UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

BACTERIAL, VIRAL AND PARASITIC ASSESSMENTS OF WALLEYE (*SANDER VITREUM*), SAUGER (*SANDER CANADENSIS*), AND YELLOW PERCH (*PERCA FLAVESCENS*) IN THE WISCONSIN MISSISSIPPI RIVER DRAINAGE

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Biology

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College of Science and Health
Aquatic Science Concentration

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Bacterial, Viral and Parasitic Assessments of Walleye (*Sander vitreum*), Sauger (*Sander canadensis*) and Yellow Perch (*Perca flavescens*) in the Wisconsin Mississippi River Drainage

By Ryan J. Katona

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree Master of Science in Biology

(Aquatic Science Concentration)

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ABSTRACT

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Yellow perch, walleye, and sauger were examined to determine the presence of target pathogens and to describe parasite communities. The scale of this investigation is within the Upper Mississippi River Drainage. Data were compiled from five collection sites, three lakes and two pools from the Mississippi River, in the state of Wisconsin. At least 21 fish from each site were sampled. No viral or bacterial pathogens were detected. Yellow perch had significantly greater mean parasite taxa (0 = 3.95) than walleye (0 = 2.77) and sauger (0 = 2.35). Walleye from Lake Owen had significantly greater mean parasite taxa (0 = 4.00) than walleye from Upper Mississippi River Pools 8 and 9 (mean = 1.98). However the mean parasite taxa of walleye (0 = 1.98) was not significantly different than mean parasite taxa of sauger (0 = 2.35) from Upper Mississippi River Pools 8 and 9. Yellow perch and walleye also had significantly greater mean total parasite count (0 = 34.2 yellow perch and 0 = 30.9 walleye) than sauger (0 = 11.1). The three lakes had significantly greater percid parasite taxa than the Upper Mississippi River Pools 8 and 9. The cestode *Bothriocephalus cuspidatus* was the most dominant species in walleye (Berger-Parker dominance = 0.45) and sauger (Berger-Parker dominance = 0.29). The digenetic trematode *Bunodera sacculata* was the most dominant species in yellow perch (Berger-Parker dominance = 0.41). This is the first report describing parasite communities from the three percid species from the five collection sites.

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Introduction

Walleye, Sauger, and Yellow Perch Life History.—Walleye (*Sander vitreum)* are one of the most popular sport fish in the Midwestern states. A survey conducted by the U.S. Fish and Wildlife Service in 2006 showed that of the 1.4 million anglers that fished in the Great Lakes, 0.5 million of them were specifically fishing for walleye. In Wisconsin, walleye accounted for 7 million of the 88 million fish caught in 2006, the third most fish species caught during that year (Wisconsin DNR 2008).

Walleye are known to significantly influence predator-prey relationships in aquatic habitats (Becker 1983). Their diet consists of zooplankton, phytoplankton, and plankton when they are freshly hatched, insects when they are young fry, and eventually smaller fish as the walleye matures. As adults, they are able to control overpopulations of smaller fish, such as sunfish, which maintains a more balanced ecosystem.

Besides walleye, sauger (*Sander canadensis*) and yellow perch (*Perca flavescens*) are two other percid fish species that are highly sought after sport fish. Sauger, which are similar to walleye in appearance, are most abundant in the Upper Mississippi River and the largest reaches of its lowest tributaries, whereas yellow perch are found in ponds, rivers and lakes throughout the state (Lyons et al. 2000). Populations of yellow perch have been declining throughout Wisconsin, especially in Lake Michigan. Since the late 1980's restoration plans have been put in place to help stabilize Lake Michigan yellow perch populations (Wisconsin DNR 2009). These plans included reducing the harvest limits for commercial and sport fishermen, and implementation of research to assess

factors that may affect the population, such as habitat change, predation, and invasive species.

Diets of sauger and yellow perch overlap that of walleye. Both will eat aquatic insect larvae when they are young and eventually smaller fish as they mature. But studies have shown that a perch's diet can vary from year to year or from one body of water to another (Becker 1983). This may be due to shortage of one food source, or how easily accessible a food source may be.

Pathogens and Parasites of Walleye, Sauger, and Yellow Perch.—There are numerous diseases and parasites (Appendices A, B) that can infect walleye, sauger, and yellow perch. However, there are few published studies that deal specifically with these three species.

Bacterial Pathogens.—Bacterial pathogens that have been documented in walleye, sauger, and yellow perch include *Aeromonas hydrophila*, *Aeromonas salmonicida*, and *Flexibacter columnaris* (Michel 1961, Noga 1996). These bacterial pathogens can vary in their pathogenicity, causing disease signs such as deep skin ulcerations, skin hemorrhaging, gill lesions, and even fin rot, if the infection is severe (Noga 1996).

Viral Pathogens.—Two viral diseases have been reported in walleye, sauger, and yellow perch including dermal sarcoma (Martineau et al. 1990) and a recent emerging virus known as Viral Hemorrhagic Septicemia Virus (VHSv) (USDA-APHIS 2008). Dermal Sarcoma Virus is a virus that causes warty growths (tumors) to form on the skin and fins of fish, and is not usually fatal (USFWS 2004). Dermal Sarcoma Virus mainly infects walleye, but has been experimentally transmitted to sauger and yellow perch

(Bowser et al. 2001). It is found throughout the world, and primarily in adult walleye in the upper Midwest region of the United States and central and western Canada (USFWS 2004).

VHS is a severe disease of freshwater and marine fish (Gagne et al. 2007). There are four known genotypes of VHSv, including Genotype IVb, which is also known as the Great Lakes strain (Lumsden et al. 2007). VHSv IVb genotype was first identified in Lake Ontario in 2005 in freshwater drum, muskellunge, and round goby (USDA-APHIS 2008). Since then, it has been isolated in lakes Erie, Huron, and Michigan, and also from inland lakes in New York, Ohio, Michigan, and Wisconsin. VHSv has also been detected in nearly 40 different species of fish in the Great Lakes region, including walleye and yellow perch (USDA-APHIS 2008).

VHS can be transmitted when fish come into contact with urine and sexual fluids of an infected fish or by ingestion of an infected fish (NPS 2008). VHS is also capable of being vertically transmitted via ovarian fluids and seminal fluids. Fish infected with VHSv may show clinical signs such as external hemorrhages in the skin, fins, and eyes, hemorrhages of internal organs, exophthalmia (popeye), and extended abdomens. However, these signs are not limited to VHS clinically infected fish, as other viral and bacterial pathogens may cause similar disease signs. Additionally, not all fish infected with VHS exhibit clinical signs of disease.

Common Parasites.—A wide range of parasites have been reported from walleye, sauger, and yellow perch. The more common parasites include the tapeworm *Bothriocephalus cuspidatus*, allocreadid trematodes *Crepidostomum spp.*, and *Bunodera*

spp., the nematode *Camallanus* spp., and the ancryocephalid monogenes *Urocleidus* sp. and *Cleidodiscus* sp. (Hoffman 1999).

Bothriocephalus cuspidatus is one of the most prevalent parasites from walleye, sauger, and yellow perch (Robinson and Lawrence 1980; Muzzal and Haas 1998; Carney and Dick 1999). Mature adults of *B. cuspidatus* are found in the intestine of fish. Eggs from gravid adults are released into the water and ingested by a copepod, where it develops into a procercoid, and then into a metacestode. The infected copepod is then ingested by a suitable fish host, and the tapeworm develops into an adult in the intestine (Hoffman 1999). A diagnostic or identifying feature of *B. cuspidatus* is a large scolex containing two narrow bothria (Cooper 1917).

Bunoderid trematodes are prevalent in yellow perch, especially *B. luciopercae*. It is identified by its expanded saccate (uterus) in mature adults, and reduced papillar bases that are broad and almost contiguous (Choudhury and Regagnon 2005). *Bunodera sacculata* has frequently been reported in yellow perch and walleye (Hoffman 1999, Muzzall 2002). *Bunodera sacculata* is identified by observing the posterior glands of the cirrus sac, which have a large, dense, obscuring seminal vesicle (Choudhury and Regagnon 2005). They also have papillae with a reduced papillar base that is broad and almost contiguous. Other allocreadid trematodes, like *Crepidostomum* spp., are also prevalent in yellow perch and walleye. They are distinguished by 4-6 muscular lobes surrounding the oral sucker (Hoffman 1999).

The nematode *Camallanus oxycephalus* (Family Camallanidae) have been identified in walleye, sauger, and yellow perch (Anderson 2000). They are identified by the presence of a buccal capsule that is divided into two lateral chitinous valves, with

spiral thickenings absent (Hoffman 1999). *Camallanus oxycephalus* larvae are released from the viviparous gravid female which infects the gastrointestinal tract of fish definitive hosts. Larvae rupture out of the anus of the definitive fish host after they are released. The larvae then penetrate the intestine of a copepode and develop into the infective larval stage. The copepod is then eaten by the paratenic host, a small planktivorous fish, where it develops into the fourth stage. The paratenic host is then eaten by a piscivorous fish, where the nematode develops into an adult (Anderson 2000).

Urocleidus spp. and *Cleidodiscus* spp. are two genera of ancyrocephalid monogenes that have been reported from the gills of walleye, sauger, and yellow perch (Beverley-Burton 1984), and identified largely by male reproductive organs. The *Urocleidus* species are identified by difference in penis length, and the presence or absence, and shape of the accessory piece (Beverley-Burton 1984). *Urocleidus aculeatus*, which has been found in walleye and sauger, have a longer penis length and an accessory piece. *Urocleidus adspectus*, from yellow perch, have a shorter penis and no accessory piece (Beverley-Burton 1984). *Cleidodiscus* spp. are larger and more robust then *Urocleidus spp.* as they can range from 900-1600 µM in length, compared to 450-750 µM in length in *Urocleidus* spp. (Beverley-Burton 1984).

The parasites discussed above usually do not cause major harm to the fish unless infections are heavy. Histopathologies of fish heavily infected with parasites include skin and gill hemorrhages, inflammation, cell necrosis, and tissue proliferation, which can cause impaired growth and reduced reproductive success. Parasites can also lead to secondary infections of bacterial and viral pathogens, and even cause mortality (Hoffman 1999).

Parasite Communities.—Describing parasitic communities can provide valuable information on the health of fish populations and the aquatic communities they live in (Pietrock et al. 2001). Fragmentation and degradation of aquatic habitats, and other abiotic or biotic factors can promote transmission and exchange of parasites (Holmes 1996). Therefore, species richness and evenness of parasite fauna correlates with the different biotic and abiotic factors, such as invasive species, temperature, and pollution that occur within the aquatic habitats (Bush et al. 2001). These factors influence or affect parasite assemblages between different species of fish and between different organs within the fish. Habitat fragmentation and degradation also can increase invasions of new parasites, which can lead to the development of new pathogenic strains of parasites (Holmes 1996).

Although some studies have supported the theory that characteristics of an aquatic habitat may directly correlate with the parasite fauna and the assemblage of the parasites, there has also been studies that support the theory that regardless of characteristics of a body of water, fish will have similar parasite assemblages. Some studies show that there is a relative constant relationship between fishes and their parasites regardless of the location and the abiotic or biotic factors within a body of water (Leong and Holmes 1981). Leong and Holmes (1981) showed that parasitic communities within an aquatic habitat are characterized by the parasites of the dominant host.

There are few studies that describe or compare parasite communities, and other pathogens, in fish among different aquatic habitats. There are especially very little published reports on walleye, sauger, and yellow perch parasite communities within the Mississippi River drainage. Determining pathogens and parasite community structures

can provide valuable information to help manage the populations of walleye, sauger, and yellow perch. Fisheries mangers use fish translocations to help improve existing fish stocks, to rehabilitate fish, to reintroduce extirpated stocks, and possibly to establish a population in a new area (Fenichel et al. 2008). However fish translocation can be costly and have undesirable effects on fish populations if a serious pathogen is present (Fenichel et al. 2008). Fish translocation can also play a role in the emergence of novel diseases if infected with a pathogen that has not been exposed to that area (Murray et al. 2002).

The purpose of this study is to conduct health assessments of walleye, sauger, and yellow perch in the Wisconsin Mississippi River drainage in order to better understand pathogens of these fish. The study objectives are:

1. Screen fish for select viral and bacterial pathogens from each site, with emphasis on possible detection of the recent emerging virus, VHSv.
2. Identify the parasite fauna of walleye, sauger, and yellow perch from five study sites within the Wisconsin Mississippi River drainage. These studies will allow me to describe host-parasite relationships, and compare parasite communities between host species and the study sites.
3. Calculate variance to mean ratio to determine if mean intensity can be used as an indicator of parasite aggregation among host species.

Methods

Fish Collection.— Fish were sampled from five sites within the Wisconsin Mississippi River drainage: 60 yellow perch from Big Round Lake (BRL) (Lat: 45.31`49.858 and Long: 92.18`50.420), 60 walleye from Lake Owen (LO) (Lat:

46.18.103 and Long: 91.13.217), 60 yellow perch from Lac Vieux Desert (LVD) (Vilas County), 24 total walleye and sauger from the Upper Mississippi River Pool 8 (UMR Pool 8) (Dresbach Landing, MN), and 240 walleye and sauger (120 each) from the Upper Mississippi River, Pool 9 (UMR Pool 9) (Genoa, WI). Adult fish were collected by electrofishing and by angling during the fall of 2007, and the spring and fall of 2008. Fish from the three lakes were collected by the Great Lakes Indian Fish and Wildlife Commission (GLIFWC).

Bacteriology.—Bacteriology was conducted only on fish from the Mississippi River Pools 8 and 9. Eighty Four sauger and 61 walleye were sampled for target bacteria. The posterior kidney of each fish was stabbed with a 1 µL disposable sterile loop and inoculated onto a tube of brain-heart infusion agar (BHIA). Tubes were incubated for approximately one week at 20°C. The bacterial colonies were then isolated by streaking onto a BHIA plate. Isolated colonies were screened for target pathogens (Appendix B) following the procedures described in USFWS and AFS-FHS (2007).

Virology.—Samples of kidney, spleen, and swim bladder (approximately 0.2g each) were taken from each individual fish (440 total) and diluted 1:10 in Hank's Balanced Salt Solution (HBSS). Tissue samples from 5 fish (each species, each site) were pooled into a single HBSS tube, homogenized with a stomacher, and diluted 1:1 (HBSS:sample). Samples were then incubated at 15 °C for 2 hours or at 4°C overnight. Mississippi River Pools 8 and 9 samples (0.2 ml) were placed on bluegill fry (BF-2) cells, epithelial papulosum cyprini (EPC) cells, and chinook salmon embryo (CHSE) cells on a 24 well plate, and incubated at room temperature with gentle rocking on a plate rocker for 1 hour. Big Round Lake, Lac Vieux Deert, and Lake Owen samples (0.2 ml) were placed

on EPC's on a 24 well plate, and incubated at room temperature with gentle rocking on a plate rocker for 1 hour. Plates were then incubated at 20°C for 14 days (25°C for BF-2 plates), and observed for cytopathic effect (CPE) three times a week. Typical CPE is exhibited by infected cells rounding up and becoming detached from the monolayer. Wells that exhibit CPE were considered presumptive positives and PCR was used to confirm viral identity (Appendix B) using standard PCR protocols described in USFWS and AFS-FHS (2007). Wells that did not show CPE after 14 days were blind passed and observed for an additional 14 days. These blind passed samples were combined in up to a five well pool samples (representing 25 fish). The samples were diluted 1:5 and plated following the same procedure as the original samples. Wells exhibiting CPE were considered presumptively positive and PCR was used to confirm viral identity using standard PCR protocols described in USFWS and AFS-FHS (2007). Wells that do not show CPE after a total of 28 days were reported as negative, and discarded by autoclaving.

Parasitology.—Forty five walleye, and 45 sauger from the Upper Mississippi River Pools 8 and 9 were sampled for parasites. Thirty walleye were sampled from Lake Owen. Thirty nine yellow perch were sampled from Lac Vieux Desert and Big Round Lake. The gastrointestinal tracts (GI tracts) and the gills were removed from each fish, and frozen by using 95% ethanol that was cooled to -80°C (Bush and Holmes 1986). For parasite examination, the GI tract and the gills were thawed and examined for parasites with the aid of a stereomicroscope. Parasites recovered were recorded by parasite species or taxa, location, and host species. Trematodes, cestodes, and monogenes were preserved in alcohol-formol-acetic acid (AFA) fixative, and nematodes were fixed in glycerine

alcohol (Hoffman 1999). The parasites were stained and whole mounted following the procedure outlined in Daily (1996). Each parasite was identified to genera using keys and descriptions found in Hoffman (1999). Parasites were identified to species using keys and descriptions from Van Cleave (1919), Hopkins (1931a, 1931b, 1934), Van Cleave and Muller (1934), Wooten (1957), Yamaguti (1959), Frese (1965), Kuperman (1973), Baker (1979), Beverley-Burton (1984), Caira (1985), Arai (1989), Scholz (1997), and Amin (2002).

Statistical Analyses.—Statistical analyses were conducted for each parasite species using prevalence, mean intensity and range. Prevalence of parasites is defined as the number of infected fish/number of fish tested X 100 (Bush at el. 1997). Mean intensity is the total number of individuals of a particular parasite species in a sample of a host species/the number of infected fish, and range is the minimum and maximum number of parasites observed in each host (Bush at el. 1997).

Kruskal-Wallis, a non-parametric alternative to one way analysis of variance, was used to test equality of population medians among walleye, sauger, and yellow perch and among the five study sites. Tukey's Honest Significant Difference (HSD) test was also used to test for differences in the mean number of parasite taxa infected in individual fish, between the five study sites, and between walleye, sauger, and yellow perch. Whitney-Mann U statistical test was used to test for differences in the mean number of parasite taxa in walleye from UMR Pool 8 and 9 compared to LO. Whitney-Mann U was also used to test for differences in the mean number of parasite taxa infected in individual walleye from UMR Pools 8 and 9 compared to sauger from UMR Pools 8 and 9. Significance will be determined if p-value is ≤ 0.05 in all statistical tests.

This study also determined the diversity of parasite communities among walleye, sauger, and yellow perch by measuring dominance. The Berger-Parker dominance index was used to calculate the relative importance of the predominant parasite species (Krebs 1999).

$$d = N_{max} / N_t$$

The index (d) expresses the proportion of the total parasite count (N_t) that is due to the most abundant individuals (N_{max}).

The variance-to-mean ratio was used to determine the spatial distribution of parasite taxa in walleye, sauger, and yellow perch. Spatial distribution is described by one of three types: overdispersed (clumped), random, or underdispersed (uniform) (Krebs 1999). Overdispersed is when the variance-to-mean ratio is greater than one. Random is when the variance-to-mean ratio equals one, and underdispersed is when the variance-to-mean ratio is less than one.

Parasite taxa were also grouped into core, secondary, or satellite species. Core species refers to parasites with prevalence greater than 60%. Satellite species refers to parasites with prevalence less than 10%, and secondary species are parasites with prevalence between 10% and 60% (Bush and Holmes 1986).

Results

A total of 440 percids, 181 walleye, 143 sauger, and 120 yellow perch, were collected across five study sites from the Mississippi River drainage and screened for target viruses. 144 of the percids were screened for target bacterial pathogens, and 159

percids were examined for parasites. Target bacterial pathogens and target viral pathogens were not detected in any of the fish that were sampled.

A total of 159 percids were examined for parasites from five sites. A total of 4,212 parasites were recovered. Of these 159 percids, 96.2% were infected with at least one parasite from 18 different taxonomic groups (Table 1). The 18 parasite taxa observed were represented by 731 monogenes (17.4%), 809 digenes (19.2%), 1354 cestodes (32.1%), 533 nematodes (12.7%), and 775 acanthocephalans (18.4%), (Table 1). All monogenetic trematodes identified belonged to the Family Ancryocephalidae and were not further identified. The digenetic trematodes identified were *Allocanthocasmus* sp. (Fig. 1), *Azygia sebago* (Fig. 2), *Azygia* sp., *Bucephalopsis* sp. (Fig. 3), *Bunodera sacculata* (Fig. 4), *Neascus* sp., and *Posthodiplostomum minimum*. The cestodes identified were *Bothriocephalus cuspidatus* (Fig. 5), *Proteocephalus* sp. (Fig. 6), and *Triaenophorus nodulosus* (Fig. 7). The acanthocephalans identified were *Neoechinorhynchus cylindratus* (Fig. 8), *Leptorhynchoides thecatus* (Fig. 9), and *Pomphorhynchus bulbocolli*. The nematodes were identified from the Family Anisakidae, and the Genera *Camallanus* (*C. oxycephalus* and *Camallanus* sp.), *Contracaecum* sp., and *Rhabdochona* sp. (Fig. 10).

The most prevalent parasite among the 159 percids collected was *Bothriocephalus cuspidatus* at 61.6%, followed by *Lepthorynchoides thecatus* at 41.5% (Table 1). The parasites with the highest mean intensity among the percids were the ancryocephalids at 17.8, followed by *Bunodera sacculata* at 17.5 (Table 1). *Bunodera sacculata* had the widest range (1, 357), followed by the ancryocephalids (1, 138) for the percids (Table 1). The study sites exhibited high parasite diversity ranging from 7 to 12 different parasite

taxa. Lac Vieux Desert and the Mississippi River Pool 9 were the most diverse with 12 different taxa, and the Mississippi River Pool 8 was the least diverse with 7 different taxa. Individual percids contained 0 to 8 species, with 2 species being the most common (Fig. 11).

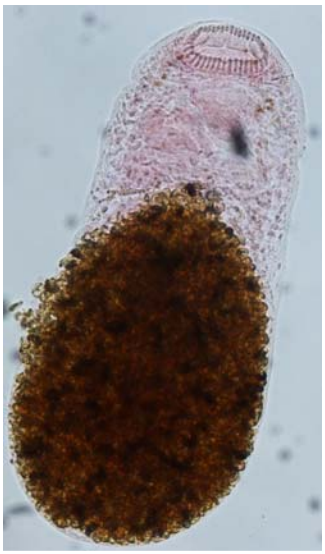

Figure 1. Whole mount of *Allocanthocasmus* sp. from walleye (new host record). Uterus is filled with eggs.

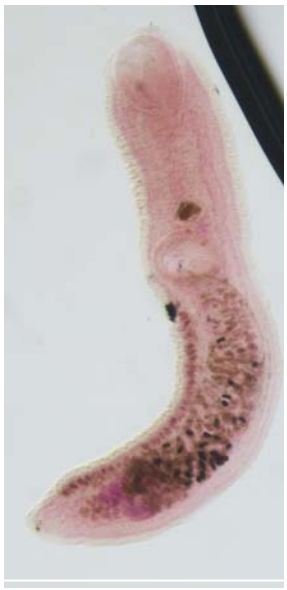

Figure 2. Whole mount of the digenetic trematode *Azygia sebago* from walleye.

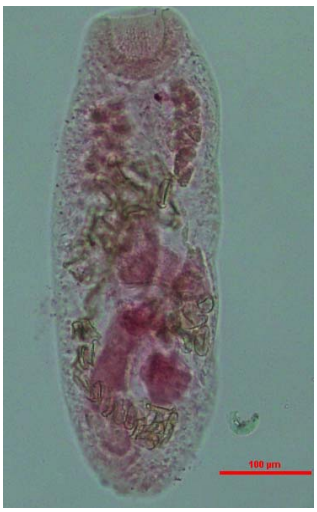

Figure 3. Whole mount of the digenetic trematode *Bucephaloposis* sp. from sauger.

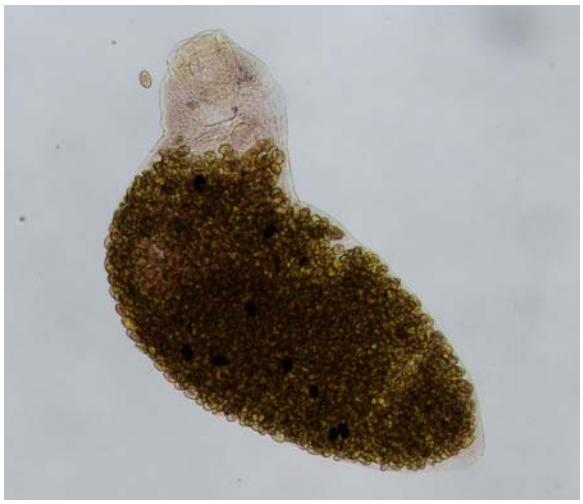

Figure 4. Whole mount of the digenetic trematode *Bunodera sacculata* (uterus filled with eggs) from yellow perch.

Figure 5. Whole mount of the scolex of *Bothriocephalus cuspidatus* from walleye.

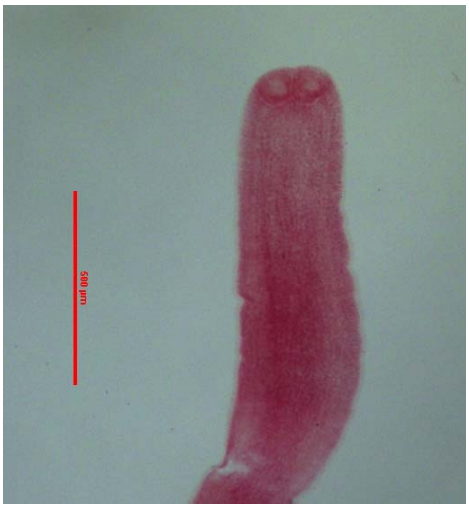

Figure 6. Whole mount of the cestode *Proteocphalus* sp. from yellow perch.

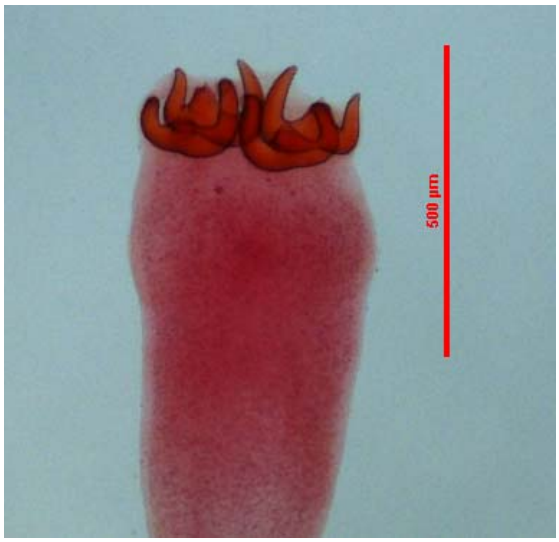

Figure 7. Whole mount of the scolex showing two pairs of trident shaped hooks of *Triaenophorus nodulosus* from yellow perch.

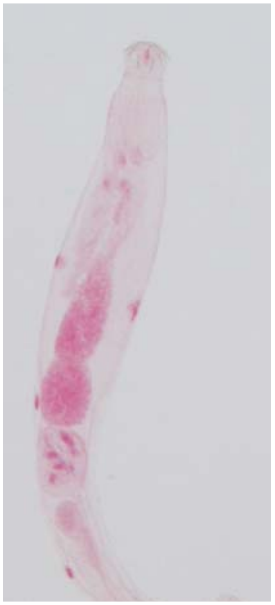

Figure 8. Whole mount of the acanthocephalan *Neoechinorhynchus cylindratus* from yellow perch.

Figure 9. Male (right) and female (left) of the acanthocephalan *Leptorhynchoides thecatus* from sauger.

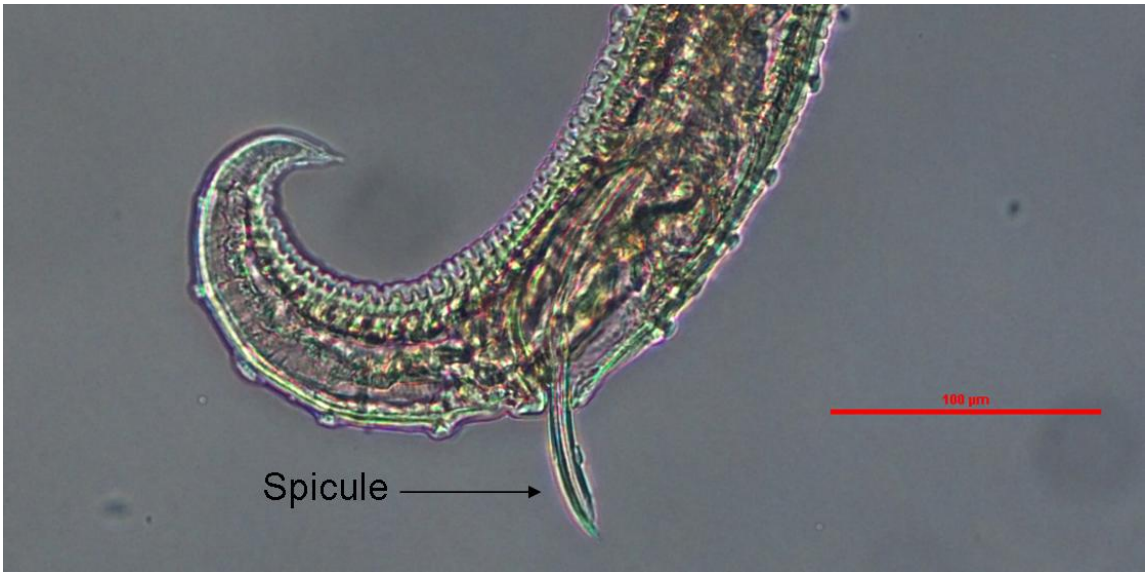

Figure 10. Whole mount of the posterior end of a male nematode *Rhabdochona* sp. from sauger.

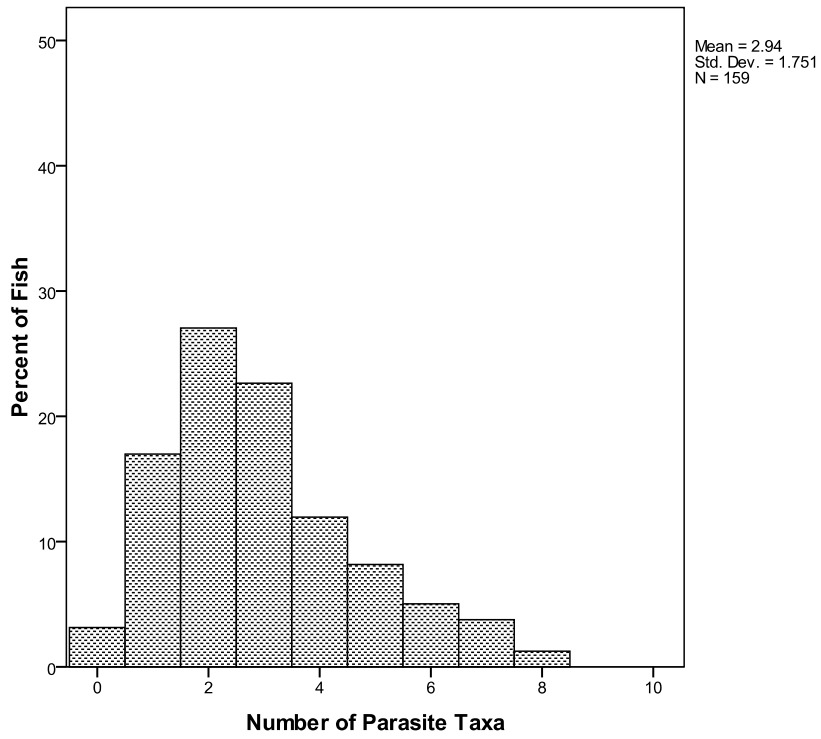

Figure 11. Number of parasite taxa infecting the 159 percids from the five collection sites (Upper Mississippi River Pools 8 and 9, Big Round Lake, Lac Vieux Desert, and Lake Owen).

The most prevalent and dominant parasite among the 39 yellow perch was *Bunodera sacculata* at 79.5 %, and 0.41 respectively, followed by *Neoechinorhynchus cylindratus* at 66.7%, and 0.26 (Table 2). The most prevalent and dominant parasite among the 75 walleye was *Bothriocephalus cuspidatus* at 90.7% and 0.45 (Table 3). The most prevalent parasite among sauger was *Contracaecum* sp. at 71.1 %, but *B. cuspidatus* was the most dominant at 0.30 (Table 4). The parasite with the highest mean intensity among the yellow perch was *Bunodera sacculata* at 18.1, followed by *Neoechinorhynchus cylindratus* at 13.4 (Table 2). The parasites with the highest mean intensity among walleye were the ancryocephalids at 27.7, followed by *Bothriocephalus cuspidatus* at 15.6 (Table 3). The parasites with the highest mean intensities for sauger

were *Bucephalopsis* sp. at 7.6, followed by *Bothriocephalus cuspidatus* at 6.5 (Table 4). *Bunodera sacculata* had the highest range among the yellow perch (Table 2), while ancryocephalids had the highest range among the walleye (Table 3). *Bucephalopsis* sp. had the highest range among sauger (Table 4).

Tukey HSD Statistical Test.—Individual yellow perch were infected with 0 to 8 parasite taxa, with 3 being most common (Fig. 12). Individual walleye contained 0 to 7 parasite taxa with 2 being most common (Fig. 13). Individual sauger contained 0 to 5 parasite taxa, with 2 also being most common (Fig. 14). Mean parasite taxa richness for yellow perch was 3.95, and was significantly different ($p < 0.001$) than mean parasite taxa richness for walleye and sauger (Table 5).

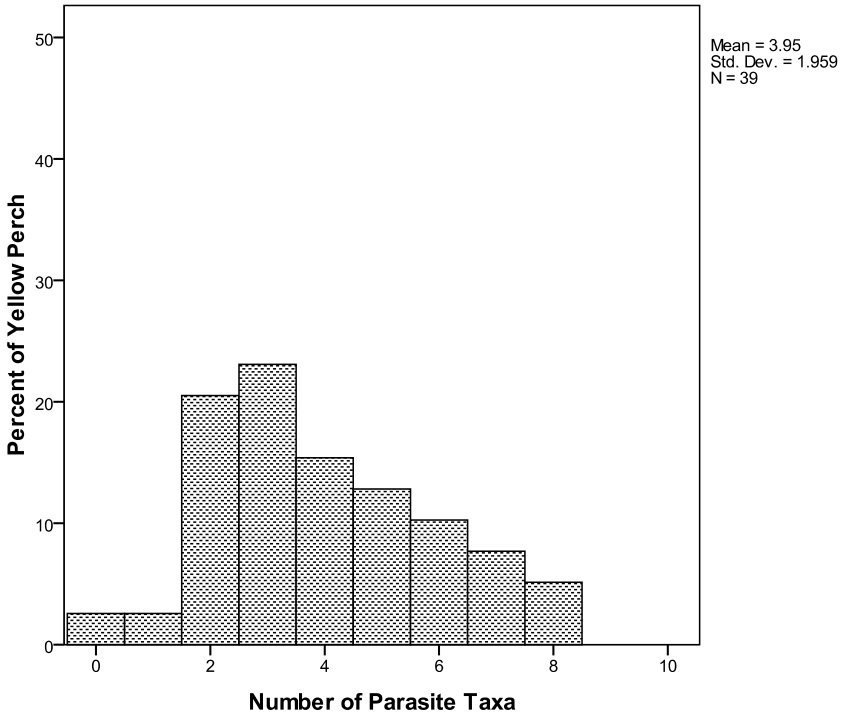

Figure 12. The number of parasite taxa infecting 39 yellow perch from Big Round Lake and Lac Vieux Desert (Tukey HSD test).

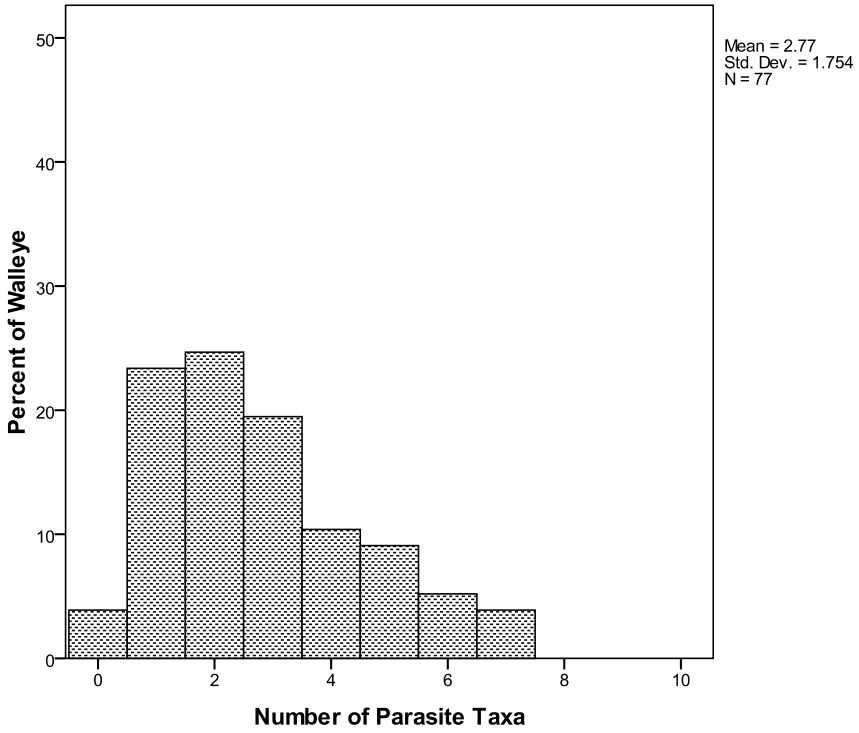

Figure 13. Number of parasite taxa infecting 75 walleye from Lake Owen and Upper Mississippi River Pools 8 and 9 (Tukey HSD Test).

Individual yellow perch from LVD were infected with the most parasite taxa, and had a range of 2 to 8 parasite taxa with 3 being most common (Fig. 15). Individual walleye, and sauger from UMR Pool 8 were infected with the least parasite taxa, with a range of 0 to 4, with 2 being the most common (Fig. 17). LVD (Fig. 15), and LO (Fig. 16) had the two highest mean parasite taxa richness among fish sampled, 4.27 and 4.00, respectively, and were significantly different ($p < 0.001$) then UMR Pools 8 (Fig. 17) and 9 (Fig. 18, and Table 6). BRL (Fig. 19), with an average of 2.89 taxa per fish, was not significantly different than that of any other sites (Table 6).

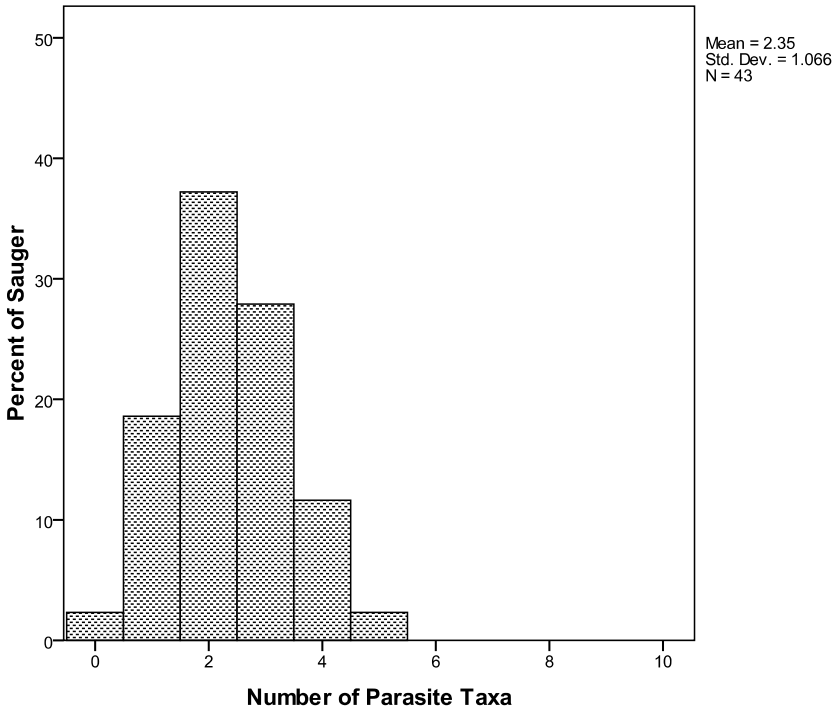

Figure 14. Number of parasite taxa infecting 45 sauger from Upper Mississippi River Pools 8 and 9.

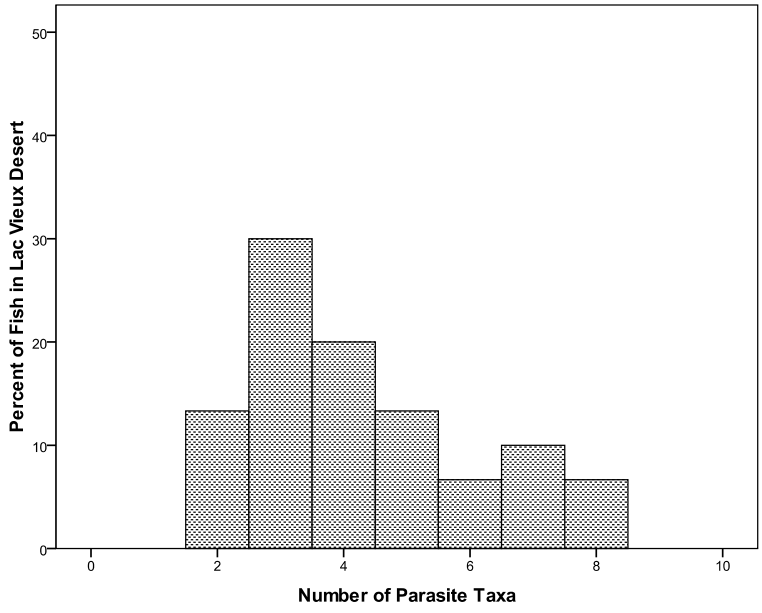

Figure 15. Number of parasite taxa infecting 30 yellow perch from Lac Vieux Desert, Vilas County.

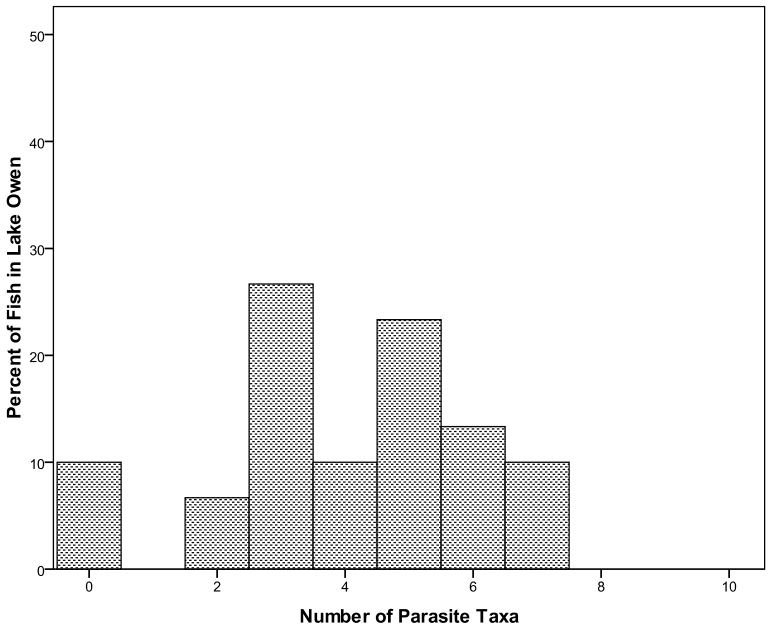

Figure 16. Number of parasite taxa infecting 30 walleye from Lake Owen.

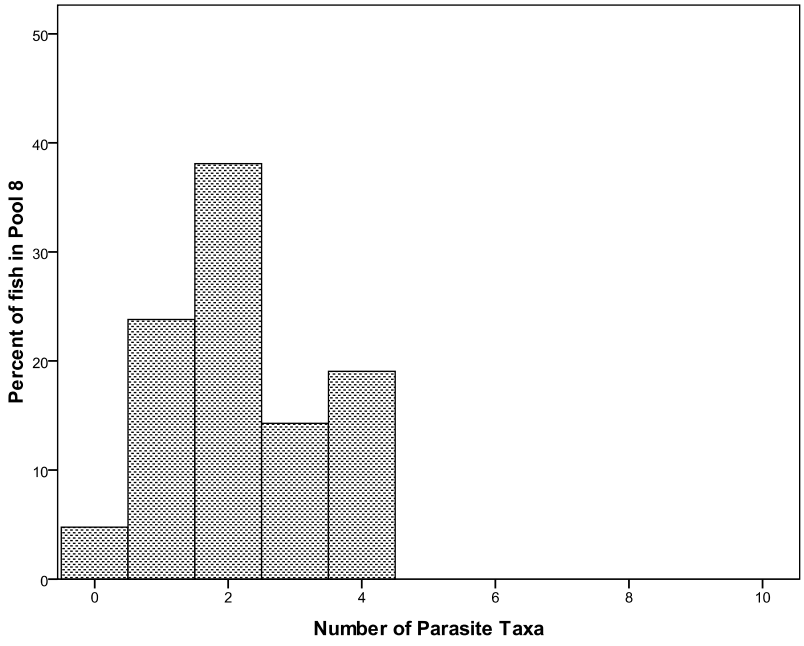

Figure 17. Number of parasite taxa infecting 20 sauger, and one walleye from Upper Mississippi River Pool 8.

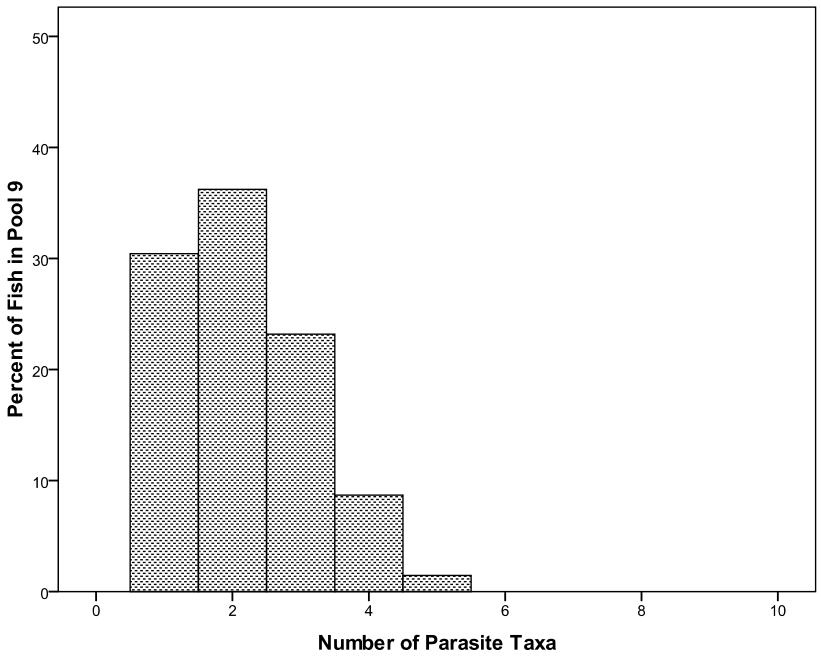

Figure 18. Number of parasite taxa infecting 44 walleye, and 25 sauger from Upper Mississippi River Pool 9.

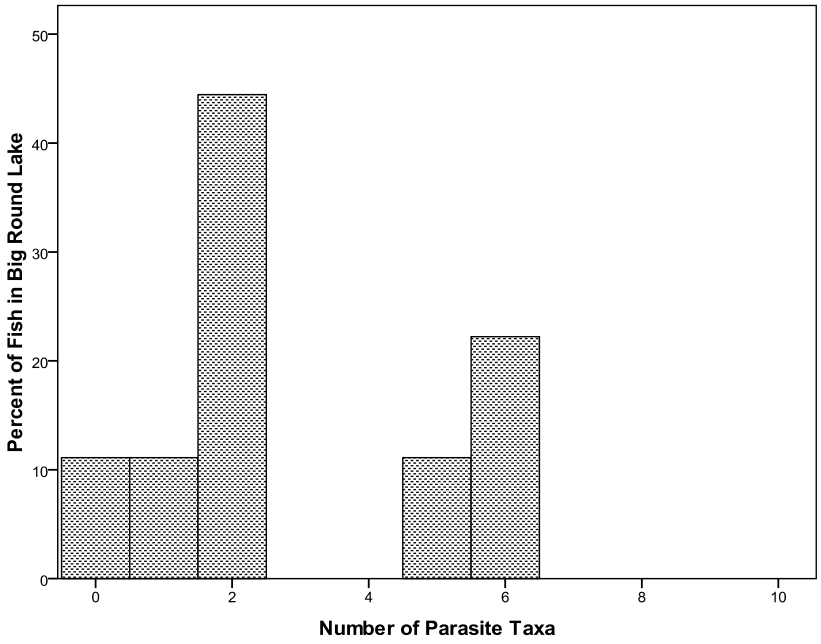

Figure 19. Number of parasite taxa infecting nine yellow perch from Big Round Lake, Polk County.

Kruskal-Wallis Statistical Test.—Mean total parasite count for all 159 percids was 26.34 (Table 7). Mean total parasite count for 39 yellow perch and 75 walleye, 34.18 and 30.91, respectively, were significantly different ($p < 0.001$) than mean total parasite count for the 45 sauger (Table 7). The Kruskal-Wallis test also showed a statistical difference between mean total parasite count from the five study sites. Mean total parasite count for LVD and LO, 55.57 and 40.57, respectively, were significantly different ($p < 0.001$) amean total parasite count for BRL, and UMR Pool 8 and 9 (Table 8).

Whitney-Mann U Statistical Test.—Mean parasite taxa of walleye from LO (0=4.00) was significantly different ($p<0.001$) than mean parasite taxa of walleye from UMR Pool 8 and 9 (0= 1.98) (Fig. 20). However, the mean parasite taxa of walleye (0= 1.98) from UMR Pool 8 and 9 was not significantly different ($p=0.067$) than mean parasite taxa of sauger (2.35) from UMR Pool 8 and 9 (Fig. 21).

Variance-to-Mean Ratio.—Most parasite taxa from walleye, sauger, and yellow perch were overdispersed in their distribution (Tables 9-12). For sauger, the mean intensity of parasite taxa explained almost 82% of the variability in the variance (Fig. 22). In yellow perch, the mean intensity of the parasite taxa accounted for almost 62% of the variability in the variance (Fig. 23). In walleye, the mean intensity of the parasite taxa explained almost 84% of the variability in the variance from UMR Pool 8 and 9 (Fig. 24), and only 23% of the variability in the variance from LO (Fig. 25).

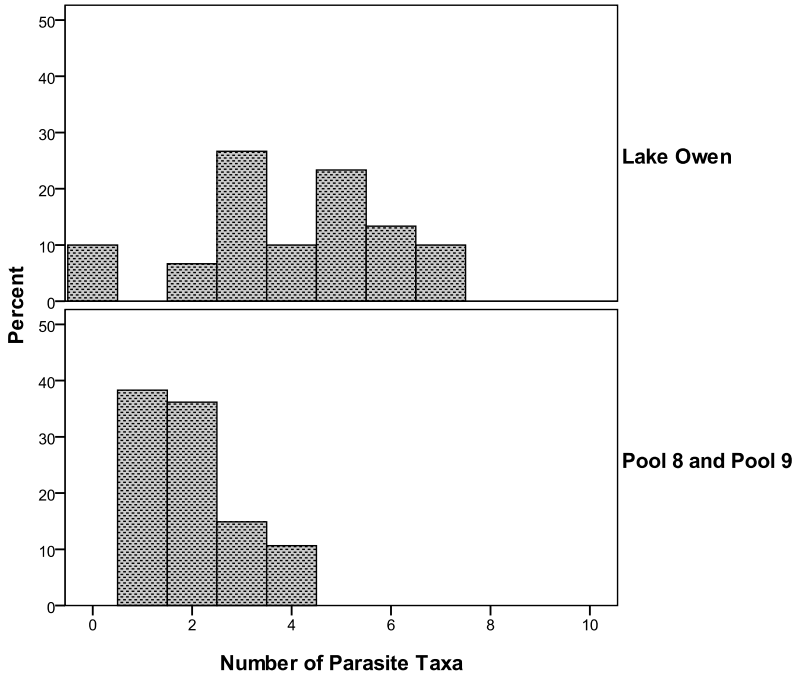

Figure 20. Number of parasite taxa infecting 30 walleye from Lake Owen and 45 walleye Upper Mississippi River Pools 8 and 9.

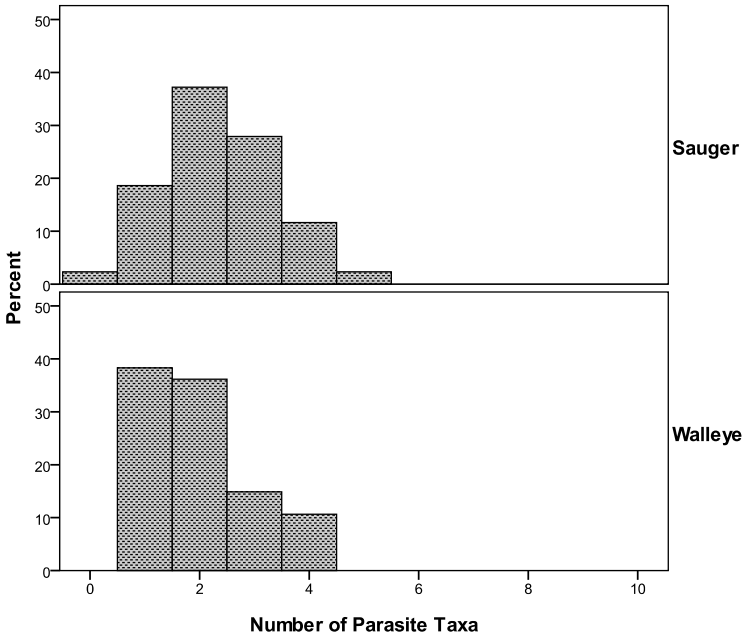

Figure 21. Number of parasite taxa infecting 45 sauger and 45 walleye from the Upper Mississippi River Pool 8 and 9.

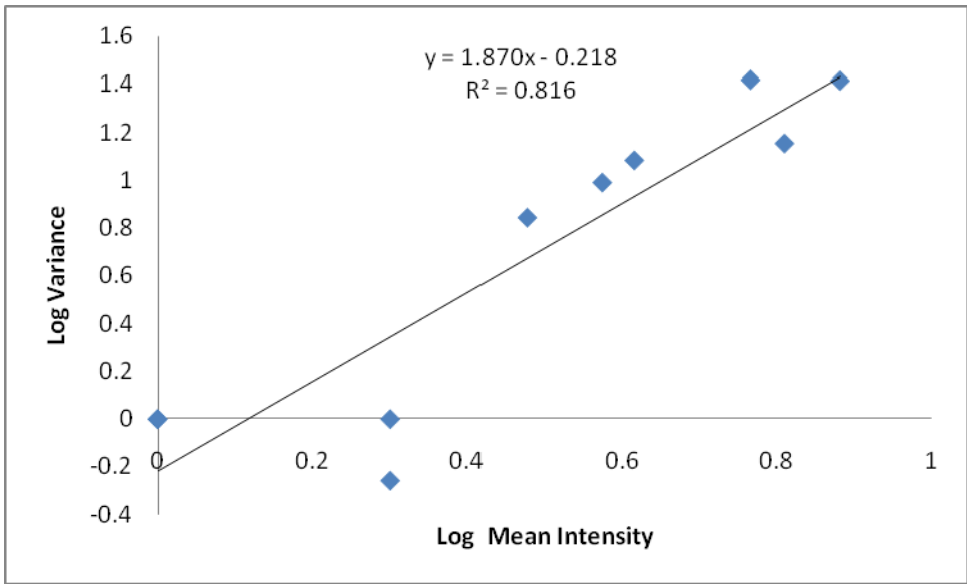

Figure 22. Relationship between the variance and the mean intensity of parasite taxa from 45 sauger from the Upper Mississippi River Pools 8 and 9.

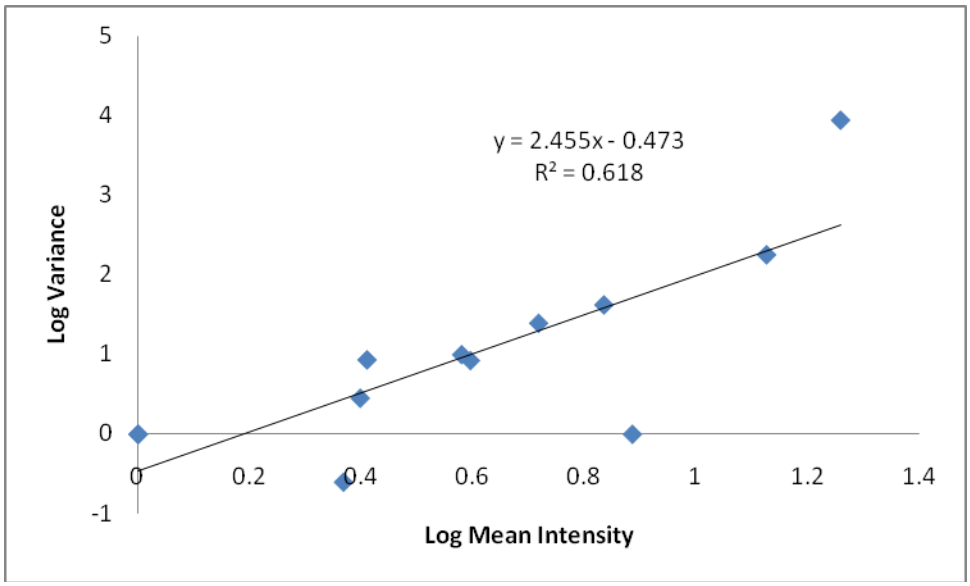

Figure 23. Relationship between the variance and the mean intensity of parasite taxa from 39 yellow perch from Big Round Lake and Lac Vieux Desert.

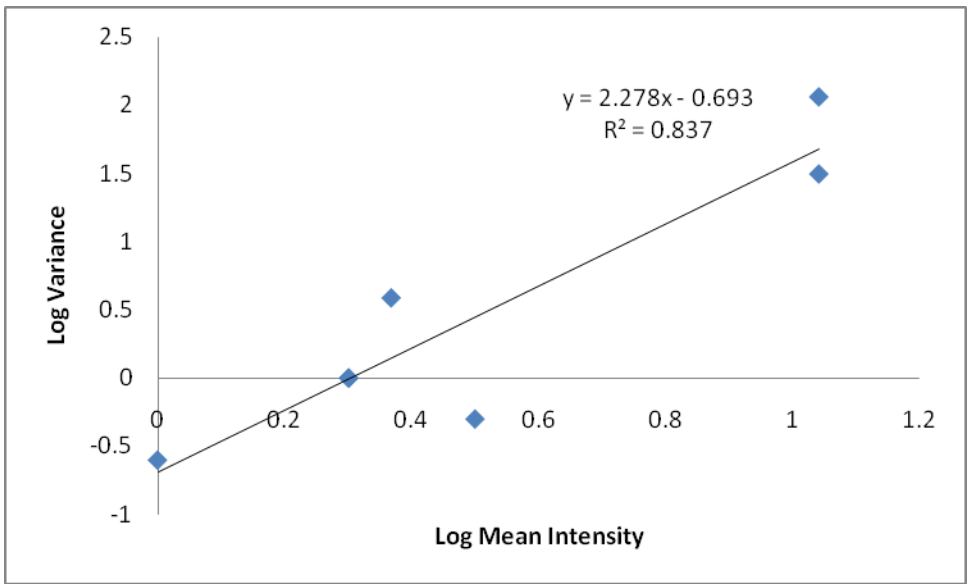

Figure 24. Relationship between the variance and mean intensity of parasite taxa from 45 walleye from Upper Mississippi River Pools 8 and 9.

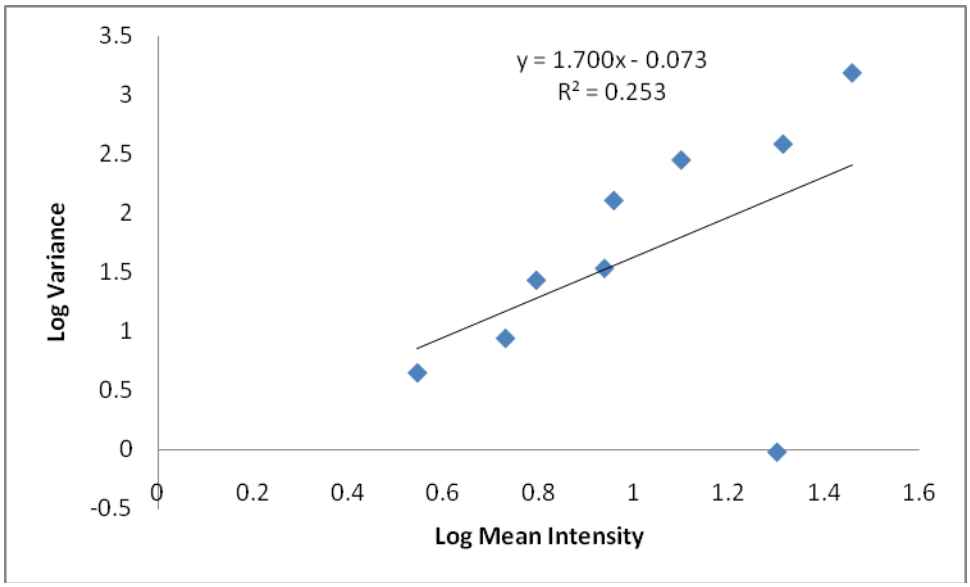

Figure 25. Relationship between the variance and mean intensity of parasite taxa from 30 walleye from Lake Owen.

Table 1. Prevalence, mean intensity and range of parasites collected from 159 percids from the Mississippi River Drainage.

Parasites	Prevalence (%)	Mean Intensity ± Standard Deviation	Range
Monogenes			
Ancryocephlidae[b]	25.8%	17.8 ± 31.6	(1, 138)
Digenetic Trematodes			
Azygia sebago	6.9%	5.4 ± 3.0	(1, 12)
Azygia sp.	1.8%	2.0 ± 0.0	(2, 2)
Allocanthocasmus sp.	1.9%	2.0 ± 1.0	(1, 3)
Bucephalopsis sp.	8.2%	7.6 ± 5.1	(1, 17)
Bunodera sacculata	19.5%	17.6 ± 60.5	(1, 357)
Neascus sp.[a]	9.4%	6.6 ± 12.4	(1, 49)
Posthodiplostomum minimum[a]	0.6%	1.0	-

Table 1. Continued.

Parasites	Prevalence	Mean Intensity ± Standard Deviation	Range
Cestodes			
Bothriocephalus cuspidatus	61.6%	12.5 ± 11.5	(1, 108)
Proteocephalus sp.[a]	13.2%	5.2 ± 4.5	(1, 16)
Triaenophorus nodulosus[a]	5.0%	2.6 ± 1.7	(1, 6)
Nematodes			
Anisakidae	14.5%	6.2 ± 9.5	(1, 40)
Camallanus oxycephalus	1.9%	2.0 ± 0.0	(2, 2)
Camallanus sp.[a]	21.4%	5.6 ± 5.8	(1, 33)
Contracaecum sp.[a]	34.0%	3.6 ± 3.2	(1, 16)
Rhabdochona sp.	0.6%	1.0	-

Table 1. Continued

Parasite	Prevalence	Mean Intensity ± Standard Deviation	Range
Ancanthocephalan			
Neoechinorhynchus cylindratus	23.3%	10.6 ± 12.1	(1, 47)
Leptorhynchoides thecatus	41.5%	5.2 ± 6.0	(1, 42)
Pomphorhynchus bulbocolli	7.5%	3.3 ± 2.6	(1, 11)
Total Parasites			
Total	96.2%	27.5 ± 18.8	(0, 357)

[a]Larval Parasite, [b]No females for identification

Table 2. Site, prevalence, mean intensity, and range of parasites collected from 39 Yellow Perch.

Parasite	Site[a]	n	Prevalence	Mean Intensity	Range
Monogenes					
Ancryocephlidae	BR, LVD	17	43.6%	3.9	(1, 12)
Digenetic Trematodes					
Azygia sp.	BR, LVD	3	7.7%	2.0	-
Bunodera sacculata	BR, LVD	31	79.5%	18.2	(1, 357)
Cestodes					
Bothriocephalus cuspidatus	LVD	7	17.9%	2.6	(1, 9)
Proteocephalus sp.	BR, LVD	15	38.5%	3.8	(1, 13)
Triaenophorus nodulosus	LVD	8	20.5%	2.5	(1, 6)
Nematodes					
Anisakidae	LVD	3	7.7%	1.0	-

Table 2. Continued

Parasite	Site[a]	n	Prevalence	Mean Intensity	Range
Nematodes					
Camallanus sp.	BR, LVD	25	64.0%	6.8	(1, 33)
Contracaecum sp.	LVD	1	2.6%	1.0	-
Acanthocephalan					
Leptorhynchoides thecatus	BR, LVD	18	46.2%	5.2	(1, 19)
Neoechinorhynchus cylindratus	BR, LVD	26	66.7%	13.4	(1, 47)
Pomphorhynchus bulbocolli	LVD	3	7.7%	2.3	(1, 2)
Total Parasites					
Total	BR, LVD	39	97.4%	35.1	(0, 357)

Site[a]: Big Round Lake = BR, and Lac Vieux Desert = LVD

Table 3. Site, prevalence, mean intensity, and range of parasites collected from 75 walleye.

Parasite	Site[a]	n	Prevalence	Mean Intensity	Range
Monogenes					
Ancryocephlidae	UMR 9, LO	24	32.0%	27.7	(1, 138)
Digenetic Trematodes					
Azygia Sebago	LO	11	14.6%	5.4	(1, 12)
Neascus sp.	UMR 9, LO	11	14.6%	8.6	(1, 49)
Posthodiplostomum minimum	UMR 9	1	1.3%	2.0	-
Allocanthocasmus sp.	UMR 9	3	4.0%	2.0	(1, 3)
Cestodes					
Bothriocephalus cuspidatus	UMR 8, 9, LO	68	90.7%	15.6	(1, 108)
Proteocephalus sp.	LO	6	8.0%	8.0	(1. 16)

Table 3. Continued.

Parasites	Site[a]	n	Prevalence	Mean Intensity	Range
Nematodes					
Anisakidae	UMR 9, LO	17	22.7%	7.7	(1, 40)
Camallanus sp.	LO	9	12.0%	2.2	(1, 3)
Contracaecum sp.	UMR 8, 9	20	26.7%	2.9	(1, 10)
Acanthocephalan					
Leptorhynchoides thecatus	UMR 8, 9, LO	37	49.3%	6.1	(1, 42)
Neoechinorhynchus cylindratus	UMR 8, 9, LO	5	6.6%	2.2	(1, 5)
Pomphorhynchus bulbocolli	UMR 9	1	1.3%	2.0	-
Total Parasite					
Total	UMR 8, 9, LO	75	96.0%	33.2	(0, 138)

Site[a]: UMR 8 = Upper Mississippi River Pool 8, UMR 9 = Upper Mississippi River Pool 9, and LO = Lake Owen.

Table 4. Site, prevalence, mean intensity, and range of parasites collected from 45 sauger.

Parasite	Site[a]	n	Prevalence	Mean Intensity	Range
Digenetic Trematodes					
Bucephalopsis sp.	UMR 8, 9	13	28.9%	7.6	(1, 17)
Neascus sp.	UMR 8. 9	4	8.9%	1.0	-
Cestodes					
Bothriocephalus cuspidatus	UMR 8, 9	22	48.9%	6.5	(1, 14)
Nematodes					
Anisakidae	UMR 9	3	6.7%	3.0	(1, 6)
Camallanus oxycephalus	UMR 9	3	6.7%	2.0	-
Contracaecum sp.	UMR 8, 9	32	71.1%	4.1	(1, 16)

Table 4. Continued.

Parasite	Site	n	Prevalence	Mean Intensity	Range
Nematodes					
Rhabdochona sp.	UMR 8	1	2.2%	1.0	-
Acanthocephalan					
Leptorhynchoides thecatus	UMR 8, 9	11	24.4%	2.0	(1, 3)
Neoechinorhynchus cylindratus	UMR 8, 9	6	13.3%	5.8	(1, 13)
Pomphorhynchus bulbocolli	UMR 8, 9	8	17.8%	3.8	(1, 11)
Total Parasites					
Total	UMR 8, 9	45	95.6%	11.3	(0, 17)

Site[a]: UMR 8 = Upper Mississippi River Pool 8, UMR 9 = Upper Mississippi River Pool 9.

Table 5. Mean parasite taxa richness among sauger, walleye, and yellow perch from the five collection sites.

Fish Species	n	Mean Parasite Taxa Richness
Sauger	45	2.35
Walleye	75	2.77
Yellow Perch	39	3.95[a]

[a]Yellow perch mean taxa richness is significantly different than walleye and sauger when p-value is ≤ 0.05

Table 6. Mean parasite taxa richness among the five collection sites.

Collection Site	n	Mean Parasite Taxa Richness[*]
Mississippi River Pool 9	69	2.14[a]
Mississippi River Pool 8	21	2.19[a]
Big Round Lake	9	2.89[b]
Lake Owen	30	4.00[c]
Lac Vieux Desert	30	4.27[c]

* Indicates that superscript letters that are different are significantly different when p-values are ≤ 0.05.

Table 7. Kruskal-Wallis statistical test of mean total parasite count among sauger, walleye, and yellow perch.

Fish Species	n	Mean ± Standard Deviation	Mean Rank
Sauger	45	11.1 ± 9.8	58.1
Walleye	75	30.9 ± 37.7	88.6
Yellow Perch	39	34.2 ± 60.7	87.2
Total Fish	159	26.3 ± 41.1	-

Table 8. Kruskal-Wallis statistical test of mean total parasite count among the five study sites.

Collection Sites	n	Mean ± Standard Deviation	Mean Rank
Mississippi River Pool 8	21	11.2 ± 10.5	57.6
Mississippi River Pool 9	69	13.8 ± 11.5	68.3
Big Round Lake	9	12.9 ± 13.5	60.3
Lac Vieux Desert	30	40.6 ± 67.8	95.3
Lake Owen	30	55.6 ± 49.6	113.4

Table 9. Dispersion ratios, distribution patterns and core, secondary, or satellite parasite taxa of yellow perch from Big Round Lake and Lac Vieux Desert.

Parasite Taxa	Dispersion Ratio (s^2/x)	Spatial Distribution	Core, Secondary, or Satellite
Ancryocephlidae	2.14	Overdispersed	Secondary
Azygia sp.	0	Underdispersed	Satellite
Bunodera sacculata	488.75	Overdispersed	Core
Bothriocephalus cuspidatus	3.36	Overdispersed	Secondary
Proteocephalus sp.	2.64	Overdispersed	Secondary
Triaenophorus nodulosus	1.14	Overdispersed	Secondary
Anisakidae	0	Underdispersed	Satellite
Camallanus sp.	6.19	Overdispersed	Core
Contracaecum sp.	0	Underdispersed	Satellite
Leptorhynchoides thecatus	4.76	Overdispersed	Secondary
Neoechinorhynchus cylindratus	13.5	Overdispersed	Core
Pomphorhynchus bulbocolli	0.11	Underdispersed	Satellite

Table 10. Dispersion ratios, distribution patterns and core, secondary, or satellite parasite taxa of Sauger from Upper Mississippi River Pools 8 and 9.

Parasite taxa	Dispersion Ratio (s^2/x)	Spatial Distribution	Core, Secondary, Satellite
Bucephalopsis sp.	3.43	Overdispersed	Secondary
Neascus sp.	0	Underdispersed	Satellite
Bothriocephalus cuspidatus	2.22	Overdispersed	Secondary
Anisakidae	2.33	Overdispersed	Satellite
Camallanus *oxycephalus*	0	Underdispersed	Satellite
Contracaecum sp.	2.95	Overdispersed	Core
Rhabdochona sp.	0	Underdispersed	Satellite
Leptorhynchoides thecatus	0.28	Underdispersed	Secondary
Neoechinorhynchus cylindratus	4.51	Overdispersed	Secondary
Pomphorhynchus bulbocolli	2.62	Overdispersed	Secondary

Table 11. Dispersion ratios, distribution patterns, and core, secondary, or satellite parasite taxa of walleye from Lake Owen.

Parasite taxa	Dispersion Ratio (s^2/x)	Spatial Distribution	Core, Secondary, Satellite
Ancryocephlidae	53.15	Overdispersed	Core
Azygia Sebago	1.6	Overdispersed	Secondary
Neascus sp.	22.38	Overdispersed	Secondary
Bothriocephalus cuspidatus	18.65	Overdispersed	Core
Proteocephalus sp.	3.95	Overdispersed	Secondary
Anisakidae	14.13	Overdispersed	Secondary
Camallanus sp.	0.05	Underdispersed	Secondary
Leptorhynchoides thecatus	4.37	Overdispersed	Core
Neoechinorhynchus cylindratus	1.29	Overdispersed	Satellite

Table 12. Dispersion ratios, distribution patterns, and core, secondary, or satellite parasite taxa of walleye from Upper Mississippi River Pools 8 and 9.

Parasite taxa	Dispersion Ratio (s^2/x)	Spatial Distribution	Core, Secondary, Satellite
Ancryocephlidae	0	Underdispersed	Satellite
Neascus sp.	0.25	Underdispersed	Satellite
Allocanthocasmus sp.	0.5	Underdispersed	Satellite
Bothriocephalus cuspidatus	2.85	Overdispersed	Core
Contracaecum sp.	1.66	Overdispersed	Secondary
Leptorhynchoides thecatus	10.46	Overdispersed	Secondary
Pomphorhynchus bulbocolli	0	Overdispersed	Satellite

Discussion

No viruses were detected by tissue cell culture using CHSE and EPC cell lines incubated at 20ºC, and BF-2 cells at 25ºC (Appendix B). CHSE, EPC and BF-2s were used for walleye and sauger sampled from the UMR, whereas EPCs were used for fish sampled at the other three sites. The EPC cell line incubated at 20ºC would detect VHSv if present in the kidney and spleen tissues of the fish. The main goal the Great Lakes Indian Fish and Wildlife Commission had in testing the fish from BRL, LO, and LVD, was to determine if VHSv was present in these lakes and in these important sport fish. VHSv was not detected; therefore, GLIFWC could use walleye and yellow perch from these bodies of waters as brood stock without fear of spreading this serious viral pathogen. This was the first study to test for viral pathogens, especially VHSv.

Because VHSv is a deadly pathogenic virus that can be carried by numerous species and can be easily transmitted, continued surveillance is important. VHSv has been detected in walleye from Conesus Lake, New York in 2006 and from walleye from Lake Huron near Roger City, MI in 2007. These fish showed clinical signs of VHSv, but no mortalities were reported from either location. VHSv also was detected from Lake Erie, OH in 2006. This epizootic caused a huge die off of yellow perch in commercial traps. In 2008 VHSv was found in yellow perch from Lake Michigan, Milwaukee, WI (USDA-APHIS 2008). Because of the seriousness of VHSv and other viral pathogens it is recommended that GLIFWC test 60 fish per species per lake one time each year during the spring (water temperatures between 4ºC to 15ºC).

VHSv is also a concern in the UMR. VHSv has not yet been detected in the Mississippi River, but has been isolated from yellow perch and round gobies in Southern

Lake Michigan (Milwaukee, WI). The Cal-Sag Channel and Illinois River connect Lake Michigan to the Mississippi River. In addition, numerous species of fish were also infected with VHSv in the Ohio River drainage, which flows into the Mississippi River at Cairo, IL (USDA-APHIS 2008). Therefore, it is important to continue to monitor the Upper Mississippi River for VHSv and other target viral pathogens (Appendix B).

No target bacterial pathogens were detected in walleye and sauger from the UMR. *Aeromonas hydrophila* would have been the most likely bacterial pathogen detected in these fish. Motile aeromonad septicemia (MAS), which is associated with *Aeromonas hydrophila* and other members of the genus *Aeromonas* are ubiquitous in freshwater environments (Noga 1996). Although it is a pathogen that is found throughout freshwater environments, it is still a pathogen of concern. Motile aeromonads vary in pathogenicity, and can cause high mortality rates if environmental stressors are present (Noga 1996).

Aeromonas salmonicida, *Edwardsiella ictaluri*, and *Yersnia ruckeri* (Appendix B) have not previously been detected in walleye and sauger. However, these pathogens are widespread throughout freshwater environments and they have the potential to infect new hosts. There are few published surveys on bacterial pathogens of walleye and sauger in wild populations and no studies describing bacterial pathogens from fish in the Upper Mississippi River.

Bush et al. (2001) reports that parasite populations are affected by density-dependent factors (e.g., predation, competition), and density-independent factors (e.g., pollution, temperature, seasonal changes and other climatic conditions external to the host). Species richness can also be influenced by parasite competition, host size, and host geographical range (Bush et al. 2001). An extended host geographical range implies that

the host will encounter a wide range of intermediate hosts, thus encountering more parasites. Therefore, habitats that have high host diversity can also have high parasite species richness.

In this study the mean total parasite count and mean parasite taxa richness was significantly greater in the three lakes compared to Mississippi River Pools 8 and 9. Pitlo et al. (1995) and Sauer (2004) reported a wide diversity in the fish and wildlife fauna that occupy the Upper Mississippi River system (UMR): 163 species of fish (89 in Pool 8), 19 species of waterfowl, and high diversity of major macroinvertebrate taxa (Sauer 2004, Kirby 2006, USFWS 2008). Even though the vast diversity of animals in the UMR would have provided the necessary hosts for a large number of parasites to complete their life cycles, in this study it did not correlate to a more diverse parasite community compared to the percid parasite communities in the lakes. Therefore, other factors may have influenced parasite diversity, including sampling times.

Seasonal patterns of parasite prevalence and mean intensity could have influenced the parasite species richness found in this study. Studies have shown the acanthocephalan *Neoechinorhynchus* sp. to exhibit seasonal patterns in prevalence and mean intensity (Eure 1976, Jilek 1978, Amin 1986, Lasee 1989). Lasee (1989) reported higher prevalence and mean intensity of *Neoechinorhynchus pungitius* in brook stickleback in the spring, and low prevalence and mean intensity in the fall. The UMR Pools 8 and 9 were sampled in the fall whereas the lakes were sampled in the spring. This limiting factor could have influenced the parasite diversity.

The type of water system, open versus closed, may also have influenced study results. Bush et al. (2001) reported that pH, dissolved oxygen, substrate types, depth, and

water flow rates are variables that affect parasite distributions. Open systems, such as the UMR, are more apt to experience fluctuations from these variables compared to closed systems (the three lakes). The mean parasite taxa of walleye from Lake Owen was statistically greater then mean parasite taxa of walleye from UMR Pools 8 and 9. Mean parasite taxa of walleye from the UMR were not statistically different than the mean parasite taxa of sauger. Therefore, parasite assemblages may not always be similar in same host species, and are affected by aquatic habitats.

The diversity was higher in Lake Owen compared to UMR, even though the sites shared some core and secondary parasite taxa. *Bothriocephalus cuspidatus* was a core species in both the UMR and Lake Owen. *Leptorhynchoides thecatus* was also a core species in Lake Owen, but a secondary species in UMR. Overall, the lakes displayed more core and secondary parasite taxa than that of the UMR. The UMR had fewer total taxa, and more satellite species.

There was diverse parasite fauna in all three species of percids examined. However, mean parasite taxa was significantly greater in yellow perch than in walleye and sauger. Yellow perch had a higher prevalence of *N. cyclindratus* and *Camallanus* sp., which were also found in walleye and sauger. These parasites were approximately eight times more prevalent in yellow perch. Yellow perch also had high prevalence in parasites that were not found in walleye and sauger. *Bunodera sacculata* and *Triaenophorus nodulosus* were recovered from yellow perch, each with prevalence greater than 20%. The presence of these parasites combined with the high prevalence of *N. cylindratus* and *Camallanus* sp. contributed to the greater mean parasite taxa in yellow perch. Yellow perch diets can vary in the number of different prey consumed (Chabot

and Maly 1986). This variability in the prey consumed could contribute to the greater mean parasite taxa in yellow perch.

Yellow perch and walleye also had a significantly greater mean total parasite count, parasite taxa, higher prevalence, and greater mean intensities than that of sauger. These two species also hosted more dominant taxa of parasites than sauger. *Bothriocephalus cuspidatus* was the dominant parasite of walleye and also the most prevalent. It was found in almost all the walleye sampled, and it composed approximately half of the total parasites recovered in walleye. *Bunodera sacculata* was the most dominant and prevalent species in yellow perch. *Neoechinorhynchus cylindratus* was the second most dominant species in yellow perch. Combined, these two parasites made up 66% of the total parasite count of yellow perch. The high mean intensity of the two species also increased the total number of parasites found in yellow perch. The parasite taxa in sauger exhibited low prevalence and low mean intensities.

Poulin (2007) reported that parasites are aggregated among host individuals and if the mean intensity of parasites is known, the level of aggregation can be predicted. This general law was developed based on past studies of variance-to-mean ratios of parasites (Shaw and Dobson 1995). In this study, the regression of variance against mean intensity of parasite taxa from walleye and sauger from the UMR was comparable to those reported by Shaw and Dobson (1995). However, mean intensities of parasites from walleye from Lake Owen and yellow perch from Big Round Lake and Lac Vieux Desert had lower r^2 values. A few statistical outliers in walleye (from Lake Owen) and yellow perch may have influenced these results. Small sample size could also contribute to the differences observed.

There were two new host records in this study. *Pomphorhynchus bulbocolli* was reported in sauger for the first time and *Allacanthocasmus* sp. was identified in walleye for the first time. *Pomphorhynchus bulbocolli* is an acanthocephalan that requires two hosts to complete its life cycle, the amphipod *Hyalella azteca* as its intermediate host and a fish as its definitive host. It also has been reported in walleye and yellow perch and is present in many fish species from the Mississippi River (Hoffman 1999). *Allacanthocasmus* sp. is a digenetic trematode that resides in the intestine of freshwater fish, but its life cycle is unknown (Hoffman 1999). It is commonly reported from centrarchids, such as bluegills and smallmouth bass, but has not previously been reported in walleye, yellow perch, or sauger. *Allocanthocasmus* sp. has been reported in fish from the Mississippi River.

Several of the parasites identified in this study cause pathology in their fish host. Fischer and Kelso (1988) reported high intensities of *Allocanthocasmus sp*. can cause parasite-induced host mortality in age-0 bluegills. The circle of spines on the oral sucker may have contributed to the pathology. In this study there was no evidence of histo-pathology from *Allocanthocasmus* sp. Acanthocephalans have a spined proboscis that they use for attachment to the intestinal wall of their host. This may cause inflammation of surrounding tissues, proliferation of the intestinal wall, and edema, especially if the acanthocephalans are in high numbers (Hoffman 1999). Three acanthocephalans were found in this study, *Leptorhynchoides thecatus*, N. *cylindratus*, and P. *bulbocolli*. They were not found in high intensities, but some fish did have obvious intestinal lesions at the attachment site. Larval *Proteocephalus* sp. have also been shown to cause pathology in fish. Migration of *Proteocephalus ambloplitis* metacestodes can cause serious

pathological lesions in visceral organs (Elsayed and Faisal 2008). They can also cause fibrosis of the gonads, which can sterilize the fish (Hoffman 1999). *Proteocephalus* sp. metacestodes were recovered from fish, but because they were immature, the species could not be determined. The bass tapeworm *Proteocephalus ambloplitis* is also common in walleye, yellow perch, and sauger. Fish that were infected with *Proteocephalus* sp. did not show any obvious pathology. Metacestodes of *Triaenophorus nodulosus* has been reported to induce liver lesions in many fish species and mortalities in yellow perch (Matthey 1963, Hoffmann 1986). In this study there was no evident pathology from *T. nodulosus* due to its low mean intensities and prevalence.

This study provides baseline information on fish parasite communities from three important sport fish species. This data can be used in future studies to assess effects of climate change on ecosystem stability. Parasite data can be used as indicators of predator-prey relationship within a habitat (Marcogliese 2004). Predator-prey interactions provide information on the stability of the ecosystem; therefore, parasite fauna of a host can be indicators of ecosystem stability (Marcogliese 2003). Future studies to assess ecosystem stability would include sampling 30 walleye, 30 sauger, and 30 yellow perch from each collection site twice a year, in the spring and fall. Parasite community studies are usually limited by lack of expertise and the time it takes to identify parasites. However, due to initial identification of parasites, it would be possible to necropsy more fish and catalog more parasites species in less time.

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APPENDIX A

HELMINTH PARASITES THAT HAVE BEEN REPORTED FROM WALLEYE, SAUGER, AND YELLOW PERCH.

Parasite	Host
Monogenea	
Ancryocephalus sp.	YEP
Cleidodiscus spp.	YEP
Gyrodactylus spp.	WAE, SAU, YEP
Urocleidus adspectus	YEP
Urocleidus aculeatus	WAE, SAU
Dactylogyrus extensus	WAE
Trematoda	
Allocreadium lobatum	WAE
**Apophallus spp.*	WAE, YEP
Asymphylodora amnicolae	YEP
Asymphylodora sp.	YEP
Azygia spp.	WAE, YEP
Bucephalopsis pusillus	WAE, SAU, YEP
Bucephalus elegans	YEP
Bunodera luciopercae	YEP
Bunodera nodulosum	YEP
Bunodera sacculata	WAE, YEP
Centrovarium lobotes	WAE, YEP

Appendix A. continued

Parasite	Host
**Clinostomum complanatum*	WAE, SAU, YEP
**Cotylurus communis*	WAE, SAU
**Crassiphiala bulboglossa*	WAE, YEP
Crepidostomum spp.	WAE, YEP
Cryptogonimus chili	YEP
**Diplostomulum spp.*	WAE, SAU, YEP
**Echinochasmus donaldsoni*	YEP
**Euparyphium melis*	YEP
Leuceruthrus sp.	YEP
Maritrema medium	YEP
**Metorchis conjunctus*	YEP
Microphallus medius	YEP
Microphallus opacus	YEP
**Neascus spp.*	WAE, SAU, YEP
**Ornithodiplosomum ptychocheilus*	YEP
**Petasiger nitidus*	YEP
Phyllodistomum americanum	YEP
Phyllodistomum superbum	WAE, SAU, YEP
**Posthodiplostomum minimum*	WAE, YEP

Appendix A. Continued

Parasite	Host
Prosorhynchoides pusilla	SAU
Ptychogonimus fontanus	WAE, YEP
Rhipidocotyle papillosa	YEP
Riberioria ondatrae	YEP
Sanguinicola occidentalis	WAE, YEP
Stephanophiala farionis	YEP
**Tetracotyle spp.*	WAE, SAU, YEP
**Uvulifer ambloplitis*	WAE, YEP
Cestoidea	
Bothriocephalus spp.	WAE, SAU, YEP
Corallobothrium sp.	YEP
Cyathocephalus truncaus	YEP
**Diphyllobothrium spp.*	WAE, SAU, YEP
Eubothrium sp.	WAE
**Ligula intestinalis*	YEP
Proteocephalus spp.	WAE, SAU, YEP
**Schistocephalus solidus*	YEP
**Triaenophorus spp.*	WAE, SAU, YEP

Appendix A. Continued

Parasite	Host
Nematoda	
Camallanus spp.	WAE, SAU, YEP
Capillaria catenata	WAE, YEP
Contracaecum spp.	WAE, SAU, YEP
Cucullanellus cotylophora	WAE, YEP
Cystidicola lepisostei	WAE
Dacnitoides cotylophora	WAE, YEP
**Eustrongylides sp.*	WAE, SAU, YEP
Oxyurid	WAE
Philometra spp.	WAE, YEP
Raphidascaris sp.	WAE, YEP
Rhabdochona Spp.	YEP
Spinitectus spp.	WAE, YEP
**Spiroxys spp.*	YEP
Thynnascaris brachyurum	WAE, SAU, YEP
Acanthocephala	
Acanthocepahius spp.	YEP
Echinorhynchus spp.	WAE, YEP
Fessisentis tichiganensis	YEP
Leptorhynchoides thecatus	WAE, YEP

Appendix A. Continued

Parasite	Host
Metechinorhyncus salmonis	SAU
Neoechinorhynchus spp.	WAE, SAU, YEP
Pomphorhynchus bulbocoli	WAE, YEP

* Larval forms are denoted by an asterisk

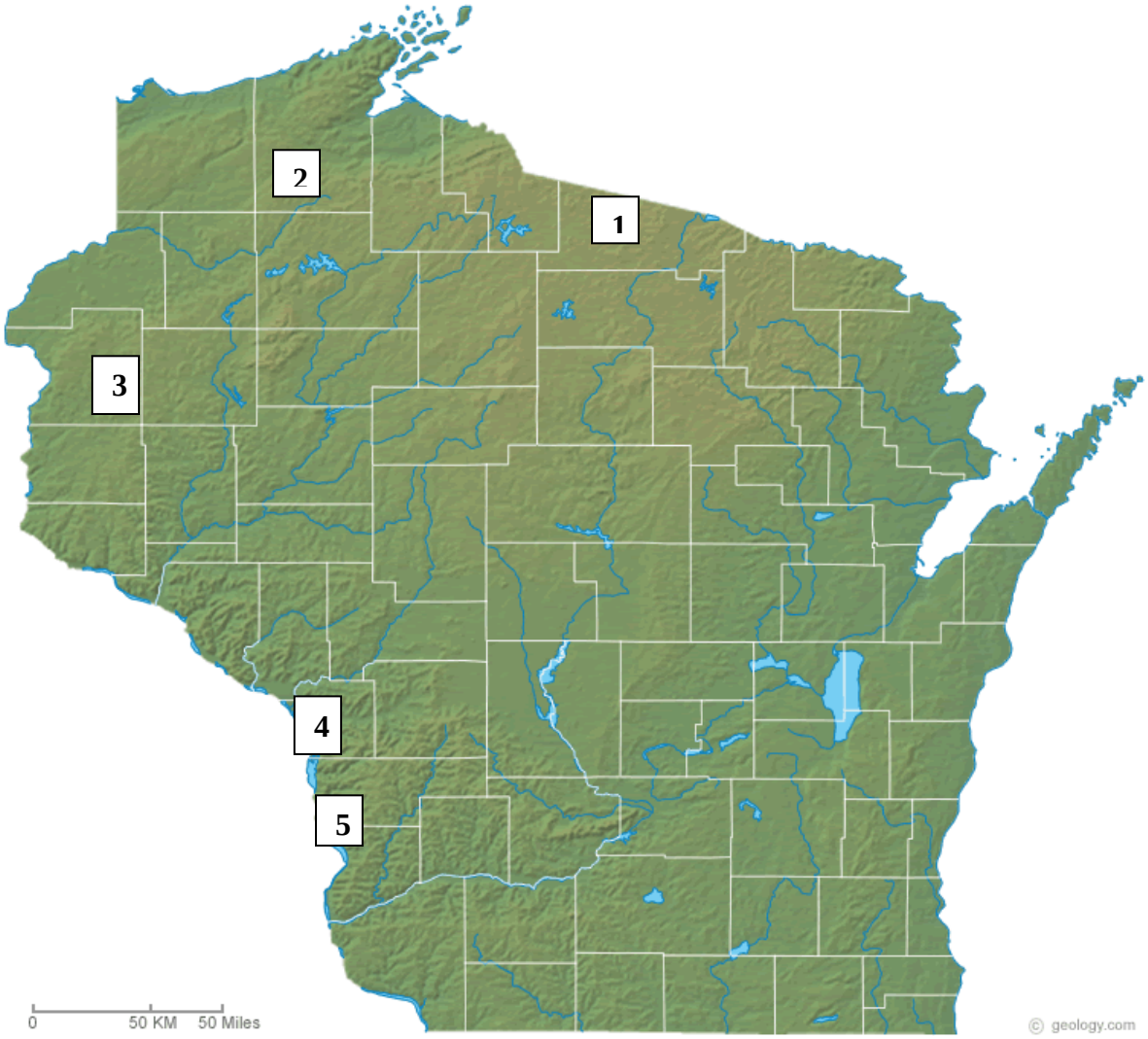
APPENDIX B

THE TARGET PATHOGENS THAT WALLEYE, SAUGER, AND YELLOW PERCH WERE TESTED FOR DURING THE SPRING AND FALL OF 2007 AND 2008 FROM THE MISSISSIPPI RIVER DRAINAGE

Pathogen	Disease
Viruses	
Viral Hemorrhagic Septicemia Virus (VHSV)	VHS
Infectious Pancreatic Necrosis Virus (IPNV)	IPN
Spring Viremia of Carp Virus (SVCV)	SVC
Largemouth Bass Virus (LMBV)	LMBVD
Bacteria	
Aeromonas hydrophila	Motile Aeromonid Septicemia
Aeromonas salmonicida	Furunculosis
Edwardsiella ictaluri	Enteric Septicemia
Yersinia ruckeri	Enteric Redmouth Disease

APPENDIX C

A MAP OF THE SITES THAT FISH WERE COLLECTED FROM DURING THE SPRING AND FALL OF 2007 AND 2008. 1 = LAC VIEUX DESERT, 2 = LAKE OWEN, 3 = BIG ROUND LAKE, 4 = MISSISSIPPI RIVER POOL 8, 5 = MISSISSIPPI RIVER POOL 9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