Parasitic Nematodes (*Eustrongylides spp.)* In Lake Erie's Yellow Perch (*Perca flavescens)*

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and approved by the senior thesis committee.

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Abstract

Two species of *Eustrongylides* parasites (*E. tubifex* and *E. ignotus*) are appearing in the western and central basins of Lake Erie. These parasites have been found by fishermen in yellow perch and have been linked to the collapsed fishing industry in Erie, Pennsylvania. The parasites can affect the lifespan and growth of the fish as well as the health of humans and waterfowl. Studying the surface temperature of Lake Erie, the number of oligochaete worms (first intermediate host) in the sediment, and number of yellow perch infected, may yield a relationship. In this study 446 yellow perch were dissected for parasites, the surface temperature of Lake Erie was taken, and sediment samples were collected in six locations off the shore of Erie, PA. No *Eustrongylides spp.* were found, but an unknown parasitic worm was discovered in the meat and/or the gut of 8 yellow perch. Without a positive identification of this unknown worm, it is impossible to say whether or not a relationship is present between the three factors. Although, possible relationships can be made independent of the identification of the parasite by comparing temperature and the size of yellow perch with the number of fish infected.

Introduction

The parasitic nematodes *Eustrongylides spp.* have raised many questions in and around Lake Erie*.* Two species of *Eustrongylides* are found in the United States, *E. tubifex* and *E. ignotus* (Cole, 1999)*.* These parasites appear in yellow perch and many other fish species mostly in the western basin of Lake Erie and in the central basin (Crites et al., 2003). Many fishermen find the nematodes in the meat and throwing the yellow perch away (Cooper et al., 1978). This parasite can also shorten the life span of the fish and stunt growth (Post, 1989). These nematodes have affected the already collapsing fish industry in Erie, Pennsylvania. Lake Erie's fishing industry has been steadily declining since the 1960's when the lake was declared "dead" from pollution (LaSpada, 2004). The fishing industry declined further in 1995 when stricter fishing regulations were put into place (Los Angeles Times, 1994). These regulations include the banning of gill nets and a stricter catch limit. Today there are many people who fish for sport, but there are few fish caught and sold on the market (Egan, 2013).

Yellow perch, also known as *Perca flavescens,* inhabit some freshwater ecosystems. They usually grow to be 10.16-25.4 centimeters long and take three to four years to reach adulthood (DNR, 2001). Yellow perch eat insects, fish eggs, and small and large invertebrates (Burr, 1991). They prefer waters around 21.1 degrees Celsius (DNR, 2001). Yellow perch like any other living organism, can contract diseases and infections and when eaten, they can pass infections on to their predators. In the case of *E. tubifex* and *E. ignotus,* the infections can be spread to larger fish. This nematode infection can be detrimental to the health of the yellow perch. It may shorten the life span of the fish or stunt it's growth (Post, 1989).

Eustrongylides tubifex and *E. ignotus* prefer warm waters (20-30 degrees Celsius) and are often found in bodies of water that have experienced large amounts of pollution and eutrophication (Friend et. al, 1999). *Eustrongylides tubifex* can easily be identified by its' red color, length (11-83mm), and location in the host's body (Yanong, 2012). The parasite can be found in the mesenteries or in the muscle of hosts (Yanong, 2012). It is unclear why so many *E. tubifex* inhabit the western basin of Lake Erie, specifically. A study done in the 1970's on the impacts of E. *tubifex* on yellow perch in the western basin of Lake Erie touched on the high amount of parasites found in the fish (73.63% of all yellow perch sampled) (Crites, 1979). The lifecycle of the parasite must be understood to determine why they are so abundant. *Eustrongylides ignotus* is larger and is known as "The Big Red Worm" (Ohio State University, 2013). This nematode can grow up to 15 cm long and 4 cm wide (Ohio State University, 2013). *Eustrongylides ignotus* more commonly infects mosquito fish and blue gill by attaching themselves to the stomach wall of these fish (Coyner et. al, 2001). The lifecycle of *E. ignotus* and habitat is similar to *E. tubifex* (Ohio State University, 2013).

The lifecycle of *E. tubifex* and *E. ignotus* begins with water birds. The water birds carry the adult nematodes in and around their digestive tracts (Ohio State University, 2013). The nematodes lay eggs and are passed into the water through the bird's waste. From there the eggs develop further and are consumed by an oligochaete worm, the first intermediate host (Yanong, 2012). The intermediate host provides nutrients for a parasite and the parasite does not sexually reproduce in this host (Jacobs, 2014). Oligochaete worms are found in the sediment of a body of water (Yanon, 2012). The Oligochaete worm usually infected is *Tubifex tubifex.* This worm is sometimes referred to as a "sludge worm" because its preferred habitat is mostly polluted waters where they feed on dead organic matter (EOL, 2012). The *Tubifex tubifex* worm is red in color due to the high amount of hemoglobin stored in their body cavities (EOL,2012). This is because they need very little oxygen to survive (EOL, 2012). Low oxygen content is associated with polluted warm waters because warmer water contains less oxygen. The oligochaete worm is then eaten by a fish like the yellow perch (Ohio State University, 2013). The fish is considered the second intermediate host because the nematodes do not sexually reproduce in this host (Jacobs, 2014). From there the worm develops further and when eaten, invades the digestive tract and the rest of the body. Figure 1 illustrates the lifecycle of both *Eustrongylides spp*.

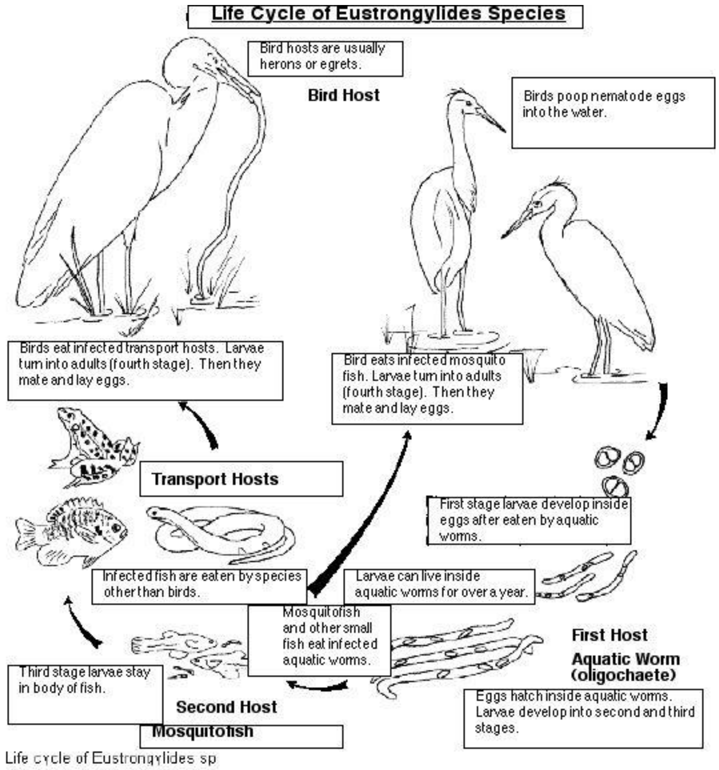


Figure 1. This figure shows the lifecycle of *Eustrongylides spp..* (Cole, 1999)

Once in the fish, the fish can be eaten by a water bird or by a transport host. This transport host is just like an intermediate host except it can be another fish, snake, or amphibian (Ohio State University, 2013). This transport host can then be eaten by the definitive host, a water bird, and ultimately passed on to the next intermediate host or definitive host (Ohio State University, 2013). A definitive host is the final host where the adult nematodes sexually reproduce (Jacobs, 2014).

This parasitic species can also infect humans, if the meat is not cooked properly. Only one worm is needed to cause an infection in humans (FDA, 2013). If infected, gastrointestinal issues may develop and in some cases worms may need to be surgically removed (Friend et. al, 1999). This had been seen in 1989 when a 17-year old boy ate live minnows and had to get the worms surgically removed. (Eberhard et. al, 1989).

Another problem with *Eustrongylides spp.* is that they infect waterfowl, mainly wading birds such as egrets (*Ardea alba*), mallards (*Anas platyrhynchos*), and herons (*Ardeldae*) (Ohio State University, 2014). The parasite can be more harmful to nestlings and cause a higher mortality rate in the younger birds (Field Manuel of Wildlife Disease, 2014). There have been many studies conducted which show the harmful effects and prevalence of *E. ignotus* and *E. tubifex* in wading birds in the United States. One study showed that at least five species of wading birds were infected with *Eustrongylides* in the western basin of Lake Erie (Cooper et. al, 1978). When infection occurs, the parasite can cause lesions in many organs including the liver and the intestines (Spalding, 1990). Researchers often over look deaths of birds caused by *Eustrongylides spp.* and mistake the death for starvation (Spalding, 1990).

Without an abundance of knowledge as to how prevalent these parasites, a cause and a solution cannot be put into place. A few studies have been conducted to determine how prevalent this parasitic infection is in different species of fish in Lake Erie, but never specifically in the Erie, Pennsylvania area. Oligochaete worms are not commonly studied and these roundworms are important to count because it can carry stage two larvae of *Eustrongylides spp.* (Crites et al., 2003). It has been found in the past, that higher temperature has a relationship with more parasitic infections in fish (Crites, 1979). A study done in the 1970's on the impacts of E. *tubifex* on yellow perch in the western basin of Lake Erie touched on the high amount of red worms found in the fish (73.63% of all yellow perch sampled) (Crites, 1979). In this research a relationship between all three factors by surveying Erie Pennsylvania waters of Lake Erie should be found. The objective of this study was to determine if there is a relationship between the number of *Eustrongylides spp.* infections in yellow perch, the temperature of the water, and the number of oligochaete worms in the sediment. The information from this study can be used to benefit the fishing community, Presque Isle State Park, fisheries, and the DEP by providing more information about *Eustrongylides spp.* to use in further studies. This research topic was chosen because of past experiences finding strange worms in fish in Lake Erie, especially last summer (summer of 2013). It was also chosen because of research previously carried out on oligochaete worms with Gannon University.

Methods

Locations for sampling were chosen in Lake Erie off the shores of Erie, PA. Each location was recorded and surface water temperature was taken using a fish finder or buoy data (USGS). Air temperature, wind speed, weather, time, date, number of people fishing, and location were recorded. The locations differed within the lake in order to provide more variation in samples and to find more fish. Locations 3, 4, 5, and 6 were chosen in the same coordinate. This was mainly because the yellow perch were known to be caught more in this area by many local boat captains and fishermen. A fishing boat was used along with the public boat the Edward John in Erie, PA. Table 1 references the number of people and hours spent fishing to demonstrate the amount of time and effort spent fishing in each location.

(Table 1) Number of People and Hours Spent Fishing per Location

Location	1	2	3	4	5	6
Number of People Fishing	4	4	5	4	20	20
Hours Spent Fishing	1	1	2.5	3	4.5	4

Secondly a dredge was used, provided by Allegheny College, to collect one (1 liter) sample of sediment from the bottom at each location. Sediment was placed in a five-gallon bucket and analyzed later in the lab for the number of oligochaete worms. In order to count the worms, a liter of sediment was analyzed one tablespoon at a time. Each tablespoon was put onto a fine mesh screen and water poured over the surface of the sediment. This allowed the sediment to fall through the screen and the worms to stay on top. The worms were counted and stored in vials of 70% ethanol. This process was repeated until the whole sample was complete.

Fishing rods baited with earthworms or minnows were used to catch yellow perch. The number of fish caught in each selected spot varied. It was a goal to catch 200 fish over the course of the study. Two hundred yellow perch is a reasonable number to sample according to studies done by Rosinski, (2011), Muzzall (2011), and Crites (1979). The size of the fish varied and was recorded. Fish under the size of 15.24 centimeters were immediately released. This was because they are not fully mature (PA Fish and Boat Commission, 2014). Catching yellow perch under age does not give them sufficient time to develop properly and reproduce (Brazo et. al, 1975).

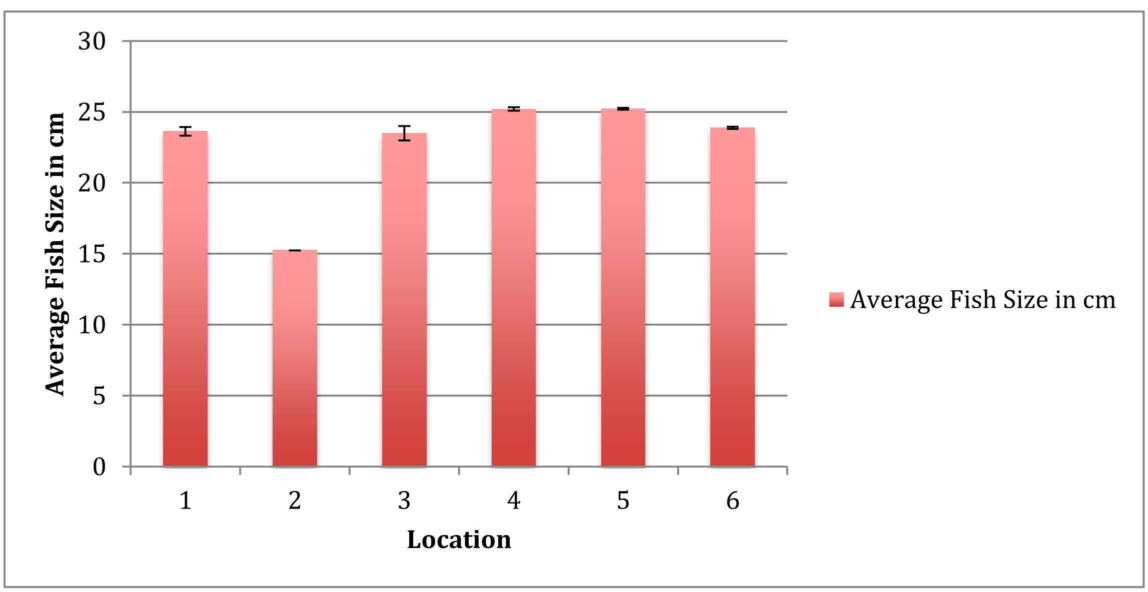
Once caught, the yellow perch were put on ice in the boat and measured. Measuring the fish gave an idea of how old the fish was based on its' size. The fish's guts and meat were dissected for any *Eustrongylides* parasites that may be in the body cavity of the fish. Usually the parasite was found around the mesenteries of the host, red in color, and was around 11-83mm long (Yanong, 2012). If not put on ice quickly it could migrate into the muscle or other close by areas (Crites, 2003). The nematodes were placed in ethanol and taken to the lab. In the lab the parasitic nematodes were placed under a microscope and photographed for possible identification.

Results

There were six locations sampled in total. Location 1,3,4,and 6 were in Lake Erie a mile or two from shore. Location 2 was in the bay. Locations 3, 4, 5, and 6 all were in the same coordinate. All samples were taken with minimal wind (4.5 mps or less) and on days with less than .914 meter waves. All locations can be seen in Figure 2.

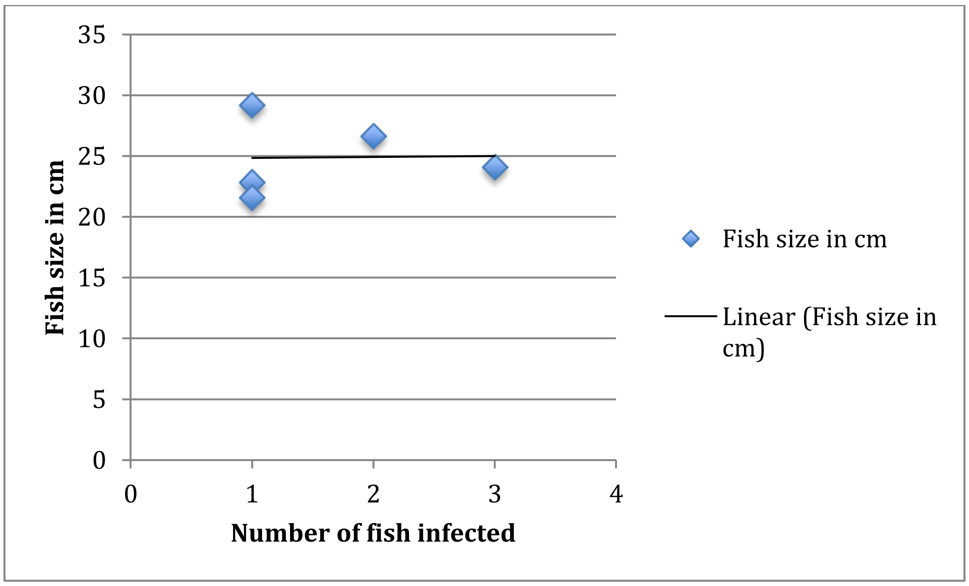
(Figure 2) This shows the six locations that were sampled during the study. Four of the locations were all in the same coordinate but in different locations within the coordinate.

There were 446 yellow perch caught in total. The average size of fish was calculated for each location. The average fish sizes are compared below in Figure 3. All fish averages were around the same size except location 2.



(Figure 3) This figure shows the average fish size in centimeters per location. Standard error is calculated for each fish average value. All locations have similar sized fish except for location two.

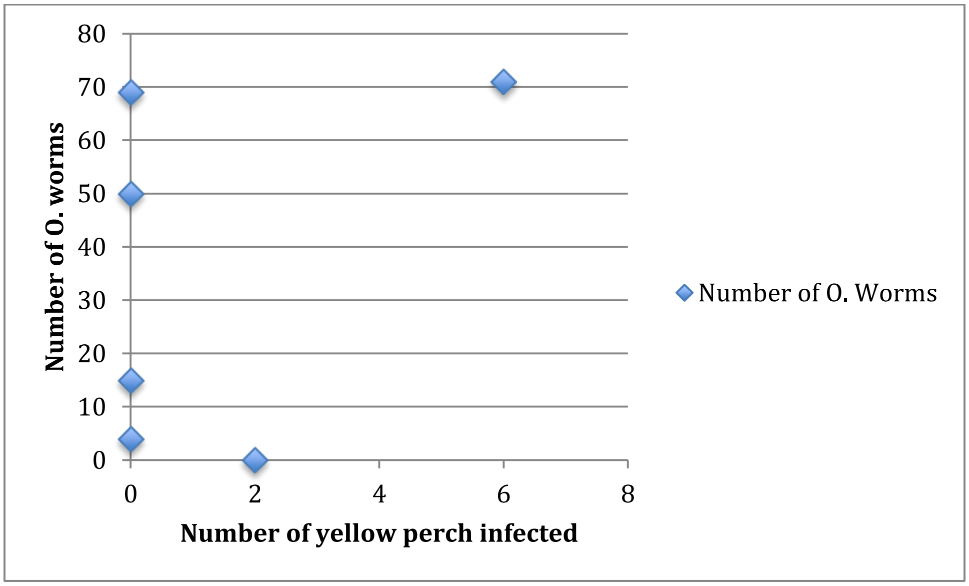
There were eight fish infected with a parasite in total. None of the eight parasites found were *Eustrongyldides spp.* The parasite was found in either the meat of the fish or in the gut (12.5% found in the gut and 87.5% found in the meat). Each fish infected was between the sizes 21.59 cm and 29.21 cm. Fish sizes 24.13 cm and 26.67 cm had the most infections (Figure 4).



(Figure 4) This figure shows the relationships between the number of fish infected by size in centimeters. There were three fish infected that were 24.13 cm long. A possible relationship can be seen.

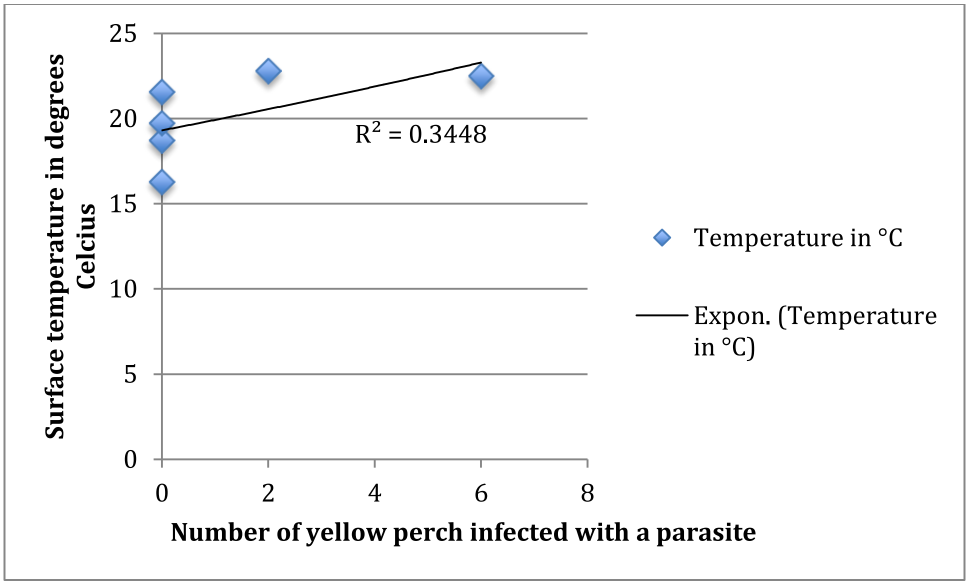
There were two findings during this study that were not intended. The first was the finding of Chironomidae larvae in the sediment in locations one, two, and three. In location one, 1 Chironomidae was found. In location two, 4 Chironomidae were found and in location three, 3 Chironomidae were found. This could indicate pollution and low oxygen levels due to their capacity to hold hemoglobin in their circulatory systems. The second discovery was the finding of a green string or thread in the meat of a 21.59 cm long yellow perch. The string was lodged in between the meat and the skin of the fish.

All six locations were sampled for oligochaete worms. In location 5, the most amount of oligochaete worms were found in the sediment. This is compared to location 4 where there were no oligochaete worms found, but there were two yellow perch infected. There is no relationship between the number of yellow perch infected and the number of oligochaete worms in the sediment (figure 5).

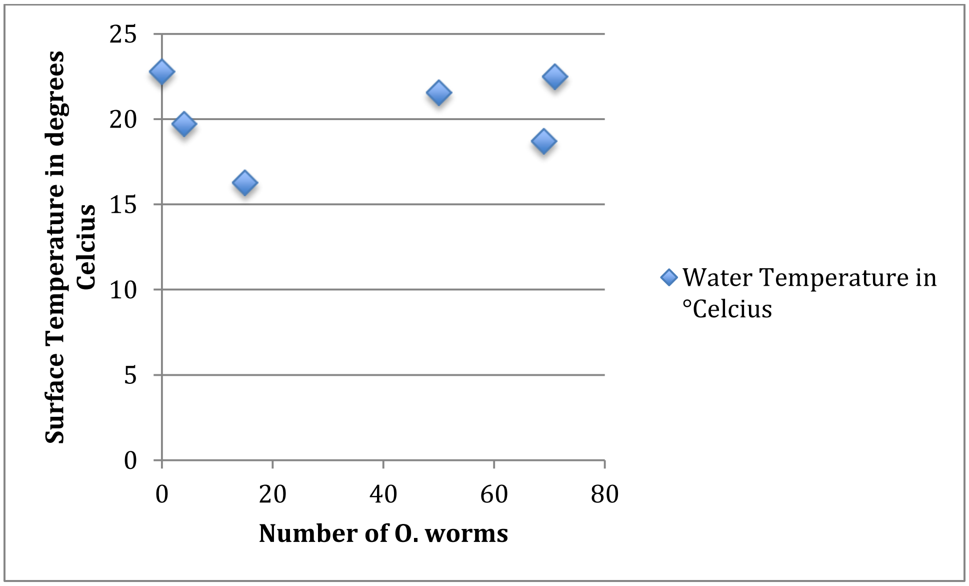


(Figure 5) This figure shows the relationship between the number of oligochaete worms found in the soil and the number of yellow perch infected. No relationship can be seen between these two factors.

It was found that numbers in the low 20's in degrees Celsius yielded the most amount of parasites. Locations 4 and 5 both yielded fish infected with parasites. The temperatures of these locations were 22.78 and 22.5 degrees Celsius (figure 6). Although location 2 did not yield any parasites and the temperature was 22.11 degrees Celsius. It was also found that water temperature does not affect the number of oligochaete worms found in the sediment. There were very similar water temperatures in locations 2, 4, and 5 and the locations had differing oligochaete worm totals (71, 0, 69) (figure 7).



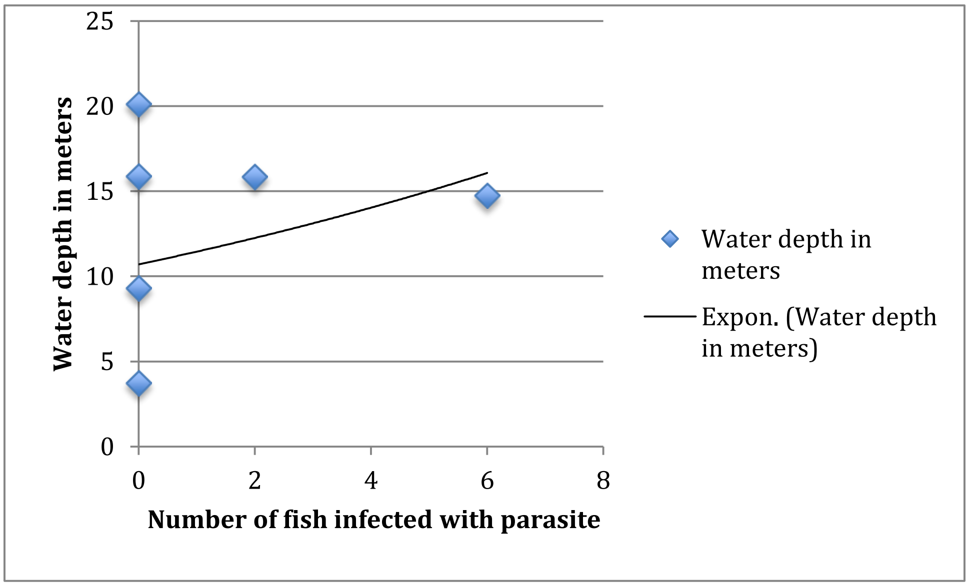
(Figure 6) This figure shows the relationship between the surface temperature of Lake Erie and the number of yellow perch infected with an unknown parasite. The data shows a correlation between these two factors.



(Figure 7) This figure shows the relationships between the number of oligochaete worms in the sediment of Lake Erie and the surface temperature of the water. There is no relationship between these two factors.

All 8 fish infected were found between 14.75 meters and 15.85 meters deep. Although, there were no parasites found in fish in location 3 with a depth of 15.88 meters (figure 8).

The date indicates no relationship between the depth and the intermediate host (oligochaete worms). This is because in location 4, no worms were found even though the depth was 15.88 meters, which is similar to the depths from locations 3 and 5. In locations 3 and 5 there were oligochaete worms found.



(Figure 8) This chart shows the relationship between the water depth in meters and the number of yellow perch infected with the unknown parasite. According to the data there could be a relationship between these factors.

Discussion

The six locations were chosen throughout this entire study by the boat captain. The boat captain knew where the yellow perch were biting and was able to pick a location based on his/her experiences. The samples were taken in the months of June, July, and September of 2014. Mechanical issues prevented collections in August.

Four locations were chosen in the same coordinate because yellow perch were "biting" in these locations according to local fishermen. This could be because of a number of factors. This summer (2014) the water was colder due to the lake freezing completely during the winter and because of colder water from deeper parts of the lake moved into more shallow water (NOAA, 2014). Yellow perch are a cold-water fish species and because of global warming the population is suffering (NOAA, 2014). It has also been found in Lake Erie that warmer winters affect the number of white perch (*Morone Americana)* that can survive (Egan, 2013). White perch are predators of yellow perch eggs and have been causing a decline in the yellow perch population (Meyerson, 2013). These white perch are also claimed to be “bait stealers” and a nuisance to fishermen (Egan, 2013). The white perch population is increasing because of the decrease in walleye (*Sander vitreus)* (Egan, 2013). Walleye are the main predator of the invasive white perch (Egan, 2013).

The average size of fish was about the same in every location except location 2. This location had an average of 15.24 cm, which is a smaller average than the other locations. This is because there was only one fish caught and location two was in the bay. Only one fish was caught from this location because the fish were not biting and the water was very shallow and hard to navigate a boat through due to thick algae and aquatic plants.

There were eight yellow perch infected with an unknown parasite in total. Unfortunately, these parasites could not be identified. Many experts and local DEP members were contacted, none of which were able to give a positive identification. Although, it is not believed the parasites found were *Eustrongylides spp.*. The species found were white, thin, and only up to 7.62 centimeters long. *Eustrongylides spp.* can be up to 83 cm long and 4cm wide (Ohio State University, 2013) (Yanong, 2012). They are also characterized by a red color and their location in the gut of the fish (Yanong, 2012).

There was also a second finding during this study. This finding has to do with a midge in the family Chironomidae*.* The larvae found were identified by their elongated and cylindrical body shape (Hammond, 2009). They also were segmented and had a hard head capsule (Hammond, 2009). The particular Chironomidae found were a bright red in color. This could indicate that this species has hemoglobin in their circulatory system. This allows them to survive in low-oxygenated waters (Hammond, 2009). Chironomidae were found in locations 1, 2, and 3 all in the month of June. This could indicate that these locations have low levels of oxygen and that they could possibly have higher pollution levels. This is because low-oxygenated waters are often associated with pollution and are used as a bio-indicator (Minnesota Pollution Control Agency, 2009). Although Chironomidae can also live in very clean oxygenated waters in abundance (Johnson et al., 2005). These larvae have been studied in the Erie area of Lake Erie before. Chironomidae have been used to determine wetland age on Presque Isle State Park (Botts, 2003). There needs to be further research in order to say that the areas where midge larvae were found are polluted (Hammond, 2009).

Each fish that was infected with the same unknown parasite was between the sizes of 21.59 cm and 29.21 cm. This suggests that perch size may have an influence on the number and size of perch being infected (Figure 3). Without a positive identification on the parasites found, it is unknown if the parasite could affect the size and growth of the fish or if the parasite only infects certain sizes of fish.

The number of oligochaete worms in the sediment did not have an effect on the number of yellow perch infected with parasites in this study. This is because in location 4, there were no oligochaete worms found in the sediment. This could be because of a very rocky bottom and large clusters of zebra (*Dreissena polymorpha)* and quaga mussels (*Dreissena rostriformis*). In some locations oligochaete worms were found in the sediment and in other locations there were little or no oligochaete worms found. These results could be because of the types of sediment being found in each location (Leppänen et al.,2006). In locations 1, 2, 3, and 5 the sediment was soupy and grey. This sediment also had an unpleasant odor and seemed to be made of clay. In location 4 there was almost no sediment. The dredge was able to capture numerous Zebra and Quaga Mussels as well as rocks and bits of sand. In location 6, the sediment was very sandy and rocky with little mud. This sample also smelled fowl, similar to the sediment from locations 1, 2, 3, and 5. All of these sediment types differed which could cause a larger or smaller amount of oligochaete worms due to the habitats conditions. These worms are usually found in mud or detritus of pond or lake bottoms because the muddy lake bottom can provide more nutrients (Micrographia, 2013). Therefore, more oligochaete worms would be found in the muddier clay like sediments and not in the sandy sediment locations (Leppänen et al.,2006).

Temperature in this study yielded that there could be a possible relationship between the temperature of the water and the number of infected yellow perch. Although, it is impossible to tell whether or not there is a relationship between the temperature and the number of perch infected without an identification of the parasites found inside the fish. The temperature was taken at the surface of the water during sample collection. This could also influence whether or not there is a relationship between temperature and the number of infected perch. If temperature would have been collected at the bottom of the Lake Erie, the data may be more accurate. This is because yellow perch mainly live at the bottom of the lake (DNR, 2001). In locations 4 and 5, infected perch were found. In these locations the temperatures were very close. Although, in location 2 the water temperature was 22.11 degrees Celsius, very similar to the temperature of location 5.There was only 1 fish caught in location 2. Because of the lack of fish caught, it is impossible to see a relationship with such a small sample size. Yellow perch prefer waters around 21.11 degrees Celsius (DNR, 2001). This could also show a relationship because the fish infected with parasites were in waters around 21.11 degrees Celsius.

The data shows no relationship between the temperature of the water and the total of oligochaete worms found in the soil for each location. This could be explained because the temperature was taken at the surface of the lake and not at the bottom where the oligochaete worms are found. This could affect the validity of the data. No relationship is shown because there were no oligochaete worms found in location 4. This location had very similar temperatures to locations 3 and 5. Both locations 3 and 5 had oligochaete worms present. Also no relationship can be seen because of the sediment type (sandy, rocky, etc.). This was previously discussed above.

Depth is another factor in the study that was not originally thought to yield any relationship. Without a positive identification of the parasitic worms found in the meat and the gut of the fish, no relationship can be seen. However, there could be a relationship between the number of yellow perch infected and the depth in meters if the parasites were identified. Figure 7 shows that locations 4 and 5 had similar depths. In both these locations infected fish were found. In location 3 however, there were not any infected fish found even though its depth is very similar to location 4. This could be due to the small sample size of 8 yellow perch caught. There is little research to support that depth has a direct relationship with yellow perch parasitic infections. Knowing this, depth might influence temperature, which could intern influence the number of infected yellow perch. It has been found in the past that temperature has been linked to the number of parasitic infections in yellow perch (Crites, 1979). The higher the temperature, the more parasites that were found (Crites, 1979)

The depth of Lake Erie in these six locations also did not have an affect on the number of oligochaete worms found. Locations 3, 4, and 5 all had similar depths. In location 4 there were no oligochaete worms found. But, in locations 3 and 5 there were. This could also be due to the different sediment types (rocky, sandy, etc.) as discussed above (Micrographia, 2013).

A green object appeared in one fish in location 3. This object was pulled from the meat of the yellow perch during dissection. The green object was put underneath a microscope and identified as a piece of string due to the fact that the string was unraveling. There is no research or explanations for why this green string was in the fish meat. The object looked like the string could have been a part of fishing material.

Conclusion

This study was not able to yield any findings about *Eustrongylides spp.* in yellow perch. Therefore, more research needs to be done in order to determine if there is a correlation between temperature, the number of oligochaete worms in the soil, and the number of *Eustrongylides spp.* infected yellow perch. More research also needs to be done on the temperature at the bottom of the lake and the correlations with perch infections and oligochaete worms. Findings about the oligochaete worms could mostly be explained by their habitat. The lack of identification of the parasitic worms found, make it almost impossible to say if there are relationships between any of the data. For future studies a back up boat and plan should exist incase of mechanical issues. In addition, equipment to measure the temperature at the bottom of the lake should be used.

Eustrongylides spp. may be more easily found in yellow perch in future years. This is because the water of Lake Erie may be warmer. Last summer (2013) more parasitic worms were found (previous to this study) because of warmer lake temperatures. According to the National Weather Service (NOAA) the water temperatures of Lake Erie during the month of July were below 21.11 degrees Celsius and in 2013 the water temperature was above 21.11 degrees. Yellow perch prefer warmer waters (DNR, 2001). This might have contributed to the smaller amount of perch caught during this study. Also *Eustrongylides spp.* were found in months with warmer waters in previous studies (Crites, 1979).

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