Table 1).

I.2. pH Data.

pH readings were taken from Lake Wapalanne and Lake Ocquittunk and compared. Usually, the pH readings are effected by geology and primary production of a lake, and the pH value can change with productivity. The normal range of pH in freshwater is between 6.5- 8.2. When our data were compared (Figure 2), the average pH for Lake Wapalanne came out to be 7.90 and average pH for Lake Ocquittunk 7.72 (Table 1). Our data show that in June, July and August pH values are higher in Lake Wapalanne, with the peak on August 7th. There is a peak for Lake Ocquittunk on August 8th with very high, value of pH 10 (Figure 2- arrow). This high peak suggests increase in primary production for Lake Ocquittunk.

I.3. Dissolved Oxygen Data.

Oxygen readings vary during the day, due to the variations in photosynthesis. All our readings are scattered, however the averages are similar. Lake Wapalanne's average is 9.02 ppm, and Lake Ocquittunk's is 8.27ppm (Table 1). Looking at our results (Figure 3), our data cannot really be compared. Ideally, in order to draw conclusions, compare the pattern of dissolve oxygen data in both lakes, measurements should be taken at the same time of a day, every time samples are taken. Our measurements were recorded mostly in the morning, but not all at the same time. Therefore this problem can be alleviated by very high use of monitoring producing better results.

I.4. Conductivity.

Conductivity is an indicator of Total Dissolve Solids (TDS). TDS increase due to increase of salts and dissolved ions in a body of water mostly due to the mineralization and decomposition of organic matter. Our results show that the conductivity in Lake Ocquittunk was higher throughout the sampling period (from June to November) (Figure 4, Table 1). The one possible conclusion is that Lake Ocquittunk had higher mass of decomposition of organic matter. Furthermore, Lake Ocquittunk is located downstream, about 100 feet lower in elevation from Lake Wapalanne, and lies in a different sub set of the watershed. Normal range of TDS is between 50 – 250 μS. The average conductivity of Lake Wapalanne is 72.68 μS, and average of Lake Ocquittunk is 97.47 μS (Table 1: red).

II. Plankton Data.

II.1. Groups of organisms found in Lake Wapalanne and Lake Ocquittunk.

Abundances of organisms from Lake Wapalanne and Lake Ocquittunk are quite variable. There is not a strong coincident from place to place, the peaks tend not to coincide (Figure 5). Everything is highly variable where we see lower abundances at the beginning and the end (time when our samples were collected: from May to November). There are however, some representatives of organisms that appear the same in both lakes. Monera (Figure 5-A) were similar in abundance in both lakes in June and November. Abundance of Protista (Figure 5-B) was similar in July, October and November. Rotifera occurrence was similar in both lakes in June, July, October and November, and very similar in September. Cladocera (Figure 5-D) abundances were similar in June, September, October and November and very similar for July. The Copepoda representatives were the same in both lakes for June, September, November, and similar in July. Representatives of Ostracoda and Decapoda (Figure 5-F, G) were in Lake Wapalanne only and Insecta (Figure 5-H) abundances were the same in July.

The fresh water biota graphs for Lake Wapalanne (Figure 6-A) and Lake Ocquittunk (Figure 6-B) show us peaks of highest abundances of organisms in these lakes. The highest peaks for both lakes are shown by Protista (mostly *Volvox sp.*) and Monera (Cyanobacteria) which are very common. For Lake Wapalanne (Figure 6-A) Protista is highest in June and September, for Lake Ocquittunk in August (Figure 6-B). Monera is highest for Lake Wapalanne in July and August (Figure 6-A) and September in Lake Ocquittunk (Figure 6-B). There are also high peaks of Cladocera in May, and

Copepoda in September and October for Lake Wapalanne (Figure 6-A), where Cladocera and Copepoda is very abundant in August for Lake Ocquittunk (Figure 6-B).

II.2. Food Web Analysis.

The food web analysis of Lake Wapalanne and Lake Ocquittunk show several trophic levels in both lakes (Figure 7). The food chain starts with detritus which is decomposed by bacteria. Bacteria on the other hand is grazed on by a host of small ciliates and flagellates, these in turn become victims of larger ciliates and micro-zooplankton such as cladocerans. The large ciliates and dinoflagellates are the food for rotifers and copepods. The copepods feed on diatoms as well. Some rotifers are preyed on by large copepods and even by other rotifers. The copepods and rotifers become victims of fish and insects (fish prey on insects as well). *Spirogyra* is a good food source for amphipods (which are preyed on by fish) and ostracods which are in addition feed on bacteria. Decapoda prey on aquatic plants and they are preyed on by fish (fish also feed on aquatic plants) and they, in turn, are food for birds (Figure 7).

Taking into consideration both lakes, the food web analyses are very similar with exception of Ostracoda, Amphipoda and Decapoda representatives being absent in Lake Ocquittunk, and their low numbers in Lake Wapalanne (Figure 7, Table 2, Table 3).

II.3. Higher Taxon Similarity Dendrogram.

These analyses show us that with regards to higher taxa (Order and above), there is overall 79% similarity between samples from Lake Wapalanne to samples from Lake Ocquittunk (Figure 8). Samples from: June, July and August of Lake Ocquittunk are 100% similar to samples in July, August and September of Lake Wapalanne, also November samples from Lake Wapalanne are 100% similar (Figure 8: balack arrow) to

September and October from Lake Ocquittunk. Furthermore, these two groups are about 91% similar to each other (Figure 8: red arrow). Finally, samples from October of Lake Wapalanne are 83% similar the previous samples and November samples from Lake Ocquittunk are 82% similar to all the others. May and June samples from Lake Wapalanne are 80% similar to each other and 79% to all the other samples.

II.4. Similarity Dendrogram Comparing Lake Wapalanne and Lake Ocquittunk.

When we compare samples due to the date when they were collected, the similarity between gathered samples falls between 65% and 85% (Figure 9: blue box). It is high and it suggests that the collected samples contained very similar species in the similar abundance (Clarke and Warwick 1994).

II.5. Multi-Dimensional Scaling (MDS).

MDS analyses show us how close samples are related. If they are located very close in each other this suggests they have a lot in common. If samples have no species in common, the groups placed in the MDS plots area going to be far apart (Clarke and Warwick 1994). Our data show that all samples from both lakes are closely related except June 22nd and July 27th. This gives us stress level of 0.18 which is potentially low with a useful two-dimensional picture (Figure 10).

II.6. Higher Taxon Similarity Dendrogram in Both Lakes.

This diagram shows that there is 100% similarity in abundance of Protista, Monera and Rotifera, 93% Cladocera and around 92% similarity of Copepoda (green arrow), about 72% between Insecta of both lakes. The similarity between Decapoda, Amphipoda and Ostracoda shows less then 20% due to the absence of representatives in Lake Ocquittunk (Figure 11). Furthermore, this is an artifact of analysis by PRIMER

program because the percentage for these groups should be zero.

II.7. Species Level Comparison for Both Lakes.

This figure (Figure 12) compares two sites based on species level representatives. The similarities fall between 45%-85% (Figure 12: from green to red arrows); this suggests that both lakes have many species in common

II.8. Evenness (J') and Shannon Diversity Index (H') for both lakes.

There are moderate J' (Figure 13) and H" (Figure 14) data from our trips. Because these readings were influenced by *Volvox* sp. blooms as well as Cyanobacteria amounts in the samples the values came out to be distorted.

II.9. Lake Wapalanne's and Ocquittunk's Chlorophylls Collected on a Filter Paper.

The quantities of chlorophyll a and c in the lake suggests that there is a rich assemblage of diatoms and dinoflagellates in these lakes. When there is substancial chlorophyll a and b it suggests dominance by green algae such as the filamentous *Spirogyra sp.* or planktonic desmids. When green algae, diatoms and dinoflagellates appear in large numbers, chlorophyll b and c values are higher. At the end of June there was an abundance of photosynthetic biomass floating in the water, at the end of July dinoflagellates took over, and the high peak of chlorophyll b on September 14th suggests mats of spirogyra in the water of Lake Wapalanne (Figure 15). In Lake Ocquittunk the peak of chlorophyll c in June shows lots of dinoflagellates in samples, and same as for Lake Wapalanne another peak of chlorophyll c at the end of July appears (Figure 16). When we compare abundances of chlorophylls a, b and c in both lakes (Figure 17), the low r values suggest that there is little relation of chlorophyll a (A), chlorophyll b (B) and chlorophyll c (C) amounts between two sample sites.

DISCUSSION AND CONCLUSION

Based on the data analyses, it can be concluded that plankton ecology of Lake Wapalanne and Lake Ocquittunk is very similar. The environments in both lakes are very similar. When comparing physical data of temperature, pH, dissolved oxygen and conductivity, the average numbers from both lakes are very close (Table 1). Some of the parameter readings are scattered and they differ, however these are possible anomalies that occurred while measurements were taken. For example the time difference between sample collections from the two lakes could result in different values due to period of solar exposure. These anomalies many times were caused by the weather conditions and in the case of dissolve oxygen readings were collected at different times of the days (it should have been at the same time for each trip as well as the same time in each lake), which caused the variation in our data.

Species compositions in both lakes were very similar, even though different techniques were used when samples were collected. Based on these results it can be concluded that both lakes are rich in dynamic populations of phytoplankton and zooplankton where as insects do not play a major role in plankton dynamics in my study (Figure 6: A and B). The food web analysis shows that major consumers in both lakes are cladocerans and copepods (Figure 7). The food web structure is similar to those observed in Lakes Peter, Paul and Long in Wisconsin. They have food webs rich in populations of cyanobacteria, heterotrophic flagellates, dinoflagellates, rotifers, copepods and cladocera. They receive energy from the sun and from dissolved organic carbon (Christiansen et al. 1996, Pace et al. 1998).

Lake Oglethorp in Georgia has a similar food web with the predacious insect larva, *Chaoborus* playing an important role as a consumer of rotifers, copepods and cladocera. (Porter et al, 1996) Large species of cladocera, such as *Daphnia pulex*, play an important role in controlling smaller microzooplankton. Some rotifers are less susceptible to predation due to their size, behavior or the presence of spines (Pace et al, 1991). In my study there were diverse rotifer species with varied spination. This could result in increased survival in the face of predatory pressure.

In studies of Lakes Peter and Paul in Michigan, Pace and Funke (1991) observed top-down control of microzooplankton, but not of cyanobacteria. In my study chlorophyll concentrations remained relatively stable. Top-down control of microzooplankton was probably promoted when larger Cladocera and *Chaoborus* were abundant (Pace and Funke 1991).

The huge abundance of protists (dinoflagellates, ciliates and diatoms) is a good food source for many organisms (Table 2, Table 3, and Figure 7). Additionally, the similarities of organisms between both lakes were very high, especially when higher taxon groups were compared. The overall similarities fall between 65% and 85% when sampling dates were compared (Figure 9). This suggests that collected samples contained very similar species composition as per explanation by Clarke and Warwick (1994). The high similarities between lakes gave a low stress level of 0.18 (Figure 10), meaning the sample sites have many species in common.

Other analyses were performed on higher taxon groups including Monera, Protista, Rotifera, Cladocera, Copepoda, Ostacoda, Decapoda and Insecta. These analyses showed that there was 100% similarity of Monera, Protista, and Rotifera between Lake

Wapalanne and Lake Ocquittunk and about 93% of Cladocera, 92% of Copepoda and 71% of Insecta (Figure 11). All these results are very high, which means many of the same organisms thrive in both lakes. However, the timing of peaks for Protista, Cladocera and Copepoda differed between the two lakes. Possible explanations include patchy distribution, short-lived blooms of protists such as *Volvox* sp. or *Ceratium* sp., or variations in predation intensity. Even though, representatives of Decapoda, Ostracoda and Amphipoda were not found in Lake Ocquittunk we can still conclude that the environments of both lakes are comparable. The presence of these taxa in Lake Wapalanne may be due to the shallow water of Lake Wapalanne. Even though plankton samples were collected from the surface of the water, the benthos may have been sampled due to the low depth (half meter on the southern site) of Lake Wapalanne. Consequently we touched upon the benthic community in that lake, which is the favorite environment for decapods, ostracods and amphipods (Pennak 1989, Cole 1994, Raven and Johnson 2001). That is most likely why they were represented in my samples of Lake Wapalanne.

When species analyses were done (Figure 12), the presence of similar species is within a 45% to 85% range, which is, a good representation of our data (Clarke and Warwick 1994). Taking into consideration the evenness and diversity of species in both lakes, it is hard to draw any final thoughts about the data (Table 4: A and B). These scattered data were influence by blooms of *Volvox* sp. and Cyanobacteria which were not coordinated with the time frame of both lakes (Figure 13, Figure 14). The high appearance of Monera (Cyanobacteria) and Protista (dinoflagellates and volvocines) led to high peaks of chlorophyll abundances in both lakes, for example: high peak of protists

in September (Figure 6: A) gave us high peak of chlorophyll b (Figure 15) from Lake Wapalanne in September as well.

Although the hydrology was studied in both lakes throughout the study, no association can be made between the physical-chemical character of Lakes Wapalanne and Lake Ocquittunk and their ecology. Water quality parameters were not highly variable, but showed some seasonal trends, as would be expected. The nature of the species diversities, as well as food webs and other biological associations, appear to be independent of any variations in the temperature, pH, dissolved oxygen or conductivity.

To improve the results when comparing Lake Wapalanne to Lake Ocquittunk, data should be collected same way in both lakes and the use of continuous monitoring of both lakes is highly recommended in the future.

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APPENDIX I

Figure 1: Temperature Readings from Lake Wapalanne and Lake Ocquittunk Recorded Over Six Months Period.

Lake Wapalanne has slightly lower readings comparing to Lake Ocquittunk. The temperature readings from Lake Wapalanne were always taken first. The gap between temperature values on August 8th (arrow pointing) may be, due to the two hours delay in recording of the data between one sample site (Lake Wapalanne) to the next (Lake Ocquittunk).

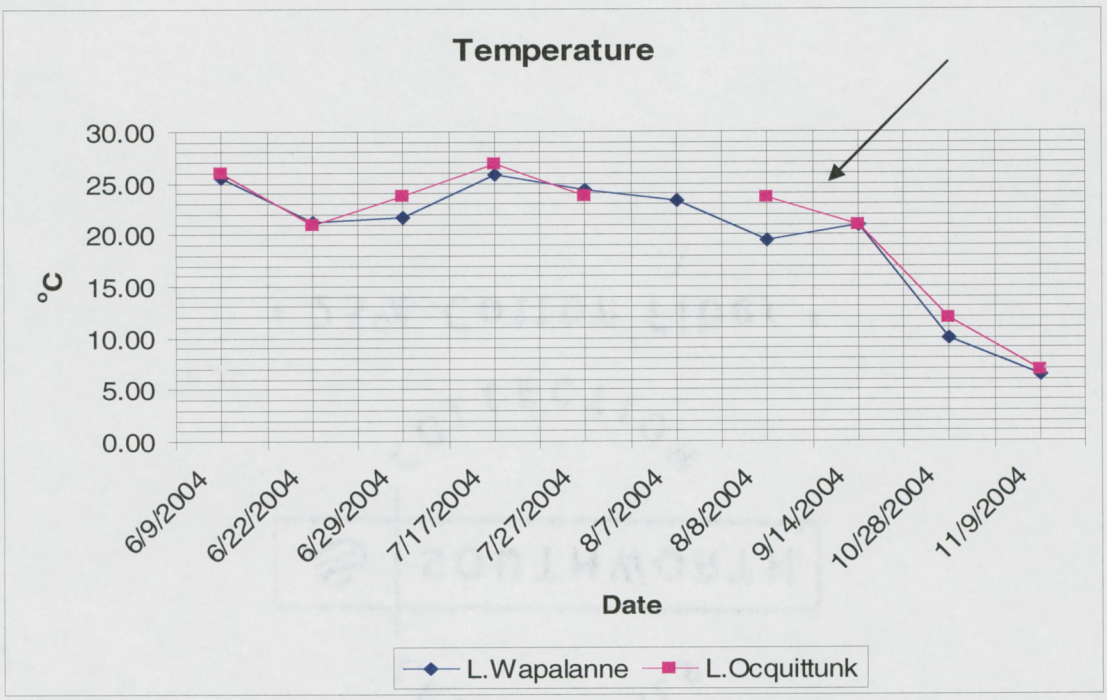

Temperature
30.00
25.00
20.00
15.00
10.00
5.00
0.00
°C
6/9/2004
6/22/2004
6/29/2004
7/17/2004
7/27/2004
8/7/2004
8/8/2004
9/14/2004
10/28/2004
11/9/2004
Date
L.Wapalanne
L.Ocquittunk

Figure 2: pH Data from Lake Wapalanne and Lake Ocquittunk.

The normal range of pH in a freshwater lake is between 6.5- 8.2, therefore the peak from Lake Ocquittunk on August 8th (arrow pointing) suggests an abnormal reading, due to possible phytoplankton bloom. The average pH for Lake Wapalanne is 7.90 and Lake Ocquittunk is 7.72 (Table 1-red), which is normal.

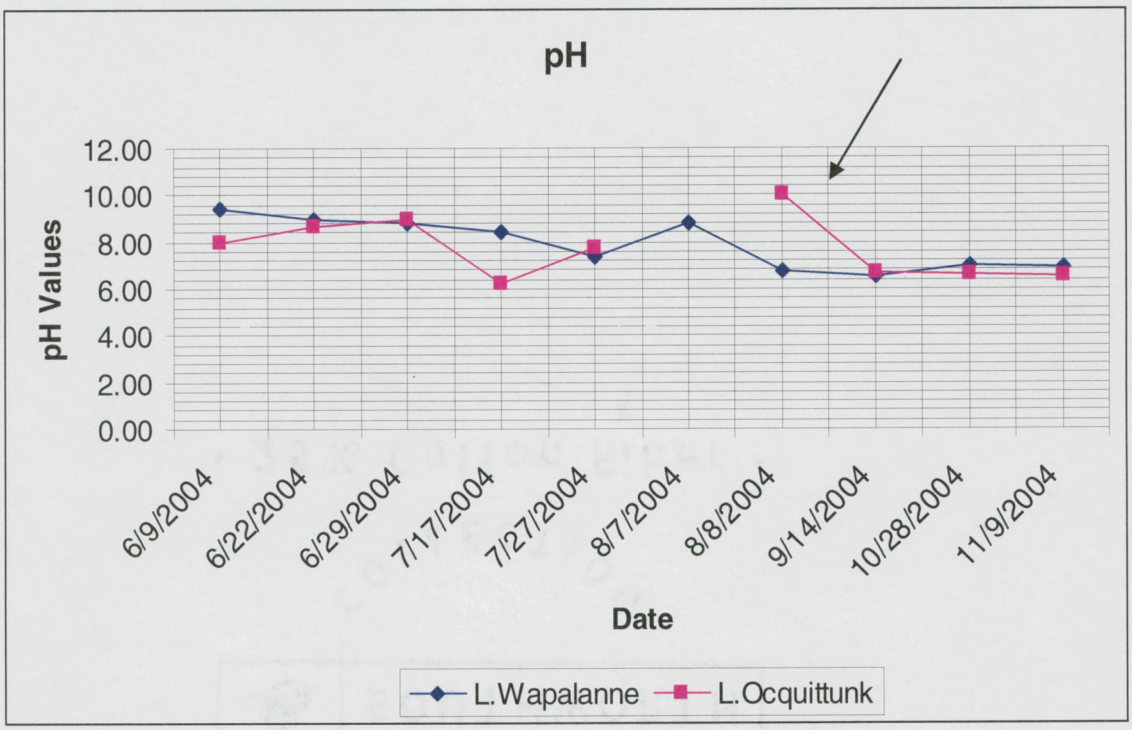

pH
12.00
10.00
8.00
6.00
4.00
2.00
0.00
pH Values
6/9/2004
6/22/2004
6/29/2004
7/17/2004
7/27/2004
8/7/2004
8/8/2004
9/14/2004
10/28/2004
11/9/2004
Date
L.Wapalanne
L.Ocquittunk

Figure 3: Dissolved Oxygen Readings from Lake Wapalanne and Lake Ocquittunk.

Oxygen varies during the day due to variations in photosynthesis, but we cannot say any further about our results because our readings are very scattered and cannot be compared. In order to draw the best conclusions, one should compare and contrast readings of dissolve oxygen taken at the same time of a day. This was not possible in our study. Looking at the graph (Figure 3) most of our readings are between 6 and 12 ppm, with no trend up or down.

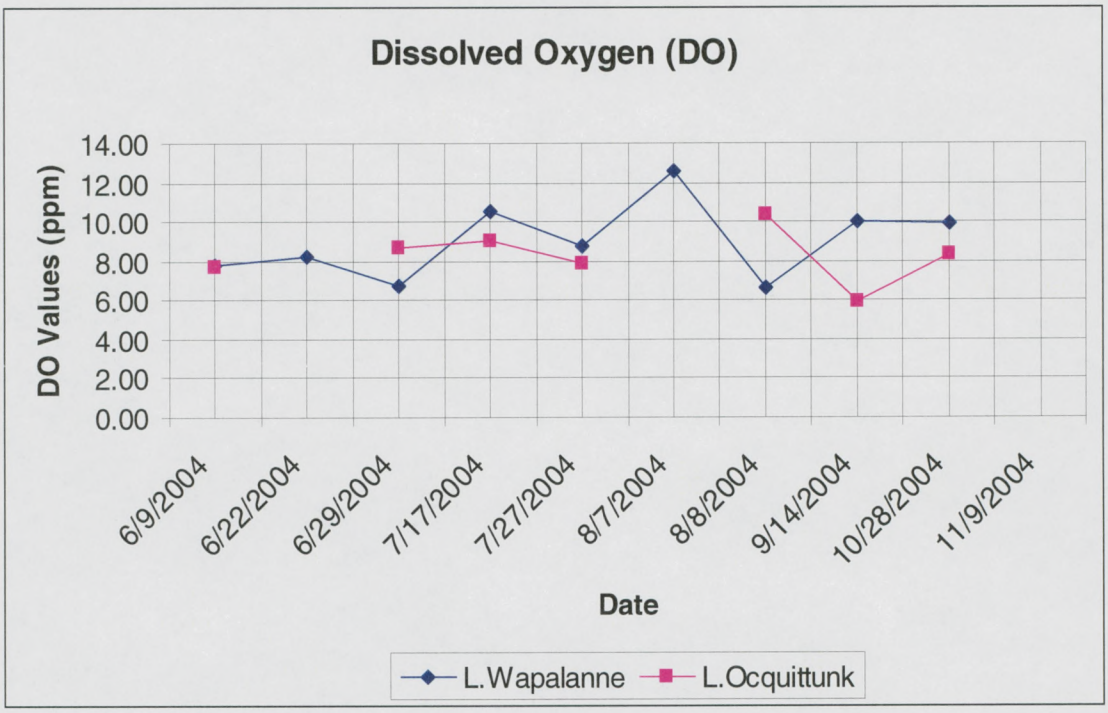

Dissolved Oxygen (DO)
DO Values (ppm)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
6/9/2004
6/22/2004
6/29/2004
7/17/2004
7/27/2004
8/7/2004
8/8/2004
9/14/2004
10/28/2004
11/9/2004
Date
L.Wapalanne
L.Ocquittunk

Figure 4: Conductivity Data from Lake Wapalanne and Lake Ocquittunk.

Looking at our conductivity data we can see the pattern of our results. The CO values for Lake Ocquittunk are higher comparing to Lake Wapalanne.

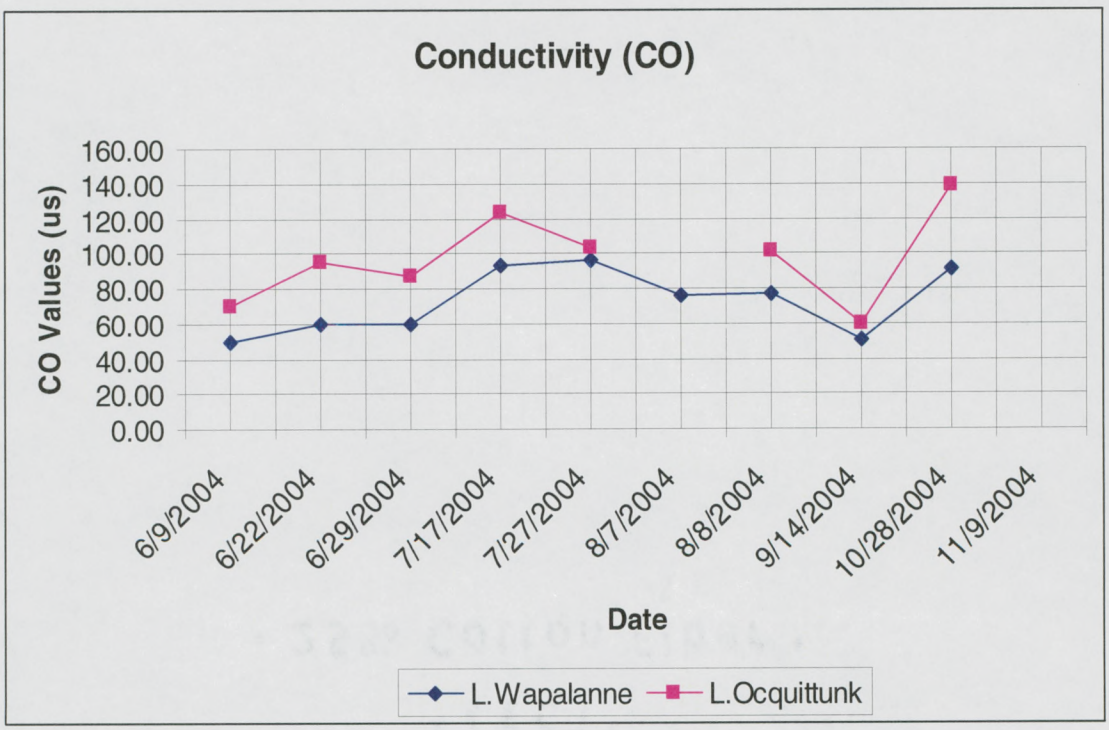
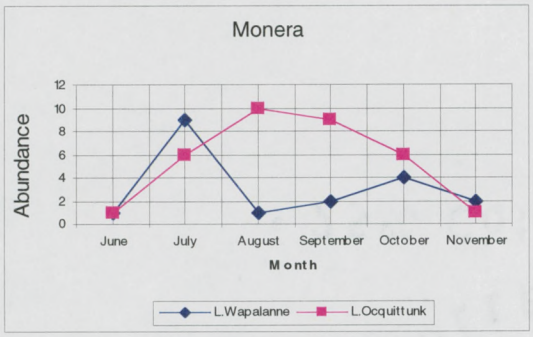

Conductivity (CO)
CO Values (us)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
6/9/2004
6/22/2004
6/29/2004
7/17/2004
7/27/2004
8/7/2004
8/8/2004
9/14/2004
10/28/2004
11/9/2004
Date
L.Wapalanne
L.Ocquittunk

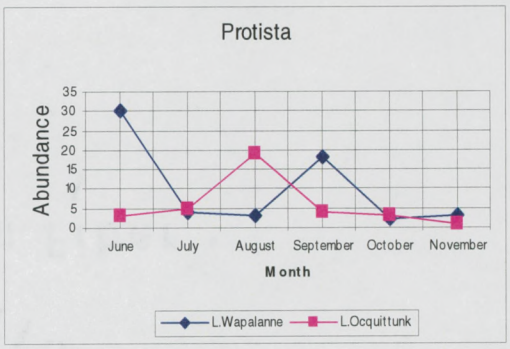
Figure 5: Groups of Organisms Found in Lake Wapalanne and Lake Ocquittunk.

Data presented are average abundance per sample.

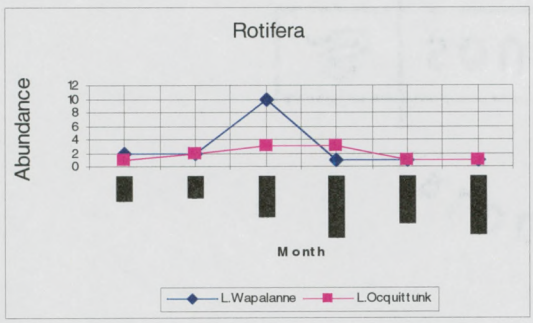
A:


Monera
Abundance
12
10
8
6
4
2
0
June
July
August
September
October
November
Month
L.Wapalanne
L.Ocquittunk

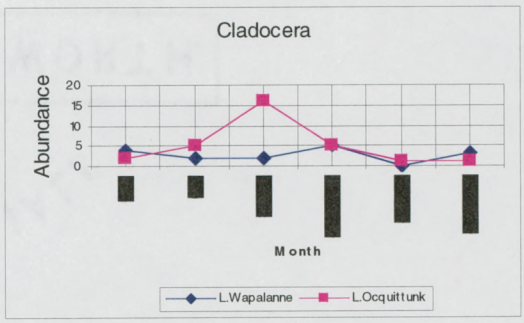
B:


Protista
Abundance
35
30
25
20
15
10
5
0
June
July
August
September
October
November
Month
L.Wapalanne
L.Ocquittunk

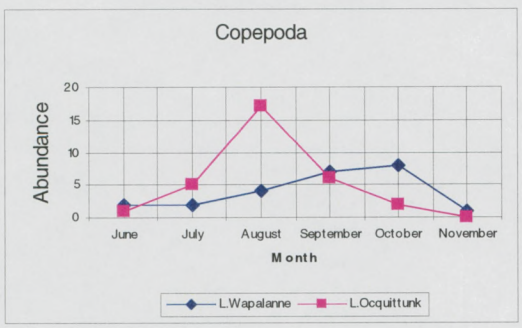
C:


Rotifera
Abundance
12
10
8
6
4
2
0
Month
L.Wapalanne
L.Ocquittunk

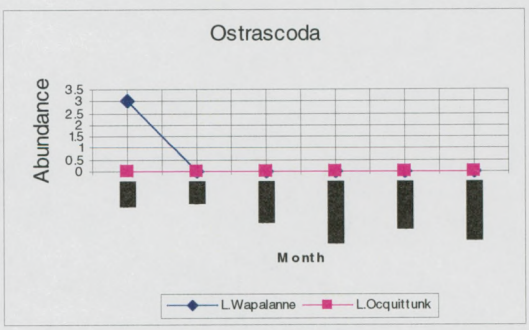
D:


Cladocera
Abundance
20
15
10
5
0
Month
L.Wapalanne
L.Ocquittunk

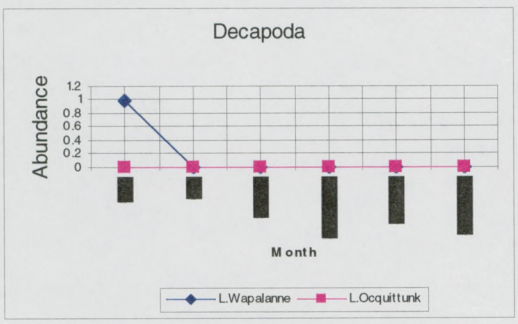
E:


Copepoda
Abundance
20
15
10
5
0
June
July
August
September
October
November
Month
L.Wapalanne
L.Ocquittunk

F:


Ostrascoda
Abundance
3.5
3
2.5
2
1.5
1
0.5
0
Month
L.Wapalanne
L.Ocquittunk

G:


Decapoda
Abundance
1.2
1
0.8
0.6
0.4
0.2
0
Month
L.Wapalanne
L.Ocquittunk

H:

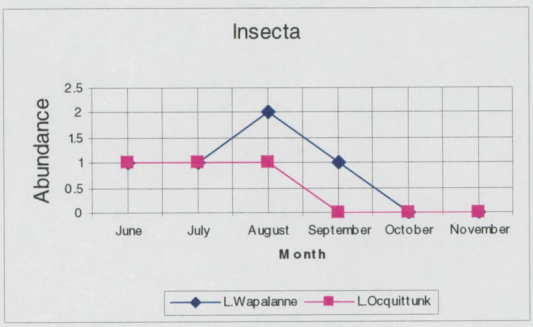
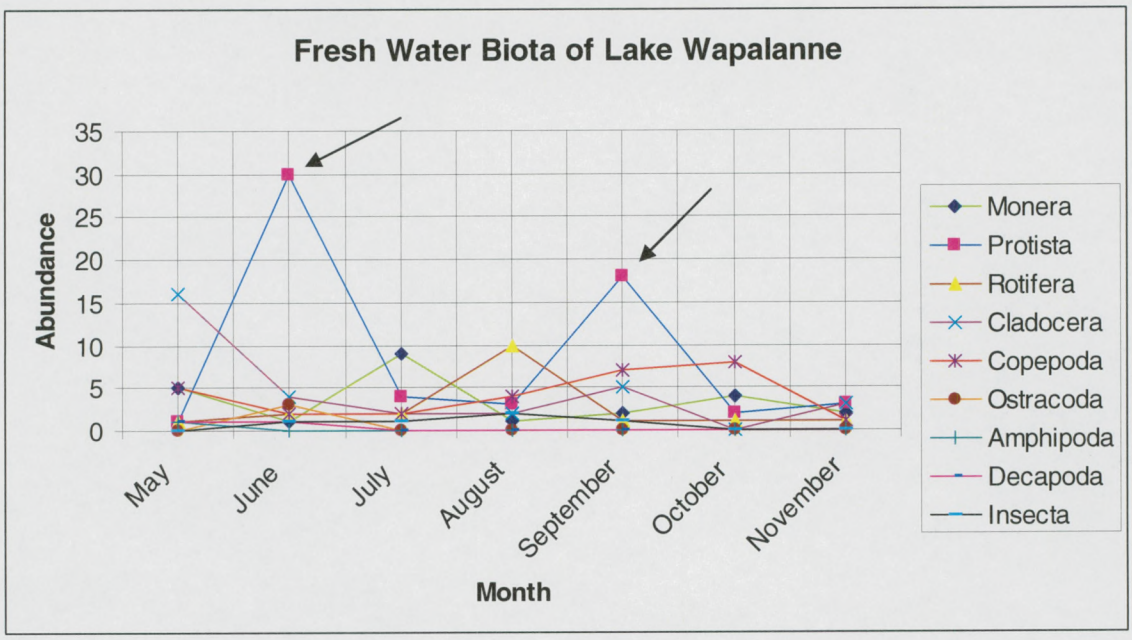

Insecta
Abundance
2.5
2
1.5
1
0.5
0
June
July
August
September
October
November
Month
L.Wapalanne
L.Ocquittunk

Figure 6: Fresh Water Biota Found in Lake Wapalanne and Lake Ocquittunk.

The Peaks represent high abundances of Protista, mostly *Volvox* sp. and from Monera group, mostly Cyanobacteria in our plankton samples (arrows pointing) from Lake Wapalanne (A) and Lake Ocquittunk (B).

A:


Fresh Water Biota of Lake Wapalanne
Abundance
35
30
25
20
15
10
5
0
May
June
July
August
September
October
November
Month
Monera
Protista
Rotifera
Cladocera
Copepoda
Ostracoda
Amphipoda
Decapoda
Insecta

B:

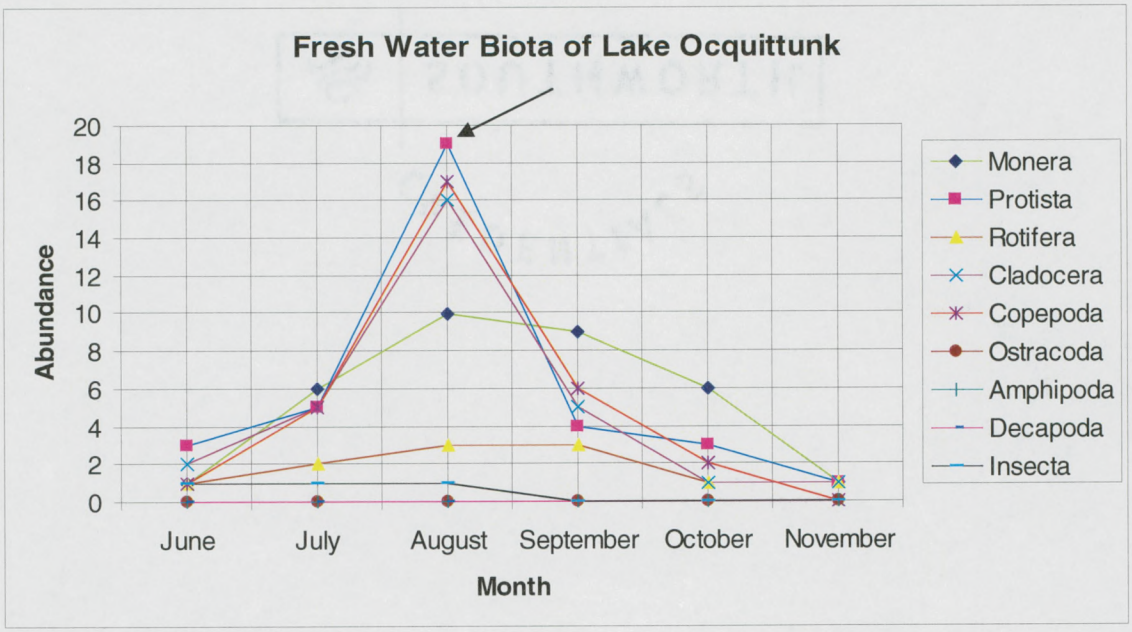
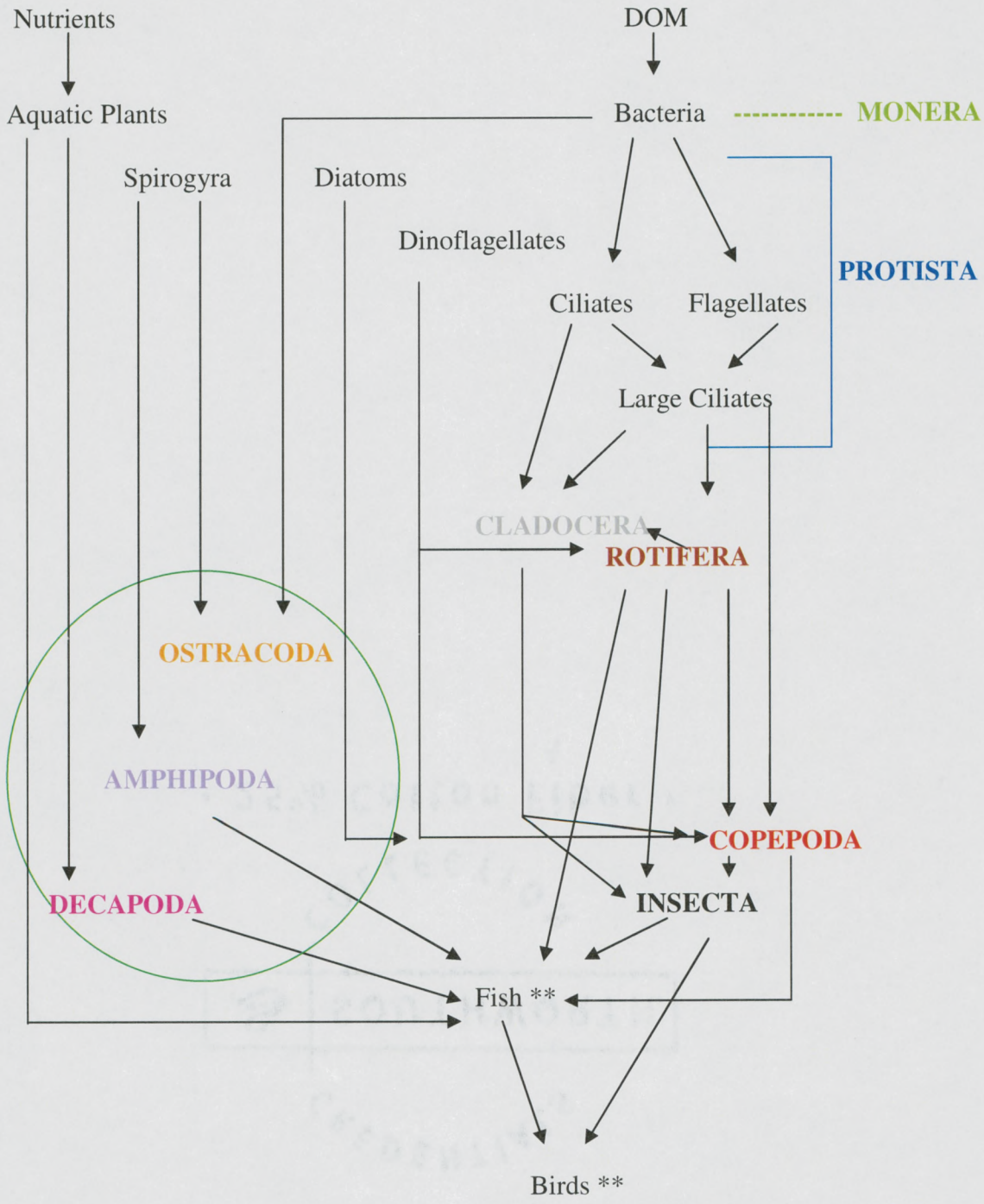

Fresh Water Biota of Lake Ocquittunk
Abundance
20
18
16
14
12
10
8
6
4
2
0
June
July
August
September
October
November
Month
Monera
Protista
Rotifera
Cladocera
Copepoda
Ostracoda
Amphipoda
Decapoda
Insecta

Figure 7: Food Web Analysis.

This figure show energy flow starting from decomposers (bacteria and fungi), to primary producers (algae, diatoms, aquatic plants), through a diversity of consumers for Lake Wapalanne and Lake Ocquittunk. Please note, Lake Ocquittunk did not have representatives of Ostracoda, Amphipoda and Decapoda (inside the green circle).

Food Web Analysis



KEY:
** Organisms were observed, but not collected
DOM = Dissolved Organic Matter

Figure 8: Higher Taxon Similarity Dendrogram for Both Lakes Shown Monthly.

The overall similarity of higher taxon samples in both lakes is about 79% (green arrow). There is about 91% similarity in June, July, August, September, October in Lake Ocquittunk to samples taken in July, August, September and November of Lake Wapalanne (red arrow), and perpendicular black lines (black arrow pointing) show 100% similarity between sites.

Higher Taxon Similarity Dendrogram

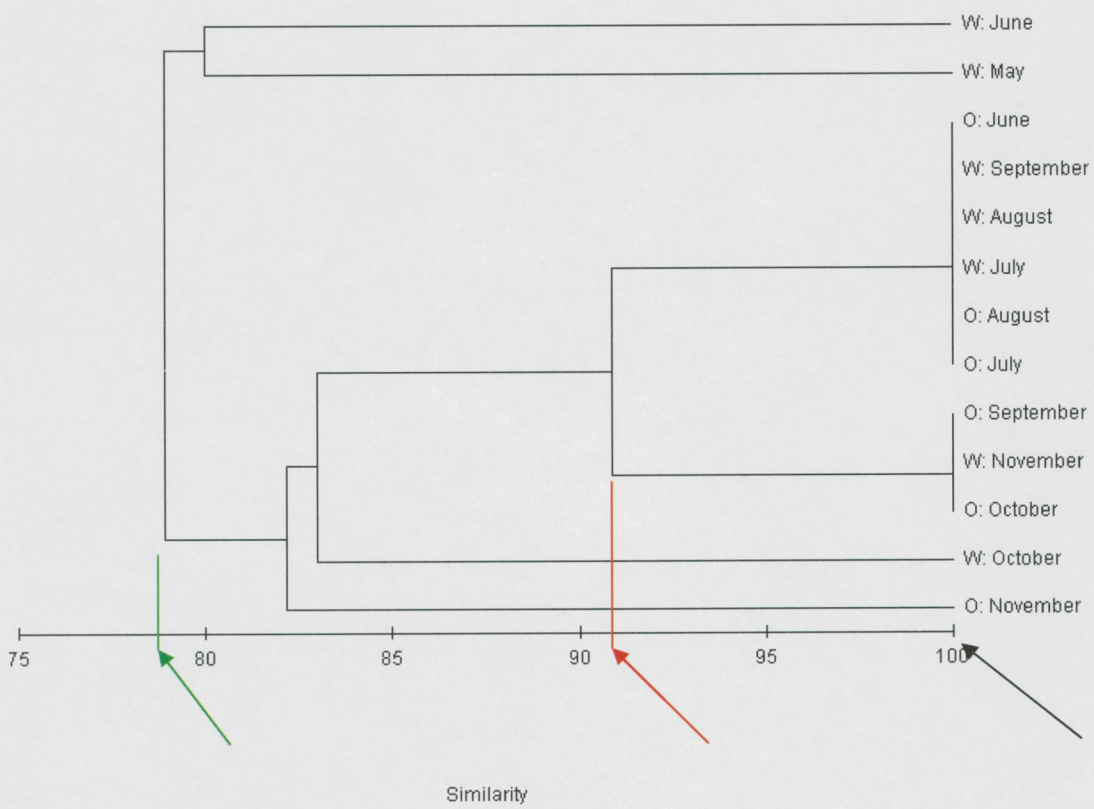
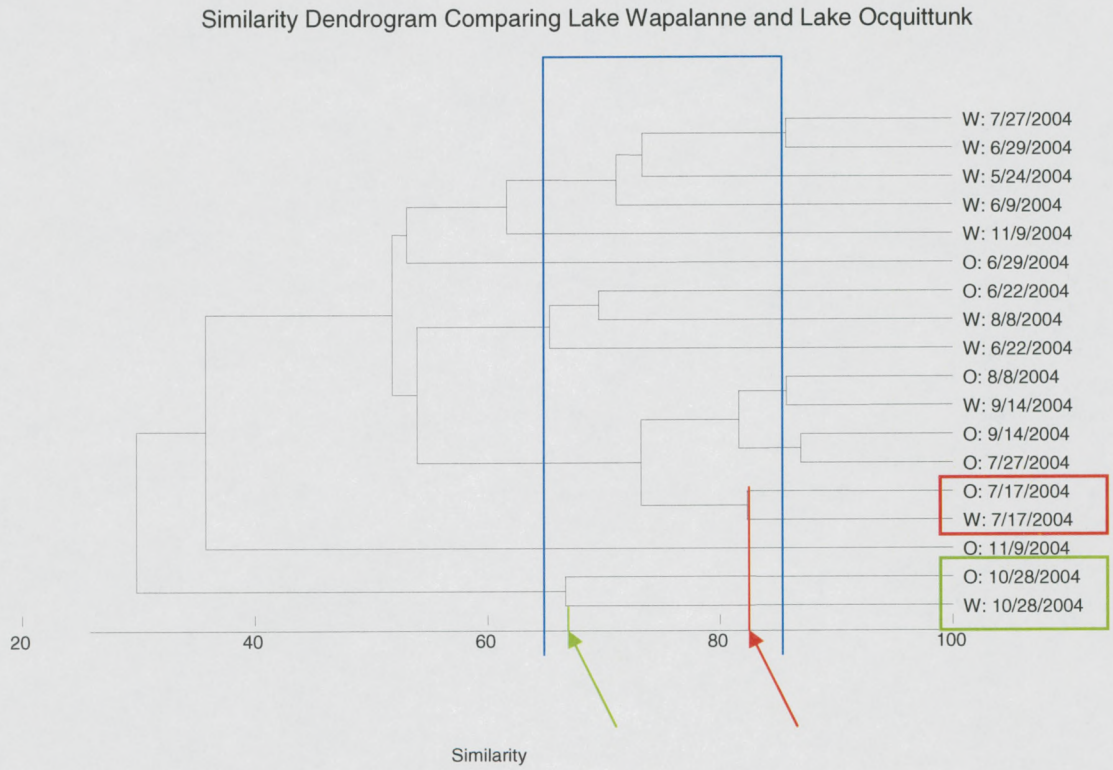


Figure 9: Similarity Dendrogram Comparing Lake Wapalanne and Lake Ocquittunk.

Overall similarity of organisms in both lakes falls between 65% and 85% (blue box), which suggests that collected samples contained very similar species composition. Nice combination is seen in samples from July 17th (red box) in Lake Wapalanne and Lake Ocquittunk, which shows about 83% similarities between organisms (red arrow). Also 67% (green arrow) of similarities on October 28th in both lakes (green box).



KEY:
W= Lake Wapalanne
O= Lake Ocquittunk

Figure 10: Multi-Dimensional Scaling (MDS).

The two dimensional picture of MDS shows that the sample sites have many species in common which gives the potentially low stress level of 0.18.

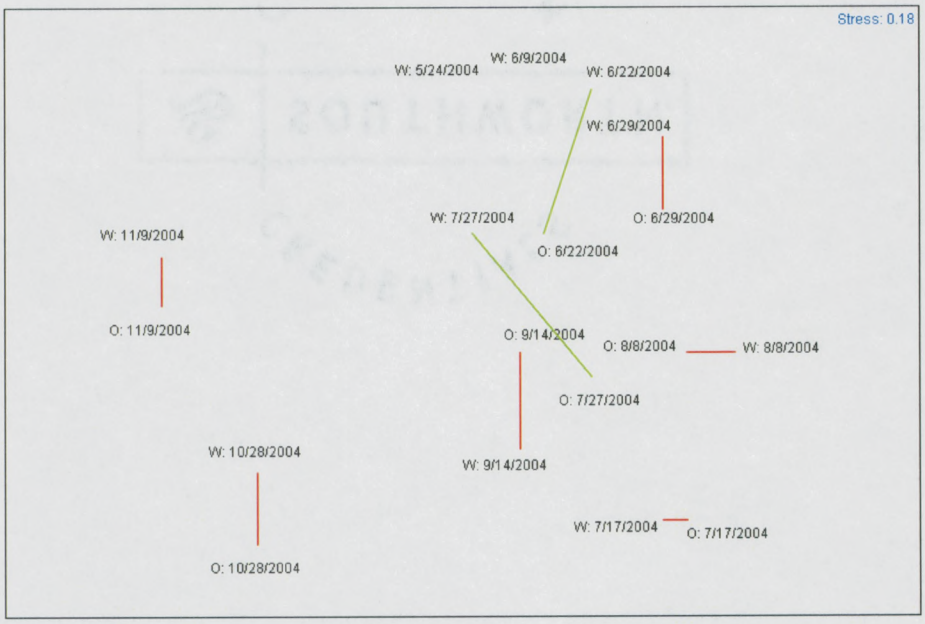

Stress: 0.18
W: 5/24/2004
W: 6/9/2004
W: 6/22/2004
W: 6/29/2004
O: 6/29/2004
W: 7/27/2004
O: 6/22/2004
W: 11/9/2004
O: 11/9/2004
O: 9/14/2004
O: 8/8/2004
W: 8/8/2004
O: 7/27/2004
W: 10/28/2004
W: 9/14/2004
W: 7/17/2004
O: 7/17/2004
O: 10/28/2004

Figure 11: Higher Taxon Similarity Dendrogram for Both Lakes.

This diagram shows similarity between sample sites when we take into consideration higher taxon data. The Protista, Monera, and Rotifera are 100% similar (red arrows). The Cladocera about 93%, Copopoda 92% (green arrow), and Insecta 71% similar (blue arrow) in both lakes.

Higher Taxon Similarity Dendrogram

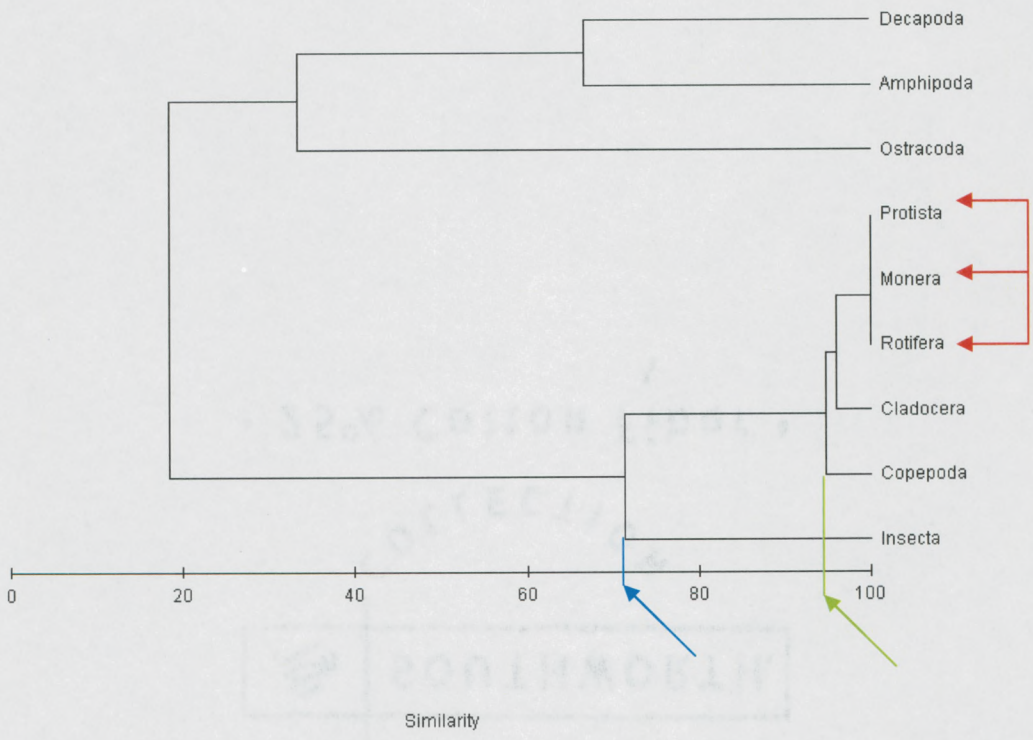


Figure 12: Species Level Comparison for Both Lakes.

This figure consists of comparison of two sites based on species level representatives. The similarities fall between 45% (green arrow) -85% (red arrow).

KEY:
Decapoda = pink
Amphipoda = lavender
Ostracoda = orange
Protista = blue
Monera = green
Rotifera = brown
Cladocera = plum
Copepoda = light red
Insecta = black

Figure 13: Evenness for Lake Wapalanne and Lake Ocquittunk (J').

The evenness values are fluctuating, and they are opposite comparing two lakes.

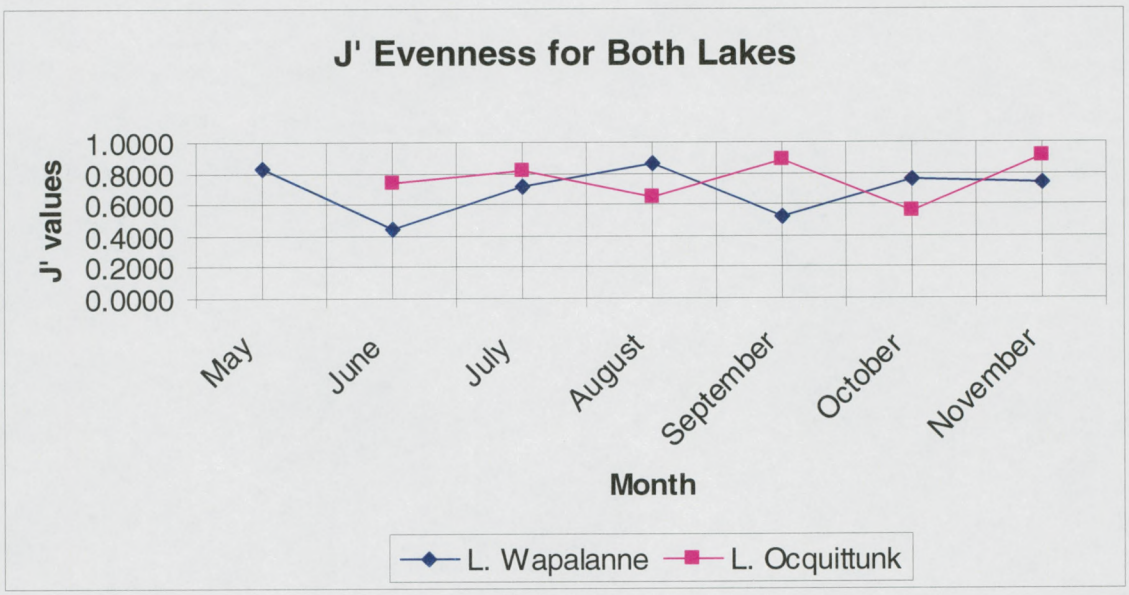

J' Evenness for Both Lakes
J' values
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
May
June
July
August
September
October
November
Month
L. Wapalanne
L. Ocquittunk

Figure 14: H' Shannon Diversity Index for Lake Wapalanne and Lake Ocquittunk.

The graph shows inverse trends when we compare two lakes.

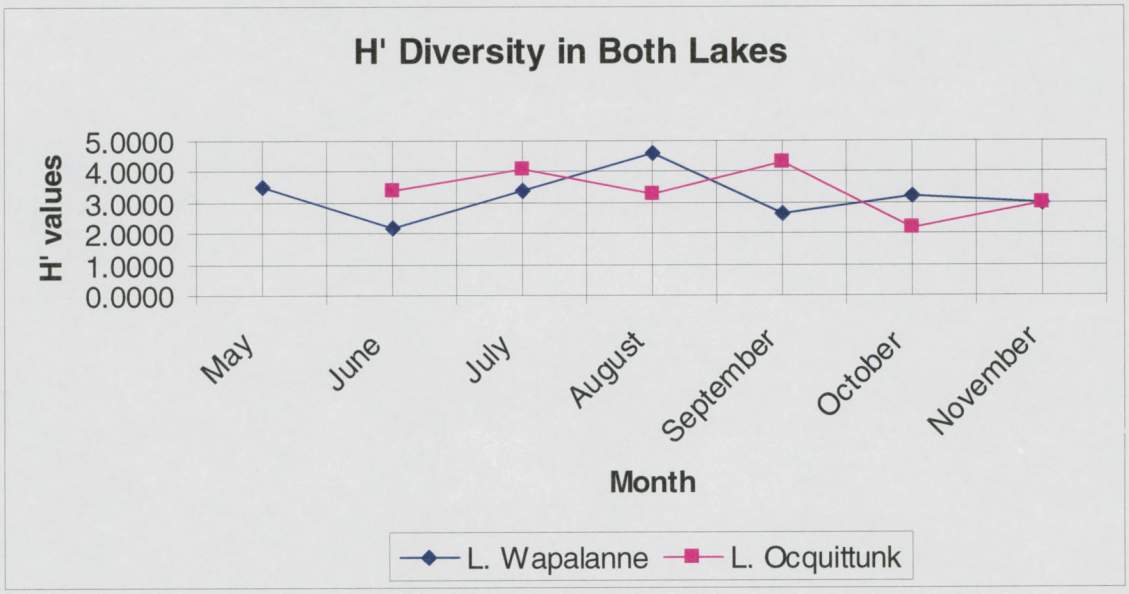

H' Diversity in Both Lakes
H' values
5.0000
4.0000
3.0000
2.0000
1.0000
0.0000
May
June
July
August
September
October
November
Month
L. Wapalanne
L. Ocquittunk

Figure 15: Lake Wapalanne's Chlorophylls Collected from a Filter Paper.

At the end of June there was a great amount of photosynthetic biomass floating in the water. At the end of July dinoflagellates took over, and the high peak of chlorophyll b on September 14th (arrow pointing) suggests mats of spirogyra in the water of Lake Wapalanne.

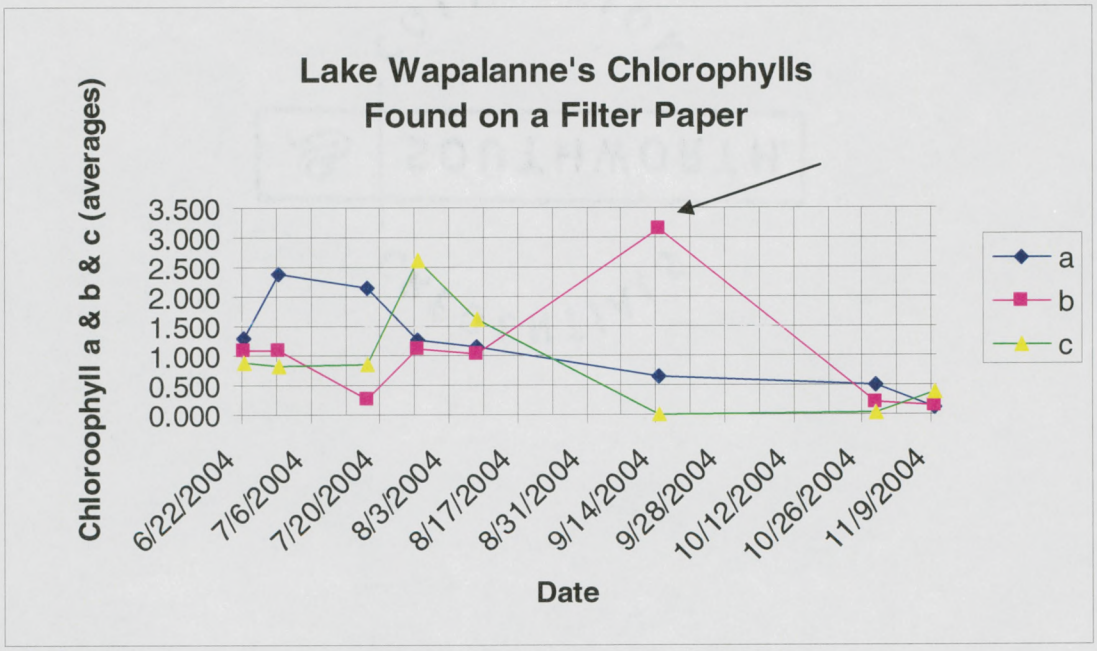

Lake Wapalanne's Chlorophylls
Found on a Filter Paper
Chloroophyll a & b & c (averages)
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
6/22/2004
7/6/2004
7/20/2004
8/3/2004
8/17/2004
8/31/2004
9/14/2004
9/28/2004
10/12/2004
10/26/2004
11/9/2004
Date
a
b
c

Figure 16: Lake Ocquittunk's Chlorophylls Collected on a Filter Paper.

The peak of chlorophyll c in June reflects of increase abundance of dinoflagellates in samples. A similar peak of chlorophyll c at the end of July appears in Lake Wapalanne.

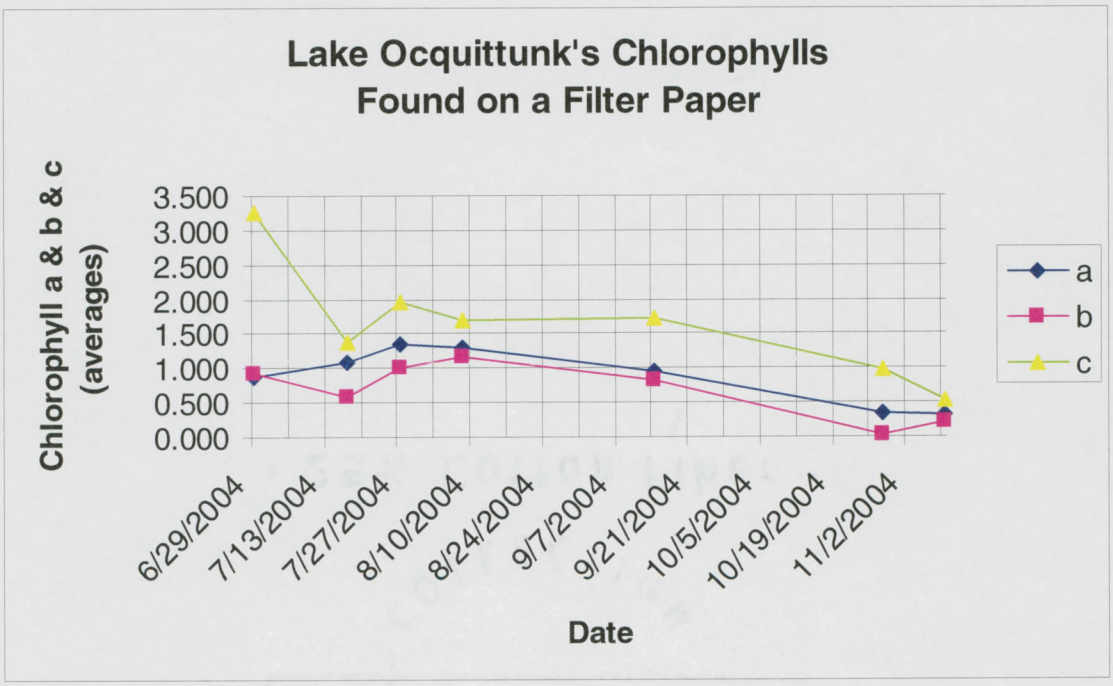
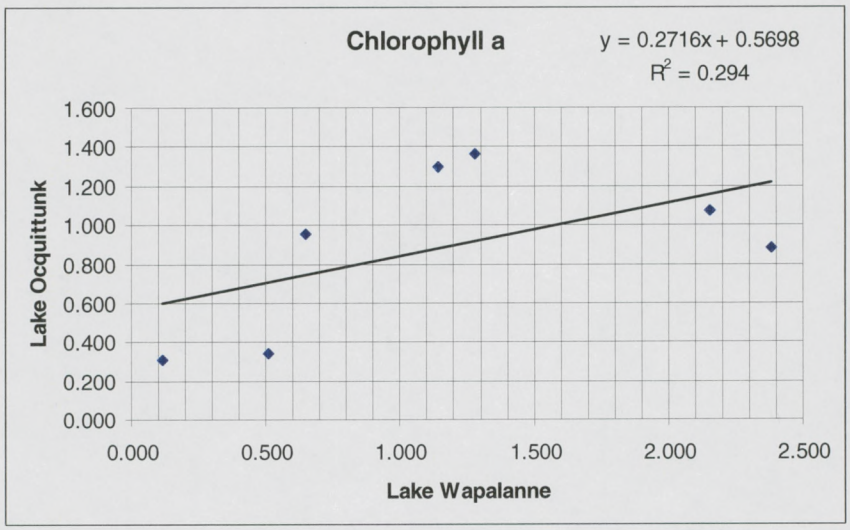

Lake Ocquittunk's Chlorophylls
Found on a Filter Paper
Chlorophyll a & b & c
(averages)
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
6/29/2004
7/13/2004
7/27/2004
8/10/2004
8/24/2004
9/7/2004
9/21/2004
10/5/2004
10/19/2004
11/2/2004
Date
a
b
c

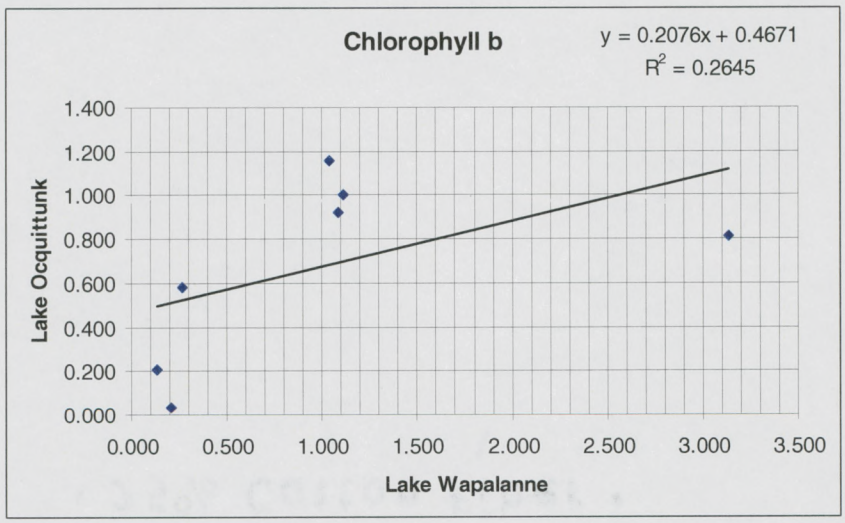
Figure 17: Chlorophyll a, b and c Abundances in Both Lakes.

The low r value suggests that there is little relation of chlorophyll a (A), chlorophyll b (B) and chlorophyll c (C) amounts between two sample sites.

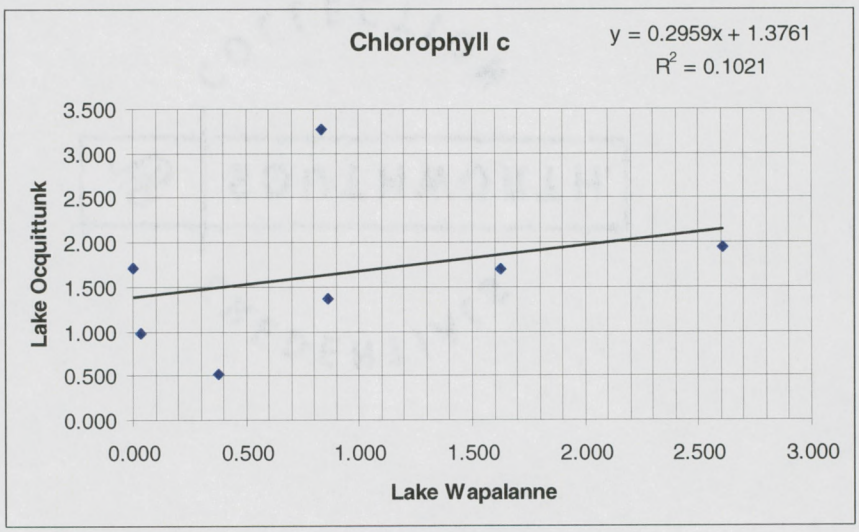
A:


Chlorophyll a
y = 0.2716x + 0.5698
R2 = 0.294
Lake Ocquittunk
Lake Wapalanne
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0.000
0.500
1.000
1.500
2.000
2.500

B:


Chlorophyll b
y = 0.2076x + 0.4671
R2 = 0.2645
Lake Ocquittunk
Lake Wapalanne
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500

C:


Chlorophyll c
y = 0.2959x + 1.3761
R2 = 0.1021
Lake Ocquittunk
Lake Wapalanne
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
0.000
0.500
1.000
1.500
2.000
2.500
3.000

APPENDIX II

Table 1: Parameters Data from Lake Wapalanne and Lake Ocquittunk.

Comparing two lakes together we can see resemblance between them. The temperature and pH data are very similar. The dissolve oxygen data are 1.25 ppm higher in Lake Wapalanne (blue) than in Lake Ocquittunk (green), and the conductivity of Lake Ocquittunk is 24.79 μs higher comparing to Lake Wapalanne.

Date	Lake W. T (°C)	Lake O. T (°C)	Lake W. pH (pH)	Lake O. pH (pH)	Lake W. DO (ppm)	Lake O. DO (ppm)	Lake W. CO (µs)	Lake O. CO (µs)
6/9/2004	25.50	26.00	9.40	8.00	7.83	7.70	50.00	70.00
6/22/2004	21.25	21.00	9.00	8.65	8.20		60.00	95.00
6/29/2004	21.75	23.83	8.83	9.00	6.70	8.67	60.00	86.67
7/17/2004	25.88	26.83	8.40	6.21	10.55	9.00	92.75	124.00
7/27/2004	24.30	23.73	7.40	7.73	8.80	7.87	96.25	103.33
8/7/2004	23.25		8.79		12.55		76.13	
8/8/2004	19.53	23.55	6.73	10.04	6.68	10.40	76.98	101.60
9/14/2004	20.93	20.97	6.53	6.70	9.98	5.93	50.43	60.20
10/28/2004	10.00	11.87	6.98	6.63	9.90	8.33	91.55	138.93
11/9/2004	6.33	6.80	6.93	6.50				
Averages	19.87	20.51	7.90	7.72	9.02	8.27	72.68	97.47

KEY:
W= Lake Wapalanne
O= Lake Ocquittunk

Table 2: Appearance of Biota in Both Lakes.

This table shows average number of representatives found from each group in samples taken from Lake Wapalanne and Lake Ocquittunk. Please note, there is no collection from Lake Ocquittunk in May, and there are no representatives from Ostracoda, Amphipoda and Decapoda group in Lake Ocquittunk.

	May	June		July		August		September		October		November	
	W	W	O	W	O	W	O	W	O	W	O	W	O
Monera	5	1	1	9	6	1	10	2	9	4	6	2	1
Protista	1	30	3	4	5	3	19	18	4	2	3	3	1
Rotifera	1	2	1	2	2	10	3	1	3	1	1	1	1
Cladocera	16	4	2	2	5	2	16	5	5	0	1	3	1
Copepoda	5	2	1	2	5	4	17	7	6	8	2	1	0
Ostracoda	0	3	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	1	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda	1	1	0	0	0	0	0	0	0	0	0	0	0
Insecta	0	1	1	1	1	2	1	1	0	0	0	0	0

KEY:
W= Lake Wapalanne
O= Lake Ocquittunk

Table 3: All the Organisms Found in Lake Wapalanne and Lake Ocquittunk.

All the representatives of fauna and flora found in samples taken from Lake Wapalanne and Lake Ocquittunk identified to *Genus* and *species*, when possible (107 species were identified). They were organized to the higher taxon groups. Totals collected for each species are listed.

	Genus species	Totals	References
Monera	*Oscillatoria*/chain	169	Cole (1994)
Monera	*Anabaena* /chain	155	Cole (1994)
Monera	*Aphanizomenon flosaquae*	115	Taras et al. (1971)
Monera	*Microcystis aeruginosa*	43	Cole (1994)
Monera	*Merismopedia glauca*	29	Prescott (1978)
Protista	*Ceratium hirundinella*	5150	Cole (1994)
Protista	*Coelosphaeriun*	698	Cole (1994)
Protista	*Colacium sp.*	608	Jahn (1949)
Protista	*Volvox aureus*	387	Prescott (1978)
Protista	*Asterionella sp.*	360	Cole (1994)
Protista	*Dinobryon sertularia*	262	Prescott (1978)
Protista	*Chlorella vulgaris Beij*	206	Prescott (1978)
Protista	*Navicula sp.*	187	Krammer and Lange-Bertalot (1997)
Protista	*Spirogyra* /chain	78	Cole (1994)
Protista	*Melosira*	63	Cox (1996)
Protista	*Ciliates*	54	Cole (1994)
Protista	*Mallomonas caudata*	53	Prescott (1978)
Protista	*Pediastrum boryanum*	41	Prescott (1978)
Protista	*Tabelaria fenestrata*	38	Cox (1996)
Protista	*Meridion circulare*	31	Round et al. (1990)
Protista	*Vorticella campanula*	31	Pennak (1989)
Protista	*Closterium parvuhum*	27	Prescott (1978)
Protista	*Synedra ulna*	26	Jensen (1985)
Protista	*Synura sp.*	23	Cole (1994)
Protista	*Ankistrodesmus falcatus*	19	Taras et al. (1971)
Protista	*Epithemia sp.*	19	Partrick and Reimer (1975)
Protista	*Nitzschia sp.*	18	Partrick and Reimer (1966)
Protista	*Pediastrum tetras*	17	Prescott (1978)
Protista	*Lyngbya birgei*	16	Prescott (1978)
Protista	*Fragilaria construens*	16	Round et al. (1990)
Protista	*Scenedesmus sp.*	12	Cole (1994)
Protista	*Gomphonema sp.*	12	Partrick and Reimer (1975)
Protista	*Heliozoan sp.*	12	Jahn (1949)
Protista	*Sorastrum spinulosum*	10	Prescott (1978)
Protista	*Arcella sp.*	9	Taras et al. (1971)
Protista	*Cerasterias irregular*	7	Prescott (1978)
Protista	*Carchesium popinum*	7	Pennak (1989)
Protista	*Closterium lunula*	6	Prescott (1978)
Protista	*Spinoclosterium curvatum*	6	Prescott (1978)
Protista	*Closteriopsis longissima*	5	Prescott (1978)
Protista	*Micrasterias sp.*	5	Vymazal (1995)
Protista	*Staurastrum leptocladum*	4	Cole (1994)
Protista	*Fragilaria crotonensis*	4	Cox (1996)
Protista	*Fragilaria islandica*	4	Jensen (1985)

Protista	*Licmophora sp.*	**4**	Round et al. (1990)
Protista	*Nemalionopsis shawi*	**4**	Prescott (1978)
Protista	*Cosmarium sp.*	**3**	Prescott (1978)
Protista	*Desmidium sp.*	**3**	Prescott (1978)
Protista	*Mallomonas chrysophycaea*	**3**	Prescott (1978)
Protista	*Pinnularia sp.*	**3**	Partrick and Reimer (1966)
Protista	*Didinium sp.*	**3**	Jahn (1949)
Protista	*Eudorina elegans*	**3**	Jahn (1949)
Protista	*Euglena viridis*	**3**	Jahn (1949)
Protista	*Pleurogaster sp.*	**2**	Prescott (1978)
Protista	*Plangiotropis lepidoptera*	**2**	Round et al. (1990)
Protista	*Squatinella sp.*	**1**	Pennak (1989)
Protista	*Frustulia rhomboides*	**1**	Jensen (1985)
Protista	*Eousttkus cambari*	**1**	Pennak (1989)
Protista	*Eunotia sp.*	**1**	Cox (1996)
Rotifera	*Keratella cochlearis*	**128**	Pennak (1989)
Rotifera	*Brachionus calyciflorus*	**58**	Cole (1994)
Rotifera	*Brachionus rubens*	**53**	Pennak (1989)
Rotifera	*Monostyla (=Lecane)*	**40**	Pennak (1989)
Rotifera	Juvenile rotifer	**27**	McCormick (2004)
Rotifera	*Asplanchna sieboldi*	**24**	Cole (1994)
Rotifera	*Argulus flouesiens* / parasite	**20**	Pennak (1989)
Rotifera	*Polyarthra sp.*	**20**	Cole (1994)
Rotifera	*Kellicottia longispina*	**10**	Pennak (1989)
Rotifera	*Vampegrella lateritia*	**8**	Pennak (1989)
Rotifera	*Brachionus pterodinoides*	**7**	Pennak (1989)
Rotifera	*Kellicottia bostoniensis*	**5**	Pennak (1989)
Rotifera	*Platyias patulus*	**5**	Pennak (1989)
Rotifera	*Resticula sp.*	**5**	Pennak (1989)
Rotifera	*Anuraeopsis fissa*	**3**	Pennak (1989)
Rotifera	*Conochilus sp.*	**3**	Pennak (1989)
Rotifera	*Trichocera sp.*	**3**	Pennak (1989)
Rotifera	*Tetramastix opopliensis*	**2**	Pennak (1989)
Rotifera	*Harringia sp.*	**1**	Pennak (1989)
Rotifera	*Mictrocodon clavus*	**1**	Pennak (1989)
Rotifera	*Myersinella sp.*	**1**	Pennak (1989)
Rotifera	*Philodina sp.*	**1**	Pennak (1989)
Cladocera	*Bosmina longirostris*	**196**	Pennak (1989)
Cladocera	*Moina wierzejskii*	**117**	Cole (1994)
Cladocera	Cladocera egg	**98**	Cole (1994)
Cladocera	*Daphnia pulex*	**56**	Pennak (1989)
Cladocera	*Daphnia magna*	**53**	Pennak (1989)
Cladocera	Cladocera larvae	**34**	Cole (1994)
Cladocera	*Moina macrocopa*	**8**	Pennak (1989)
Cladocera	*Daphnia thorata*	**1**	Pennak (1989)
Copepoda	*Nauplii*	**429**	McCormick (2004)
Copepoda	*Senecella calanoides*	**79**	Cole (1994)
Copepoda	*Limnocalanus macrurus*	**56**	Cole (1994)
Copepoda	*Eucyclops serrulatus*	**46**	Pennak (1989)

Copepoda	*Eucyclops agilis*	**5**	Pennak (1989)
Copepoda	*Leptodiaptomus minutus*	**5**	Pennak (1989)
Copepoda	*Canthocamptus*	**4**	Cole (1994)
Copepoda	*Cyclopoid copepodid*	**1**	Pennak (1989)
Copepoda	*Diaptomid nauplius*/immature	**1**	McCormick (2004)
Ostracoda	*Platyias platulus*/juvenile	**8**	Pennak (1989)
Amphipoda	*Gammaridae sp.*	**1**	Pennak (1989)
Decapoda	Juvenile shrimp	**1**	Pennak (1989)
Decapoda	*Palaemonetes paludosus*	**1**	Pennak (1989)
Insecta	Mayfly larvae	**13**	Borror and White (1970)
Insecta	Tanytarsus, Chironomidae	**4**	Cole (1994)
Insecta	*Arrenurus laversi*	**1**	Pennak (1989)
Insecta	*Naiad* or Nymph	**1**	Borror and White (1970)
Insecta	Stonefly larvae	**1**	Borror and White (1970)

Table 4: Evenness and Diversity of Organisms Found in Lake Wapalanne and Lake Ocquittunk.

These tables show values of evenness and diversity calculated from each trip (A) and their monthly averages (B).

A:

Date	L.W.	L.O.	L.W.	L.O.
	J'	J'	H'	H'
5/24/2004	0.824	0.000	3.501	0.000
6/9/2004	0.680	0.000	3.516	0.000
6/22/2004	0.557	0.748	2.519	3.336
6/29/2004	0.106	0.734	0.486	3.488
7/17/2004	0.857	0.907	4.325	4.213
7/27/2004	0.578	0.732	2.498	3.995
8/8/2004	0.865	0.649	4.604	3.300
9/14/2004	0.524	0.883	2.644	4.331
10/28/2004	0.760	0.556	3.227	2.172
11/9/2004	0.733	0.908	2.997	3.017

B:

Month	Lake W. Evenness (J')	Lake O. Evenness (J')	Lake W. Diversity (H')	Lake O. Diversity (H')
May	0.8241	0.0000	3.5010	0.0000
June	0.4476	0.7408	2.1737	3.4120
July	0.7177	0.8195	3.4115	4.1040
August	0.8651	0.6487	4.6040	3.3000
September	0.5242	0.8827	2.6440	4.3310
October	0.7596	0.5561	3.2270	2.1720
November	0.7333	0.9081	2.9970	3.0170

KEY:
L.W. and Lake W. = Lake Wapalanne
L.O. and Lake O. = Lake Ocquittunk

Table 5: Lake Wapalanne's and Lake Ocquittunk's Chlorophylls.

These tables show calculated average number for chlorophylls a, b and c collected on filter paper from Lake Wapalanne (A) and Lake Ocquittunk, and their standard deviations and standard errors.

A: Averages (Ave) of Lake Wapalanne's Chlorophylls Collected on a Filter Paper

Date	**Chlorophyll a**			**Chlorophyll b**			**Chlorophyll c**		
	Ave	Standard Deviation	Standard Error	**Ave**	Standard Deviation	Standard Error	**Ave**	Standard Deviation	Standard Error
22-Jun	**1.305**	0.582	0.411	**1.092**	0.026	0.018	**0.894**	0.047	0.034
29-Jun	**2.381**	2.029	1.172	**1.087**	0.662	0.382	**0.834**	0.758	0.438
17-Jul	**2.151**	2.105	1.216	**0.269**	0.985	0.568	**0.864**	0.665	0.384
27-Jul	**1.278**	0.443	0.256	**1.110**	0.347	0.201	**2.606**	1.177	0.679
8-Aug	**1.141**	0.260	0.150	**1.037**	0.326	0.188	**1.627**	0.375	0.217
14-Sep	**0.645**	0.368	0.212	**3.132**	4.707	2.717	**0.000**	2.600	1.501
28-Oct	**0.511**	0.262	0.152	**0.208**	0.206	0.119	**0.032**	0.407	0.235
9-Nov	**0.113**	0.078	0.045	**0.133**	0.092	0.053	**0.378**	0.262	0.151

B: Averages (Ave) of Lake Ocquittunk's Chlorophylls Collected on a Filter Paper

Date	**Chlorophyll a**			**Chlorophyll b**			**Chlorophyll c**		
	Ave	Standard Deviation	Standard Error	**Ave**	Standard Deviation	Standard Error	**Ave**	Standard Deviation	Standard Error
29-Jun	**0.885**	0.056	0.032	**0.923**	0.442	0.255	**3.269**	2.356	1.360
17-Jul	**1.074**	0.957	0.553	**0.582**	0.374	0.216	**1.369**	1.362	0.786
27-Jul	**1.365**	0.934	0.539	**1.002**	0.288	0.166	**1.950**	0.398	0.230
8-Aug	**1.294**	0.350	0.247	**1.156**	0.282	0.200	**1.702**	0.241	0.170
14-Sep	**0.955**	0.299	0.173	**0.811**	0.084	0.048	**1.718**	0.081	0.047
28-Oct	**0.340**	0.040	0.023	**0.033**	0.192	0.111	**0.983**	1.211	0.699
9-Nov	**0.306**	0.046	0.027	**0.210**	0.079	0.046	**0.518**	0.666	0.384