

THE UNIVERSITY OF CALGARY

The Metazoan Parasite Fauna of Yellow Perch
(*Perca flavescens* Mitchell) in Alberta

by

Derek A. Zelmer

A THESIS

**SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
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DEGREE OF MASTER OF SCIENCE**

DEPARTMENT OF BIOLOGICAL SCIENCES

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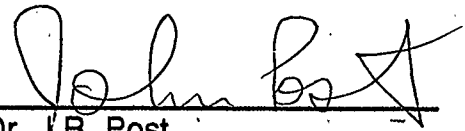


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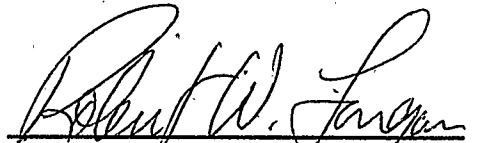
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ABSTRACT

Over 600 yellow perch (*Perca flavescens*) from 16 water bodies in Alberta were examined, and 14 species of metazoan parasites were recovered. Older, larger perch harboured more parasite species than did younger fish, both in a given water body and when all the data were combined.

The number of perch parasite species present in a given water body is dependent on its surface area, with larger lakes supporting a greater number of parasite species. A regression line was developed for this relationship using five lakes that were assumed to be at an equilibrium in terms of perch parasite species richness. This equilibrium line was supported by data from stocked lakes.

Autogenic species dominated the stable systems, and were the important factor deciding the component parasite community composition in these systems. The role of allogenic parasite species was important only in those systems that had suffered a recent disturbance.

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CHAPTER I GENERAL INTRODUCTION AND METHODOLOGY

INTRODUCTION

In 1991 a study program was initiated by the Canadian Society of Zoologists (CSZ) aimed at quantifying the distribution of the metazoan parasites of yellow perch (*Perca flavescens* Mitchell) in Canada. The parasite fauna of yellow perch in Alberta has never been thoroughly investigated, and leaves a noticeable gap in the studies on Canadian perch parasites that have already been conducted (Margolis and Arthur 1979). This study was undertaken with the goal of providing the CSZ with a data set for their zoogeographical work, as well as using the results to clarify the relationship between yellow perch and their metazoan parasites in the province of Alberta.

The number of lakes studied facilitated an analysis of the optimal sample sizes required for the determination of the component parasite community of yellow perch. The evident dependence of required sample sizes on lake size resulted in a guideline for sampling effort that will enhance the efficiency of any further studies in this area.

Combining perch samples from all of the lakes studied created a data base large enough to examine the relationship between the age and size of yellow perch and their parasite fauna. The sample size from one lake was sufficiently large that the effects of size and age on parasite load could be teased apart for certain parasite species.

The lakes containing natural populations of yellow perch covered a wide range of sizes, permitting the quantification of the relationship between perch parasite species richness and lake surface area. This analysis produced assumptions which were tested using water bodies containing perch that had been

originally transferred from one of these natural perch populations.

The trends and relationships produced by all of the above analyses were combined to produce a stocking protocol aimed at the reduction of parasitic transfaunation during perch transfer.

GENERAL METHODS

Samples of yellow perch were collected from sixteen lakes (listed with their respective sample sizes in Table 1.1) from July 10, 1992 to June 8 of 1994 by gill netting, seine netting, Windermere traps and angling. Samples from certain lakes were sent to us by Alberta Fish and Wildlife regional offices. The locations of the water bodies are given in Figure 1.1.

Prior to examination all fish were stored in a -70° C ultrafreezer. The standard length, blotted wet mass and sex of each fish were recorded. The following tissues and organs were examined for parasites: external body surface, fins, eyes, brain, buccal cavity, gills, heart, liver, gall bladder, stomach, pyloric caeca, intestine, urinary bladder, gonads, swim bladder, kidneys, and musculature. The organs were dissected out, and examined in separate dishes under a bottom-lit dissecting scope. The liver and heart of each fish was first pressed between glass plates before examination. In all examinations the types and numbers of parasites found were recorded. The operculum bone of each fish was removed and used to determine the age of the fish according to the method of Le Cren (1947).

Parasites were fixed and preserved in alcohol-formalin-acetic acid (AFA), with the exception of crustaceans and nematodes which were placed in 70% ethanol and lactophenol respectively. Platyhelminths and acanthocephalans were stained with acetic carmine and mounted in balsam for identification. Crustaceans were placed in 10% KOH to digest the soft tissues before being mounted in

Table 1.1: A list of the sampling localities, their assigned numbers, locations, and the numbers of *Perca flavescens* examined from each lake

Number	Name of Waterbody	Location	Sample size
1	Spruce Coulee Reservoir	49° 40' N 110° 11' W	216
2	Elkwater Lake	49° 39' N 110° 18' W	10
3	Rattlesnake Reservoir	49° 58' N 111° 01' W	30
4	Sherburne Reservoir	49° 46' N 111° 49' W	30
5	Fincastle Reservoir	49° 50' N 111° 59' W	19
6	Lagoon Lake	50° 59' N 114° 02" W	15
7	Pine Lake	52° 04' N 113° 27' W	25
8	Sylvan Lake	52° 18' N 114° 06' W	30
9	Burntstick Lake	51° 59' N 114° 53' W	13
10	Hastings Lake	53° 25' N 113° 55' W	52
11	Coal Lake	53° 08' N 113° 21' W	29
12	Pigeon Lake	53° 01' N 114° 02' W	19
13	Garner Lake	54° 12' N 111° 32' W	60
14	Beta Lake	53° 44' N 115° 35' W	30
15	Sturgeon Lake	55° 06' N 117° 32' W	3
16	Joker Lake	56° 23' N 115° 35' W	30

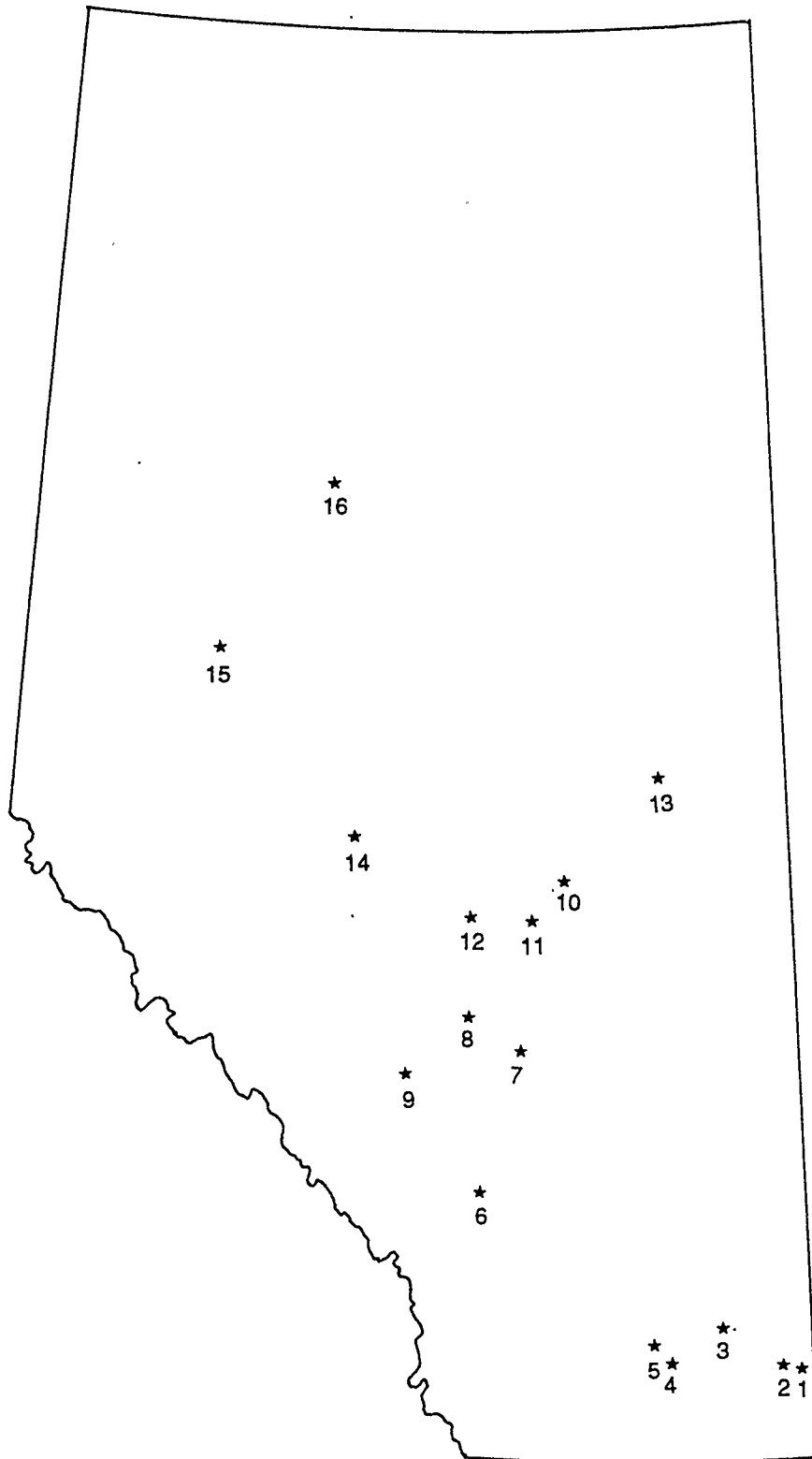


Figure 1.1: A map of Alberta showing the distribution of the sampling localities.

balsam. Nematodes were cleared in lactophenol, and examined in temporary glycerine whole mounts. For long term storage, platyhelminthes and crustaceans were kept in 70% ethanol with glycerine added to prevent evaporation, while nematodes were kept in glycerin.

The term prevalence (expressed as a percentage) will be used to indicate the number of hosts infected of the number of hosts examined. Mean intensity denotes the mean number of individuals of a particular parasite species per infected host in a sample. Relative density indicates the mean number of individuals of a particular parasite species per host examined. These definitions are as recommended by Margolis et al (1982).

Statistical methods specific to a given chapter of this thesis will be given in the methods section of that chapter. In all cases the Type I error rate (α) is equal to 0.05.

CHAPTER II

DETERMINATION OF SAMPLE SIZE

INTRODUCTION

In general, a recommended sample size should be determined only after a preliminary survey has been done, and the variance of the results is analyzed. In parasitological work, the characteristic overdispersion of parasites in and on their hosts greatly complicates any such calculations (Croll and Sole 1981), which has resulted in efforts to simplify the determination of sample size.

Ossiander and Wedemeyer (1973) developed a computer program designed to calculate the minimum sample size required to detect fish pathogens based on the lowest incidence to be detected, the population size, and a 95% confidence interval. The published tables were expanded by Simon and Schill (1984) to triple the coverage of the data at the 95% confidence interval, and to include the 90% and 99% confidence intervals. These determinations have been especially useful for the inspection of fish products to ensure that they are free of specific infectious diseases, but are of little use if the population size is not known or cannot be accurately estimated.

Croll and Sole (1981) suggested the use of a cumulative species curve to estimate sample size. The number of parasite species found in a sample is plotted against the number of specimens examined, the results being continually monitored to the point of redundancy. When the number of species found is thought to be at or near an asymptote the recommended sample size is taken as double the number of specimens examined. If further species are found before this sample size is reached, the number is again doubled at the point that the parasite was found. In other words, the end point is estimated by doubling the sample size at each presumed end point.

As the curve approaches the asymptote only rarer species will be added to the total. If the distribution can be described by a log-normal curve then sample sizes would need to be increased exponentially to find new, rarer species (Croll and Sole 1981). The cumulative species method minimizes the sampling effort required to determine the common parasite fauna of a given host assemblage.

The method of Croll and Sole (1981) was applied to data obtained from yellow perch populations in 10 Alberta lakes to determine whether or not the sample sizes used were adequate, and to test for a relationship between lake size and required sample size.

METHODS

The fish samples obtained for study were not examined in a random fashion. In most cases larger fish were examined first, as they gave a better indication of the overall parasite fauna. This meant that the data from these samples had to be randomized. Continuous random ordering to determine sample size resulted in the mean values approaching the values that would be obtained if the rarest of the species was assumed to be evenly spread throughout the sample. The required sample size was, therefore, calculated by:

$$N_{\text{est}}=2(N_{\text{tot}}/N_{\text{inf}})$$

where N_{tot} is the total number of fish in the sample, and N_{inf} is the number of fish infected by the parasite with the lowest prevalence in the sample. $N_{\text{tot}}/N_{\text{inf}}$ is merely the reciprocal of that parasite's prevalence, the doubling of which is in accordance with the method of Croll and Sole (1981). Parasites that were only represented in one host of a sample were not included in the calculations as their prevalence could not be determined with any degree of certainty.

The required sample size was calculated for each lake, and regressed on

lake surface area to determine if there was any dependence of sample size on lake surface area.

The required sample sizes were calculated for two lakes (Beta and Hastings) that had suffered partial winterkills, and a pair of reservoirs that had been joined (Rattlesnake/Sauder), and compared to estimates derived from the regression line to determine the effect of disturbance on required sample size.

Lake surface areas were obtained from Mitchell and Prepas (1990) and from Alberta Fish and Wildlife records.

RESULTS

Figure 2.1 shows the observed relationship between required sample size and lake surface area, both of which are measured on a log scale. The relationship is significant ($F=21.311$, $d.f.=1,8$, $p=0.0017$), with the calculated line accounting for over 70% of the variance ($r^2=0.7271$).

The disturbed lakes are listed in Table 2.1 along with their required sample sizes, and the estimated values that were calculated from the regression line. The required sample sizes were much higher than the estimates in all three waterbodies.

A comparison of the sample sizes used in the study, and the required sizes as determined in the manner described in the methods section is given in Table 2.2. In all instances the sample sizes were found to be adequate.

DISCUSSION

There does appear to be a dependence of required sample size on lake size, as can be seen from Figure 2.1. This dependence may result from what may be termed as a larger functional density in smaller water bodies. In other words,

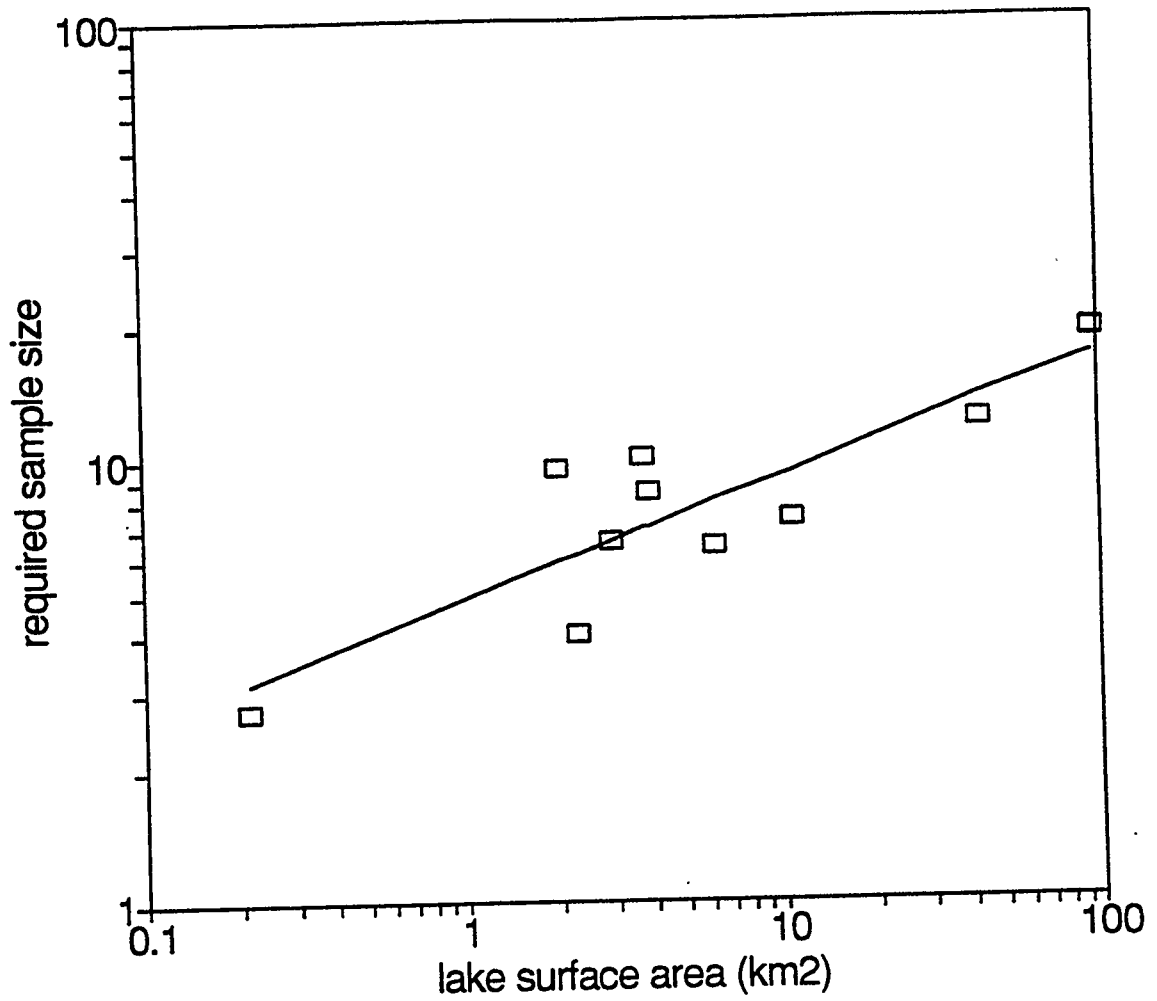


Figure 2.1: The relationship between required sample size and lake surface area for 10 Alberta Lakes. The regression line was drawn according to the equation: $\ln N = 0.274479 \cdot (\ln SA) + 1.572816$. $SS_R = 1.95305$, $SS_E = 0.73316$, $MS_E = 1.95305$.

Table 2.1: Comparisons of the required sample sizes for three lakes that suffered disturbance with estimates derived from the regression line depicted in Figure 1. The estimates include the 95% confidence interval.

Lake	Surface Area (km ²)	Required Sample Size	Estimated Sample Size
Beta	0.38	20.00	3.71 +/- 0.84
Hastings	8.71	14.86	8.73 +/- 0.76
Rattlesnake/ Sauder	10.27	20.00	9.14 +/- 0.75

Table 2.2: A comparison of the required and actual sample sizes used for the study of yellow perch parasite fauna in 13 Alberta lakes.

Lake	Required Sample Size	Actual Sample Size
Spruce Coulee	2.75	216
Fincastle	9.50	19
Elkwater	4.00	10
Burntstick	6.50	13
Sherburne	10.00	30
Pine	8.33	25
Garner	6.32	60
Coal	7.25	29
Sylvan	12.00	30
Pigeon	15.83	19
Beta	20.00	30
Hastings	14.86	52
Rattlesnake/ Sauder	20.00	30

the perch populations come into closer proximity with each other and the same sources of infectious agents, resulting in a more uniform probability of infection in these perch populations.

Large sample sizes are not required for perch, even in the larger lakes (Figure 2.1). This, however, should only be used as a guide to make sampling efforts more efficient. Correct sample size should still ultimately be determined by the method of Croll and Sole (1981) or an equivalent analysis. In actual practice it may be prudent to collect a sample of approximately 30 fish to counter the effects of a possible disturbance that will increase the required sample size (Table 2.1).

CHAPTER III

THE METAZOAN PARASITE FAUNA OF YELLOW PERCH IN ALBERTA

INTRODUCTION

The parasite fauna of yellow perch has been well documented throughout Canada, with the exception of Alberta. No citation of a perch parasite from Alberta appeared in a synopsis of fish parasites of Canada (Margolis and Arthur 1979). Paetz and Nelson (1970) reported that the larval stages of *Ligula intestinalis*, *Neascus* sp., *Tetracotyle* sp., *Triaenophorus nodulosus* and *Diphyllbothrium latum* had all been found in yellow perch in Alberta, but no specific water body locations were given. In an unpublished study of Cache Lake in Alberta, a sample of 8 yellow perch harboured *Proteocephalus* sp., *Schistocephalus* sp., *Tetracotyle* sp., and the larvae of *Raphidascaris acus* (Pybus and Samuel 1978).

In 1991 the Canadian Society of Zoologists began a study aimed at quantifying the distribution of the metazoan parasites of yellow perch. The lack of material from Alberta leaves a noticeable gap in the Canadian study, which this study endeavors to fill.

METHODS

Paired sample T-tests were used in the comparison of the mean intensities of the two stages of *Pomphorhynchus bulbocolli* found in a number of the sample sites.

RESULTS

A total of 611 perch were examined from 16 water bodies in Alberta. Parasite species recovered included 1 monogenean, 5 digeneans, 4 cestodes, 2 nematodes, 1 acanthocephalan and 1 copepod, for a total of 14 species.

The following parasites are recorded for the first time in Alberta: *Urocleidus adspectus* Mueller, 1936; *Apatemon gracilis* Szidat, 1928; *Diplostomulum scheuringi* Hughes, 1929; *Diplostomum adamsi* Lester and Huizinga, 1977; *Crepidostomum isostomum* Hopkins, 1931; *Tetracotyle diminuta* Hughes, 1928; and *Ergasilus caeruleus* Wilson, 1911. A complete list of the parasites recovered is given below, along with their location and distribution among the water bodies sampled, which are numbered according to Table 1.1; Chapter I.

PHYLUM PLATYHELMINTHES

Class Monogenea

Urocleidus adspectus Mueller, 1936

Synonyms: *Cleidodiscus adspectus* (Mueller, 1936)

Cleidodiscus sp. of Mizelle and Donahue, 1944

Site: gills

Distribution: 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15

Class Trematoda

Subclass Digenea

Apatemon gracilis Szidat, 1928 (metacercaria)

Synonyms: *Apatemon gracilis pellucidus* (Yamaguti, 1933)

Site: eye, body cavity, musculature, gills

Distribution: 3, 4

Diplostomulum scheuringi Hughes, 1929 (metacercaria)

Synonyms: *Diplostomum scheuringi* (Hughes, 1929)

Site: vitreous humor of eye

Distribution: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16

Diplostomum adamsi Lester and Huizinga, 1977 (metacercaria)

Site: retina of eye

Distribution: 3, 4, 5, 6, 12, 13, 15

Crepidostomum isostomum Hopkins, 1931

Synonyms: *Crepidostomum laureatum* of Cooper, 1915

Crepidostomum canadense Hopkins, 1931

Site: pyloric caeca, intestine, gall bladder

Distribution: 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15

Tetracotyle diminuta Hughes, 1928

Site: pericardial cavity, eye, mesenteries

Distribution: 8, 9, 10, 11, 12, 14, 15, 16

Class Cestoidea

Subclass Cestodaria

Bothriocephalus cuspidatus Cooper, 1917 (plerocercoid)

Synonyms: *Bothriocephalus cuspidatus luciopercae* Wardle, 1932

Bothriocephalus cuspidatus hiodontos Wardle, 1932

Bothriocephalus cuspidatus cuspidatus Cooper, 1917

Site: pyloric caeca, intestine

Distribution: 4, 8, 12, 13, 15

Ligula intestinalis Gmelin, 1790 (plerocercoid)

Site: body cavity

Distribution: 10, 12

Proteocephalus sp. (plerocercoid)

Site: pyloric caeca, intestine

Distribution: 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 15, 16

Triaenophorus nodulosus Rudolphi, 1819 (plerocercoid)

Site: liver, mesenteries

Distribution: 8, 12, 13

PHYLUM NEMATODA

Contracaecum spiculigerum RAILLET and HENRY, 1912 (larva)

Site: mesenteries

Distribution: 1, 2, 3, 4, 5

Raphidascaris acus RAILLET and HENRY, 1915 (larva)

Site: liver, mesenteries

Distribution: 2, 3, 4, 5, 6, 7, 8, 12, 13, 15

PHYLUM ACANTHOCEPHALA

Pomphorhynchus bulbocolli LINKINS in VAN CLEEVE, 1919

Site: intestine

Distribution: 5, 7, 8, 11, 12, 15, 16

Pomphorhynchus bulbocolli (juvenile)

Site: encysted in mesenteries

Distribution: 5, 8, 9, 11, 12, 15, 16

PHYLUM ARTHROPODA

Class Crustacea

Ergasilus caeruleus Wilson, 1911

Site: gills

Distribution: 13

Table 3.1 lists the prevalence of each parasite species by lake. The mean intensity of each species by lake is given in Table 3.2.

Table 3.3 gives the mean intensities for the two stages of *Pomphorhynchus bulbocolli* found in yellow perch at the sampling localities, and the results of paired sample T-tests for the individual localities. In all comparisons, with the exception of Pine Lake, the mean intensity of the juvenile stage was significantly higher than that of the adult form. In the sample from Pine Lake, *P. bulbocolli* was represented by a single adult helminth.

Figure 3.1 depicts the distribution of both *Apatemon gracilis*, which appears restricted to the southern localities, and *Tetracotyle diminuta*, which is only found in the central and northern lakes. Figure 3.2 shows the distribution of *Contracaecum spiculigerum*, which appears restricted to the same region as *A. gracilis*.

Table 3.1: Prevalence of listed parasite species from *Perca flavescens* by locality.

Lake Number	Prevalence of Parasites:													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	0.0	0.0	96.8	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	72.7	0.0	0.0
2	70.0	0.0	90.0	0.0	100.0	0.0	0.0	0.0	50.0	0.0	0.0	10.0	100.0	0.0
3	76.7	46.7	93.3	26.7	10.0	0.0	0.0	0.0	76.7	0.0	0.0	30.0	20.0	0.0
4	30.0	50.0	83.3	20.0	100.0	0.0	40.0	0.0	96.7	0.0	0.0	20.0	100.0	0.0
5	52.6	0.0	73.7	10.5	100.0	0.0	0.0	0.0	78.9	0.0	52.6	21.1	100.0	0.0
6	73.3	0.0	33.3	100.0	13.3	0.0	0.0	0.0	53.3	0.0	0.0	0.0	0.0	0.0
7	88.0	0.0	100.0	0.0	88.0	0.0	0.0	0.0	24.0	0.0	4.0	0.0	100.0	0.0
8	100.0	0.0	66.7	0.0	100.0	100.0	73.3	0.0	76.7	16.7	93.3	0.0	33.3	0.0
9	100.0	0.0	100.0	0.0	100.0	100.0	0.0	0.0	30.8	0.0	92.3	0.0	100.0	0.0
10	0.0	0.0	15.4	0.0	0.0	86.5	0.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0
11	93.2	0.0	27.6	0.0	100.0	100.0	0.0	0.0	55.2	0.0	100.0	0.0	0.0	0.0
12	100.0	0.0	94.7	94.7	100.0	100.0	68.4	5.3	57.9	21.1	84.2	0.0	10.5	0.0
13	33.3	0.0	1.7	100.0	76.7	0.0	33.3	0.0	31.7	1.7	0.0	0.0	50.0	41.7
14	0.0	0.0	90.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16	0.0	0.0	40.0	0.0	0.0	36.7	0.0	0.0	3.3	0.0	23.3	0.0	0.0	0.0

A-*Urocleidus adspectus*, B-*Apatemon gracilis*, C-*Diplostomulum scheuringi*, D-*Diplostomum adamsi*, E-*Crepidostomum isostomum*, F-*Tetracotyle diminuta*, G-*Bothriocephalus cuspidatus*, H-*Ligula intestinalis*, I-*Proteocephalus* sp., J-*Triaenophorous nodulosus*, K-*Pomphorhynchus bulbocolli*, L-*Contracaecum spiculigerum*, M-*Raphidascaris acus*, N-*Ergasilus caeruleus*

Table 3.2: Mean intensity of given parasite species of yellow perch by locality. (The standard error is given in brackets below appropriate data)

Lake Number	Mean Intensity of Parasites:													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	0.0	0.0	7.1 (0.3)	0.0	1.4 (0.0)	0.0	0.0	0.0	0.0	0.0	0.0	3.0 (0.2)	0.0	0.0
2	3.1 (0.6)	0.0	6.1 (1.1)	0.0	229.1 (57.8)	0.0	0.0	0.0	2.2 (0.3)	0.0	0.0	1.0 (0.0)	133.3 (31.4)	0.0
3	13.2 (3.6)	1.9 (0.1)	6.5 (0.9)	1.0 (0.0)	4.3 (0.9)	0.0	0.0	0.0	24.0 (6.8)	0.0	0.0	1.4 (0.2)	1.0 (0.0)	0.0
4	6.5 (0.9)	1.5 (0.1)	7.6 (1.5)	1.3 (0.1)	69.0 (12.5)	0.0	1.5 (0.1)	0.0	93.4 (21.0)	0.0	0.0	2.7 (0.3)	24.4 (2.6)	0.0
5	14.6 (3.9)	0.0	3.3 (0.5)	1.0 (0.0)	110.4 (16.3)	0.0	0.0	0.0	17.5 (6.1)	0.0	2.5 (0.4)	1.0 (0.0)	51.3 (8.8)	0.0
6	6.1 (0.8)	0.0	1.2 (0.1)	15.9 (3.3)	1.5 (0.2)	0.0	0.0	0.0	5.8 (1.2)	0.0	0.0	0.0	0.0	0.0
7	15.6 (3.6)	0.0	7.3 (1.3)	0.0	6.9 (1.1)	0.0	0.0	0.0	5.2 (1.1)	0.0	1.0 (0.0)	0.0	58.0 (11.4)	0.0
8	65.7 (13.5)	0.0	1.8 (0.2)	0.0	107.6 (12.9)	46.3 (15.1)	4.5 (0.7)	0.0	12.0 (3.3)	1.4 (0.1)	7.6 (0.9)	0.0	1.5 (0.1)	0.0
9	156.8 (34.4)	0.0	12.8 (1.9)	0.0	44.5 (11.6)	7.6 (1.1)	0.0	0.0	4.7 (1.0)	0.0	12.5 (3.4)	0.0	60.9 (17.7)	0.0

A-*Urocleidus adspetus*, B-*Apatemon gracilis*, C-*Diplostomulum scheuringi*, D-*Diplostomum adamsi*, E-*Crepidostomum isostomum*, F-*Tetracotyle diminuta*, G-*Bothriocephalus cuspidatus*, H-*Ligula intestinalis*, I-*Proteocephalus* sp., J-*Triaenophorus nodulosus*, K-*Pomphorhynchus bulbocolli*, L-*Contracaecum spiculigerum*, M-*Raphidascaaris acus*, N-*Ergasilus caeruleus*

Table 3.2 (continued from previous page)

Lake Number	Mean Intensity of Parasites:													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
10	0.0	0.0	1.0 (0.0)	0.0	0.0	4.7 (0.9)	0.0	1.0 (0.0)	0.0	0.0	0.0	0.0	0.0	0.0
11	11.1 (1.6)	0.0	1.8 (0.3)	0.0	37.1 (3.3)	12.0 (1.3)	0.0	0.0	13.1 (5.2)	0.0	17.7 (1.8)	0.0	0.0	0.0
12	116.2 (12.1)	0.0	18.7 (2.5)	14.1 (2.5)	50.1 (9.6)	29.4 (9.4)	8.5 (3.3)	1.0 (0.0)	9.1 (3.9)	2.3 (0.6)	14.2 (1.8)	0.0	1.0 (0.0)	0.0
13	5.6 (0.8)	0.0	1.0 (0.0)	233.5 (15.9)	27.1 (3.9)	0.0	2.5 (0.2)	0.0	2.8 (0.3)	1.0 (0.0)	0.0	0.0	7.3 (1.0)	3.1 (0.6)
14	0.0	0.0	3.1 (0.3)	0.0	0.0	1.0 (0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16	0.0	0.0	1.4 (0.2)	0.0	0.0	2.9 (0.5)	0.0	0.0	1.0 (0.0)	0.0	3.9 (0.6)	0.0	0.0	0.0

A-*Urocleidus adspectus*, B-*Apatemon gracilis*, C-*Diplostomulum scheuringi*, D-*Diplostomum adamsi*, E-*Crepidostomum isostomum*, F-*Tetracotyle diminuta*, G-*Bothriocephalus cuspidatus*, H-*Ligula intestinalis*, I-*Proteocephalus* sp., J-*Triaenophorus nodulosus*, K-*Pomphorhynchus bulbocolli*, L-*Contraecum spiculigerum*, M-*Raphidascaris acus*, N-*Ergasilus caeruleus*

Table 3.3: Respective mean intensities of the juvenile and adult stages of the acanthocephalan *Pomphorhynchus bulbocollis*, and the results of paired sample T-tests comparing the mean intensities of the two stages within each sample group. The Type I error rate is 0.05 for all comparisons.

lake no.	mean intensity of juvenile	mean intensity of adult	$T_{(\alpha=0.05)}$	degrees freedom
5	2.0 +/- 0.2	1.8 +/- 0.3	2.475*	8
7	0.0	1.0 +/- 0.0	NA	(n=1)
8	7.0 +/- 0.9	2.3 +/- 0.3	6.854*	27
9	12.5 +/- 3.4	0.0	3.676*	11
11	15.0 +/- 1.5	2.9 +/- 0.5	8.569*	28
12	12.3 +/- 7.6	3.0 +/- 2.8	4.981*	15
16	3.6 +/- 0.6	1.0 +/- 0.0	2.913*	6

*-indicates a significant difference

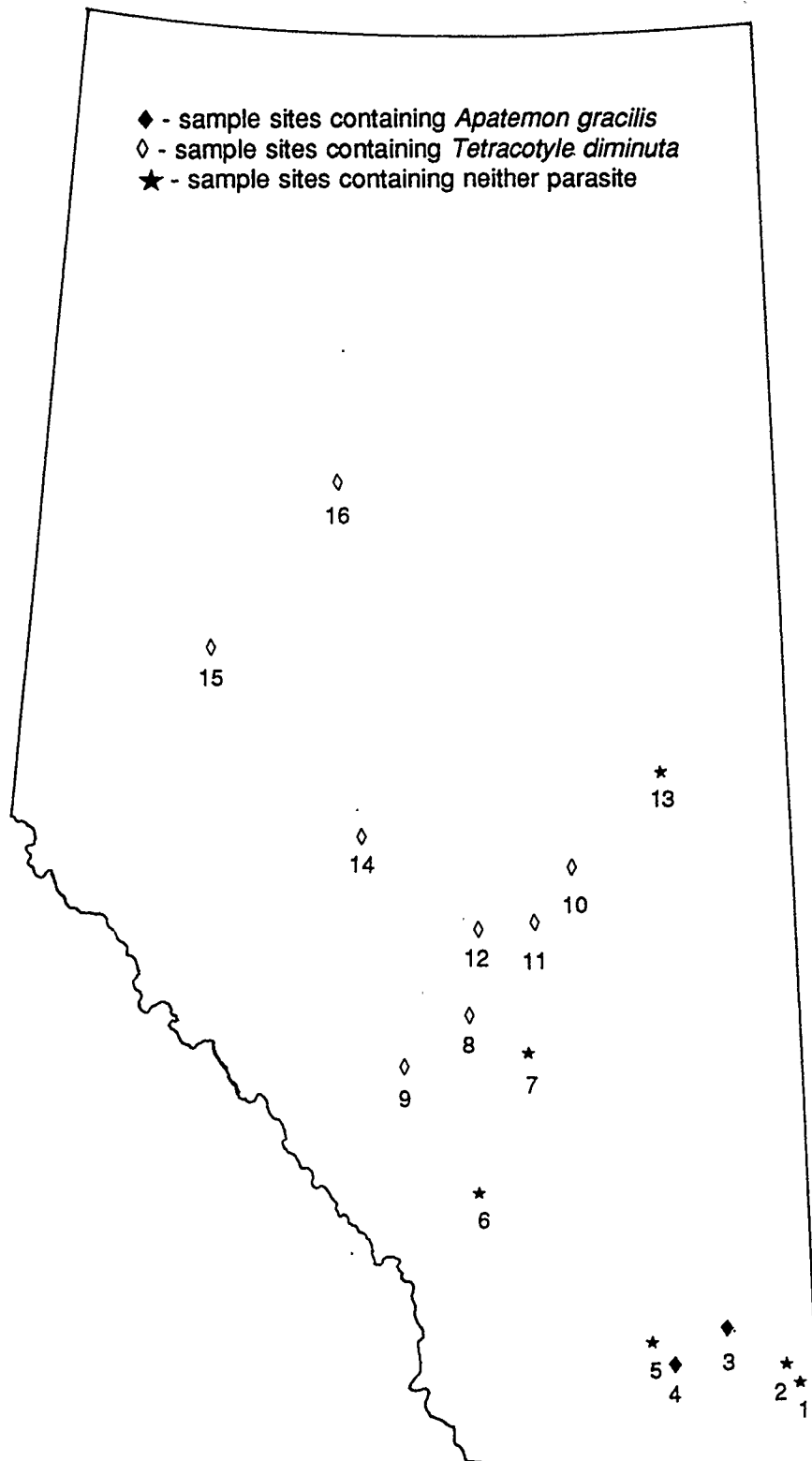


Figure 3.1: A map of Alberta showing the distribution of *Apatemon gracilis* and *Tetracotyle diminuta* throughout the sampling localities.

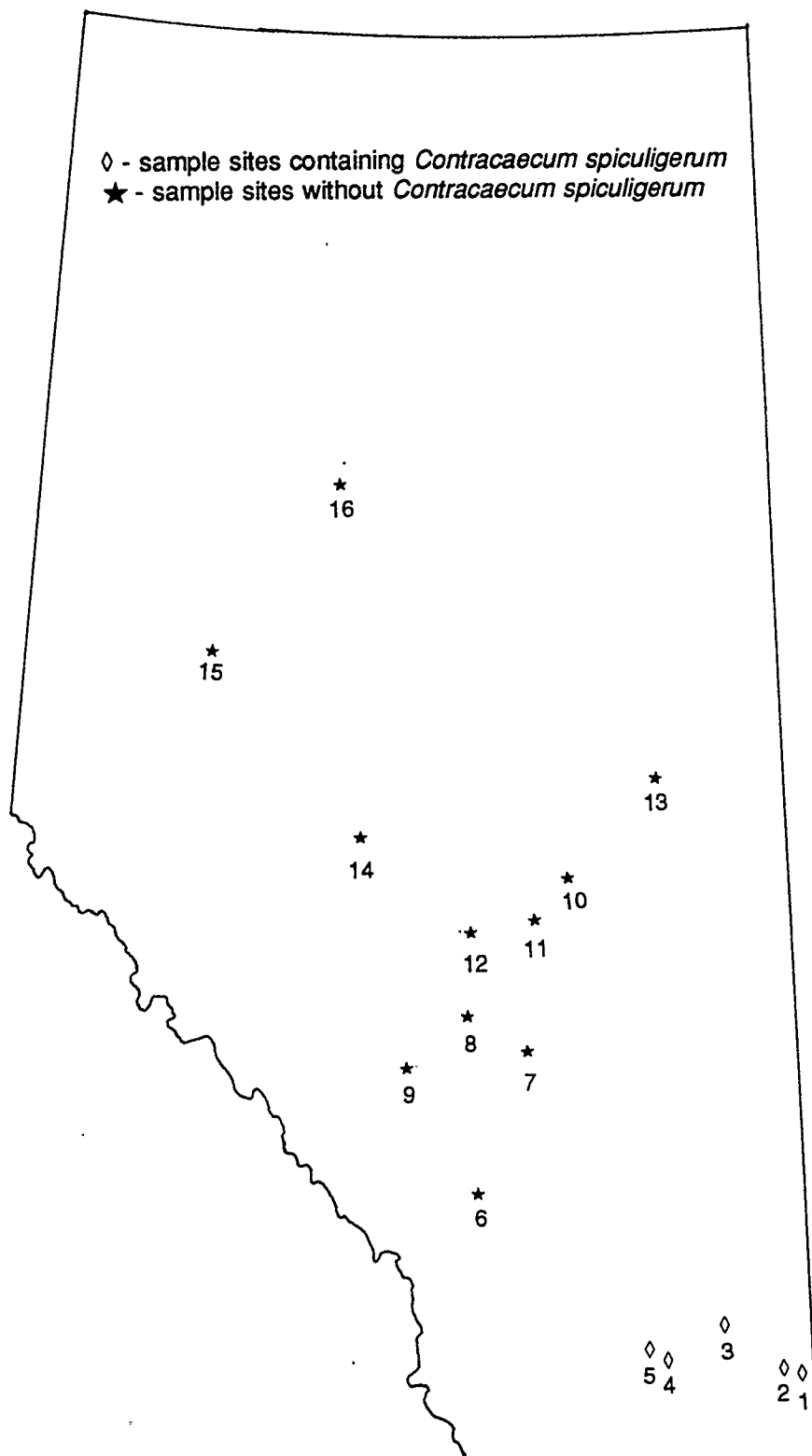


Figure 3.2: A map of Alberta showing the distribution of *Contracaecum spiculigerum* throughout the sampling localities.

DISCUSSION

Urocleidus adspectus - The distribution of *Urocleidus adspectus* in Alberta is rather extensive, with samples of the worm being recovered from 11 of the 16 lakes studied. This monogenean has a direct life cycle and a life span of one year (Cone and Burt 1985). Prevalence ranged from 30 to 100% (Table 3.1), and mean intensities were relatively low with the exception of Burntstick and Pigeon Lakes, where the mean intensity was over 100 worms per infected fish (Table 3.2). *Urocleidus adspectus* is specific to *Perca flavescens* in Canada (Margolis and Arthur 1979).

Apatemon gracilis - The encysted metacercaria of this digenean appear to be restricted to the southernmost lakes in the province (Figure 3.1). Despite their location in the eye of the perch, the low mean intensity (Table 3.2) and prevalence (Table 3.2) in both lakes in which it was found would indicate that it was not a source of great harm to infected perch. Mergansers, cormorants and gulls act as final hosts for the worm through the ingestion of infected fish (Yamaguti 1958).

Diplostomulum scheuringi - Every site examined in this study produced perch with *D. scheuringi* infections. The mean intensity was only higher than 8 worms per fish in Burntstick Lake and Pigeon Lake, and was usually much lower (Table 3.2). These metacercaria occur primarily in the vitreous humor of the eye, and although they have never been found to affect the lens, their large size could cause visual problems for infected fish (Hughes 1929). In experimental infections *D. scheuringi* has been recovered from brain tissue (Hughes 1929; Etges 1961), but no example of this parasite was noted in brain tissue during this study. Sporocysts of this digenean are found in the hepatopancreas and gonads of snails of the genus *Helisoma* (Etges 1961). The definitive host remains unknown, although it is presumed to be a piscivorous bird.

Diplostomum adamsi - This parasite only occurred in 6 of the lakes, with very light representation in 4 of the 6 (Table 3.2). These metacercaria most often lie between the photoreceptor cell layer and the pigment epithelium of the eye, which can, in heavy infections, lead to retinal detachment and loss of vision in the infected perch (Lester and Huizinga 1977). Lester (1977) has estimated that high mortality can be caused by *D. adamsi* in fish infected with 200-400 worms, but such a high mean intensity was only observed in Garner Lake (Table 3.2). The metacercaria appear to be specific to *Perca flavescens*, with lymnaid snails acting as first intermediate hosts (Lester and Huizinga 1977). Only herring gulls have been successfully infected experimentally with *D. adamsi*.

Crepidostomum isostomum - This digenean occurred in 12 of the sixteen water bodies, often with 100% prevalence (Table 3.1). At Spruce Coulee Reservoir, which had been illegally stocked in 1985 or 1986, the only fish infected with *C. isostomum* were those that were older than the presumed time since stocking. This restricted infection combined with a mean intensity of only 1.4 worms per infected fish (Table 3.2) seems to indicate that the fish retained these worms from their previous habitat, and that the life cycle of the parasite could not continue in its new environment. The perch examined came from a stunted population, so increased consumption of intermediate hosts due to the larger body size of older fish could not be the cause of the skewed distribution. Lagoon Lake had a similarly low mean intensity of 1.5 (Table 3.2), but the parasites were spread through several age classes. There would appear to be the possibility that the adults of *C. isostomum* can have a life span of up to 7 years, under certain conditions. Mayfly nymphs have been shown to act as intermediate hosts for the parasite (Hopkins 1931).

Tetracotyle diminuta - This particular species has not been previously recorded from Alberta, although there has been a report of yellow perch infected with *Tetracotyle* spp. in Cache Lake, Alberta (Pybus and Samuel 1978). This small, encysted metacercaria was found in the eyes and in large numbers in the

pericardial cavity and liver of perch from almost all of the central and northern localities. *T. diminuta* was not found in any of the southern lakes. A comparison of the distribution of *T. diminuta* and *Apatemon gracilis* (Figure 3.1) shows a division of the two tetracotylid strigeids which may reflect boundaries set by avian definitive hosts, or molluscan intermediates.

Bothriocephalus cuspidatus - The plerocercoid of this cestode was found in perch from 4 of the 16 lakes. A few juveniles were observed, but no gravid worms were found. Copepods of the genus *Cyclops* act as intermediate hosts for this cestode, that is thought to develop plerocercoid and adult stages within the same final hosts, which include *Esox lucius* and *Stizostedion vitreum* (Essex 1928). In a survey of parasites from Lake of the Woods, Ontario (Dechtiar 1972), no gravid forms of *B. cuspidatus* were found. It would seem, excluding the possibility of yellow perch acting as a second intermediate host, that perch may be a dead end for *B. cuspidatus*. Another possibility is that of a truncated life cycle with characterized by fast larval development, a short lived adult stage, and the loss of the second intermediate host as described by Ginetsinskaya (1970).

Ligula intestinalis - The plerocercoid of this cestode has been previously reported from yellow perch in Alberta (Paetz and Nelson 1970). Only fish from two lakes (Hastings and Pigeon) harboured this parasite, both with low prevalences (Table 3.1). The life cycle involves a copepod first-intermediate host and an avian final host (Ginetsinskaya 1970).

***Proteocephalus* sp.** - This plerocercoid was found in 13 of the 16 water bodies, with a wide range of prevalences (Table 3.1). Plerocercoids of this genus have also been reported from Cache. Lake in Alberta (Pybus and Samuel 1978). The intermediate host for the proceroid is a copepod, although in some species the life cycle is truncated, accelerating development in the copepod to the plerocercoid stage (Ginetsinskaya 1970). In such a case, the worm becomes gravid immediately

upon entering the definitive host, and begins the shedding of eggs. As with *Bothriocephalus cuspidatus*, no gravid worms were encountered in this survey. In the Bay of Quinte in Lake Ontario, a survey that covered a span of one year, no yellow perch with gravid *Proteocephalus* (Tedla and Fernando 1969a) were reported. Again, perhaps yellow perch are either a dead end, or act as a phoretic host for *Proteocephalus*.

Triaenophorus nodulosus - The encysted plerocercoid of *T. nodulosus* was found in only 3 of the 16 localities. The prevalence (Table 3.1) and mean intensities (Table 3.2) were relatively low. This cestode is acquired by yellow perch from cyclopodid copepods, and is passed from yellow perch to the northern pike, *Esox lucius* (Lawler 1969). The low prevalence of the parasite in perch should not be used as an estimate of the metapopulation size of *T. nodulosus* because of the minimal overlapping of the two life cycles. Perch have been shown to spawn as late as July in Canada (Scott and Crossman 1973), while the spawn of *T. nodulosus* in Alberta occurs in May or June (Miller 1945). This could put the young perch out of the temporal window in which infected copepods are available for feeding. For this reason Miller (1945) determined that young burbot (*Lota lota*) are more important as second intermediate hosts.

Pomphorhynchus bulbocollis - This acanthocephalan was found in perch from 7 of the 16 localities sampled. This parasite utilizes a wide range of fish hosts, with an amphipod intermediate. Encysted juveniles are also found in the mesenteries of fish hosts, most likely after transfer from the amphipod, with no increase in development (Ward 1940). Both the adult and the encysted juvenile form were found, with the mean intensity of the adult infection being significantly lower than that of the cystacanth, in all localities, except Pine Lake (Table 3.3), where the species was represented by only one adult worm. This would indicate that the perch are either an unsuitable host for *P. bulbocollis*, or that perhaps established adult worms inhibit the development of subsequent juvenile infections. The adult

worms were observed in almost all instances, to have punctured the wall of the intestine with the proboscis, suggesting that a large infection would be potentially harmful to the host.

Contraecum spiculigerum - The encysted larvae of this nematode were found in the mesenteries of fish from the southernmost water bodies sampled (Figure 3.2). Fish contract the parasite by the ingestion of either infected copepods, or the free living larvae of the nematode (Huizinga 1966). Cormorants, gulls, mergansers and pelicans act as definitive hosts (Hoffman 1967). Transfer of the larvae from the perch intermediate to carnivorous fish is also a possibility (Yamaguti 1961). It would seem that the distribution of *C. spiculigerum* in Alberta (Figure 3.2) is limited in some manner by the range of a piscivorous avian final host.

Raphidascaris acus - The larvae of this nematode were found encysted in the liver and mesenteries of yellow perch in 10 of the 16 localities. Yellow perch are the main natural intermediate host for this parasite in North American freshwater systems (Poole and Dick 1984). The worm is contracted from amphipods containing second stage larvae, or by the ingestion of larvated eggs (Smith 1984). Despite the sometimes extensive liver damage caused by the parasite, no mortality has yet been shown to be associated with larval infections of *R. acus* (Poole and Dick 1984). Pike (*Esox lucius*) acts as a final host for this worm, while walleye (*Stizostedion vitreum*) can be either a second intermediate or a final host for the parasite, depending on which stage of the worm is ingested (Poole and Dick 1986).

Ergasilus caeruleus - This was the only copepod parasite encountered in the study and was only found in the gills of perch from Garner Lake. Species of this genus show little host specificity (Tedla and Fernando 1970b) and have been shown to coexist noncompetitively with *Urocleidus adspectus* (Tedla and Fernando 1970a).

CHAPTER IV
EFFECTS OF SIZE AND AGE
ON THE PARASITE LOAD OF YELLOW PERCH

INTRODUCTION

The parasite load of fish hosts can vary with host age in one of three ways: it can decrease with host age, be independent of host age, or increase with host age. The third relationship is by far the most common; both for numbers of an individual species and for members of a parasite infracommunity (Dogiel 1970). This trend could be explained simply by accumulation and the increased consumption of older, larger fish, but in the case of yellow perch, the short life span (1-3 years) of the most common parasites (Chubb 1964; Ward 1940; Cannon 1972; Tedla and Fernando 1969; Lawler 1969; Cone and Burt 1985) indicates that other factors may be involved.

Crofton (1971) found that the distribution of a species of parasite within a host population is almost always over-dispersed (variance greater than the mean). Of the 6 circumstances he outlined as causes of this distribution, at least 4 could result from age or size differences. The first cause described is one in which hosts encounter a series of random exposures, with the chance of infection changing at each exposure. In instances where parasite life cycles involve a free swimming stage, larger fish would have a greater chance of infection than smaller fish providing phototaxis or chemotaxis is employed by the parasite larva for host location. Any increase in host specificity by the parasite should serve to strengthen this trend.

Infective stages that are not randomly distributed can be another cause of the negative binomial distribution (Crofton 1971). Applying this concept at the infracommunity level, different parasite species utilize different intermediate hosts, causing a clustering of infective stages within certain host food resources. Smaller

fish are more susceptible to parasites utilizing zooplankton as a host, and larger fish are more susceptible to infection from larger prey (i.e. zoobenthos or fish) containing infective stages. This size specific infection, combined with any degree of parasite accumulation over time would lead to older, larger fish suffering from heavier parasite loads than younger fish. Short life spans of parasites, and decreased consumption of smaller prey by larger fish under this system could also account for the decrease in parasite load noted in very old fish by Dogiel (1970).

Crofton's (1971) last two causes of the negative binomial can be directly attributed to age. The first deals with variations in host individuals, the last with temporal variation in infection probabilities.

Size and age in fish are so closely related that it is difficult to separate the effects of the two on parasite load. It may, however, be possible to accomplish this by studying yellow perch, because of their sexual dimorphism. Female perch 3 years and older are larger than males of the same age in most Alberta lakes (Mackay 1989). If these size differences at equivalent ages are measurable and reasonably consistent, the involvement of age and size in the structuring of the size and makeup of the parasite load of yellow perch may be clarified, assuming the feeding habits and behaviours do not differ between the two sexes. Cannon (1973) found that female perch ate proportionally more fish than males of the same size class, with males preferring microcrustacea. The parasitic infection of only one fish-borne parasite reflected this; the data from the other 7 species did not support this conclusion. The small male sample used may have obscured the true relationship. Pending the availability of further data, the assumptions will be taken as correct.

Clarifying the age/size relationship of parasite loads for individual species will provide a better understanding of the relationship between the parasite and the host. An increase in parasite relative density with host age would suggest

accumulation by the host, and a relatively long parasite life span. Increases in relative density that are more size related would be the result of the higher consumption rate of larger fish, or an increase in chance of infection by, for example, host seeking larval stages.

METHODS

For pairwise comparisons a two-sample T-test was employed, and was replaced by the Kruskal-Wallis analysis of variance where the assumptions of that analysis were not met. Comparisons of 3 or more groups were also done with the Kruskal-Wallis test as the assumptions for an analysis of variance were not met.

Data on the mean number of parasite species per host were combined from all of the sample locations, with the exception of Sturgeon Lake, which had not been sampled at the time of writing.

For the analysis of individual parasite species, all data except that for *Diplostomulum scheuringi* and *Contracaecum spiculigerum* are from Garner Lake, which was chosen for its large sample size, and the distribution of the sex and age classes within the sample. Data for *D.scheuringi* and *C.spiculigerum* were taken from Spruce Coulee Reservoir, from a total sample of 204 fish. Fish of ages 2+ to 5+ were utilized for both analyses.

Table 4.1 lists the sample sizes for the 8 age classes used to analyze the change in mean number of parasite species per host with host age. Table 4.2 lists the sample sizes for the 5 length classes used to quantify the relationship between the mean number of parasite species harbored by hosts of a given age class. The sample sizes for the analysis of the age/size relationships of individual parasite species from Garner Lake are given in Table 4.3.

Table 4.1: Age classes of yellow perch and their respective sample sizes used to determine the effect of age on the mean number of parasite species per host.

Age Class (years)	Number in Sample
0+	31
1+	30
2+	100
3+	172
4+	133
5+	98
6+	21
>6+	23

Table 4.2: Size classes of yellow perch, and their respective sample sizes used to determine the effect of host size on the mean number of parasite species per host.

Size Class (mm)	Number in Sample
<117	294
117-141	112
142-166	82
167-191	48
>191	72

Table 4.3: Sample sizes of Garner Lake yellow perch age classes by sex.

Age Class	Female Sample Size	Male Sample Size
2+	9	8
3+	16	9
4+	7	2
5+	6	3

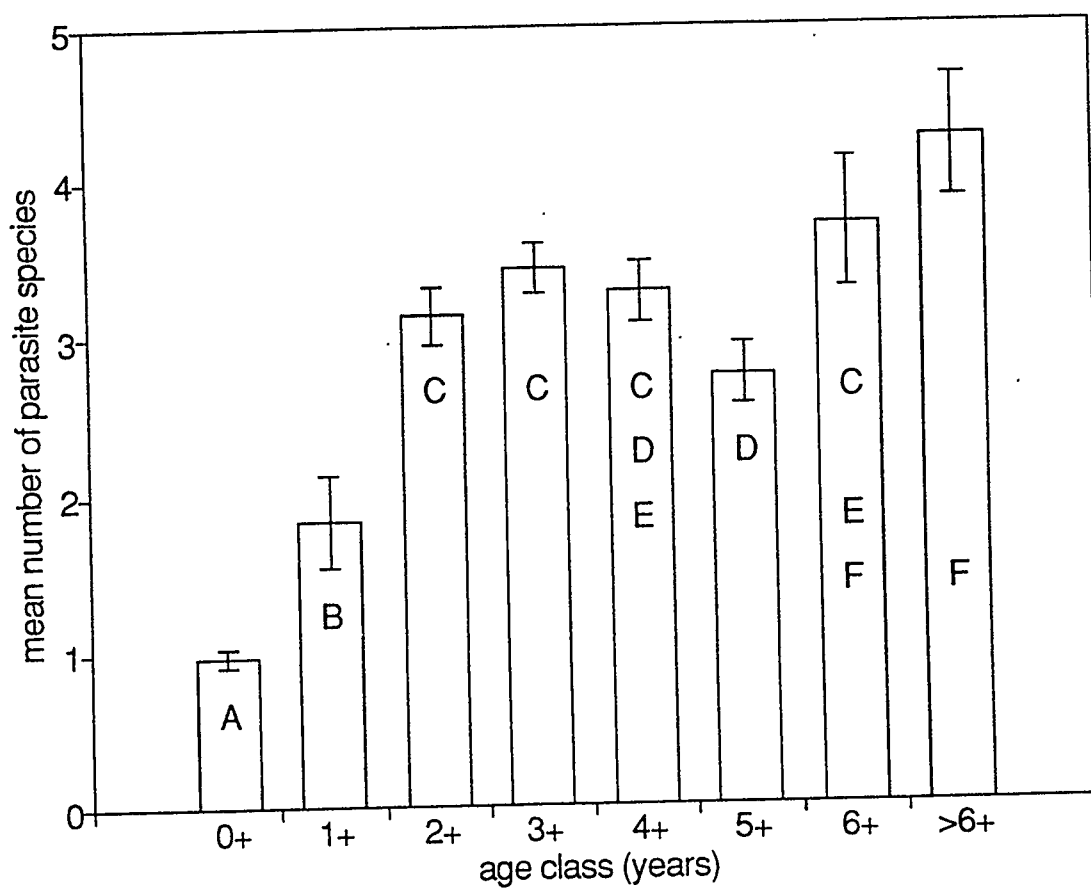


Figure 4.1: The mean number of parasite species harboured by different age classes of yellow perch. Bars with the same letter designation are not significantly different. Standard error bars are given.

Table 4.4: Pairwise comparisons of the mean number of parasite species by age class of yellow perch. The test statistic and statistical significance are given for each. For pairwise comparisons degrees of freedom = 1.

Comparison	Test Statistic (X^2)	Significance
(0+) x (1+)	5.6419	0.0175*
(0+) x (2+)	43.2650	0.0001*
(0+) x (3+)	57.2440	0.0001*
(0+) x (4+)	40.9130	0.0001*
(0+) x (5+)	33.8470	0.0001*
(0+) x (6+)	28.5890	0.0001*
(0+) x (>6+)	37.1250	0.0001*
(1+) x (2+)	13.0280	0.0003*
(1+) x (3+)	18.2000	0.0001*
(1+) x (4+)	12.0160	0.0005*
(1+) x (5+)	6.3551	0.0117*
(1+) x (6+)	11.0780	0.0009*
(1+) x (>6+)	17.5270	0.0001*
(2+) x (3+)	0.2632	0.6080
(2+) x (4+)	0.0384	0.8466
(2+) x (5+)	4.3887	0.0362*
(2+) x (6+)	1.8894	0.1693
(2+) x (>6+)	6.3763	0.0116*
(3+) x (4+)	0.8102	0.3681
(3+) x (5+)	8.7397	0.0031*
(3+) x (6+)	1.0389	0.3081
(3+) x (>6+)	4.2538	0.0392*
(4+) x (5+)	3.2377	0.0720
(4+) x (6+)	1.5758	0.2094
(4+) x (>6+)	5.3271	0.0210*
(5+) x (6+)	5.3592	0.0206*
(5+) x (>6+)	10.7880	0.0010*
(6+) x (>6+)	0.9038	0.3418

* indicates a significant difference

RESULTS

There was a significant difference ($X^2=82.614$, $df=7$, $p=0.0001$) in the number of parasite species per host with increasing age classes of perch (Figure 4.1). The results of the pairwise comparisons are given in Table 4.4.

The mean number of parasite species per host also increased significantly ($X^2=229.68$, $df=4$, $p=0.0001$) with host size, but decreased again in the largest size class (Figure 4.2). The results of the pairwise comparisons for this analysis are given in Table 4.5.

Length increased significantly with fish age in Garner Lake (Figure 4.3; Table 4.6), with female length being significantly higher than male length at all age classes above 2+ years (Figure 4.4; Table 4.7).

Urocleidus adspectus showed no significant difference in relative density between the 2+ and 5+ age classes of Garner Lake perch ($X^2=6.941$, $df=3$, $p=0.0738$).

The relative density of *Crepidostomum isostomum* in Garner Lake perch did differ significantly between host age groups (Table 4.8), showing an increase in the older age classes (Figure 4.5). The relative density of *C. isostomum* was significantly higher in female perch than in males of the 4+ age group. Relative densities of *C. isostomum* did not differ significantly between female and male perch at any other age class (Figure 4.6; Table 4.9).

Figure 4.7 shows the change in relative density of *Diplostomum adamsi* metacercaria with host age in Garner Lake. The relative density in older perch was significantly higher than that in the younger perch (Table 4.10). The relative density of *D.adamsi* is shown separated by host sex at each age class in Figure 4.8. There was no significant difference in *D.adamsi* relative density between the host

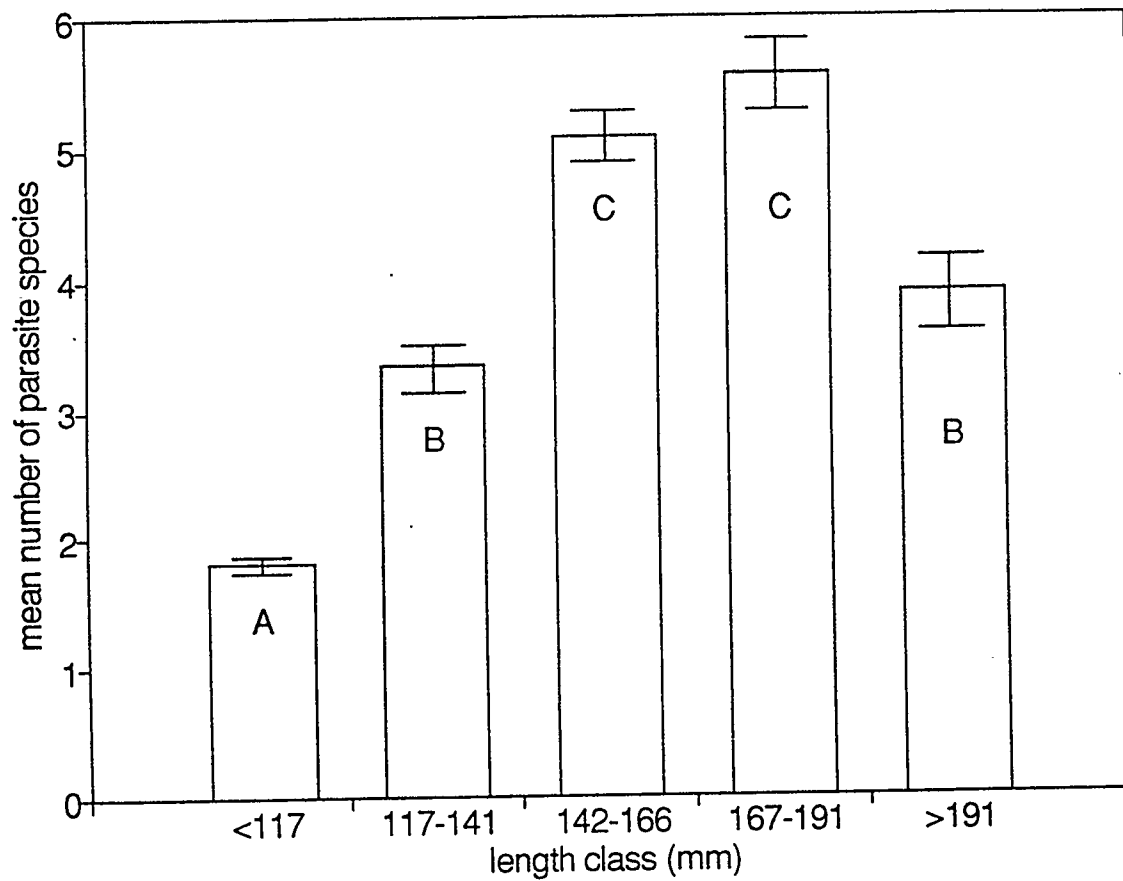


Figure 4.2: The mean number of parasite species harboured by yellow perch in different size classes. Bars with the same letter designation are not significantly different. Standard error bars are given.

Table 4.5: Pairwise comparisons of the mean number of parasitic species by length class of yellow perch. The test statistic and statistical significance are given for each. For pairwise comparisons degrees of freedom = 1.

Comparison	Test Statistic (X^2)	Significance
a x b	58.848	0.0001*
a x c	150.010	0.0001*
a x d	109.560	0.0001*
a x e	40.774	0.0001*
b x c	36.434	0.0001*
b x d	34.252	0.0001*
b x e	2.606	0.1065
c x d	1.692	0.1933
c x e	8.139	0.0043*
d x e	11.726	0.0006*

* - indicates a significant difference

a - < 117mm

b - 117-141mm

c - 142-166mm

d - 167-191mm

e - > 191mm

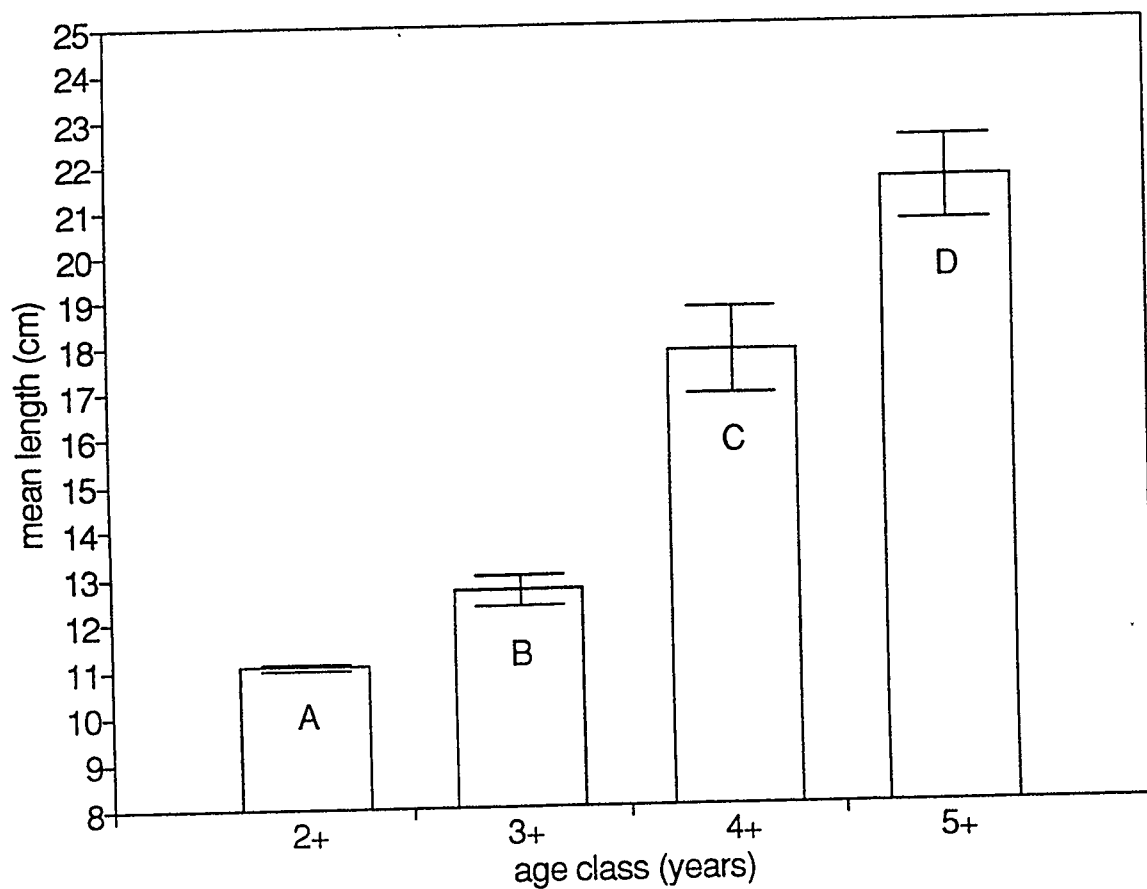


Figure 4.3: The mean length of Garner Lake yellow perch in different age classes. Bars with different letter designations are significantly different. Standard error bars are given.

Table 4.6: Pairwise comparisons of mean length by age class of Garner Lake yellow perch. The test statistic value, degrees of freedom and the statistical significance are given.

Comparison	Test Statistic	Degrees Freedom	Significance
(2+) x (3+)	$X^2=21.961$	1	0.0001*
(2+) x (4+)	$X^2=17.088$	1	0.0001*
(2+) x (5+)	$T=-10.747$	8	0.0001*
(3+) x (4+)	$X^2=14.837$	1	0.0001*
(3+) x (5+)	$X^2=18.672$	1	0.0001*
(4+) x (5+)	$X^2= 6.786$	1	0.0092*

* - indicates a significant difference

Table 4.7: Pairwise comparisons between mean lengths of male and female Garner Lake yellow perch grouped by age class. The test statistic, degrees of freedom, and statistical significance are given.

Source (Age Class)	Test Statistic	Degrees Freedom	Significance
2+	$T =0.625$	15	0.5415
3+	$X^2=6.119$	1	0.0134*
4+	$T =8.083$	7	0.0001*
5+	$T =2.574$	7	0.0368*

* - indicates a significant difference

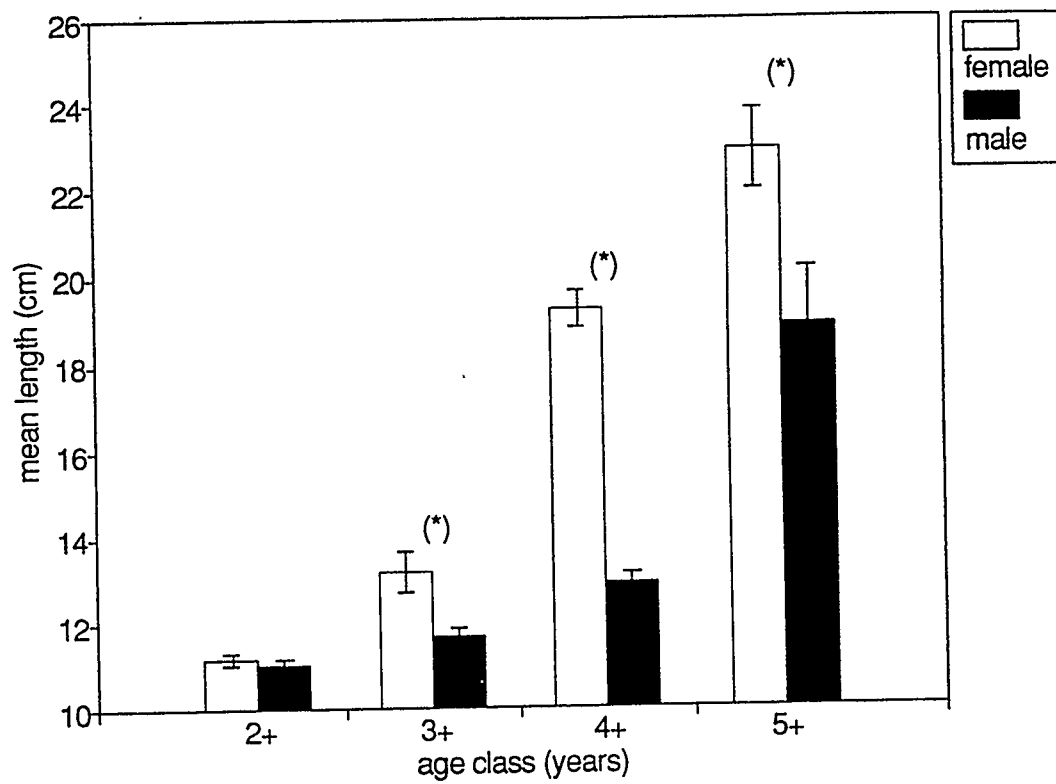


Figure 4.4: The mean lengths of Garner Lake yellow perch males and females at different age classes. (*) - indicates a significant difference between males and females in a given age class. Standard error bars are given.

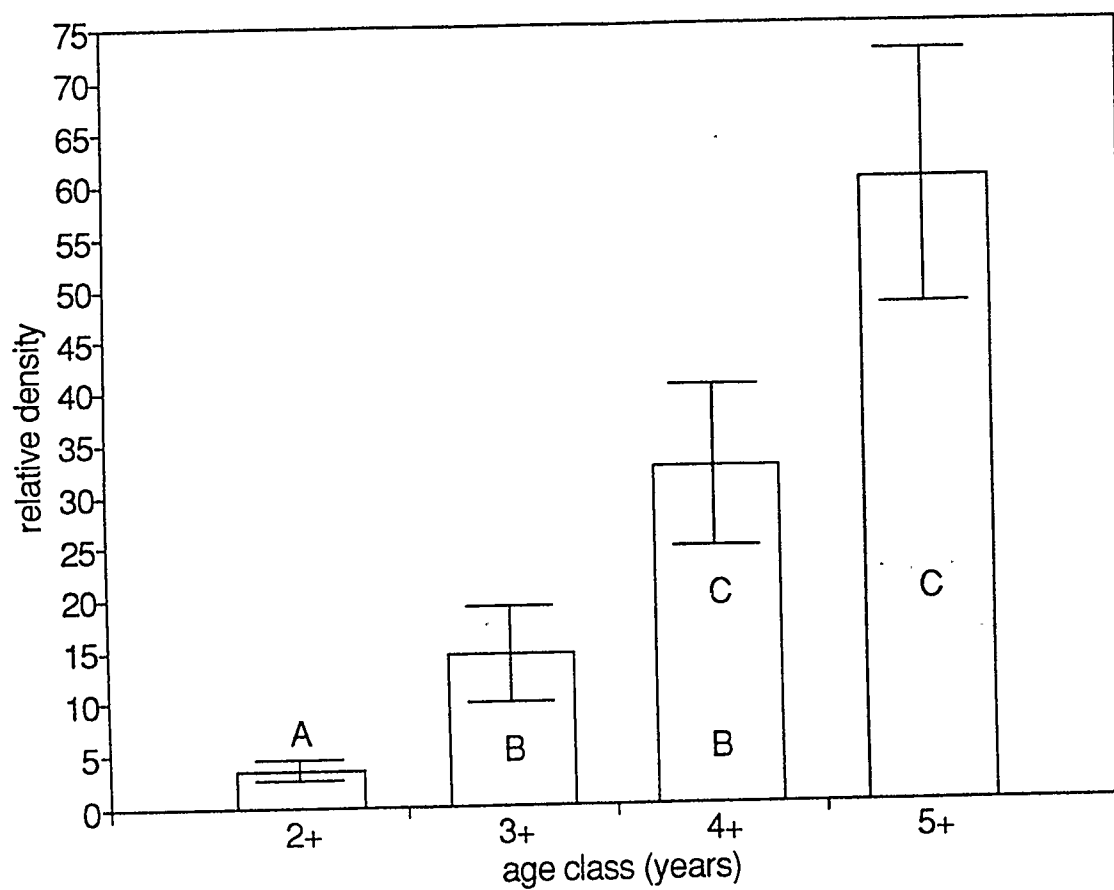


Figure 4.5: Relative density of *Crepidostomum isostomum* in Garner Lake yellow perch at different age classes. Bars with the same letter designation are not significantly different. Standard error bars are given.

Table 4.8: Pairwise comparisons of *Crepidostomum isostomum* relative density in Garner Lake yellow perch by host age class. The test statistic value, degrees of freedom and the statistical significance are given.

Comparison	Test Statistic	Degrees Freedom	Significance
(2+) x (3+)	$X^2 = 4.155$	1	0.0415*
(2+) x (4+)	$X^2 = 7.050$	1	0.0079*
(2+) x (5+)	$X^2 = 12.294$	1	0.0005*
(3+) x (4+)	$X^2 = 3.563$	1	0.0591
(3+) x (5+)	$X^2 = 14.823$	1	0.0001*
(4+) x (5+)	$T = -1.940$	11	0.1477

* - indicates a significant difference

Table 4.9: Pairwise comparisons between *Crepidostomum isostomum* relative densities of male and female Garner Lake yellow perch grouped by age class. The test statistic, degrees of freedom, and statistical significance are given.

Source (Age Class)	Test Statistic	Degrees Freedom	Significance
2+	$X^2 = 0.351$	1	0.5536
3+	$X^2 = 0.099$	1	0.7534
4+	$X^2 = 4.235$	1	0.0396*
5+	$T = 0.018$	7	0.9859

* - indicates a significant difference

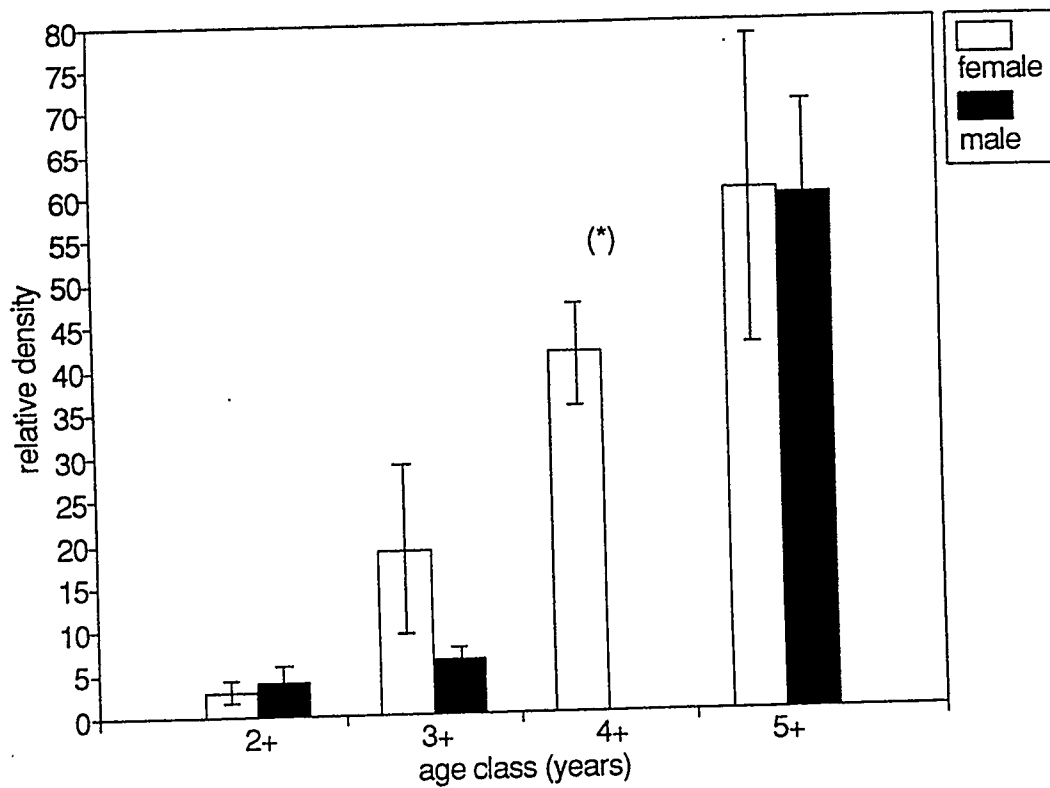


Figure 4.6: The relative density of *Crepidostomum isostomum* in Garner Lake yellow perch males and females, at different age classes. (*) - indicates a significant difference between the sexes at a given age class. Standard error bars are given.

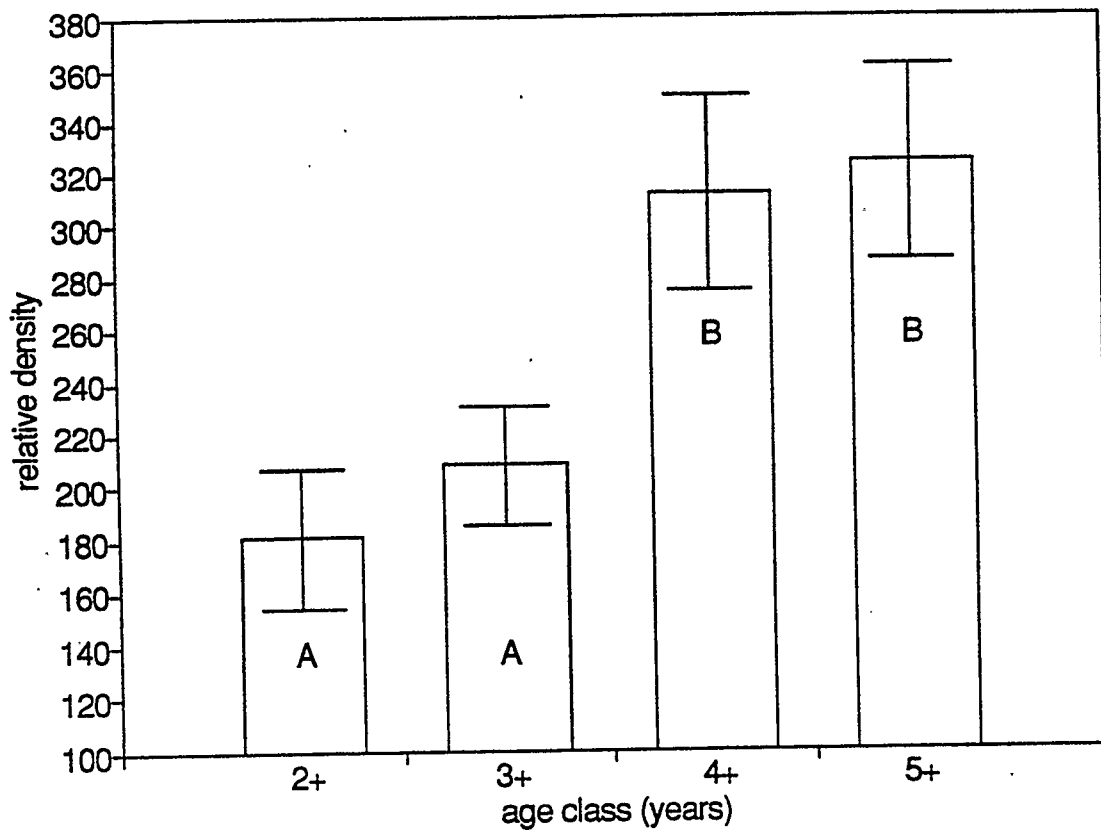


Figure 4.7: Relative density of *Diplostomum adamsi* metacercaria in Garner Lake yellow perch at different age classes. Bars with the same letter designation are not significantly different. Standard error bars are given.

Table 4.10: Pairwise comparisons of *Diplostomum adamsi* relative density in Garner Lake yellow perch by host age class. The test statistic value, degrees of freedom and the statistical significance are given.

Comparison	Test Statistic	Degrees Freedom	Significance
(2+) x (3+)	$X^2 = 0.924$	1	0.3365
(2+) x (4+)	$X^2 = 7.704$	1	0.0055*
(2+) x (5+)	$X^2 = 7.704$	1	0.0055*
(3+) x (4+)	$X^2 = 5.578$	1	0.0182*
(3+) x (5+)	$X^2 = 5.953$	1	0.0147*
(4+) x (5+)	$T = -0.220$	16	0.8286

* - indicates a significant difference

Table 4.11: Pairwise comparisons between *Diplostomum adamsi* relative densities of male and female Garner Lake yellow perch grouped by age class. The test statistic, degrees of freedom, and statistical significance are given.

Source (Age Class)	Test Statistic	Degrees Freedom	Significance
2+	$X^2 = 0.750$	1	0.3865
3+	$X^2 = 0.542$	1	0.4617
4+	$T = -0.719$	7	0.4954
5+	$T = -1.398$	7	0.2048

* - indicates a significant difference

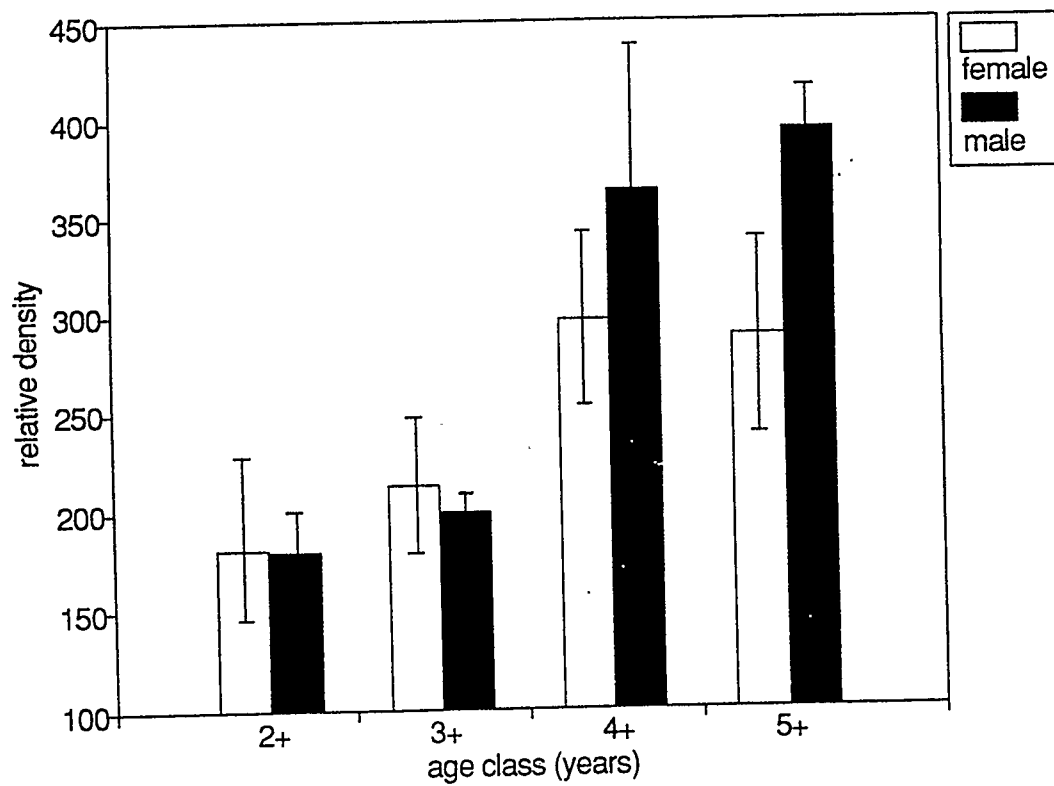


Figure 4.8: The relative density of *Diplostomum adamsi* metacercaria in Garner Lake yellow perch males and females, at different age classes. Standard error bars are given.

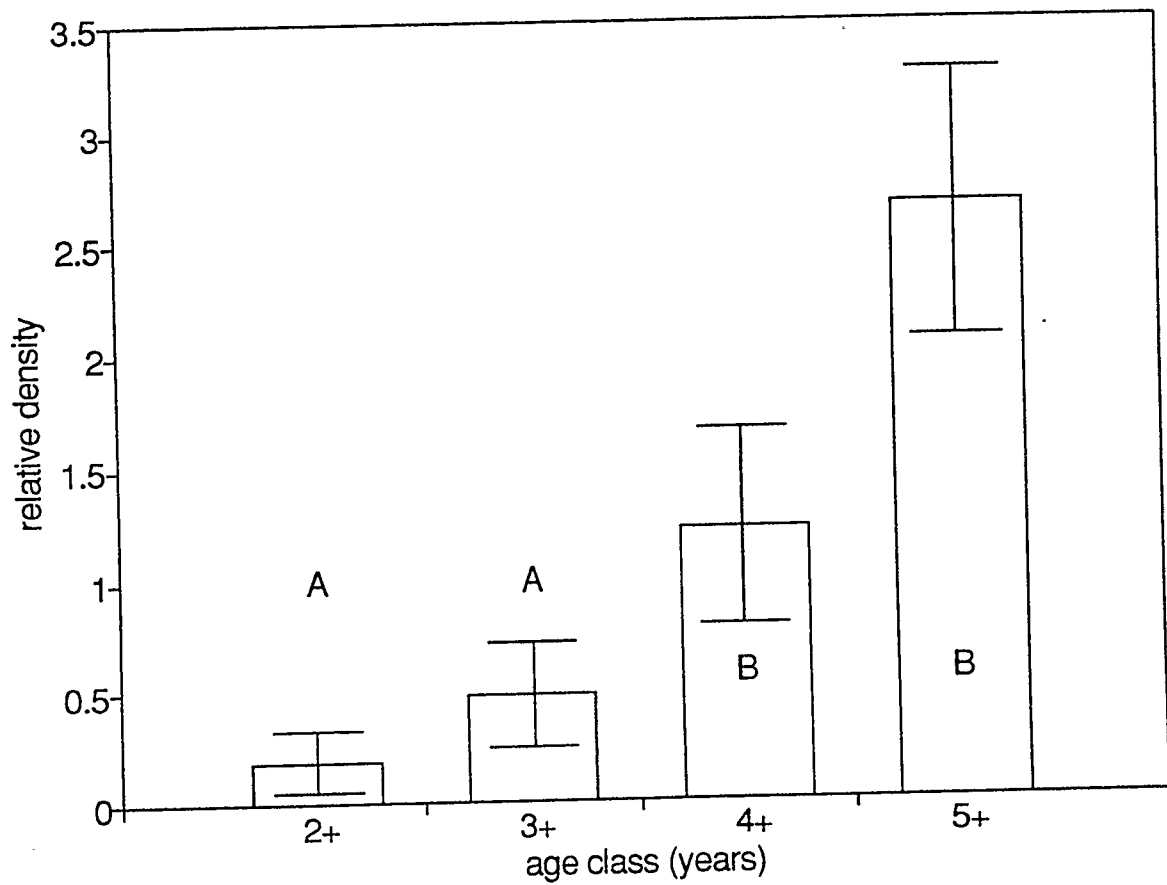


Figure 4.9: Relative density of *Bothriocephalus cuspidatus* in Garner Lake yellow perch at different age classes. Bars with the same letter designation are not significantly different. Standard error bars are given.

Table 4.12: Pairwise comparisons of *Bothriocephalus cuspidatus* relative density in Garner Lake yellow perch by host age class. The test statistic value, degrees of freedom and the statistical significance are given.

Comparison	Test Statistic	Degrees Freedom	Significance
(2+) x (3+)	$X^2 = 0.563$	1	0.4531
(2+) x (4+)	$X^2 = 6.190$	1	0.0128*
(2+) x (5+)	$X^2 = 15.586$	1	0.0001*
(3+) x (4+)	$X^2 = 3.865$	1	0.0493*
(3+) x (5+)	$X^2 = 13.606$	1	0.0002*
(4+) x (5+)	$X^2 = 2.955$	1	0.0856

* - indicates a significant difference

Table 4.13: Pairwise comparisons between *Bothriocephalus cuspidatus* relative densities of male and female Garner Lake yellow perch grouped by age class. The test statistic, degrees of freedom, and statistical significance are given.

Source (Age Class)	Test Statistic	Degrees Freedom	Significance
2+	$X^2 = 2.391$	1	0.1221
3+	$X^2 = 1.381$	1	0.2400
4+	$X^2 = 0.595$	1	0.4404
5+	$T = 1.210$	7	0.2654

* - indicates a significant difference

sexes at any age class (Table 4.11).

The relative density of *Bothriocephalus cuspidatus* in Garner Lake perch (Figure 4.9) showed significant differences between host age classes (Table 4.12), with older perch having a higher intensity of infection per fish. A comparison of *B. cuspidatus* relative densities between male and female perch of the same age class (Figure 4.10) showed no significant differences at any age (Table 4.13).

Raphidascaris acus larvae in Garner Lake perch also showed differences in relative density with host age (Figure 4.11) which were significant (Table 4.14). Differences in relative density between the host sexes (Figure 4.12) were only significant for age 5+ perch (Table 4.15).

Ergasilus caeruleus relative density did not differ significantly between any of the host age classes studied in Garner Lake ($X^2=0.51389$, $df=3$, $p=0.9158$).

In the sample from Spruce Coulee Reservoir, the relative density of *Diplostomulum scheuringi* did not vary significantly with host age ($X^2=0.92983$, $df=3$, $p=0.8182$). There was also no significant change in the relative density of *Contracaecum spiculigerum* at different host age classes ($X^2=7.0976$, $df=3$, $p=0.0689$).

DISCUSSION

The mean number of parasite species harbored by yellow perch shows a trend of increase as host age increases (Figure 4.1); a common characteristic of fish host-parasite relationships (Dogiel 1970). The data were combined from 15 of the 16 lakes studied, and included a number of stunted populations, so that there were a variety of size classes incorporated into each age class. The increase in the mean number of parasite species per host shows a much more consistent trend when the perch are grouped by length (Figure 4.2). This may be an

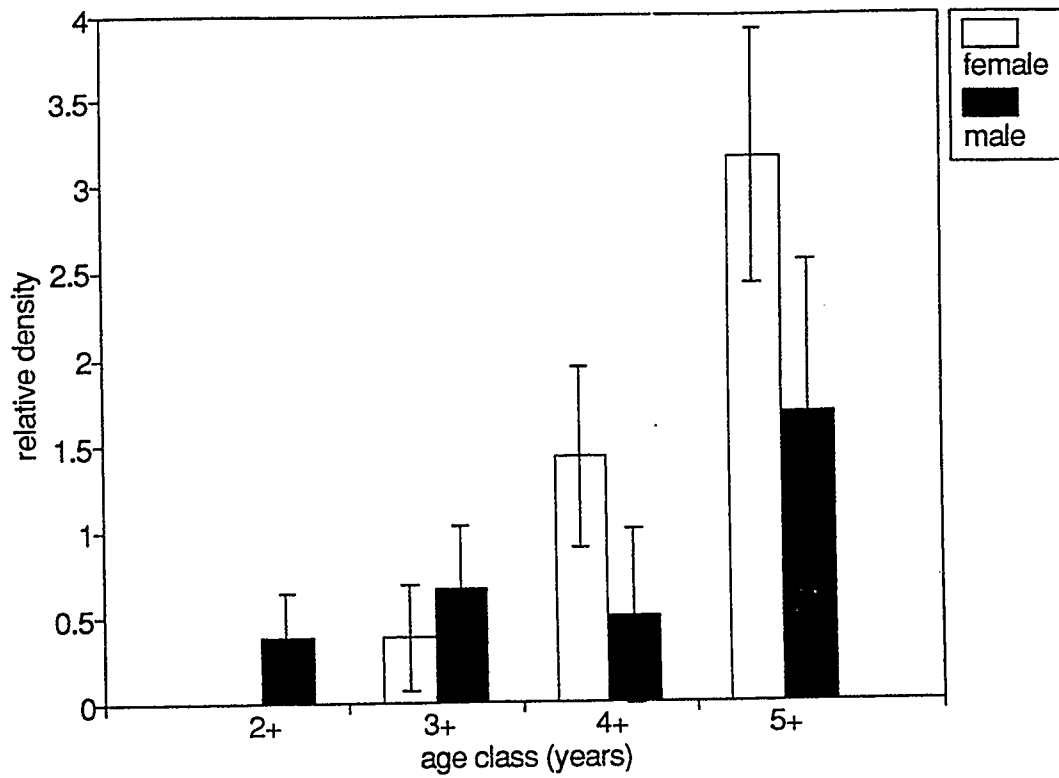


Figure 4.10: The relative density of *Bothriocephalus cuspidatus* in Garner Lake yellow perch males and females, at different age classes. Standard error bars are given.

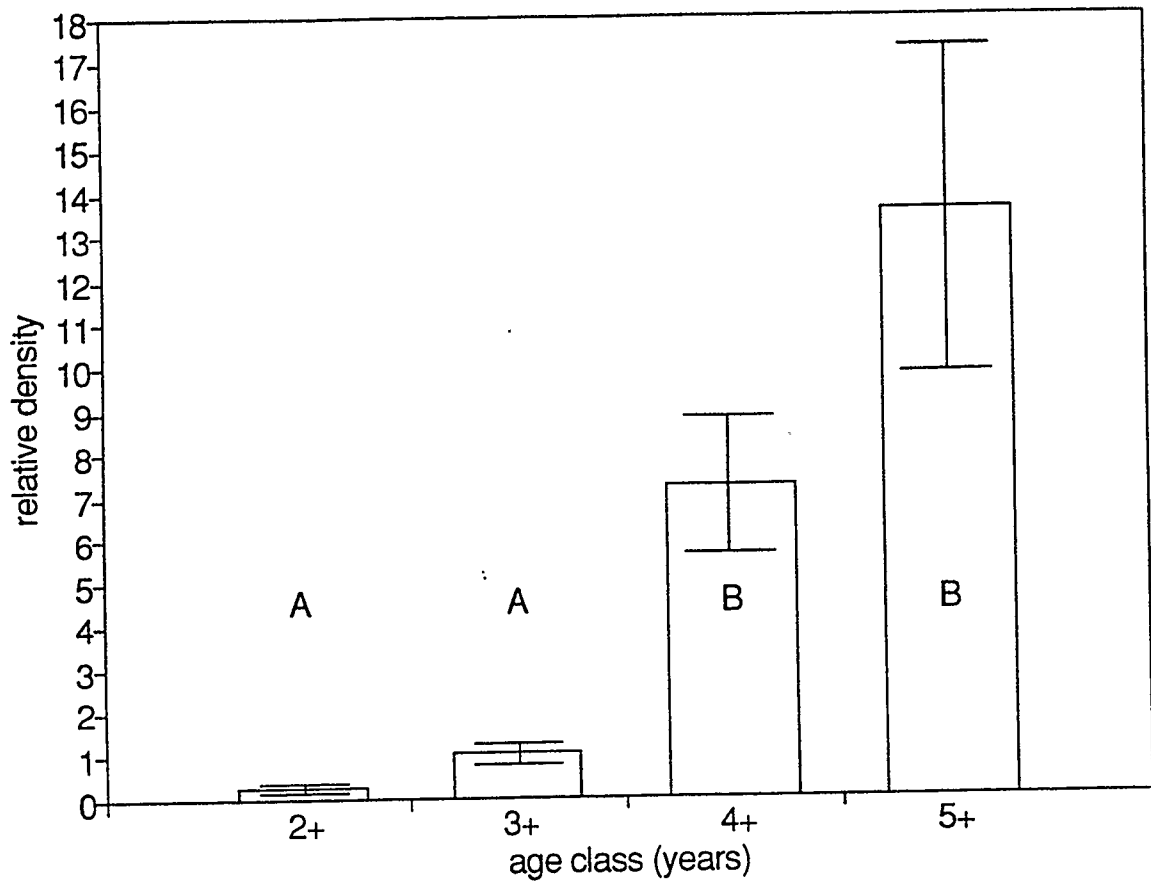


Figure 4.11: Relative density of *Raphidascaaris acus* in Garner Lake yellow perch at different age classes. Bars with the same letter designation are not significantly different. Standard error bars are given.

Table 4.14: Pairwise comparisons of *Raphidascaris acus* relative density in Garner Lake yellow perch by host age class. The test statistic value, degrees of freedom and the statistical significance are given.

Comparison	Test Statistic	Degrees Freedom	Significance
(2+) x (3+)	$X^2 = 3.243$	1	0.0717
(2+) x (4+)	$X^2 = 11.090$	1	0.0009*
(2+) x (5+)	$X^2 = 15.009$	1	0.0001*
(3+) x (4+)	$X^2 = 10.020$	1	0.0015*
(3+) x (5+)	$X^2 = 14.823$	1	0.0001*
(4+) x (5+)	$T = -1.562$	11	0.1477

* - indicates a significant difference

Table 4.15: Pairwise comparisons between *Raphidascaris acus* relative densities of male and female Garner Lake yellow perch grouped by age class. The test statistic, degrees of freedom, and statistical significance are given.

Source (Age Class)	Test Statistic	Degrees Freedom	Significance
2+	$X^2 = 0.000$	1	0.9999
3+	$X^2 = 0.120$	1	0.7294
4+	$T = 0.403$	7	0.6991
5+	$T = 2.460$	7	0.0435*

* - indicates a significant difference

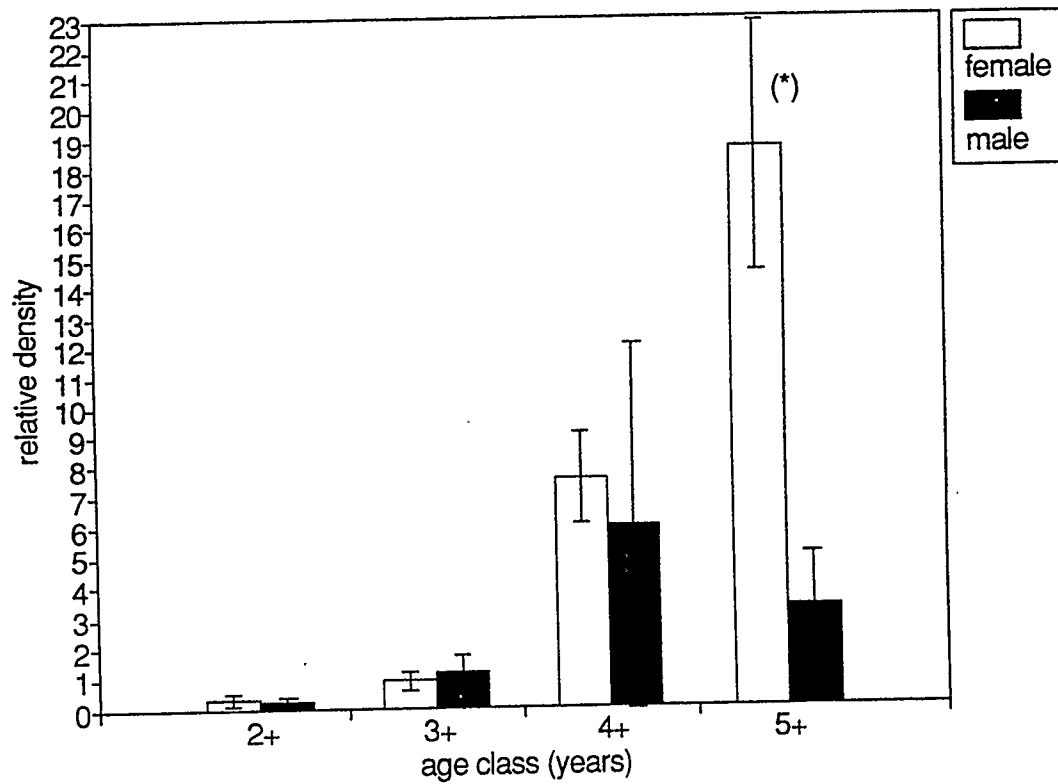


Figure 4.12: The relative density of *Raphidascares acus* in Garner Lake yellow perch males and females, at different age classes. (*) - indicates a significant difference between the sexes at a given age class. Standard error bars are given.

indication that the majority of the parasite infracommunity of yellow perch is size, rather than age dependent, and that accumulation of parasite over time plays a minor role in the composition of the total parasite load.

The comparison by length also shows the decrease in mean number of parasite species in larger perch that has been observed by Dogiel (1970) in a variety of fish species. Larger perch tend to shift their diet preference towards larger prey, consuming a much larger proportion of fish than insects and microcrustacea (Cannon 1973). This would make them less susceptible to the large number of parasites utilizing smaller prey as intermediate hosts. A decrease in the incidence of infection by these parasites, combined with a relatively short parasite life span would lead to a decrease in the richness of the fish's parasite infracommunity.

If a sexual dimorphism in terms of fish size could be determined, the effect of age and size on the relative density of individual parasite species could be clarified. Not surprisingly there is a definite increase in fish length with increasing age (Figure 4.3) in Garner Lake yellow perch. Figure 4.4 displays the sexual dimorphism in this population of yellow perch evidenced by the significantly greater female perch lengths at all age classes greater than 2+ years. This trend agrees with that described for sexual dimorphism in yellow perch by Mackay (1989). This dimorphism creates two distinct size classes for each age class greater than 2+ years within a single population sample. A comparison of the relative density of individual parasite species between male and female perch of the same age class should show whether the relative density of a given parasite species is age or size dependant.

The relative density of *Urocleidus adspectus* did not change significantly over the studied host age classes of yellow perch from Garner Lake. Cone and Burt (1985) have shown an increase in mean intensity of infection during the

midsummer in yellow perch from Magaguadavic Lake, New Brunswick, but did not determine the significance of the trend. The low prevalence and mean intensity of this parasite may have made the sample size limiting in this analysis.

Crepidostomum isostomum did show a significant increase in relative density with host age in Garner Lake perch (Figure 4.5). There was also a significant difference between the relative density of the digenean parasite in male and female perch at age 4+, followed by the almost identical relative densities of the two sexes at age 5+. This brief size dependency could be the result of the use of mayfly nymphs as second intermediate hosts by *C. isostomum*. The proportion of insects in the diet of yellow perch begins to increase at a fish length of 6-8 cm, reaching a maximum at 10-13 cm standard length (Cannon 1973). Figure 4.4 shows that female perch at the age of 3+ and 4+ years have been at and surpassed the length of that optimal feeding window, while males of the same age are just approaching it. At the age of 5+, both sexes are well past the length where maximal feeding occurs. The utilization of an insect intermediate host causes the relative density of *C. isostomum* to be initially dependent on host size due to the relationship between the increased consumption of potential intermediate hosts and the chance of infection. Once the proportional consumption of insects falls off in larger fish (age 5+) the relationship becomes age dependant, based on the accumulation over time of parasites which is made possible by the hypothesized long life span of the parasite (see Chapter III).

The relative density of *Diplostomum adamsi* metacercaria was shown to increase with host age in Garner Lake perch (Figure 4.7), but there were no significant differences between sexes at any age class. This implies that the metacercariae of *D. adamsi* have an age dependent relative density, with no length dependence. This is supported by Lester (1977) who found no correlation between host length and number of *D. adamsi* in yellow perch from the Bay of Quinte, Lake Ontario. The cercariae of *D. adamsi* lack eyespots (Lester and Huizinga 1977), and

presumably do not use phototaxis as a method of host location. The probability of host infection, therefore, would be a function of host location and not host size. The increased relative density with host age must then be the result of parasite accumulation over time, implying that the metacercarial stage of *D. adamsi* is relatively long lived.

The plerocercoids of *Bothriocephalus cuspidatus* also displayed an increase in relative density with host age in Garner Lake perch (Figure 4.9). There was no significant difference in relative density between male and female perch at any age class (Figure 4.10), which again implies accumulation, and a long lived larval stage. This information, when combined with the lack of adult worms found in any sample (see Chapter III) shows that the possibility of yellow perch acting as an intermediate host for *B. cuspidatus* is perhaps worthy of study.

The relative density of the encysted larvae of *Raphidascaris acus* did increase with the age of host Garner Lake perch (Figure 4.11), and showed a significant difference between age 5+ male and female perch (Figure 4.12). The age dependency of the parasite implied in the 2+ to 4+ age classes is to be expected from a long lived, encysted larval stage, but the suggested size dependency in the 5+ age class is difficult to explain. Yellow perch contract the parasite by ingesting larvated eggs, or amphipods and chironomids infected with the second stage larva of the parasite (Smith 1984), neither method offering size limitation past the age of 2+. One possible explanation is that perch can become infected by eating other infected fish, with no further development of the parasite, as has been shown in *Contracaecum spiculigerum* (Yamaguti 1961).

Ergasilus caeruleus showed no change in relative density between age classes in Garner Lake perch. Species of this genus lack host specificity (Tedla and Fernando 1970a), and presumably do not utilize phototaxis for host location,

which would negate any size dependency. This type of relationship may also suggest a short life span for this parasite.

Perch sampled from Spruce Coulee Reservoir showed no significant difference in the relative density of *Diplostomulum scheuringi* between age classes. The cercariae of this strigeid fluke have been shown not to use phototaxis as a method of host location, increasing their activity only under the influence of mechanical stimulation (Etges 1961). As with *Diplostomum adamsi*, host size would, therefore, not play a role in the probability of infection. The lack of an increase in relative density of the parasite with host age may be indicative of a short life span for this parasite.

The relative density of *Contracaecum spiculigerum* in perch from Spruce Coulee Reservoir also did not change significantly with host age. Infection by the ingestion of copepods would be a common occurrence in this perch population, which was stunted. This stunting would also have prevented much of the piscivorous activity seen in older, larger perch, thus clouding any size relationships that could have occurred from the eating of fish infected with *C. spiculigerum*.

Although larger sample sizes from Garner Lake may have served to clarify some of the observed relationships, it has been shown that the sexual dimorphism in yellow perch can be a useful tool for the study of host-parasite relationships.

It can also be inferred from the data that host size and age differences in parasite infection can account for some degree of the overdispersion of parasites within a host population.

CHAPTER V

FACTORS AFFECTING THE COMPONENT PARASITE COMMUNITY STRUCTURE IN YELLOW PERCH

INTRODUCTION

The theory of island biogeography (MacArthur and Wilson 1967) states that the number of species on an island should increase with increasing island size. If individual water bodies act as insular habitats, the number of parasite species comprising a given component community should be greater in larger water bodies. This trend has been shown in the helminthic parasite component community of brown trout, *Salmo trutta fario*, in the lakes of Great Britain (Kennedy 1978a), and in parasite communities of salmonids in insular Newfoundland (Marcogliese and Cone 1991).

In apparent contrast, no correlation between the number of parasite species and lake size was found in a study of char, *Salvelinus alpinus*, on Bear Island in the Arctic near Spitzbergen (Kennedy 1978b). Although the proportions of the recorded species were different, the same five parasite species inhabited all three lakes, presumably because only copepods were present to act as intermediate hosts, which precluded the establishment of any digenean, cestode, or acanthocephalan parasites. The island itself is small (178 km²), and lies 386 km from the mainland of Norway. It is presumed to possess a fauna that has colonized the island only since the last glaciation. These lakes must be considered as islands within an island that has not yet reached an equilibrium point such as that described by MacArthur and Wilson (1967), where immigration rates equals the rate of extinction.

Arrhenius (1921) theorized that the species-area relationship is a power function ($S=kA^z$) that can be approximated by a double log transformation ($\log S = \log k + z \log A$). It was argued that this function would give rise to improbably high

estimates of the species richness of large areas (Gleason 1922) and that the species-area relationship is most likely exponential ($S = \log k + z \log A$). Preston (1962) assumed that the exponential relationship was a sampling distribution derived from a truncated underlying log-normal distribution and, thus, postulated that given "true isolates" and a large number of species (50-100), the species-area relationship is best defined by the power function (log/log) model. Preston (1962) also determined that the canonical slope of the relationship should ideally be 0.262, but can range from 0.20-0.40. Preston's work has led to the near uniform acceptance of the power function as the appropriate model for the species area relationship (Conner and McCoy 1979).

Conner and McCoy (1979), through the analysis of 100 species-area data sets, have shown that the power function model should not be universally accepted, as it accounted for little more than a third of the data sets studied. The good fit ascribed to the power function model can be attributed to the ability of the double log transformation to convert virtually any monotonic function into a straight line (Preston 1962). According to Conner and McCoy (1979) either of the two models are acceptable, providing the relationship is linearized and scatter is minimized. If both models meet the assumptions of a Type I regression analysis, then the one giving the highest r value should be taken as the best model.

The regular occurrence of Preston's (1962) canonical slope of 0.20-0.40 is an expected characteristic of any regression system with a high r value and a small range in the dependent variable relative to that of the independent variable (Conner and McCoy 1979). Slope values falling within this range should be considered as the null hypothesis for these slopes, indicating a correlation between species and area devoid of a functional relationship, with, perhaps, only slopes falling outside of this range possessing any biological significance (Gould 1971).

The parasite component community of freshwater fish can be divided into

two subgroups, those that are allogenic and mature in non-piscine vertebrates such as fish and mammals, and those that mature in fish, and are termed autogenic (Lincoln et al 1982). Esch et al (1988), working in Great Britain, found parasite colonization to be a major determinant of helminth community structure in aquatic ecosystems. In perch it was found that autogenic species contributed nothing to helminth community similarity between and within localities, presumably due to their limited colonization potential.

Wisniewski (1958) has stated that the overall parasite community in a system is characterized by the parasites of the numerically dominant hosts, and that eutrophic water bodies, particularly shallow ones, will be dominated by the parasitic fauna of birds, and will be characteristic of them. While this may be true of the overall parasite community, the component community of a given species of fish may not reflect this trend.

The evaluation of the species-area relationship in yellow perch from naturally occurring populations in Alberta, combined with some analysis of dominant species and lake trophic status and primary production, should provide an understanding of what factors dominate perch parasite component community structure in Alberta, and may have value for predictive purposes.

METHODS

Five of the lakes studied were known to have naturally occurring populations of yellow perch, and have not been subject to stocking. These lakes, along with their trophic status, morphometric characteristics and nutrient data are listed in Table 5.1. Morphometric and nutrient data are from Mitchell and Prepas (1990).

A type I regression analysis was used to determine the dependence of species richness (the number of metazoan parasite species harboured by perch in a given water body) on lake morphometric characteristics, and was used to

Table 5.1: Morphometric and nutrient data for the five lakes used for the analysis of the dependence of metazoan parasite component community structure of yellow perch on these variables.

Data	Elkwater Lake	Pine Lake	Sylvan Lake	Pigeon Lake	Garner Lake
elevation (m)	1266.4	889.3	936.4	849.5	603.2
surface area (km ²)	2.3	3.9	42.8	96.7	6.2
volume (million m ³)	8.0	20.6	412.0	603.0	50.1
maximum depth (m)	8.4	12.2	18.3	9.1	15.2
mean depth (m)	3.5	5.3	9.6	6.2	8.1
shoreline length (km)	10.8	19.9	36.0	46.0	18.5
shoreline development	2.0	2.8	1.6	1.3	2.1
total phosphorous (µg/l)	43.0	56.0	20.5	32.0	47.0
chlorophyll a (µg/l)	5.9	26.3	3.8	12.0	13.9

predict the number of perch parasites harboured by Sturgeon Lake yellow perch. Pearson's correlation was used to determine the relationship between lake surface area, volume, and shoreline length. Natural log transformation of the independent variable was used in the regression analysis to ensure linearity, as a double log transformation lowered the r^2 value of the estimates, and was therefore, not utilized. The number of autogenic, allogenic, larval, and adult metazoan parasite species harboured by perch in the five lakes were also analyzed in the same manner. The acanthocephalan, *Pomphorhynchus bulbocollis*, was observed in most cases to be present in two distinct stages; larvae encysted in the mesenteries and adults in the gut. In these cases each stage was treated as a separate species for the purpose of analysis. No adult specimens of *Bothriocephalus cuspidatus* or *Proteocephalus* sp. were recovered, and, therefore, both parasites were classified as larval when present in a sample.

Total phosphate and chlorophyll a were used as measures of primary production in the 5 lakes. The numbers of total, larval, autogenic and allogenic metazoan parasites harboured by perch were analyzed for relationship with total phosphate or chlorophyll a counts using Pearson's correlation. The number of larval metazoan species harboured by perch was analyzed for the same relationship with Spearman's rank correlation because the assumption of normality was not met.

Dominance was measured in each lake utilizing the non-parametric Berger-Parker dominance index, $d=N_{max}/N_T$, where N_{max} is the number of parasites recovered belonging to the species with the highest number of parasites in the sample and N_T is the total number of parasites recovered from the sample (Southwood 1978).

RESULTS

Lake volume showed a significant correlation ($r_p=0.9719$, $p=0.0056$) with

surface area as did shoreline length ($r_p=0.9500$, $p=0.0133$). As all of the other morphometric features, with the exception of maximum depth, are a function of one or more of these features, only surface area was used to determine relationships between the perch component parasite community and lake morphometric characteristics.

Species richness was found to increase significantly with the natural log of lake surface area ($F=23.257$, $df=1,3$, $p=0.0170$, $r^2=0.8853$) for the five lakes. Figure 5.1 depicts this relationship.

The number of larval parasite species harboured by perch also increased significantly with the natural log of lake surface area ($F=16.991$, $df=1,3$, $p=0.0259$, $r^2=0.8499$). This relationship is shown in Figure 5.2.

There was no significant dependence of the number of adult parasite species found in perch on the natural log of lake surface area ($F=1.414$, $df=1,3$, $p=0.3199$, $r^2=0.3204$).

The number of autogenic parasite species of perch did show a significant increase with the natural log of lake surface area ($F=12.375$, $df=1,3$, $p=0.0390$, $r^2=0.8049$), as is shown by Figure 5.3.

No significant dependence of the number of allogenic parasite species of perch on the natural log of lake surface area was observed ($F=3.919$, $df=1,3$, $p=0.1421$, $r^2=0.5664$).

Sturgeon Lake has a surface area of 49.1 km². Utilizing the functions defined in Figures 5.1-5.3, it was predicted that Sturgeon Lake should have a total of 10.77 +/- 2.03 total species of perch parasite, of which 7.75 +/- 2.13 should be larval stages and 7.84 +/- 1.85 should be autogenic.

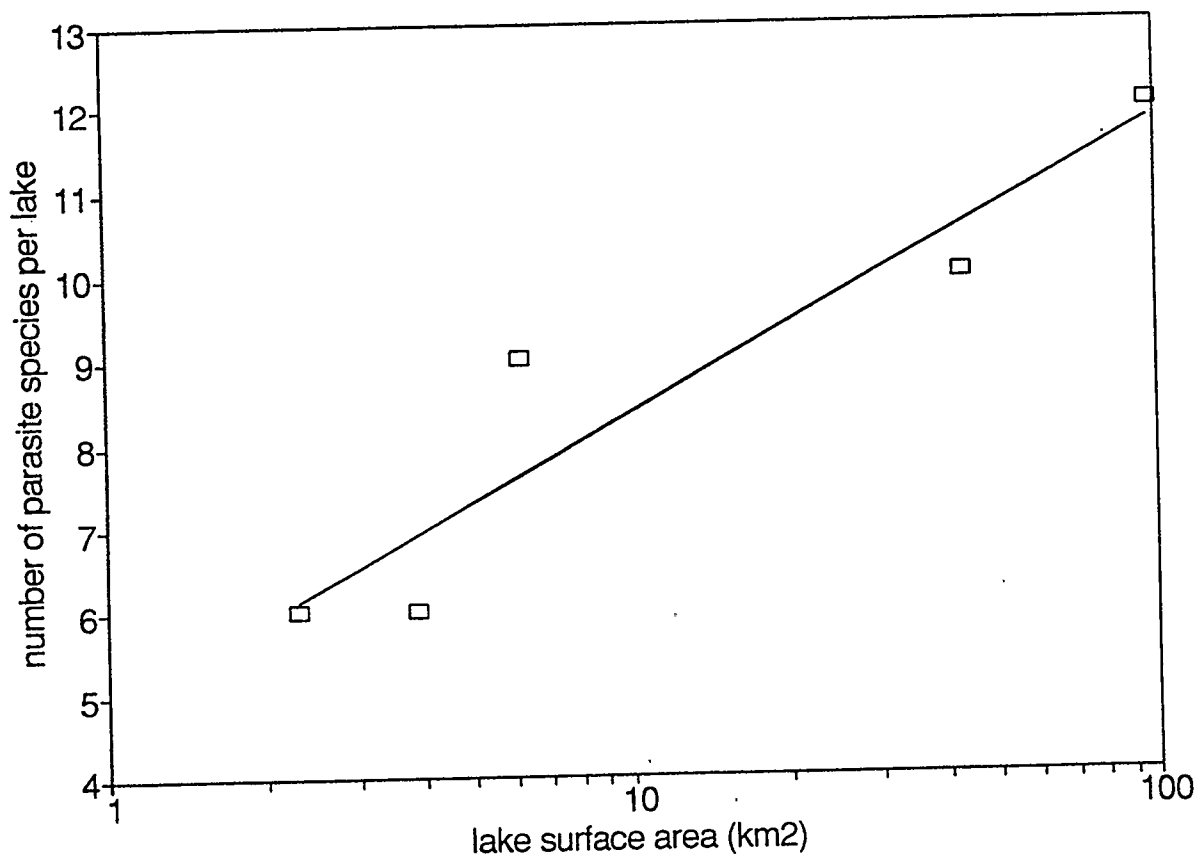


Figure 5.1: The relationship between the species richness of the parasite fauna of yellow perch (total number of perch parasite species per lake) and the natural log of lake surface area. The line of best fit was drawn to fit the following function: total number of species= $1.5226 \cdot \ln(\text{SA}) + 4.8402$. $SS_R = 24.09225$, $SS_E = 3.10775$, $MS_E = 1.03592$.

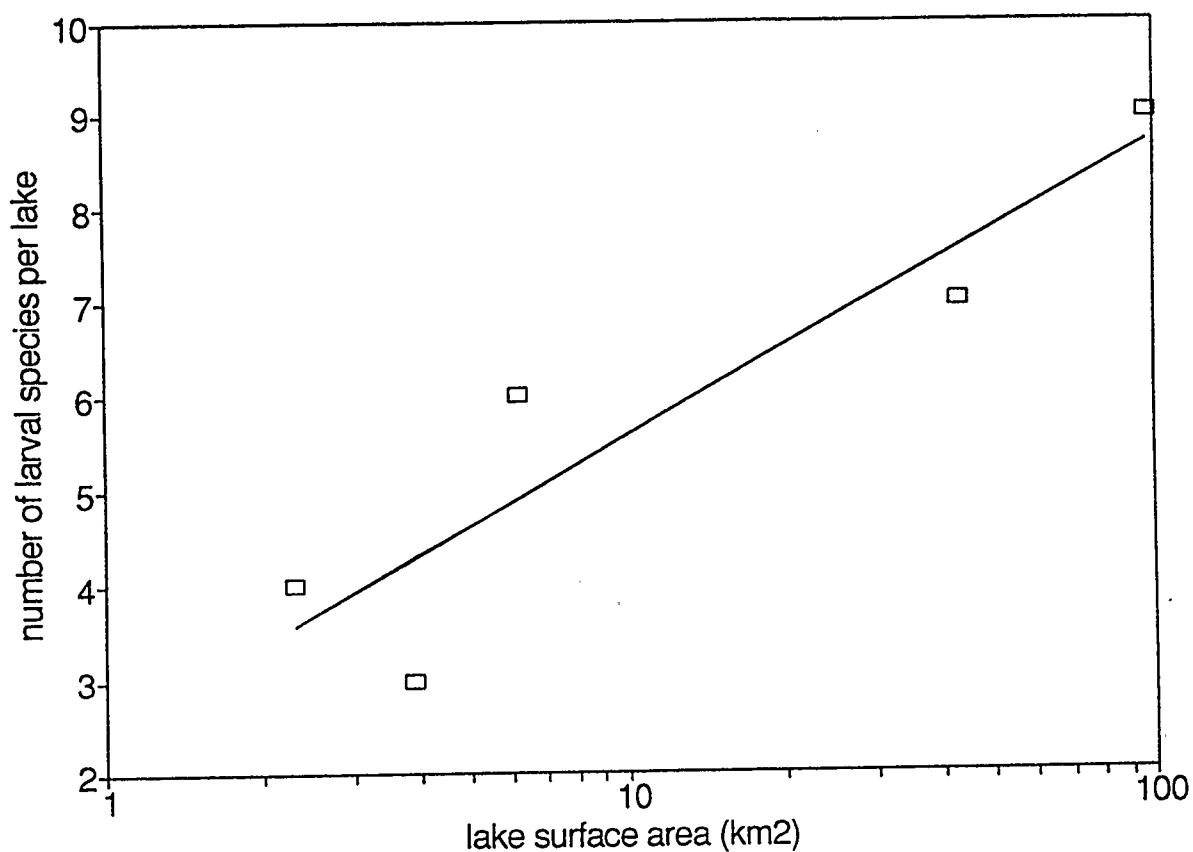


Figure 5.2: The relationship between the number of larval perch parasites in a given lake and the natural log of lake surface area. The line of best fit was drawn according to the equation: number of larval species= $1.3655 \cdot \ln(\text{SA}) + 2.4280$. $SS_R=19.37850$, $SS_E=3.42150$, $MS_E=1.14050$.

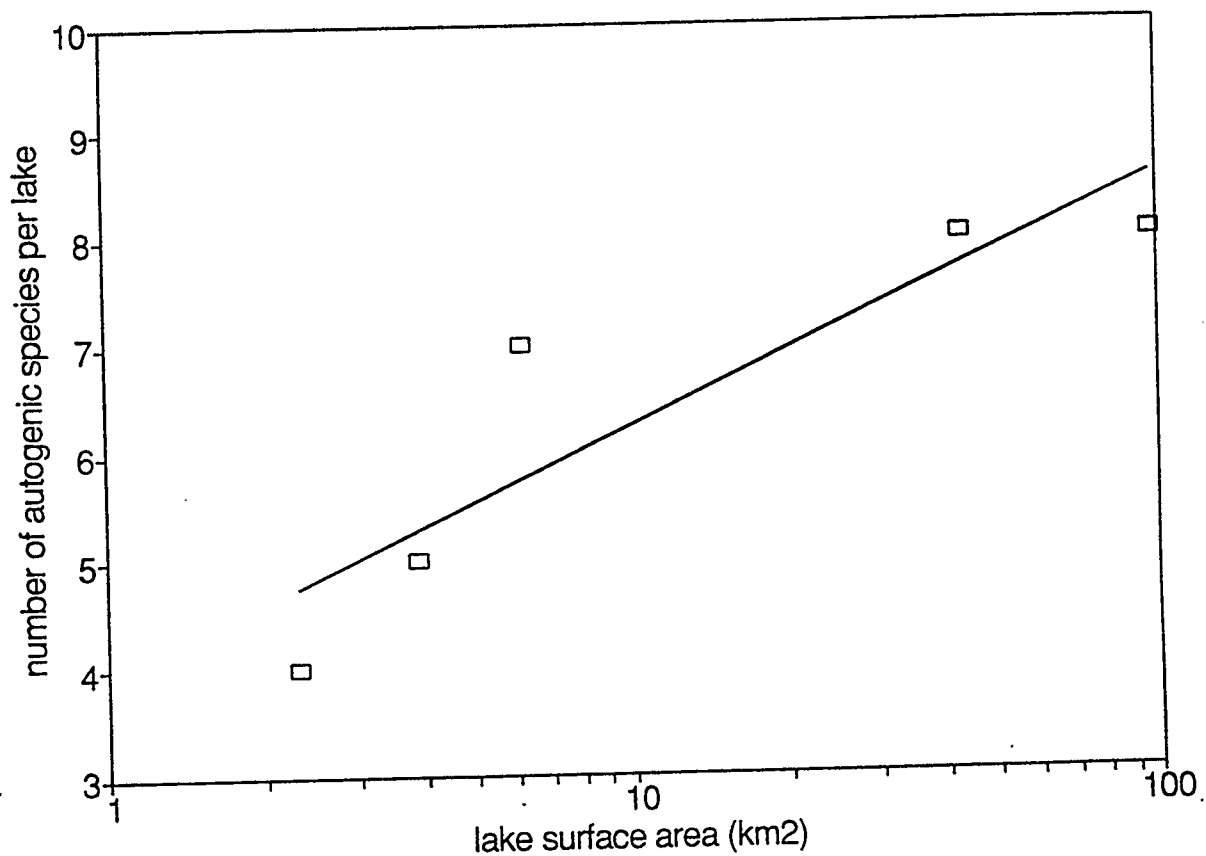


Figure 5.3: The relationship between the number of autogenic perch parasites in a given lake and the natural log of lake surface area. The line of best fit was drawn according to the equation: number of autogenic species= $1.0111 \cdot \ln(\text{SA}) + 3.9032$. $SS_R = 10.62439$, $SS_E = 2.57561$, $MS_E = 0.85854$.

The actual number of parasite species harboured by perch in Sturgeon Lake was 10. Of these species 7 were larval and 7 were autogenic. The number of species was determined from only 3 perch, one 8+ year old female and two 3+ year old males. Three walleye (*Stizostedion vitreum*) were also examined to confirm the presence and identity of the parasites because of the small sample size.

The results of the correlation analysis between the measures of lake primary production (total phosphorous and chlorophyll a) and the number of total, autogenic, and larval metazoan parasites of yellow perch (Table 5.2), showed no significant correlation between these measures of primary production, and species richness.

Table 5.3 lists the dominant species for each of the five lakes, as well as their classification (autogenic or allogenic), and Berger-Parker dominance index values. Of the five lakes only the parasite fauna of Garner Lake perch was dominated by an allogenic species. Table 5.4 lists the five lakes and their respective surface areas, followed by a list of their parasites that were common throughout the province, and showed no geographical restrictions. This was designed to show the apparent dependence of species such as *Bothriocephalus cuspidatus*, *Triaenophorus nodulosus*, and *Ligula intestinalis* on lake surface area in this region, but also indicated that the degree of similarity between lakes of the parasite fauna of perch is primarily the result of the component autogenic species.

Using Table 5.4 as a guide it was predicted that the following species would be present in Sturgeon Lake: *Urocleidus adspectus*, *Crepidostomum isostomum*, *Diplostomulum scheuringi*, *Bothriocephalus cuspidatus*, *Proteocephalus* sp., *Triaenophorus nodulosus*, *Raphidascaris acus*, and both the adult and larval stages of *Pomphorhynchus bulbocolli*. This gives a total of 9 species, 6 of which are larval and 6 of which are autogenic. To match the predicted totals, there

Table 5.2: The results of the correlation analysis of the relationship between the measures of species richness and the measures of lake primary production. For each analysis the test statistic and statistical significance are given. r_p is Pearson's correlation coefficient and r_s is Spearman's correlation coefficient.

species richness	total phosphate	chlorophyll a
total number of species	$r_p = -0.7042$ $p = 0.1843$	$r_p = -0.3482$ $p = 0.5658$
number of autogenic species	$r_p = -0.6939$ $p = 0.1937$	$r_p = -0.2715$ $p = 0.6587$
number of allogenic species	$r_p = -0.5256$ $p = 0.3630$	$r_p = -0.3787$ $p = 0.5297$
number of larval species	$r_p = -0.7440$ $p = 0.1493$	$r_p = -0.4569$ $p = 0.4392$
number of adult species	$r_s = 0.0000$ $p = 1.0000$	$r_s = 0.3535$ $p = 0.5594$

Table 5.3: The dominant species, its classification and Berger-Parker dominance index for each of the five lakes containing natural populations of yellow perch.

Lake Name	Dominant Species	Dominance Index	Classification
Elkwater	<i>Crepidostomum isostomum</i>	0.62	autogenic
Pine	<i>Raphidascaaris acus</i>	0.67	autogenic
Sylvan	<i>Crepidostomum isostomum</i>	0.45	autogenic
Pigeon	<i>Urocleidus adspectus</i>	0.46	autogenic
Garner	<i>Diplostomum adamsi</i>	0.89	allogenic

Table 5.4: List of common perch parasite species in the five lakes containing natural populations of yellow perch.

Lake:	Pigeon	Sylvan	Garner	Pine	Elkwater
Surface Area (km ²):	96.7	42.9	6.19	3.89	2.31
Species:	U.ad	U.ad	U.ad	U.ad	U.ad
	C.is	C.is	C.is	C.is	C.is
	D.sh*	D.sh*	D.sh*	D.sh*	D.sh*
	Prot	Prot	Prot	Prot	Prot
	R.ac	R.ac	R.ac	R.ac	R.ac
	P.bu	P.bu		P.bu	
	B.cu	B.cu	B.cu		
	T.no	T.no	T.no		
	L.in*				

Abbreviations: U.ad-*Urocleidus adspectus*; C.is-*Crepidostomum isostomum*; D.sh-*Diplostomulum scheuringi*; Prot-*Proteocephalus* sp.; R.ac-*Raphidascaris acus*; P.bu-*Pomphorhyncus bulbocolli*; B.cu-*Bothriocephalus cuspidatus*; T.no-*Triaenophorus nodulosus*; L.in-*Ligula intestinalis*.

* indicates an allogenic species

should be an additional 2 species that are larval and autogenic. The only two parasites that have been found in this region matching these parameters are *Diplostomum adamsi* and *Tetracotyle diminuta*.

The actual parasite species occurring in Sturgeon Lake followed the predictions, except for the absence of *Triaenophorus nodulosus* in the sample.

DISCUSSION

Figure 5.1 shows the line of best fit established for the relationship between lake surface area and the species richness of the perch parasite fauna. The line is best approximated by a natural log transformation of lake surface area, and not the log/log power function described by Preston (1962). The exponential model shown emphasizes habitat heterogeneity, rather than a dynamic equilibrium of species exchanges between "islands" (Conner and McCoy 1979).

The five lakes used for this aspect of the study have had natural perch populations for as long as Alberta Fish and Wildlife have been keeping records (Mackay 1989). This leads to the assumption that the yellow perch component parasite community in these lakes is at or near the equilibrium state defined by MacArthur and Wilson (1967), where immigration rates are equal to extinction rates. If this assumption is taken as being valid, then the relationship between lake surface area and species richness should provide a clear view of the effects of lake surface area on parasite component community structure separated from the effects of immigration. The close fit of the line ($r^2=0.8857$), indicates that the differences in trophic status between the five lakes are not large enough to limit the total number of parasite species harboured by perch; a concept supported by the lack of correlation between estimates of parasite species richness and estimates of lake primary production (Table 5.2). This should further isolate the effects of lake surface area.

Another natural population of yellow perch, that of Sturgeon Lake, was sampled to test the validity of this proposed relationship between species number and surface area. The number of parasite species recovered was within the 95% confidence interval of the prediction, as were the number of larval and autogenic species. The small sample size may have led to an underestimate of the species, but the inclusion of one female perch age 8+, and the three walleye in the examination indicates that if further species were recovered they would be rare, perhaps only adding one or two species to the total number, which would still fall within the bounds of the predictions.

Table 5.4 implies that there may be a dependence on lake size for the establishment of certain parasite species. This list was used to determine the possible composition of the Sturgeon Lake yellow perch parasite component community, which was realized in the sample with only one omission, *Triaenophorus nodulosus*. The prevalence of this larval cestode has been consistently low when it has been recovered (Table 3.1; Chapter III), so that if it were present, a much larger sample size would have been required to detect it in the Sturgeon Lake yellow perch population.

The relationship between lake surface area and perch parasite species richness implies that, in the absence of limiting factors such as trophic status and immigration, the number of perch parasite species present in an equilibrium system is determined by the size of the system. In Newfoundland the parasite fauna of salmonids was impoverished in smaller ponds, and higher in medium and large sized water bodies, but no significant differences were observed in the parasite species richness of medium and large lakes (Marcogliese and Cone 1991). All of the lakes they had studied were oligotrophic, and it seems reasonable to conclude that in this case, the potential number of parasite species that could be harboured by salmonids in the larger lakes was limited by lake productivity. There also exists the possibility, because Newfoundland itself is an island, that the salmonid parasite

fauna of the larger lakes has not yet reached an equilibrium point.

The increase in the number of larval perch parasites with lake surface area (Figure 5.2), indicates the importance of larval parasites in the structuring of these component communities, stressed by the lack of any relationship between adult parasite number and lake surface area. Esch (1971) postulated that the increased interaction of fish in eutrophic systems with non-piscine vertebrates would cause an increase in infections with larval parasites. This does not seem to be the case in these particular systems, as the number of autogenic species shows a significant increase with lake surface area (Figure 5.3), while the number of allogenic species does not. The increase in the species richness of perch parasites with lake surface area in these lakes is directly attributable to the increase in larval and autogenic species. It would seem that the role of the yellow perch as a forage fish may cause an increase in the number of larval species through increased interactions with other piscine vertebrates.

Esch et al. (1988), based on work done in Great Britain, have cited colonization as a major determinant of helminth community structure in aquatic ecosystems. This was supported by their findings that almost all of the systems in Britain were dominated by allogenic species. It was also found that autogenic species contributed nothing to the helminth community similarity between and within localities because of their limited colonization potential. The opposite was found in these five Alberta lakes. Table 5.3 shows that the dominant species was most often autogenic in nature, and Table 5.4 implies that autogenic species contribute a great deal to parasite community similarity. This does not imply that colonization is not a major factor in determining parasite community structure, it only gives an indication of the relative importance of different colonist sources over the temporal span of an aquatic system.

The concept of succession implies that any disturbance of a system from

an equilibrium point will result in a change in species composition up until a new equilibrium point is reached that is dictated by the abiotic and biotic characteristics of the system, barring any further disturbance. Both the lakes of Britain and North America may be assumed to have been disturbed by the last period of glaciation. As with any succession, the first species to be established will be those with the greatest colonization ability. Colonization ability is not equivalent to colonization potential, as a given species introduced to a system may not become established within that system due to a lack of vital requirements at a specific time (Esch et al. 1988). When dealing with freshwater aquatic systems, especially lakes, the best colonists will be borne by non-piscine vertebrates, and exhibit low host specificity. Over time, the specificity of the species within the system will increase, and more autogenic species will become established. If one considers the allogenic parasites as the "weed species", and the autogenic parasites as the major components of the "climax community", the trend from disturbance to an equilibrium point can be envisioned.

Great Britain is itself an island, whose lakes would presumably colonize at a much slower rate than those of Alberta. The differing results between the two systems can be viewed as different points along the temporal scale of parasite community succession, with Britain's lakes, because of its isolation, providing a view of a system still recovering from disturbance, and the natural perch populations in Alberta lakes depicting a system much closer to an equilibrium state. The different rates of colonization provide a "real time" view of succession at two separate points on this temporal scale.

Lake stocking greatly increases the colonization potential of the resident parasite species and therefore can provide a quick insight into the respective roles of morphometry and colonization in the structuring of parasite component communities, and will be used in the next chapter to test the ideas presented here.

CHAPTER VI
LAKE STOCKING: THE EFFECTS OF COLONIZATION
ON THE COMPONENT PARASITE COMMUNITY OF YELLOW PERCH

INTRODUCTION

The transfer of a fish species to an environment that is lacking in closely related species will result in the strong reduction of its parasite fauna, especially if the transfer occurs at a point in the fish's life cycle when it is relatively parasite free (Dogiel 1939). This trend has been shown to be characteristic of most fish transfers; those parasites with more complex life cycles tending to be lost as a result of fish transfer, while parasites with direct life cycles, such as monogeneans, prove very resistant to loss (Petrushevski 1970).

Studies in the former Soviet Union, evaluated by Petrushevski (1970), show that transferred species of fish, in addition to losing a certain component of their original parasite fauna, will also gain parasites from related fish species in their new habitat. This shift in component parasite community structure has also been observed in North America for white perch (*Morone americanus*) colonizing Oneida Lake, New York and Lake Ontario (Tedla and Fernando 1969), and in Kokanee salmon introduced into Lake Huron from the Pacific drainages of North America (Collins and Dechtiar 1974)

The transfer of epizootics should be a major concern of any fish transfer, and can be minimized by the transfer of eggs rather than adult fish (Petrushevski 1970). The trends shown for the accumulation of parasites in yellow perch with host age in Chapter IV support this trend; only young of the year stock should be considered for perch transfers.

Another way to minimize the risk of parasite transfaunation may be to stock lakes with smaller numbers of fish. The rate of acquisition by hosts of a parasite

transmitted by an infective agent such as the cercaria of digeneans and the onchomiracidium of monogeneans, is often directly proportional to the frequency of contact between the hosts and the infective stages (Anderson 1993). Reducing the number of fish used for the purpose of lake stocking should decrease the density of the parasite infective stages that are introduced to the lake, and any decrease in host density will lead to a decrease in the total number of parasites establishing in the host population during a fixed time interval (Anderson 1993). The transmission of parasites by ingestion is also influenced by host and parasite densities, but the net rate of infection is determined by feeding rate, becoming limited by the effects of handling time and satiation.

The above concepts provide the criteria that allow the formation of hypotheses about lakes stocked with perch in Alberta based on the species-area relationship formulated in the previous chapter. These hypothesis must be supported if the relationship is to be considered valid.

Hypothesis 1: Yellow perch from lakes that were stocked with adult perch from lakes with a greater surface area than the recipient lake should harbour fewer parasite species than perch from the donor lake, as the result of a loss of autogenic and/or larval species. The number of species present in perch from the recipient lake should be that which is determined by the relationships between lake surface area and species richness established in Chapter V.

Hypothesis 2: Yellow perch in lakes that were stocked with young of the year perch should harbour a number of parasite species that is less than that which is determined from the species-area relationships given in Chapter V. Common perch parasites carried by other fish species already present in a recipient water body may cause these numbers to equal the estimates, but they should never exceed them.

Hypothesis 3: Yellow perch from lakes that have suffered a recent, significant, winterkill or similar disturbance should harbour a number of parasite species that is less than that which is determined by the given species-area relationships, regardless of the size of the donor lake, or the age of the fish used for stocking.

Hypothesis 4: Only yellow perch populations from lakes stocked with young of the year perch, or from lakes that have suffered a recent, significant winterkill, should harbour a parasite component community that is dominated by allogenic species.

The process of lake stocking, especially with adult perch, provides autogenic parasite species with a colonization potential that is equivalent to or greater than that of allogenic species, greatly speeding up the process of parasite component community succession. The process can also be accelerated by the presence of fish such as pike and walleye in the recipient lakes, carrying autogenic parasites infective to perch. This may lead to the perch parasite fauna in lakes meeting the criteria of the second assumption by being at, rather than below the proposed equilibrium line.

This possible acceleration of succession is what leads to the fourth hypothesis. It has been postulated in Chapter V that the importance of allogenic species in the composition of a fish's component parasite community declines as the time since disturbance increases, and more autogenic species begin to colonize the fauna of a waterbody.

Lakes that have been stocked from three of the five lakes used for the analysis in Chapter V will be used to test these assumptions, and ultimately determine the validity of the relationships postulated in Chapter V.

METHODS

The stocked lakes, their sources and the stock used are listed in Table 6.1. All of the donor and recipient lakes are listed in Table 6.2 along with their trophic status and surface area. For each of the recipient lakes the total number of parasite species and the number of larval and allogenic species were predicted using the regression equations determined in Chapter 5, along with a 95% confidence interval for each estimate. The difference between the observed and expected species numbers was calculated and compared to the confidence interval to determine whether or not the data fit the estimate.

Dominance was determined by the use of the Berger-Parker dominance index as in Chapter V.

RESULTS AND DISCUSSION

A comparison of the observed number of perch parasite species and that which was predicted by the regression equation determined in Chapter V is shown for the stocked lakes in Table 6.3. Table 6.4 shows the same comparison for the number of larval species, and the comparison for the number of autogenic species is given in Table 6.5. Table 6.6 lists the dominant perch parasite species in each stocked lake, along with its classification and dominance index.

Spruce Coulee Reservoir

This reservoir was illegally stocked in 1985 or 1986 from an unknown source, resulting in a large, stunted perch population that outcompeted the existing brook trout (*Salvelinus fontinalis*) population. It is assumed that the illegal stocking was accomplished using a small number of young of the year (YOY) perch. Based on this assumption, and the hypotheses given in the introduction one would expect the perch parasite fauna to be composed of a total number of species less than the estimate given in Table 6.3. The number of larval and autogenic parasite species present in perch should also be lower than their respective estimates

Table 6.1: A list of the perch stocked lakes used, their sources, the times of stocking, and the number and ages of fish used for stockings. All data are from Alberta Fish and Wildlife records. YOY indicates stocking with young of the year perch.

Lake	Source	Year	Stocked with:
Spruce Coulee	unknown	1985 or 1986	presumably YOY
Rattlesnake/ Sauder	Elkwater	1983-1985	93 000 YOY
Sherburne	Cochrane	1983	1 260 adults
	Elkwater	1983	15 000 30-100mm
	Elkwater	1985	40 000 YOY
	Pine	1985	9 500 adults
Fincastle	Sherburne	1987-1988	1 800 YOY
Lagoon	unknown	unknown	presumably YOY
Burntstick	Pigeon	1970	2 700 adults
Hastings	Clear Lake	1982-1983	46 000 YOY
	Vegreville	1984	8 400 YOY
	Vegreville	1984-1985	750 adult
Coal	Pine	1983-1984	113 388 YOY
Beta	Pigeon	1989	19 786 YOY
Joker	Sturgeon	1983-1984	25 200 50-60mm

Table 6.2: A list of the studied source and stocked lakes from Alberta, their trophic status, and their respective surface areas. Trophic statuses designated with an (est) were estimated from lake fauna and water clarity, all others are as per Mitchell and Prepas (1990), and are based on chlorophyll a counts.

Lake	Trophic Status	Surface Area (km ²)
Elkwater (source)	mesotrophic	2.31
Pine (source)	eutrophic	3.89
Pigeon (source)	eutrophic	96.70
Sturgeon (source)	hyper-eutrophic	49.10
Sherburne (source)	eutrophic (est)	3.76
Spruce Coulee	oligotrophic (est)	0.21
Rattlesnake/Sauder	mesotrophic (est)	10.27
Fincastle	eutrophic (est)	2.02
Lagoon	mesotrophic (est)	0.01
Burntstick	mesotrophic (est)	2.95
Coal	hyper-eutrophic	10.90
Hastings	hyper-eutrophic	8.71
Beta	eutrophic (est)	0.38
Joker	NA	1.62

Table 6.3: A comparison between the observed number of perch parasite species found in each lake and the number estimated by the equation: total species = $1.52(\ln SA) + 4.84$. The 95% confidence interval is given for each estimate.

Lake	Observed Number of Species	Predicted Number of Species	Difference	95% C.I.
Spruce Coulee	3	2.46	0.54	1.88
Rattlesnake	8	8.39	-0.39	1.65
Sherburne	9	6.86	2.14	1.79
Fincastle	9	5.91	3.09	1.84
Lagoon	5	-2.17	7.17	1.89
Burntstick	8	6.49	1.51	1.81
Hastings	3	8.14	-5.14	1.69
Coal	6	8.48	-2.48	1.64
Beta	2	3.37	-1.37	1.88
Joker	5	5.57	-0.57	1.85

Table 6.4: A comparison between the observed number of larval perch parasite species found in each lake and the number estimated by the equation: larval species= $1.37(\ln SA)+2.43$. The 95% confidence interval is given for each estimate.

Lake	Observed Larval Species	Predicted Larval Species	Difference	95% C.I.
Spruce Coulee	2	0.30	1.70	1.97
Rattlesnake	6	5.61	0.39	1.74
Sherburne	7	4.24	2.76	1.88
Fincastle	6	3.39	2.61	1.93
Lagoon	3	-3.86	6.86	1.98
Burntstick	5	3.91	1.09	1.90
Hastings	3	5.38	-2.38	1.77
Coal	3	5.69	-2.69	1.72
Beta	2	1.11	0.89	1.97
Joker	4	3.09	0.91	1.94

Table 6.5: A comparison between the observed number of autogenic perch parasite species found in each lake and the number estimated by the equation: $\text{autogenic species} = 1.01(\ln SA) + 3.90$. The 95% confidence interval is given for each estimate.

Lake	Observed Autogenic Species	Predicted Autogenic Species	Difference	95% C.I.
Spruce Coulee	1	2.33	-1.33	1.71
Rattlesnake	4	6.26	-2.26	1.51
Sherburne	5	5.24	-0.24	1.63
Fincastle	6	4.61	1.39	1.67
Lagoon	3	-0.75	3.75	1.72
Burntstick	6	5.00	1.00	1.65
Hastings	0	6.09	-6.09	1.53
Coal	4	6.31	-2.31	1.50
Beta	0	2.92	-2.92	1.71
Joker	3	4.39	-1.39	1.68

Table 6.6: The dominant species of parasite, their life cycle type and Berger-Parker dominance index for each of the studied recipient lakes.

Lake	Dominant Species.	Dominance Index	Life Cycle
Spruce Coulee	<i>Diplostomulum scheuringi</i>	0.75	allogenic
Rattlesnake/ Sauder	<i>Proteocephalus</i> spp.	0.50	autogenic
Sherburne	<i>Proteocephalus</i> spp.	0.47	autogenic
Fincastle	<i>Crepidostomum isostomum</i>	0.59	autogenic
Lagoon	<i>Diplostomum adamsi</i>	0.66	allogenic
Burntstick	<i>Urocleidus adspectus</i>	0.53	autogenic
Hastings	<i>Tetracotyle diminuta</i>	0.93	allogenic
Coal	<i>Crepidostomum isostomum</i>	0.44	autogenic
Beta	<i>Diplostomulum scheuringi</i>	0.97	allogenic
Joker	<i>Tetracotyle diminuta</i>	0.42	allogenic

(Table 6.4 and 6.5). As well, based on hypothesis 4, the lake should be dominated by an allogenic parasite species.

The results show that for all of the measures of species richness the difference between the observed and estimated numbers was less than the 95% confidence interval. If *Crepidostomum isostomum* is considered a long lived remnant of the previous perch habitat, and not an established parasite (see Chapter III) the results change only for the number of autogenic parasite species, which move below the estimate with a difference exceeding the 95% confidence interval. The dominant species remains allogenic in both instances (Table 6.6).

The extrapolation required to generate the required estimates may invalidate these estimates, but the results appear to agree with the hypotheses in this case.

Sherburne Reservoir was poisoned in 1992 with Rotenone to remove the perch and restore the brook trout population.

Rattlesnake/Sauder Reservoir

These two reservoirs were joined after the stocking of Sauder Reservoir between 1983 and 1985 with YOY yellow perch from Elkwater Lake. The estimates for parasite species numbers were therefore based on the combined surface areas of the two systems. Tables 6.3, 6.4 and 6.5 show that the species richness trend in this reservoir was similar to that of Spruce Coulee, with both the total parasite species number and the number of larval species meeting the estimate, while the number of autogenic species fell short of the estimate. A comparison of the species between the donor and recipient lakes reveals that the higher number of perch parasite species in Rattlesnake/Sauder Reservoir was the result of the acquisition of *Diplostomum adamsi* and *Apatemon gracilis*, both of which are allogenic parasite species. Host specificity dictates that only *Urocleidus adspectus* and *Crepidostomum isostomum* can be reliably attributed to parasite transfer, as

all of the other species could possibly have been present in the reservoir at the time of stocking. This idea is supported by the fact that the dominant parasite species harboured by perch in this system was autogenic in nature.

As would be predicted by succession, the total number of parasite species harboured by perch in this reservoir was at or close to equilibrium numbers, but the number of autogenic species was lower than predicted indicating that the difference was made up for by the allogenic species because of superior colonization abilities.

Sherburne Reservoir

This reservoir was stocked over a period of 3 years from 3 different sources, using a combination of adult and YOY perch (Table 6.1). In this reservoir both the total number of perch parasite species (Table 6.3) and the number of larval species (Table 6.4) were higher than the estimates, contradicting the hypotheses from the introduction. The number of autogenic perch parasites was consistent with the predicted number (Table 6.5), in keeping with hypothesis 1.

If only the equilibrium line generated for autogenic perch species is valid, than the results from Spruce Coulee Reservoir and Rattlesnake/Sauder Reservoir may not be due to previously established species, but could also have been caused by an increase in the role of allogenic species in perch component parasite community composition in the southern lakes. This role apparently does not exceed that of autogenic species as the dominant perch parasite in this reservoir is autogenic (Table 6.6), which is in agreement with hypothesis 4.

Fincastle Reservoir

This reservoir was stocked from Sherburne Reservoir with YOY perch (Table 6.1). As with Sherburne the total number of perch parasite species (Table 6.3) and the number of larval species (Table 6.4) exceeded the estimates, but the

number of autogenic species was within the estimated range (Table 6.5). This provides further evidence that the total species and larval species lines are not valid, at least in the southern region, because of their underestimation of the role of allogenic species.

The dominant species is an autogenic parasite (Table 6.6), indicating that the number of autogenic species may be at equilibrium for perch because of parasite species already present in the reservoir fauna prior to its being stocked with perch, and not as the result of parasite transfer.

Lagoon Lake

This small pond is located in Carburn Park in the city of Calgary. The ponds in this park are man made, utilizing old gravel pits in the area. Lagoon Lake was stocked illegally from an unknown source. The species richness values are all much higher than the estimates (Tables 6.3, 6.4 and 6.5), even when the problems of extrapolation are considered. This is most likely the result of the design of the ponds. Water from the Bow River flows through gravel first into Boating Lake and then through to Lagoon Lake before finally draining back into the river. This confluence may result in Lagoon Lake having a larger functional surface area, as there has been evidence for the underground movement of dace and stickleback (Nelson and Paetz 1974). These ponds have since been drained in an attempt to remove the perch and restore the trout populations. Plans by the City of Calgary to increase the flow between the ponds and the river through the use of culverts may serve only to further increase the functional surface area of these ponds in terms of parasite colonization.

The stocking was presumably done with YOY perch, as an allogenic species dominates the perch fauna in the pond as per assumption 4.

Burntstick Lake

This lake was stocked with adults from much larger Pigeon Lake (Table 6.1). Based on the assumptions, one would expect all estimates to be at the equilibrium number, providing that the increased role of allogenic species in determining perch parasite fauna is limited to the southern region. This is in fact the case with all three measurements of species richness being within the range of their respective estimates (Tables 6.3, 6.4 and 6.5). The numbers are lower than those from Pigeon, resulting from the loss of *Bothriocephalus cuspidatus*, *Triaenophorous nodulosus*, *Ligula intestinalis* and *Diplostomum adamsi*, three of which were hypothesised to be dependent on larger lake size for establishment (Chapter V). Assumption 4 is met as well, with the dominant parasite species exhibiting an autogenic life cycle (Table 6.6).

Hastings Lake

This lake was stocked with a combination of adult and YOY perch from two separate sources, neither of which currently have reproducing perch populations (Table 6.1). The total number of parasite species (Table 6.3), the number of larval species (Table 6.4) and the number of autogenic species (Table 6.5) are all below the estimated ranges. The number of perch examined from this lake was 52, but none were older than 4+ years, and most were around the age of two. This may be indicative of an earlier winterkill in this lake, a supposition that is supported by the fact that all three species of perch parasite from this lake were allogenic. The lake itself is hyper-eutrophic (Table 6.2), so winter kill could be a definite factor. If this is the case, then Hastings Lake would provide a good example of assumption 3.

One of the allogenic species present in Hastings Lake perch was *Ligula intestinalis*, whose presence disputes its apparent dependence on larger lake surface areas. This may be in accordance with the lack of dependence that has been shown for allogenic species number on lake size.

Coal Lake

Coal Lake was stocked with YOY perch from Pine Lake in 1983 and 1984 (Table 6.1). In support of assumption 2, the total number of perch parasite species (Table 6.3), and the number of larval (Table 6.4) and autogenic species (Table 6.5) were all below the estimated ranges. The fact that Coal Lake has a larger surface area than its donor Pine Lake should also contribute to its being below the estimates. The dominant parasite species was autogenic, which may indicate the acquisition by perch of parasites already established in Coal Lake prior to the perch introduction.

Beta Lake

Stocked with YOY yellow perch from Pigeon Lake in 1989, Beta Lake suffered a partial winterkill in 1992/93. This was confirmed by the inability to capture any perch in the lake older than 0+ years, despite the lakes small size and a total of 4 days sampling. The estimates, which are presumably affected by extrapolation, were met by both the observed total number of perch parasite species in the lake (Table 6.3) and the number of larval species (Table 6.4). The number of autogenic species was below the estimated range (Table 6.5). Only two species of perch parasites were recovered, both being representative of an allogenic life style, as would be predicted by assumptions 3 and 4.

Joker Lake

Joker Lake was stocked in 1983 and 1984 with YOY perch from Sturgeon Lake. 10 parasite species were harboured by perch in Sturgeon Lake, of which only 5 were present in Joker Lake, two of which were allogenic in nature. The total number of parasite species observed was within the 95% confidence interval of the prediction (Table 6.3), as was the number of larval (Table 6.4) and autogenic (Table 6.5) species. These predictions are, again, extrapolations of the regression lines developed in Chapter V, but they appear to uphold the assumptions. The dominant species of perch parasite in Joker Lake was allogenic, which appears to

be a common characteristic of the smaller (surface area of approximately 1 km² or less) water bodies listed in Table 6.6, perhaps the result of the increased susceptibility of small systems to disturbance.

Conclusions

The results obtained from lakes stocked with perch in Alberta indicate that the regression equations generated in Chapter V were biased by the limited effect of allogenic species on yellow perch component parasite community structure in the lakes from the northern and central regions. The regression lines were calculated from five lakes, only one of which was located in the southern region.

The assumptions listed in the introduction all held for the equation generated for the number of autogenic parasite species harboured by perch in a given lake, indicating that this line may be valid for the entire region. In the southern regions, the total number of species was underestimated because of the increased role of the southern allogenic species in determining the composition of the perch parasite fauna. Two allogenic perch parasites were limited in distribution to the southern region, (*Apetamon gracilis* and *Contracaecum spiculigerum*), implying perhaps that there is a latitudinal limitation to the effects of allogenic species on parasite component community structure.

Although only one of the three lines may be considered valid, the proposed series of events for parasite component community structure given in Chapter V remains viable. The formation of a parasite fauna begins with allogenic species as the result of their superior colonization potential. The full complement of autogenic species requires more time to develop, but will eventually dominate continental freshwater systems with nutrient levels that are not limiting to parasite establishment (meso- and eutrophic systems). The number, and perhaps types of autogenic species present at equilibrium will be ultimately determined by lake size. The allogenic component may exhibit latitudinal limitations, and is likely not

governed by lake size, but more by nutrient levels and lake volume development as described by Wisniewski (1958). Under certain conditions, where the number of autogenic species is limited by lake size, or by colonization ability in a non-equilibrium system, the role of the allogenic species will become magnified, and overshadow that of the autogenic species.

This successional model may only be valid for perch parasite fauna in the region of study, but certain consistencies observed in other studies indicates that some of the concepts and patterns may be applicable to all freshwater systems.

CHAPTER VII

GENERAL CONCLUSIONS

The relationships that have been developed in the previous chapters can all be combined into a lake stocking protocol for yellow perch that will minimize the risk of parasite transfaunation during fish transfer. Although the results from Chapters V and VI imply that the parasite component community of perch will eventually reach an equilibrium, taking steps to prevent transfaunation will eliminate accidental introductions of potentially harmful species such as *Ligula intestinalis* and *Triaenophorus nodulosus*, as well as preventing oscillations in component community structure that could occur in a non-equilibrium system with the colonization of certain parasite species.

It would be good practice to perform an initial survey of the parasites of the donor lake before any stocking activity is planned. If the recent history of the lake is not known, then a capture sample size of 30 perch is recommended to ensure a large enough sample size to counter the effects of recent disturbance on required sample size. If the water body has been known to be devoid of any recent disturbances such as winter-kill or a significant lowering of the water level, then the sample size can be calculated based on lake size as shown in Chapter II.

Assuming that it is not practical to transfer only the eggs of the perch, then only young of the year perch should be used for stocking purposes. These young perch have the smallest parasite load, both in terms of number of parasites, and number of species. As well, only small numbers should be transferred, in order to minimize the chances of any transferred parasites establishing themselves in the new water body. The difficulty lies in determining the smallest size of stocking group that will survive foraging predators to reproduce, while maintaining a large enough gene pool to prevent inbreeding. Illegal introductions have shown the ability of small introductions to propagate in a new water body under certain conditions, but the process requires time. This procedure may require 4-5 years

before the established perch population is worthy of angling, but this population will be healthier and more stable, and may not require subsequent stockings to maintain it.

The selection of donor lakes should not be solely based on the availability of perch, but should take into account the relationship between parasite component community size, and lake surface area. To minimize parasite transfer, smaller lakes should be used as source lakes. The number of perch available for transfer may be smaller, but smaller stocking groups may prove beneficial, as was described previously. Even lakes with stunted perch populations should be considered as donors; perhaps preferred because of their depauperate parasite fauna. Stunting in perch is not genetically fixed, but is controlled by environmental factors such as limited food or spatial resources (Jacobson 1989). The transfer of stunted perch to suitable waters will result in an increase in the growth rates of these perch, because the stunted populations retain their potential for normal growth (Heath and Roff 1987).

It may even be possible to establish natural "hatcheries" for perch stocking in small, oligotrophic water bodies. If a small number of young of the year perch are transferred to such a water body, they will lose most of the parasite component community that was present in the donor lake. This way older, larger fish could be used from a gnotobiotic source for transfer to minimize foraging losses.

The application of any of these suggestions during lake stocking practices with perch, or other fish, should effectively minimize the practice and effects of parasite transfaunation.

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