

Invasive prey mediated enemy release hypothesis (trophic cascades of enemy release) in native smallmouth bass

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Final report to the Edna Bailey Sussman Foundation 2012

Background

Introduction of round gobies into the Great Lakes watershed has had profound effects on the functioning of these aquatic ecosystems. Gobies have had both negative and positive impacts on the life history of smallmouth bass, an important game fish in this region. Gobies feed on the eggs of smallmouth bass potentially harming their populations but gobies also reach high densities allowing smallmouth bass to switch to a diet of fish (piscivory) at a younger age and become a significant portion of their diet. This switch has also led to accelerated growth of juvenile smallmouth bass which can positively affect survival and reproduction and therefore bass populations. The effects of consuming large quantities of gobies on the parasites and therefore health of smallmouth bass are currently unknown. My current work is attempting to determine if goby consumption by smallmouth bass influences parasite diversity and abundance by comparing the parasite communities in bass across multiple ecosystems with and without gobies.

It was proposed to sample thirty smallmouth and thirty largemouth (as a control species that consumes fewer gobies) bass from at least six sites. Fish would be dissected and parasite community within each fish recorded along with identification of stomach contents for determining diet preference and to confirm goby consumption. One of these sites, Oneida Lake, has yet to be invaded by the round goby but is likely to experience this invasion within a short period of time. Both Oneida Lake and Onondaga Lake are connected by the Erie Canal through the Seneca River. Within the past two years Onondaga Lake has been invaded by gobies starting the countdown to an invasion of Oneida Lake. Oneida Lake therefore provided a site where a baseline parasite community can be established prior to goby invasion for a before and after goby invasion comparison at a later date. This baseline parasite community survey can also be compared with a survey of bass parasites that was conducted from 1929-1931, by Harley J. Van Cleave and Justus F. Mueller, to examine the differences in parasite communities separated by 80 years. It is this latter comparison that this report focuses on since the work necessary for it has been completed.

Completed Research

Three hundred forty three fish were collected from seven sites (Fig. 1). Complications with the electrofishing boat inhibited the completion of fish collection which also delayed progress on dissections. However, all 63 fish (32 smallmouth bass and 31 largemouth bass) from Oneida Lake have been examined. The findings of this resurvey of Oneida Lake bass parasites were compared to the 1929-1931 survey and some preliminary comparisons between the parasite communities of the bass species in Oneida Lake were conducted.



Figure 1. Map of the seven sampling locations chosen for this investigation; 1) Oswegatchie River above dam (non-goby site) 2) Oswegatchie River below dam 3) St. Lawrence River 4) Oswego Harbor 5) Oswego River (non-goby site) 6) Seneca River 7) Oneida Lake (non-goby site).

Methods

Thirty two smallmouth bass and 31 largemouth bass were examined from Oneida Lake in 2012 in comparison with the 20 smallmouth bass and 44 largemouth bass examined by Van Cleave and Mueller in the summers of 1929-1931. There are some important differences in methods used by the two surveys; chiefly that I have examined all parasites not just helminths (flatworms) and have provided quantitative data where the 1929-1931 survey only provided qualitative data. Quantitative data provides more detailed information for future statistical comparisons.

Fish were collected via electrofishing boat and then put on ice until they could be frozen for examination at a later date. Total length and weight for each fish were recorded. Examination of the fish included inspecting the skin, fins, eyes, gills, stomach, intestines, muscle and body cavity using a dissecting microscope. Additionally, wet mount techniques were used to view tissues for microscopic parasites in the gills, brain, heart, liver, kidney, spleen, gall bladder, urinary bladder, muscle, and gonads. Macroscopic helminths and parasitic copepods

were counted and recorded for mean abundance measures. An exception was made for monogenean flatworms, which are smaller and can be very numerous, which were only noted for presence and absence to save time. Parasitic organisms that were microscopic, including small life stages of larger adult organisms, were also only marked as present or absent for prevalence. Stomach contents of the fish were identified and divided into three groups; crayfish, fish and invertebrates. The frequency (number of fish having eaten that organism) of each of these groups was also recorded.

Results

The average length and weight for largemouth and smallmouth bass were 365.3 mm and 801.0 grams, and 347.8 mm and 785.3 grams respectively (Fig. 2). The difference in fish size was not significant. Stomach contents of smallmouth bass contained more crayfish and other invertebrates than largemouth bass, which contained more fish (Fig. 3). However, none of these frequencies were statistically significant but our sample size is likely too small to determine any real difference in food preference due to the number of empty stomachs encountered.

Thirty two species of parasites were discovered in this survey (Table I). Fifteen species of parasite were found in both species of bass, 46.9% of the total number of parasite species. Of the 15 parasites found in both host species, five had differences in prevalence (*Postodiplostomum minimum centrarchi*, *Uvuliferis ambloplites*, *Proteocephalus ambloplites* (pleurocercoids), *Achtheres pimelodi*, and *Synclathrum fusiformis*) (Fig. 4) and three had differences in mean abundance (*U. ambloplites*, *Ergasilus centrarchidarum*, *A. pimelodi*) (Fig. 5). The average number of parasite species per fish was 6.3 and 5.8 for largemouth and smallmouth bass respectively, and were not significantly different from one another (Fig. 6). Number of parasites per fish tended to decrease with increasing length for both smallmouth and largemouth bass, but correlations were fairly low (smallmouth bass, $R^2 = 0.023$ and largemouth bass, $R^2 = 0.2098$)(Fig. 7). This indicates that length was not a good predictor of parasite species per fish.

There were several significant differences between the historical survey and the current one. Six parasite species (*Leptorhynchoides thecatus*, *Rhipidocotyle papillosum*, *Caecincola parvulus*, *Azygia angusticauda*, *Crepidostomum cornutum*, and *Contracaecum brachyurum*) were all found to be less prevalent in the current survey. Three of these (*R. papillosum*, *C. parvulus* and *C. cornutum*) were common or abundant in the 1929-1931 survey but were not found at all in the current one. One parasite (*Proteocephalus ambloplitis*) was found to be more prevalent in the current survey compared to the previous one. Additionally, the current survey found seven parasites (*Myxobolus micropteri*, *Myxobilatus mictospora*, *Myxobilatus* sp., *Chloromyxum* sp., *Trichodina* sp., *E. centrarchidarum*, and *A. pimelodi*) from parasite taxa that

were not focus of and not reported in the previous survey. Furthermore, where monogeneans were described in the Van Cleave and Mueller survey their prevalence was not recorded but have been in the current survey.

Conclusions

The current survey greatly expanded our knowledge of bass parasites in Oneida Lake. This survey included groups of parasites not previously studied and provides quantitative data for comparison with other sites or future studies. Parasites found with significantly different prevalence between bass species followed predictable patterns based on their habitat preferences. The higher infection rates of three metacercarial species (*P. minimum centrarchi*, *U. Ambloplites* and neascus longicollis) and the *Myxobilatus* sp. in largemouth bass may be explained by the preference of this species for protected shallow water habitats where the intermediate hosts of these parasites typically occur. The tapeworm *P. ambloplites* is more indicative of open water habitats and is typically found more in smallmouth bass, a pattern that was also present in this survey. Dietary data also followed expected patterns with smallmouth bass preferring crayfish and largemouth bass preferring to eat small fish.

One of the surprising results of this study is that the average number of parasite species per fish was significantly higher than that found in the smallmouth bass of the St. Lawrence River (3.2)(unpublished data). The reason for the difference is not clear. Smallmouth bass from the St. Lawrence were also significantly smaller which could potentially explain this difference. Parasite numbers and diversity usually tend to increase with host age because they have a greater likelihood for exposure. However, this explanation does not seem to fit well for Oneida Lake since the number of parasites per fish actually tended to decrease with fish length. Another potential explanation may be linked to system productivity, where the St. Lawrence is less productive than Oneida Lake. Alternatively, these results may possibly support the hypothesis that consumption of gobies could be decreasing parasite diversity and numbers in their predator, the smallmouth bass. The St. Lawrence does have a significant population of gobies which were found to be a significant contributor to the diet of smallmouth bass in that system. Given the differences I've uncovered it will be useful to collect the parasite data from the other sites for comparison to see if these differences hold between goby and non-goby sites in order to aptly test this hypothesis. Examining the fish collected from the other goby and non-goby sites should also provide useful information on whether gobies are major driver of these differences or if other factors are more important.

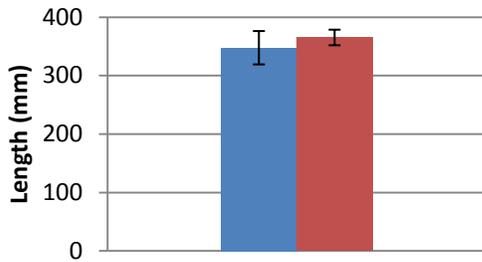
In Oneida Lake, I had the unique opportunity to compare my survey results to those conducted by VanCleave and Mueller in 1929-1931. Justus F. Mueller was a faculty member at

SUNY-ESF at the time and was a world class parasitologist (President of the American Society of Parasitologists and Editor of the Journal of Parasitology). These earlier surveys were conducted meticulously and comparing my data to these data from 80 years ago, some notable results were obtained. Three species of digenean flatworms that were common in either or both species of bass in 1929-1931 were not found in this survey at all. Most striking were two of these parasites (*Rhipidocotyle papillosum* and *Crepidostomum cornutum*) that require native freshwater mussels as an intermediate host. This is very interesting because Oneida Lake has been invaded by zebra (*Dreissena polymorpha*) and quagga (*Dreissena rostriformis*) mussels which may have either drastically reduced the abundance or even driven a local extinction of these native mussels and their parasites in Oneida Lake. Further study would be needed to confirm these results including sampling bass from multiple locations in Oneida Lake because it is a large lake and is unlikely to have identical bass parasite communities across all locations. Also a study of mussels could be conducted to determine if the mussels themselves have been extirpated. The other species of digenean that was also not found in our survey is *Caecicola parvulus* which requires a snail intermediate host. Mueller noted that this parasite was very fragile and therefore it is possible that their bodies did not hold up during the freezing and thawing processes which could explain why I did not find them. I also cannot rule out that they may still be found elsewhere in Oneida Lake. Other differences in parasite prevalence or abundance may reflect a variety of different factors such as host populations size (smallmouth bass populations are reported to have increased recently), ecological changes, seasonal or local conditions and cannot be readily examined by this survey.

The current survey has provided some insight into potential ecological changes for further examination and has contributed more information on the bass parasites of Oneida Lake. Furthermore, this survey hints that native mussels and their parasites may have been affected by the invasion of zebra and quagga mussels which is similar to reports from other locations where these invasive mussels have become established. The average number of parasites per fish was also relatively high compared to the results of another study conducted by the author on smallmouth bass of the St. Lawrence River. These differences are unlikely to be due to fish length or age, based on the data from Oneida Lake, which indicates that some other factor is driving this difference. Further research will be needed to determine if gobies, productivity or local conditions are driving these differences. In general this survey helps to contribute to our knowledge of bass parasites and more specifically the bass parasites of Oneida Lake. This parasite survey also serves as a baseline for comparison with parasite surveys that can be conducted after round gobies invade Oneida Lake which will be able to examine any changes in bass parasite communities that may occur because of the invasion. This survey of Oneida Lake bass parasites also provides information on the parasite community in a location where gobies have not invaded which will be compared with the other study sites where gobies are present.

Appendix: Tables and figures

A)



B)

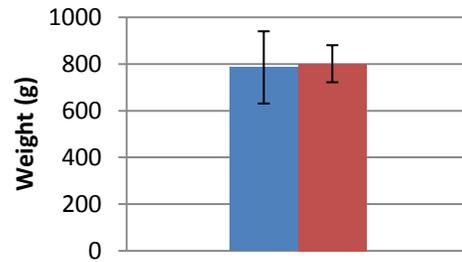


Figure 2. Graphical comparison of **A)** length and **B)** weight data for smallmouth (blue) and largemouth bass (red) from Oneida Lake with error bars representing 95% confidence intervals.

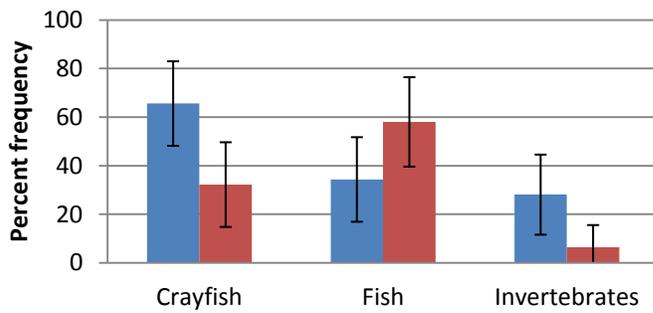


Figure 3. Frequency of prey in the stomachs of smallmouth (blue) and largemouth (red) bass in Oneida Lake.

Table 1. Prevalence and mean abundance parasite data for smallmouth (*Micropterus dolomieu*) and largemouth (*Micropterus salmoides*) bass in Oneida Lake for the 1929-1931 (Van Cleave and Mueller, 1934) and 2012 surveys.

	<i>Micropterus dolomieu</i>			<i>Micropterus salmoides</i>		
	% Prevalence (95% CI)		Mean abundance (95% CI)	% Prevalence (95% CI)		Mean abundance (95% CI)
	1929-1931 (n=20)	2012 (n=32)	2012 (n=32)	1929-1931 (n=44)	2012 (n=31)	2012 (n=31)
Acanthocephala						
<i>Neoechinorhynchus sp.</i>	Abundant	93.80 (84.9-100)	26.80 (16.1-37.6)	Abundant	93.50 (84.4-100.0)	41.70 (20.8-62.7)
<i>Leptorhynchoides thecatus</i>	Abundant	15.60 (2.3-28.9)	0.40 (0.0-1.0)	Common	12.90 (0.4-25.4)	0.10 (0.0-0.3)
<i>Pomphorhynchus bulbocollis</i>	-	-	-	Occasional	-	-
Digenea						
<i>Postodiplostomum minimum</i> (m)	-	6.30 (0.0-15.1)	-	-	-	-
<i>Postodiplostomum minimum centrarchi</i> (m)	-	15.60 (2.3-28.9)	-	-	90.30 (79.3-100.0)	-
<i>Uvulifer ambloplitis</i> (m)	-	28.10 (11.7-44.6)	-	-	90.30 (79.3-100.0)	-
<i>Neascus longicolla</i> (m)	-	6.30 (0.0-15.1)	-	-	29.00 (12.1-46.0)	-
<i>Clinostomum marginatum</i> (m)	-	3.10 (0.0-9.5)	-	Occasional	9.70 (0.0-20.7)	-
<i>Diplostomum scheuringi</i> (m)	-	-	-	Occasional	-	-
<i>Rhipidocotyle papillosum</i>	Common	-	-	Common	-	-
<i>Caecicola parvulus</i>	-	-	-	Common	-	-
<i>Azygia angusticauda</i>	Rare	21.88 (6.7-37.0)	0.25 (0.1-0.4)	Common	22.58 (7.0-38.2)	1.00 (0.0-2.3)
<i>Crepidostomum cornutum</i>	Common	-	-	Occasional	-	-
<i>Crepidostomum ictaluri</i>	-	-	-	Rare	-	-
<i>Phyllodistomum pearsi</i>	Rare	-	-	Rare	-	-
<i>Bunodera sacculata</i>	-	-	-	Rare	-	-
<i>Neochasmus umbellus</i>	-	-	-	Rare	-	-
<i>Cryptogonimus chylis</i>	Occasional	-	-	-	-	-
<i>Centrovarium lobotes</i>	Occasional	-	-	-	-	-
<i>Microphallus ovatus</i>	-	3.13 (0.0-9.5)	0.44 (0.0-1.3)	-	-	-
Digenean sp. A	-	3.13 (0.0-9.5)	0.03 (0.0-0.1)	-	-	-
Cestode						
<i>Ligula intestinalis</i> (l)	Rare	-	-	-	-	-
<i>Hymenolepis sp.</i> (l)	-	-	-	Rare	-	-
<i>Bothriocephalus sp.</i>	Rare	-	-	-	3.20 (0.0-9.8)	0.03 (0.0-0.1)
<i>Proteocephalus ambloplitis</i> (l)	Common	43.75 (25.6-61.9)	-	-	12.90 (0.4-25.4)	-
<i>Proteocephalus ambloplitis</i>	Rare	62.50 (44.8-80.2)	5.66 (2.5-8.8)	-	-	-
Copepod						
<i>Ergasilus centrarchidarum</i>	NR	50.00 (31.7-68.3)	5.78 (1.6-9.9)	NR	29.00 (12.1-46.0)	0.55 (0.1-1.0)
<i>Achtheres pimelodi</i>	NR	78.13 (63.0-93.3)	3.22 (2.1-4.4)	NR	12.90 (0.4-25.4)	0.13 (0.0-0.3)
Monogenea						
<i>Synclithrum fusiformis</i>	NR	40.63 (22.6-58.6)	-	NR	9.70 (4.3-15.1)	-

Dactylogyrus sp. A	NR	-	-	NR	64.50 (46.7-82.4)	-	
Dactylogyrus sp. B	NR	-	-	NR	9.70 (0.0-20.7)	-	
Dactylogyrus sp. C	NR	-	-	NR	9.70 (0.0-20.7)	-	
Nematoda							
<i>Contraecum brachyurum</i>	-	-	-	Common	3.20 (0.0-9.8)	0.03 (0.0-0.1)	
<i>Capillaria catenata</i>	-	-	-	Occasional	-	-	
<i>Capillaria</i> sp.	-	12.50 (0.4-24.61)	0.25 (0.0-0.5)	-	-	-	
<i>Capillaria</i> eggs	-	43.75 (25.6-61.9)	-	-	-	-	
<i>Dichelyne cotylophora</i>	Occasional	-	-	Occasional	-	-	
<i>Spinitectus carolini</i>	Occasional	-	-	-	-	-	
<i>Camallanus oxycephalus</i>	-	6.25 (0.0-15.1)	0.34 (0.0-0.7)	-	6.50 (0.0-15.6)	0.16 (0.0-0.4)	
<i>Eustrongylides</i> sp.	-	6.25 (0.0-15.1)	0.25 (0.0-0.7)	-	9.70 (0.0-20.7)	0.13 (0.0-0.3)	
<i>Rhabdochona</i> sp.	-	12.50 (0.4-24.6)	0.16 (0.0-0.3)	-	-	-	
Nematode sp. A	-	3.13 (0.0-9.5)	0.03 (0.0-0.1)	-	-	-	
Nematode sp. B	-	-	-	-	3.20 (0.0-9.8)	0.03 (0.0-0.1)	
Nematode sp. C	-	-	-	-	6.50 (0.0-15.6)	0.06 (0.0-0.2)	
Ciliates							
<i>Trichodina</i> sp.	NR	-	-	NR	6.50 (0.0-15.6)	-	
Myxozoa							
<i>Myxobolus micropteri</i>	NR	6.25 (0.0-15.1)	-	NR	19.40 (4.6-34.1)	-	
<i>Myxobilatus mictospora</i>	NR	-	-	NR	45.20 (26.6-63.7)	-	
<i>Myxobilatus</i> sp.	NR	3.10 (0.0-9.5)	-	NR	19.40 (4.6-34.1)	-	
<i>Chloromyxum</i> sp.	NR	-	-	NR	3.20 (0.0-9.8)	-	

NR - Group of parasites not reported on by Van Cleave and Mueller.

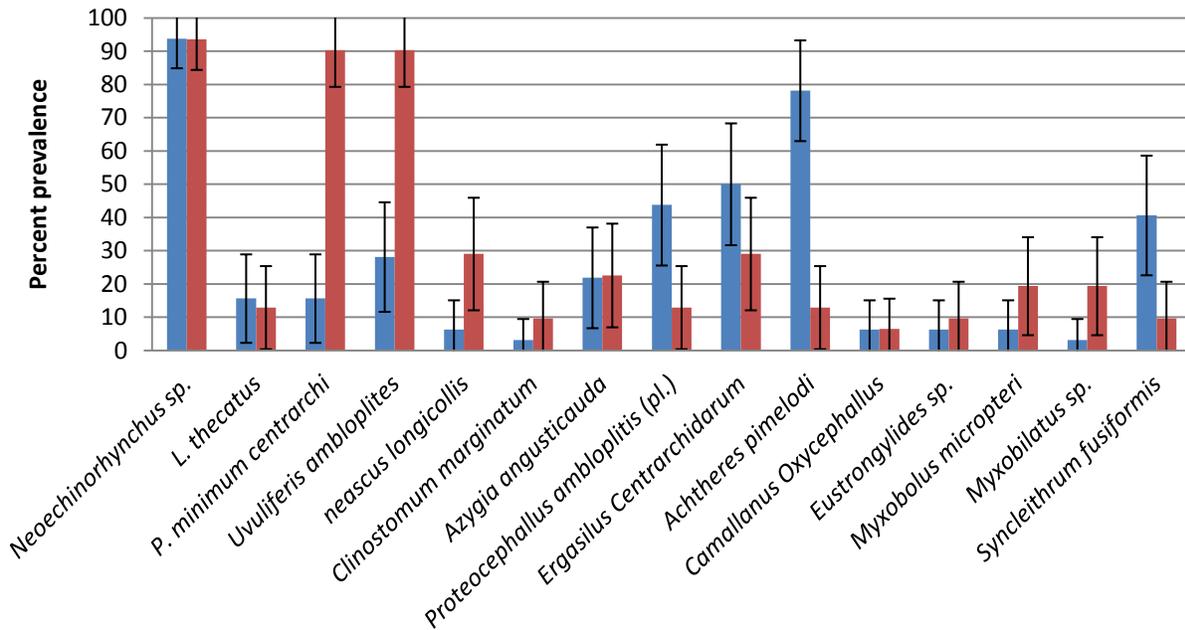


Figure 4. Percent prevalence (frequency) of parasites infecting both smallmouth (blue) and largemouth (red) bass of Oneida Lake with 95% confidence intervals.

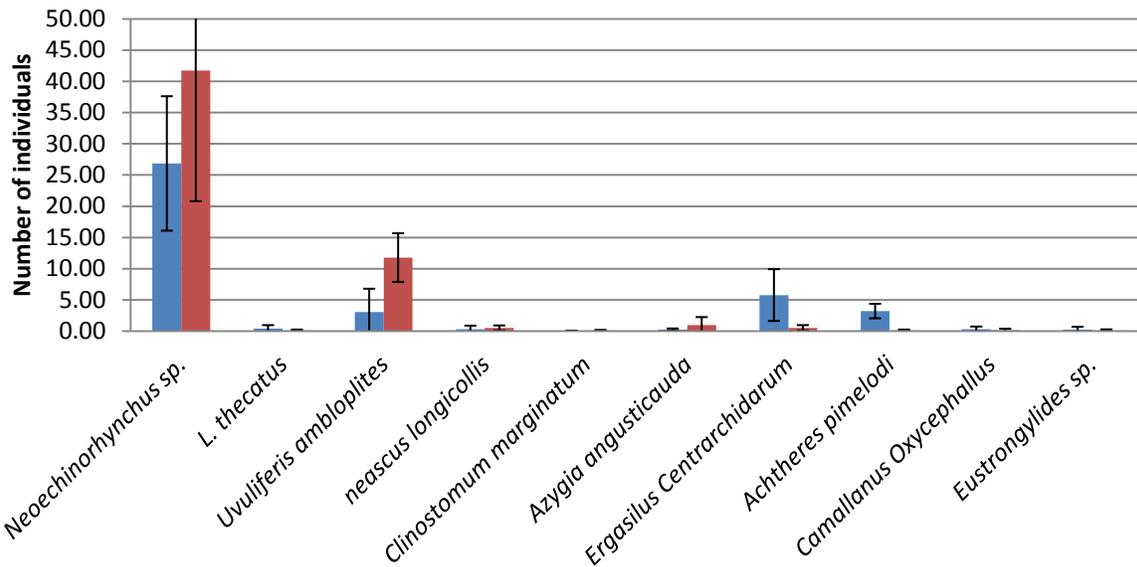


Figure 5. Mean abundance with 95% confidence intervals for species infecting smallmouth (blue) and largemouth (red) bass of Oneida Lake.

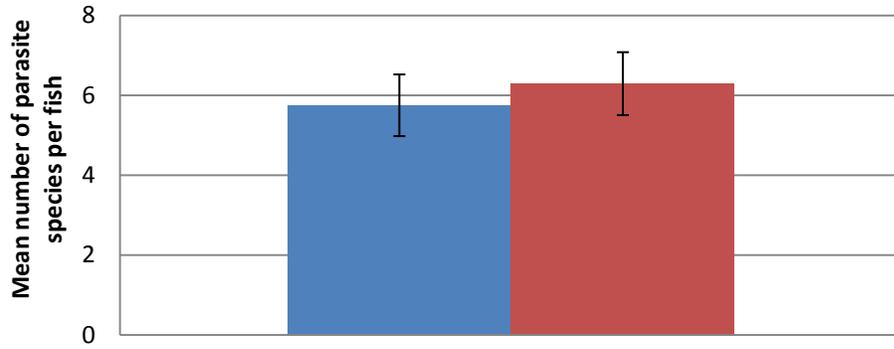


Figure 6. Average number of parasite species per fish for smallmouth (blue) and largemouth (red) bass with 95% confidence intervals.

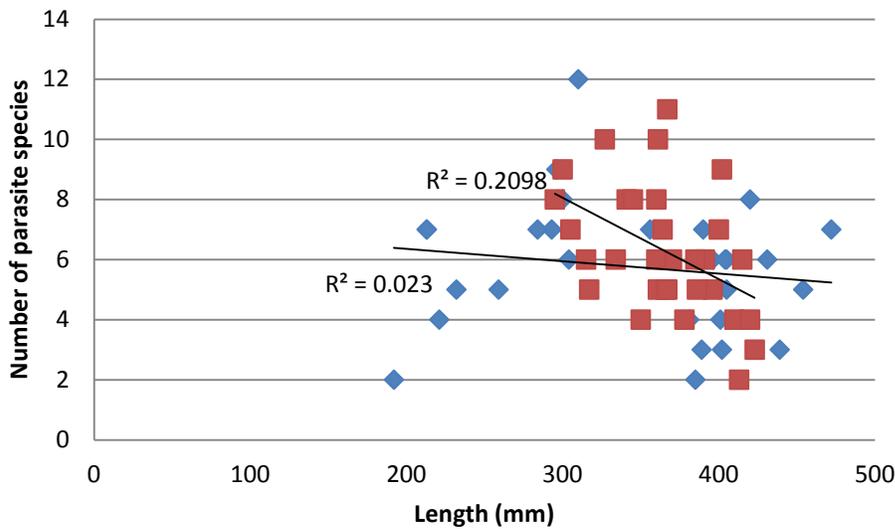


Figure 7. Number of parasites plotted against length for smallmouth (blue) and largemouth bass (red) with linear best fit trend lines.

References

Van Cleave, H. J. and J. F. Mueller. 1934. Parasites of Oneida Lake Fishes. Part III. A biological and ecological survey of the worm parasites. Roosevelt Wild Life Annals 3: 155-334.

Acknowledgements

I would like to thank the Edna Bailey Sussman Foundation for the financial support without which this research would not have been possible. The guidance and assistance of my advisor, Dr. Christopher Whipps, my host from the Cornell Biological Field Station, Dr. Randy Jackson, and his graduate student, William Fetzer, were invaluable in my research efforts over the summer. Additionally, I'd like to thank all of those who assisted me with the collection of samples, Thomas Brooking, Tony VanDe Valk, John Cleveland, Ryan Devens, Brian Henning, Mark Leopold, Danielle Hurley, Kyle Teuffel, Kean Clifford, Aaron Day, Errol Scheid, Stacy Furgal and Colby Bowman. Additionally, I'd like to thank Dr. Neil Ringler and all of his graduate students for their assistance and coordination in regards to the electrofishing boat. This endeavor took much coordination, tons of patience, and some long nights to complete. This project is a testament to the quality, integrity, flexibility, generosity and amiable nature of these friends, colleagues, financiers and mentors who were vital for the completion of this undertaking.