SUBLETHAL EFFECTS OF THREE ECTOPARASITES ON FISH

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ABSTRACT

In an attempt to determine sublethal effects of parasites on fish, vulnerability to predation, resistance to high temperature, weight-length relationships, and fecundity were compared for fish with and without or with light and heavy infestations of three ectoparasites. Species used were fathead minnow (Pimephales promelas) with anchor worm (Lernaea cyprinaceae) infestation levels ranging from 0 to 4 with a mean of 1.2 parasites per fish, brook trout (Salvelinus fontinalis) infested with gill lice (Salmincola edwardsii) at levels of 0 to 32 lice per fish with a mean of 4.1, and yellow perch (Perca flavescens) with black-spot (Neascus of Crassiphiala bulboglossa) with a range of 0 to 633 cysts per fish and a mean of 249. The only sublethal effect found was that of gill lice, which reduced resistance of brook trout to high temperature. None of the three ectoparasites increased vulnerability of fish to predation by piscivorous fish. Weight-length relationships were the same in natural populations of brook trout with and without gill lice and in two groups of yellow perch, one with a light and one with a heavy infestation of black-spot. Fecundity of brook trout was not affected by gill lice.

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INTRODUCTION

The objective of this study was to evaluate sublethal effects of three ectoparasites, anchor worm (*Lernaea cyprinacaea*), black-spot (*Neascus* of *Crassiphiala bulboglossa*), and the gill louse (*Salmincola edwardsii*), on their respective fish hosts, fathead minnow (*Pimephales promelas*), yellow perch (*Perca flavescens*), and brook trout (*Salvelinus fontinalis*).

In nature fish must withstand challenges to their existence to survive. Individual fish must find enough food to meet their metabolic requirements and to grow; they must avoid being eaten by predators, and sometimes they must withstand adverse environmental conditions such as pollutants, temperature extremes, or low dissolved oxygen levels. For a population to survive the fish must reproduce successfully. In this study I attempted to determine if the parasites affected the ability of fish to withstand some of these challenges.

Laboratory experiments were carried out in which fish with and without or with light and heavy infestations of a parasite were exposed to predation by walleye (*Stizostedion vitreum*), largemouth bass (*Micropterus salmoides*), and northern pike (*Esox lucius*). In other experiments fish with and without gill lice or black-spot were exposed to their upper lethal temperature. Also, weight-length relationships were compared in populations of brook trout with and without gill lice and in yellow perch with light and heavy infestations of black-spot, and fecundity was determined in a population of brook trout infested with gill lice.

A sample of fish obtained from each source consisting of 15 preserved specimens of each species, was examined for the presence of parasites other than those under study. So few were found that other parasites were considered to have had a negligible influence on the results of this study (Appendix, Table 1).

METHODS AND MATERIALS

Predation- Experiments were conducted in the Aquatic Research Laboratory of the University of Wisconsin-Stevens Point (Lat. 44 31 N, Long. 89 34 W) with fish obtained from the National Fish Hatchery at Lake Mills, Wisconsin, (U.S. Bureau of Sport Fisheries and Wildlife) and with fish from natural waters (Table 1). Fish were held in fiberglass, concrete, or plastic pools. Between experiments prey fishes were fed trout pellets or mealworms, *Tenebrio molitor*, and and predators were given carp, *Cyprinus carpio*, goldfish, *Carassius auratus*, and bluegill, *Lepomis macrochirus*. Fish were not fed the day before an experiment, and only fish that appeared to be healthy were used.

All experiments were performed in circular plastic pools 2.4 m or 3.0 m in diameter containing about 1700 or 3000 liters of well water respectively. Water flowed slowly into the pools maintaining a dept of 36 and 44 cm. Water temperatures ranged from 11.5 to 20 C. Two aerators maintained dissolved oxygen levels at 5.5 to 8.5 ppm. Two shelters designed to simulate plants were placed in each pool. Shelters were made of strips of black polyethylene, which were anchored and extended vertically through the water and varied from 50 to 100 cm in diameter at the surface where the free end of the strips floated. Sheets of plywood (1.2 x 2.4 m) were put on the pools to provide additional cover.

Predator species were given a 20 minute prophylactic treatment in 1:6000 formalin at the time they were acquired and after each experiment.

In most experiments equal numbers of prey (5 to 25) with and without or with light and heavy infestations of the parasite under study were anesthesized with tertiary amyl alcohol, measured, the number of parasites counted on each fish, and the fish put into pools 6 to 8 hours before predators were added. Prey species of similar size were used in each experiment so that differences in vulnerability could be attributed to presence or absence of parasites rather than to size of prey. There was no significant difference (paired t test, 0.05 level) in mean length of fish at the beginning of experiments between the two groups under comparison in any of the seven experiments. Also the change in mean length of prey from beginning to end of experiments was never significant (paired t test, 0.05 level, Appendix, Tables 2-9).

Each experiment consisted of a 7 mm wire mesh control cage (1.1 m in diameter) containing prey, but no predators, and one or two pools containing predators and prey. Usually two predators were used in an experiment. Attempts were made to end experiments when 25% of the prey were eaten. At the end of an experiment prey were removed, anesthesized, measured, the number of parasites in question counted on each infested fish, and the fish preserved in 10% formalin.

A grid system was used in assessing the number of black-spot on yellow perch in two predation experiments. The number of cysts was determined by summing the number of cysts on the left pectoral and left pelvic fin and in two, one square centimeter fields behind the left pectoral fin (Fig. 1).

In two experiments, yellow perch without black-spot were given 30-35 artificial black spots and their vulnerability to predation compared with other perch with and without black-spot (Fig. 2). India ink was placed in a syringe fitted with a 25 gauge hypodermic needle. The needle was pressed gently to the side of an anestesized fish so that it penetrated the skin covering the scales producing small black spots. Other perch used in experiments with such fish were subjected to the same treatment, but with water in the syringe.

<u>Temperature</u> <u>Tolerance</u>- Fish with and without gill lice and black-spot were exposed to their published upper TL50[1]

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[1]TL50 - Temperature (dependent upon the acclimation temperature of test species) that will kill 50% of the fish in a specified length of time (U.S. Dept. of Int., 1967).

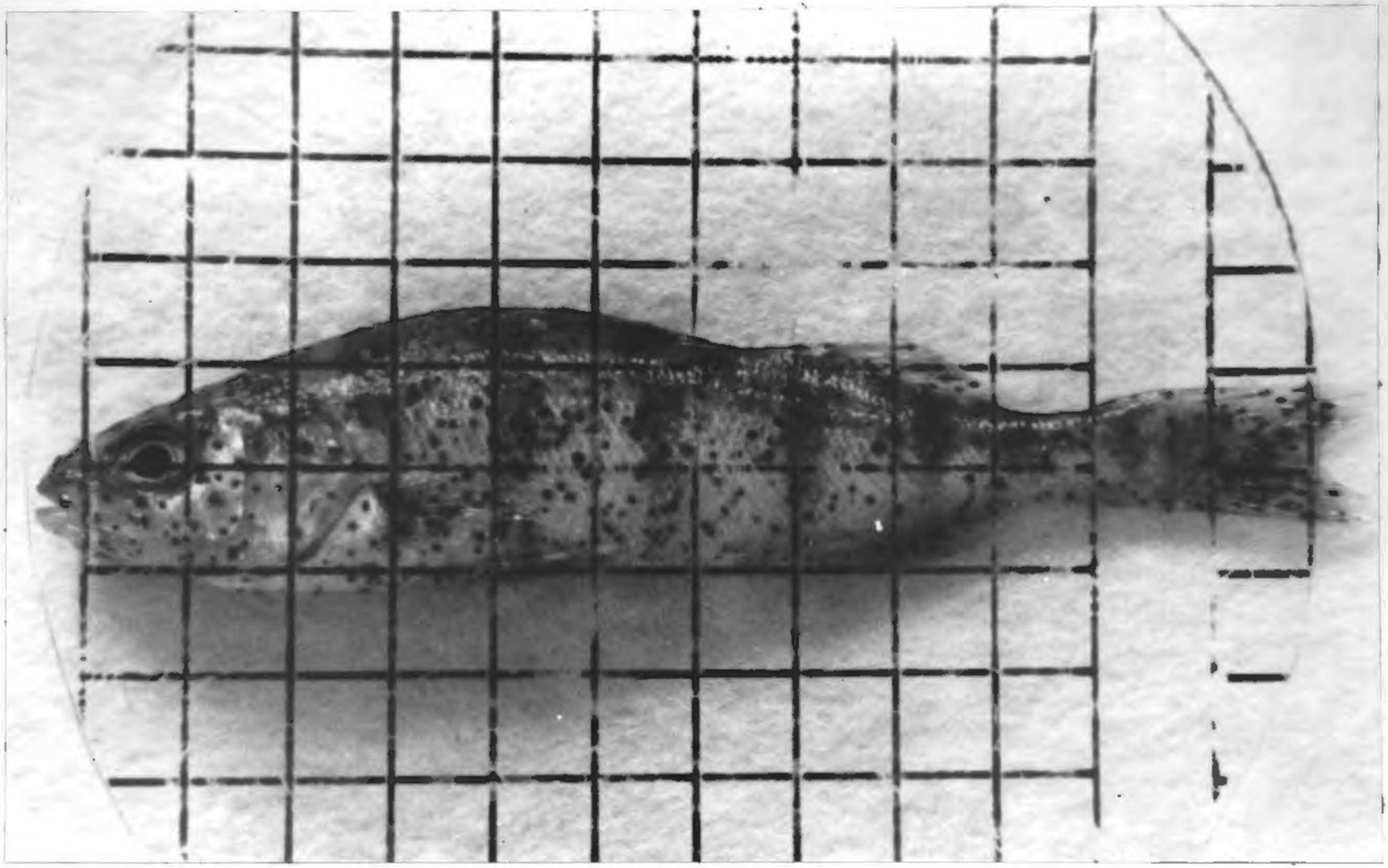

Figure 1. Counting grid used in assessing black-spot on yellow perch. Number of spots determined by summing the number of cysts on left pectoral and left pelvic fin and in two, one square centimeter fields behind the left pectoral fin.

Figure 2. Yellow perch with artificial black spots (top) and natural infestations of black-spot (bottom).

temperature (U.S. Dept. of Int., 1967). During experiments fish were held in rectangular fiberglass tanks containing 250 liters of water except in the first two experiments with brook trout from the Little Plover River and Lawrence Creek Run 1 (Run 1 was the first of two experiments conducted with fish from Lawrence Creek). Four compartments were formed in the experimental tank by perforated plastic dividers which permitted water exchange between compartments, but contained from 3 to 10 fish in each enclosure. Oxygen levels were maintained at saturation by 6 airstones. No fish were put in one end compartment, where a 120 volt 870 watt heater was placed. In all brook trout experiments, except two, a constant supply (approximately 37 liters/hour) of preheated aerated water was siphoned into the experimental tank from two 735 liter elevated reservoir tanks, and approximately 10 liters/hour of preheated aerated water was siphoned into the experiments with yellow perch.

In the two experiments with brook trout from the Little Plover River and Lawrence Creek Run 1, fish were exposed to their upper lethal temperature in 20 liter glass jars (6 trout per jar) containing one airstone. Preheated water flowed at approximately 15 liters/hour from an elevated tank to the bottom of the jars and overflowed through a 3 mm mesh screen at the top.

Fish were acclimated, brook trout to 20 C and yellow perch to 25 C by holding them for a minimum of one day for each 1 C difference between the ambient temperature at the time of capture and the acclimation temperature

(Tyler, 1964). After fish were transferred from the acclimation tank to the experimental vessel (jar or tank), the temperature was increased 1 C/hour until the upper lethal temperature (25 C for brook trout and 32 C for yellow perch) was reached. Thereafter, fish were observed every ½ hour until each experiment ended. When opercular movement ceased and a fish failed to respond to touch by a glass rod, it was considered dead and was removed, measured, and preserved in 10% formalin. Later, the gill lice were counted on the trout that died during the experiments. All yellow perch used in temperature tolerance experiments were held in water containing 5 ppm acriflavin from the time they were obtained until used in experiments.

Weight - Length Relationships- Lengths and weights were determined for brook trout captured with electrofishing gear in Spiegal and Maxwell Ponds (Langlade County, Wisconsin) by personnel of the Wisconsin Department of Natural Resources under the direction of Mr. Robert F. Carline.[2] Logarithms of weights and lengths were plotted and the resulting regression lines fitted by the method of least squares.

Spiegal and Maxwell Ponds, 0.4 and 0.9 hectares respectively, are spring fed ponds with naturally reproducing brook trout populations. All of the trout in Spiegal Pond

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[2]Coldwater Research Group, Bureau of Research, Wisconsin Department of Natural Resources, Hartman Creek Field Station, Waupaca, Wisconsin.

were infested with gill lice (mean incidence of 20 trout caught in October 1973, was 7.9; range 1 to 28); Maxwell Pond trout did not harbor the parasite. Food does not limit growth of trout in either pond (Carline, personal communication). Weights and lengths were compared for 70 trout with and 70 without gill lice captured at three month intervals during 1969 and 1970. No attempt was made to determine the sex of the trout.

Also weights and lengths were determined for 301 yellow perch infested with black-spot that were captured in Lions Lake (Portage County, Wisconsin) on September 21 and 27, 1972 (Table 1). The perch were anesthesized with tricaine methanesulfonate (MS 222), measured, weighed, and then divided according to appearance into the two groups, one (91 to 169 mm long) of 155 lightly infested and one (100 to 172 mm long) of 146 heavily infested fish (Fig. 3). A sub-sample of 20 perch of similar lengths was selected from both the lightly and heavily infested groups, and the total number of cysts on each fish counted with the aid of a bacteriological Coulter Counter. Counts ranged from 30 to 124 with a mean of 119 cysts for the light group and from 193 to 633 with a mean of 378 cysts for the heavily infested group.

Fecundity- Twenty-four female brook trout were collected from Lawrence Creek (Marquette County, Wisconsin) with a 230 volt direct current stream shocker on October 9, 1972. Eggs and the mean number of gill lice were counted in and on each fish.

Figure 3. Yellow perch lightly (top) and heavily (bottom) infested with black-spot.

RESULTS

Predation

Fathead minnow: Fathead minnow with and without *L. cyprinacaea* were exposed to predation by walleye and northern pike (Table 2). In the experiment 31 fathead minnow with and 33 without anchor worm were eaten out of 85 of each offered, and the difference in number eaten was not significant (X^2 test; 0.05 level). For prey with the parasite the mean number of anchor worm on each fish did not change from start to end of the experiment.

Brook trout: When brook trout with gill lice from Lawrence Creek and trout without the parasite from the Little Plover River were used in an experiment, fish without gill lice were more vulnerable to predation by northern pike (Table 3). Eleven trout with and 21 without gill lice were eaten out of 50 of each offered and the difference is significant (X^2 test; 0.05 level). The mean number of gill lice on brook trout from Lawrence Creek did not change from beginning to end in the experiment (paired t test; 0.05 level).

In this experiment some of the prey, five with and eight without gill lice, although not consumed, were wounded by the pike (Fig. 4) and died during the experiment. If they were included in the eaten category, the conclusion of the experiment, i.e. greater vulnerability of trout without the parasite, would remain the same (Appendix, Table 4A).

Figure 4. Brook trout wounded by northern pike.

Yellow perch: Experiments with yellow perch with black-spot from Lions Lake and perch without Neascus from Adams Lake and Severson Lake yielded contrasting results. Perch without black-spot from Adams Lake were more vulnerable to largemouth bass predation (X^2 test; 0.05 level) than perch with black-spot from Lions Lake (Table 4). Of 40 of each offered 27 yellow perch without Neascus and 12 with black-spot were eaten. On the other hand, there was no significant difference (X^2 test; 0.05 level) in vulnerability between fish without black-spot from Severson Lake and those with black-spot from Lions Lake (Table 5). In the experiment 23 of 50 without black-spot and 22 of 48 with the parasite were eaten.

These contrasting results indicated that there were differences among yellow perch from different lakes that influenced their vulnerability to predation more than the presence or absence of black-spot. Therefore, an experiment was carried out in which only perch from Lions Lake were used, and vulnerability was compared between perch with light and heavy infestations of Neascus (Table 6). The mean number of cysts counted with the grid system was 1.7, for the light group and 12.6 for the heavy group. Nine of 36 lightly infested perch and 14 of 38 heavily infested perch were eaten. The difference in vulnerability is not significant (X^2 test; 0.05 level).

In an experiment with artificial black spot, yellow perch without Neascus from Adams Lake were given artificial spots and compared with normal perch from the same lake.

There was no significant difference (X^2 test; 0.05 level) in vulnerability between the two groups of prey. Seven of 21 perch with and 6 of 25 without artificial black spots were eaten (Table 7).

In another experiment, yellow perch without black-spot from Severson Lake were given artificial black spots and their vulnerability compared with perch with *Neascus* from Lions Lake. Fish with artificial black spots were more vulnerable to predation (X^2 test; 0.05 level). There were 20 of 29 perch with artificial spots and 9 of 32 fish with *Neascus* eaten (Table 8).

Temperature Tolerance

Brook trout: Brook trout with *Salmincola edwardsii* had lower resistance to high temperature than trout without the parasite (Fig. 5; Appendix, Table 10). For trout with gill lice, time in hours at 25 C to 50% dead was 22.2 and 32.4 for separate groups of brook trout caught in Lawrence Creek on March 12 and April 7, 1972, respectively, and was 27.6 for trout collected from the Big Roche a Cri River on July 31, 1973. Trout without gill lice did not reach 50% mortality during the experiments. Extrapolation of the regression lines yielded estimates of time to 50% dead of 46.3, 50.9, and 85.7 hours for trout from the Little Plover River caught on April 6, Buena Vista Ditch Number 4 caught on April 5, and Flume Creek captured on April 6, 1972, respectively.

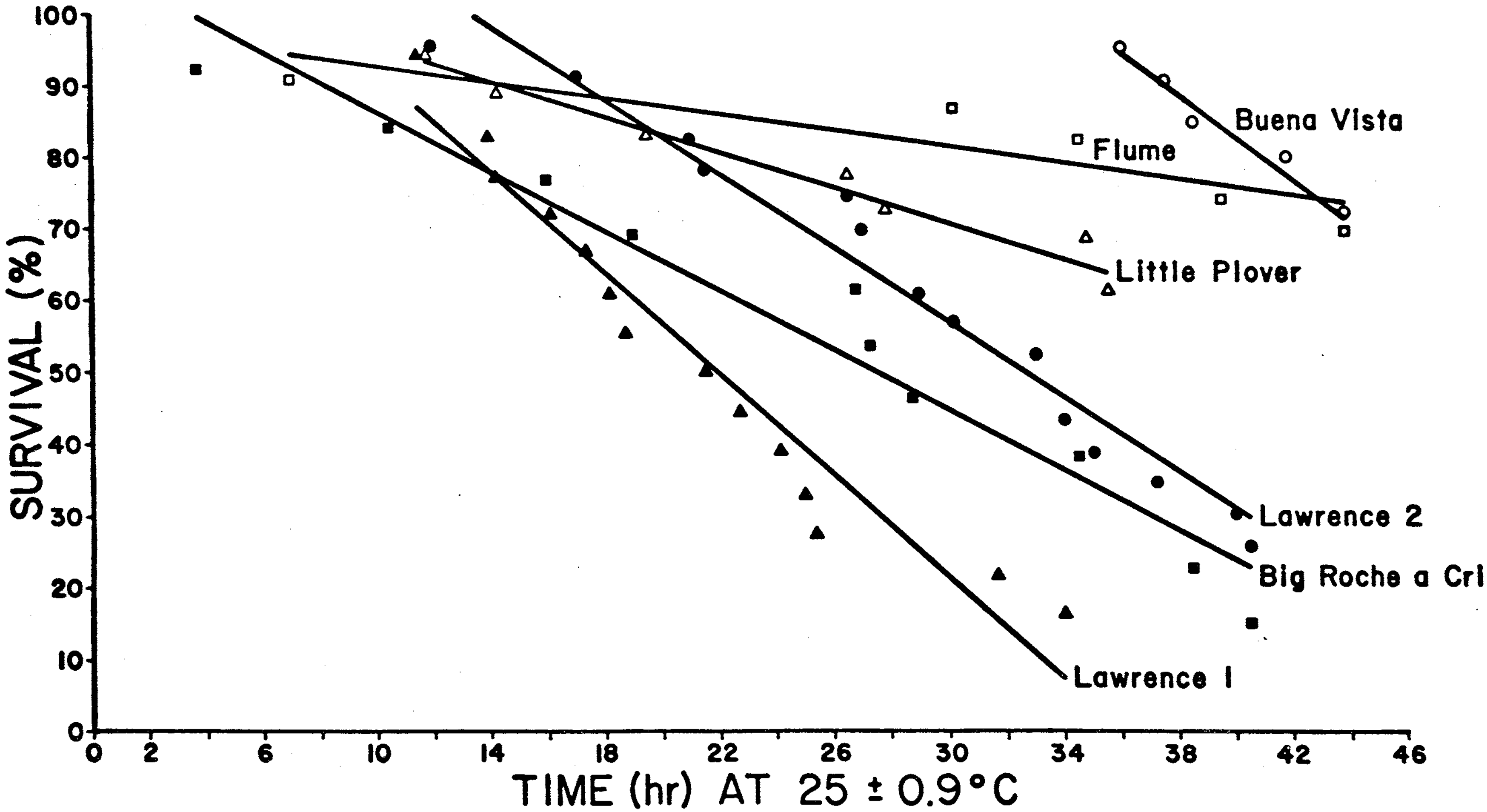

Figure 5. Cumulative percent survival versus time to death at 25 C for brook trout (120 to 140 mm long) with and without Salmincola edwardsii. Initial numbers of fish for Buena Vista, Flume Creek, and Little Plover River, populations without the parasite, and Lawrence Creek Run 1, Run 2, and Big Roche a Cri River, populations with the parasite, were 20, 23, 18, 18, 23, and 13, respectively. Regressions lines placed by the method of least squares.

All six regression lines (Fig. 5) have a significant slope (correlation coefficients range from -0.89 to-0.99), the slope of each is different from the others (F = 55.65, d.f. 5, 43 at 0.05 level) and the times at which 50% of the fish were dead are significantly different among the six groups of brook trout (F = 55.65, d.f. 5, 43 at 0.05 level).

Inverse relationships between time to death and number of gill lice on each trout were discernible although there was a good deal of variation in the data (Fig. 6; Appendix, Table 10). Slopes of the regression lines were not significant at the 0.05 level (F = 1.6, d.f. 1, 15, F = 1.7, d.f. 1, 9, and F = 0.29, d.f. 1, 13 for Lawrence Creek Run 1 and 2 and the Big Roche a Cri, respectively).

Yellow perch: Perch without Neascus from Adams Lake were least tolerant to high temperature whereas perch with black-spot from Lions Lake were most resistant, and Severson Lake perch were intermediate (Fig. 7; Appendix, Table 12). Time in hours at 32 C to 50% dead was 5.8 and 56.0 for Adams and Severson Lakes respectively, and the extrapolated value for Lions Lake was 76.4 hours.

Slopes of the regression lines are significant, correlation coefficients being -0.98, -0.96, and -0.99 for Adams, Severson, and Lions Lake respectively, and the times to 50% mortality are different (F = 22.6, d.f. 1, 14 at 0.05 level). The slope of the line representing yellow perch from Adams Lake was significantly different from that of the other two lines (F = 62.5, d.f. 1, 14 at 0.05 level),

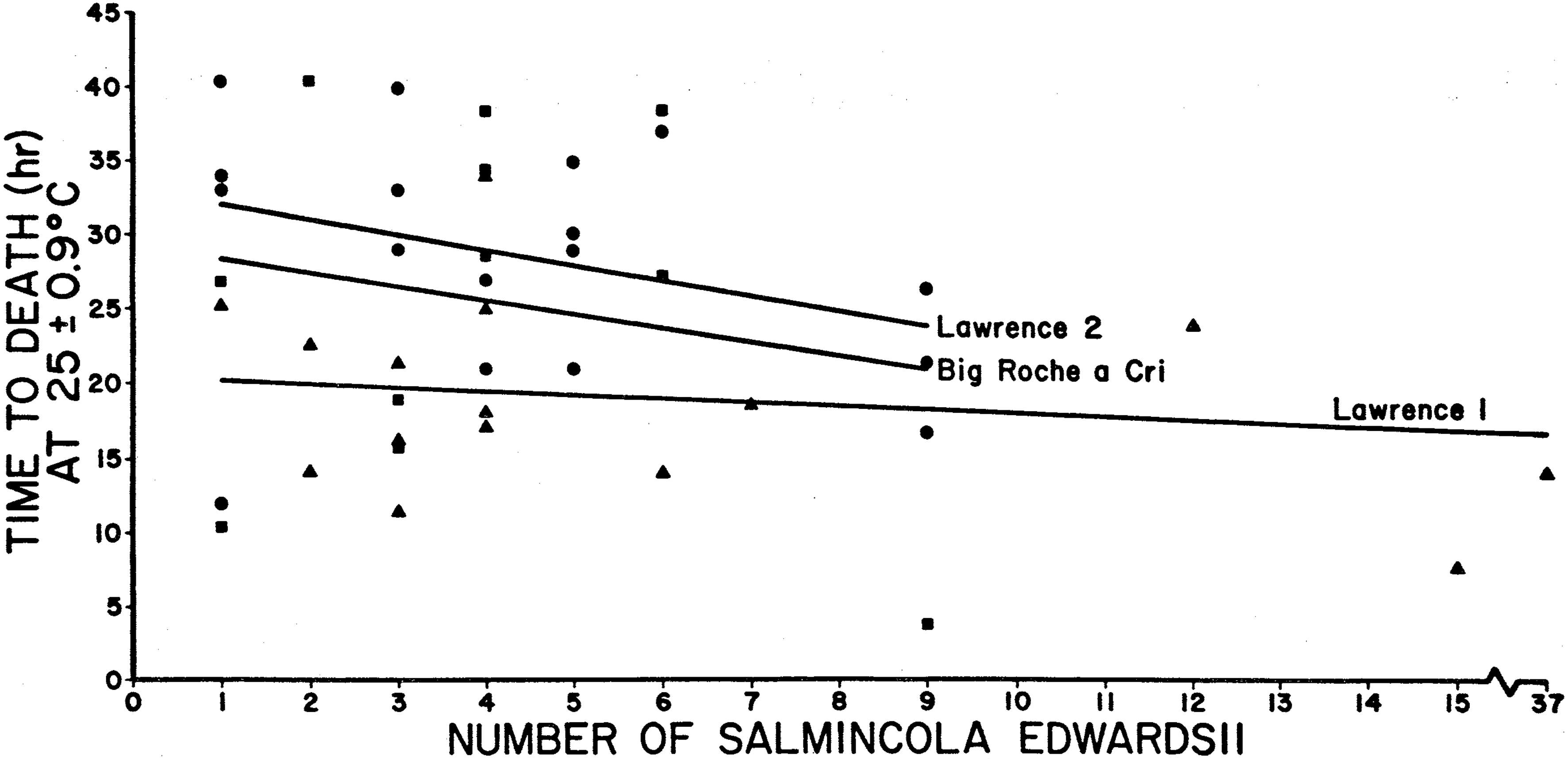

Figure 6. Number of *Salmincola edwardsii* per brook trout (122 to 140 mm long) versus time to death at 25±0.09 C. Regression lines placed by the method of least squares.

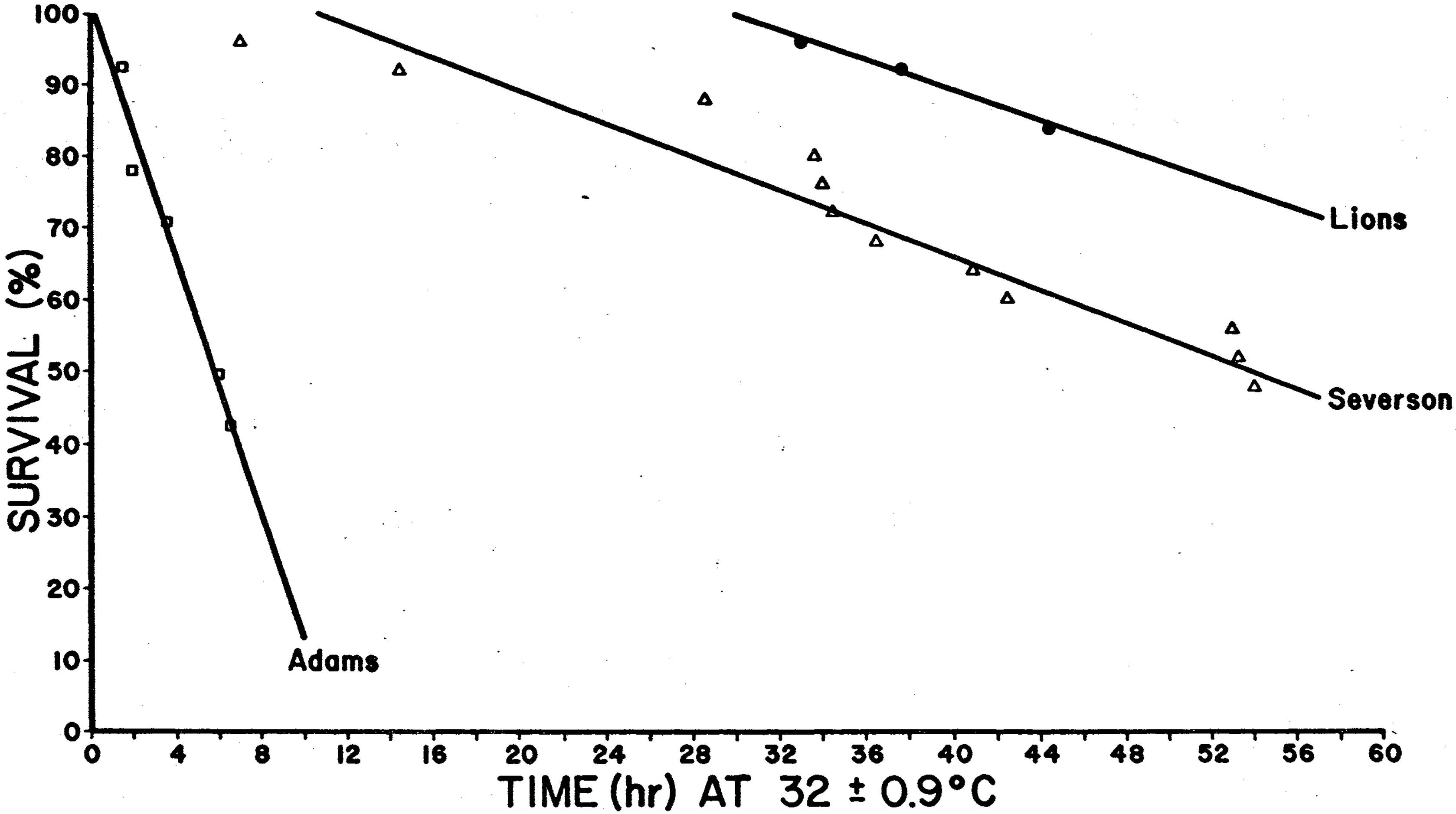

Figure 7. Cumulative percent survival in relation to time to death at 32 C for yellow perch (110 to 180 mm long) with and without the *Neascus* of *Crassiphiala bulboglossa*. Initial number of fish for Lions Lake, with the parasite, and Severson and Adams Lakes, without the parasite, were 14, 25, and 25, respectively. Regression lines placed by the method of least squares.

but slopes for Severson and Lions Lake were not different at the 0.05 level ($F = 0.01$, d.f. 1, 11).

Weight-Length Relationships

Brook trout. Brook trout infested with gill lice from Spiegal Pond were as heavy for their length as trout without gill lice from Maxwell Pond (Fig. 8 A,B,C,). Slopes of the lines of regression of log weight on log length for fish from the two ponds were not significantly different in any of the three comparisons (Table 9).

Yellow perch: Yellow perch from Lions Lake that were heavily infested with black-spot were as heavy for their length as perch that were lightly infested (Fig. 8D). Slopes of the weight-length regression lines for the two groups of perch were not significantly different (Table 9).

Fecundity

Gill lice were not found to influence fecundity of brook trout. Fecundity is related to size of fish; larger females generally carry more eggs. A statistical procedure was used to remove the effect of size on number of ova. Number of eggs was plotted against length of fish and the resulting linear relationship used in a graphical method of partial correlation analysis to adjust values for number of eggs to a single value of length to remove its effect. Then the adjusted values of number of eggs were plotted against number of parasites (Fig. 9). The relationship between adjusted number of eggs and number of parasites was not significant at the 0.05 level ($F = 0.03$, d.f. 1, 22).

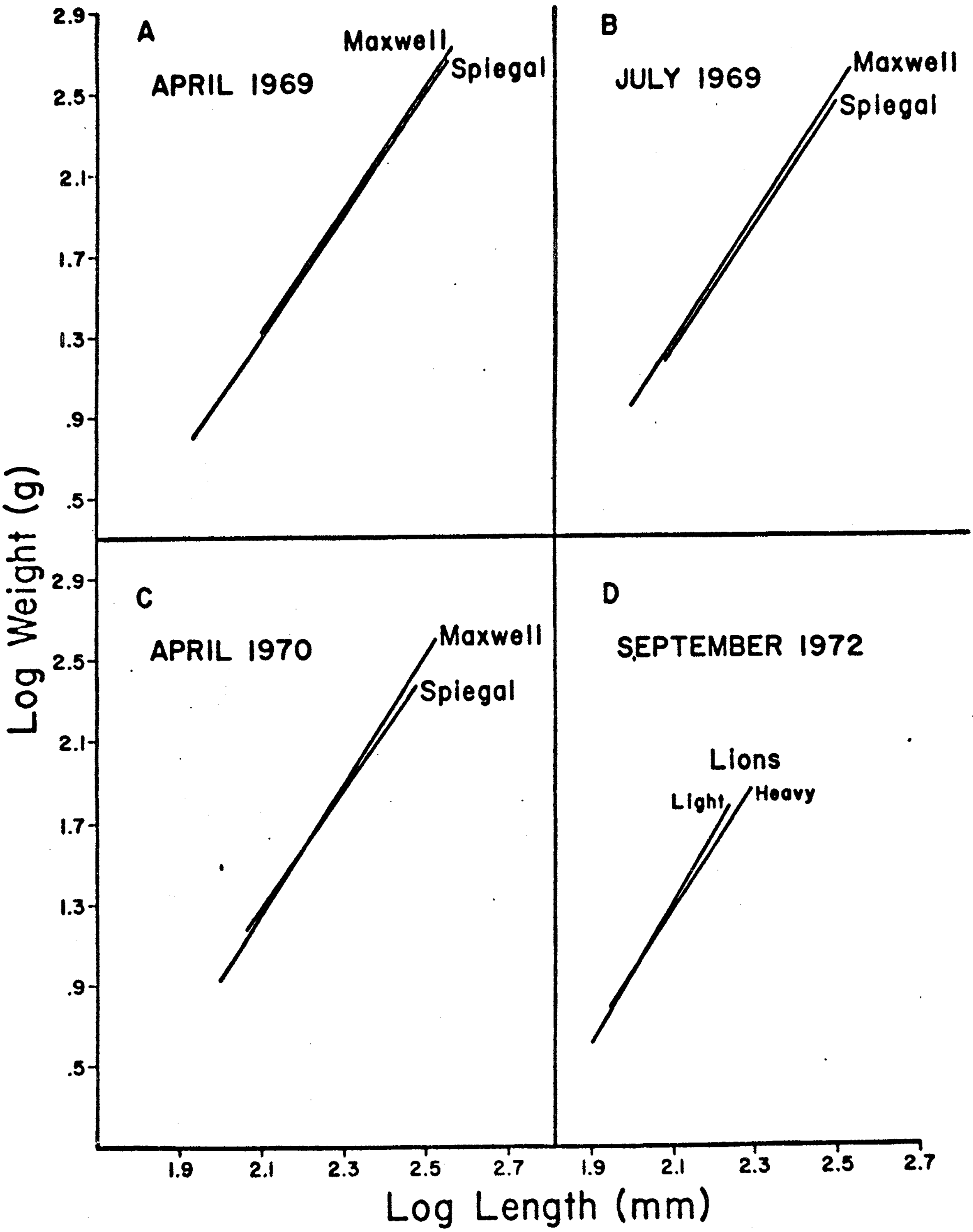

Figure 8. (A,B,C,) Weight-length relationships of brook trout with (Spiegal Pond) and without (Maxwell Pond) gill lice and (D) yellow perch from Lions Lake with light and heavy infestations of black-spot. Regression lines placed by the method of least squares.

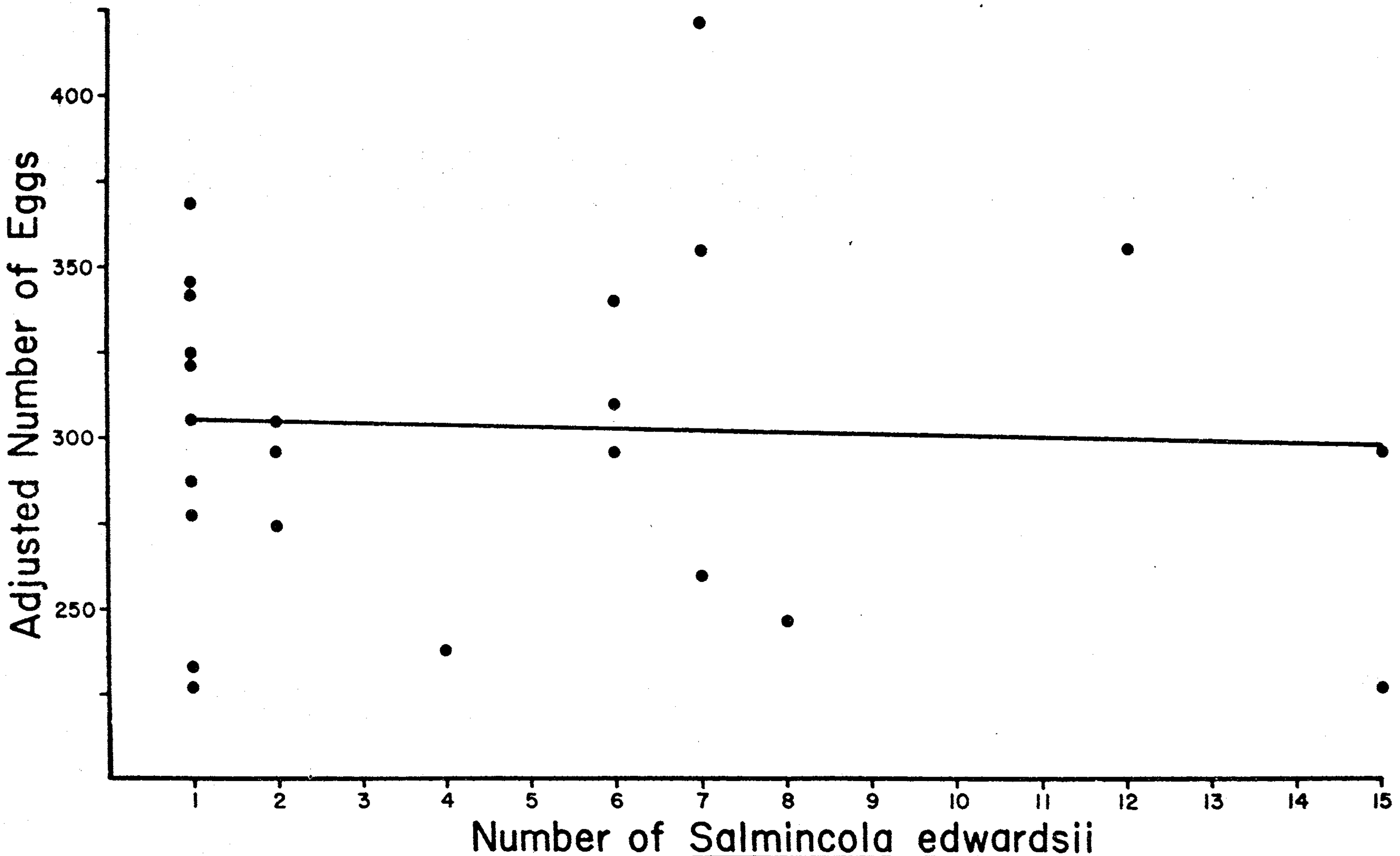

Figure 9. Adjusted number of eggs in relation to the number of gill lice on brook trout from Lawrence Creek. Regression line placed by the method of least squares.

Table 1. Species used in experiments, their sources; dates, methods, and temperatures at time of capture. All lakes and streams are in Portage County, Wisconsin, except Lawrence Creek (Marquette County), Rush Lake (Winnebago County), and Big Roche a Cri River (Waushara County). AC- alternating current, 230 volt boom shocker; DC- direct current, 230 volt stream shocker.

Fish	Parasite	Sources	Date	Method	Temperature C
Prey					
Fathead minnow	With and without anchor worm	National Fish Hatchery. Lake Mills, Wisconsin	March 1972	Seine	11
Yellow perch	With black-spot	Lions Lake	9 times between July 1972 to August 1973	AC	13-23
	Without black-spot	Adams Lake	8 times between July 1972 to August 1973	AC	14-23
	Without black-spot	Severson Lake	July 3, 1973 July 22, 1973	AC	21 22
Brook trout	With gill louse	Lawrence Creek from 300 m down stream to the bridge on County Line Road	6 times between July 1972 to April 1973	DC	7-13
	With gill louse	Big Roche a Cri River from the bridge on County trunk KK to 200 m upstream	July 31, 1973	DC	12

Table 1. Continued.

Fish	Parasite	Sources	Date	Method	Temperature C
Brook trout	Without gill louse	Buena Vista Marsh Ditch #4 from bridge on Airline Road to 400 m upstream	April 3, 1973	DC	8
	Without gill louse	Flume Creek, from bridge on County Trunk T to 200 m upstream	April 6, 1973	DC	7
	Without gill louse	Little Plover River, Interstate 51 bridge to 150 m upstream	5 times between July 1972 to April 1973	AC	7-13
Predator					
Walleye		Rush Lake	January 1972	Nets	6
Largemouth bass		Lions Lake	May 1972	AC	16
Northern pike		Lions Lake	May 1972	AC	18

Table 2. Number of fathead minnow (32-58 mm) with and without <u>Lernaea cyprinacaea</u> eaten by walleye (173-196 mm), mean number and standard deviation (in parentheses) of anchor worm on each minnow, and change in average number of parasites from beginning to end of the experiment.

Run	Duration of experiment (days)	Initial Number		Number Eaten		Number of L. cyprinacaea				Change	
		With	Without	With	Without	Start		End			
		L. cyprinacaea		*L. cyprinacaea*		With	Without	With	Without	With	Without
1	5	25	25	13	13	1.4(0.6)	0	1.2(0.4	0	0.2	0
2	5	25	25	10	6	1.3(0.7)	0	1.0(0.3)	0	0.3	0
3	4	25	25	5	11	1.1(0.3)	0	1.2(0.4)	0	-0.1	0
4[1]	2	10	10	3	3	1.1(0.3)	0	1.1(0.4)	0	0.0	0
Total		85	85	31	33						
Mean						1.2	0	1.1	0	0.1	0

[1]Northern pike (393 mm) used as predator instead of walleye.

Table 3. Number of brook trout (76-173 mm) with and without *Salmincola edwardsii* eaten by northern pike (358-397 mm), mean number and standard deviation (in parentheses) of gill lice on each trout, and change in average number of parasites from beginning to end of the experiment. Pairs of numbers with same superscript are significantly different at the 0.05 level. A and B are replicate pools.

Run	Pool	Duration of experiment (days)	Initial Number With *S. edwardsii*	Initial Number Without *S. edwardsii*	Number Eaten With *S. edwardsii*	Number Eaten Without *S. edwardsii*	Number of *S. edwardsii* Start With	Number of *S. edwardsii* Start Without	Number of *S. edwardsii* End With	Number of *S. edwardsii* End Without	Change With	Change Without
1	A	3	10	10	6	4	2.3(0.8)	0	2.2(1.0)	0	0.1	0
2	A	7	10	10	2	4	2.3(1.0)	0	2.6(1.0)	0	-0.3	0
3	A	1	10	10	2	2	2.9(2.0)	0	2.7(2.0)	0	0.2	0
	B	2	10	10	1[a]	8[a]	3.2(3.0)	0	3.4(3.0)	0	-0.2	0
4	A	11	10	10	0	3	2.7(5.0)	0	2.7(5.0)	0	0.0	0
Total			50	50	11[b]	21[b]						
Mean							2.7	0	2.7	0	-0.04	0

Table 4. Number of yellow perch (91-130 mm) with (Lions Lake) and without the <u>Neascus</u> of <u>Crassiphiala bulboglossa</u> (Adams Lake) eaten by largemouth bass (311-466 mm), mean number and standard deviation (in parentheses) of black-spot on each perch, and change in average number of parasites from beginning to end of the experiment. Mean number of <u>Neascus</u> was determined by summing the number of cysts on the left pectoral and left pelvic fin and in two, one square centimeter fields behind the left pectoral fin on each perch with the parasite and dividing by the number of fish (Fig. 1). Pairs of numbers with same superscript are significantly different at 0.05 level. A and B are replicate pools.

Run	Pool	Duration of experiment (days)	Initial Number With <u>Neascus</u>	Initial Number Without <u>Neascus</u>	Number Eaten With <u>Neascus</u>	Number Eaten Without <u>Neascus</u>	Number of <u>Neascus</u> Start With	Start Without	End With	End Without	Change With	Change Without
1	A	5	10	10	3[a]	9[a]	8.0(8.0)	0	9.7(9.0)	0	-1.7	0
2	A	3	10	10	4	6	8.3(8.0)	0	6.2(6.0)	0	2.1	0
	B	5	10	10	4	5	6.6(2.0)[1]	0	6.8(0.8)[1]	0	-0.2	0
3	A	3	10	10	1[b]	7[b]	6.5(3.0)	0	6.5(4.0)	0	0.0	0
Total			40	40	12[c]	27[c]						
Mean							7.6	0	7.5	0	0.7	0

[1] Mean number of cysts on the left side of the perch, left pectoral and left pelvic fin included.

Table 5. Number of yellow perch (90-127 mm) with (Lions Lake) and without the *Neascus* of *Crassiphiala bulboglossa* (Severson Lake) eaten by largemouth bass (311-346 mm). A and B are replicate pools.

Run	Pool	Duration of experiment (days)	Initial Number With *Neascus*	Initial Number Without *Neascus*	Number Eaten With *Neascus*	Number Eaten Without *Neascus*
1	A	5	17	17	6	6
	B	5	16	18	7	11
2	A	3	15	15	9	6
Total			48	50	22	23

Table 6. Number of perch (99-162 mm) from Lions Lake with light and heavy infestations of the *Neascus* of *Crassiphiala bulboglossa* eaten by largemouth bass (311-465 mm), mean number and standard deviation (in parentheses) of black-spot on each perch, and change in average number of parasites from beginning to end of experiment. Mean number of Neascus was determined by summing the number of cysts on the left pectoral and left pelvic fin and in two, one square centimeter fields begind the left pectoral fin on each perch with the parasites, and dividing by the number of fish (Fig. 1). A and B are replicate pools.

Run	Pool	Duration of expt. (days)	Initial Number		Number Eaten		Number of *Neascus*				Change	
							Start		End			
			Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy
1	A	4	9	10	3	3	1.4(0.8)	12.3(11.1)	1.5(0.5)	12.4(12.4)	-0.1	-0.1
	B	4	7	8	3	3	2.0(1.4)	13.0(8.9)	2.2(1.0)	14.4(10.6)	-0.2	-0.4
2	A	5	10	10	2	3	--	--	--	--		
	B	12	10	10	1	5	--	--	--	--		
Total			36	38	9	14						
Mean							1.7	12.6	1.8	13.4	-0.2	-0.2

Table 7. Number of yellow perch (109-168 mm) from Adams Lake with and without artificial black spots eaten by largemouth bass (250-450 mm).

Run	Pool	Duration of experiment (days)	Initial Number		Number Eaten	
			Artificial	Without	Artificial	Without
1	A	3	9	10	2	3
2	A	3	7	8	3	2
3[1]	A	3	5	7	2	1
Total			21	25	7	6

[1] Northern pike (450 mm) used as predator instead of largemouth bass.

Table 8. Number of yellow perch (89-160 mm) with artificial black spots (Severson Lake) and natural infestations (Lions Lake) of the *Neascus* of *Crassiphiala bulboglossa* eaten by largemouth bass (311-465 mm). Pairs of numbers with same superscript are significantly different at 0.05 level.

Run	Pool	Duration of experiment (days)	Initial Number *Neascus* Artificial	Initial Number *Neascus* Natural	Number Eaten *Neascus* Artificial	Number Eaten *Neascus* Natural
1	A	3	10	10	6[a]	0[a]
2	A	3	5	8	2	3
3	A	2	14	14	12[b]	6[b]
Total			29	32	20[c]	9[c]

Table 9 Species used in weight-length comparisons, their sources, dates of capture, length, weights, and linear weight-length relationships where Y=log weight and X=log length. Lions Lake is in Portage County and the ponds are in Langlade County, Wisconsin. All fish captured using 230 volt D.C. boom shocker.

Number of fish	Parasite	Sources and Date collected	Length Mean	Length Range	Weight Mean	Weight Range	Least Square Formula	F-Value For Slope	and df
Yellow perch 155	black-spot light infestation	Lions Lake September 21 and 27, 1973	123.4	74-177	19.6	2-53	Y=5.43+3.19X	0.26	1,296
Yellow perch 146	black-spot heavy infestations	Lions Lake September 21 and 27, 1973	135.3	78-193	25.8	4-78	Y=-5.34+3.15X		
Brook trout 70	with gill louse	Spiegal Pond April 7 1969	177.6	88-365	66.9	7-422	Y=-5.03+3.00X	0.01	1,136
Brook trout 70	without gill louse	Maxwell Pond April 9, 1969	216.9	127-373	144.9	18-520	Y=5.02+3.01X		
Brook trout 70	with gill louse	Spiegal Pond July 22, 1969	185.5	116-314	67.7	14-254	Y=-5.11+3.04X	0.09	1,136
Brook trout 70	without gill louse	Maxwell Pond July 24, 1969	176.9	99-345	77.1	6-440	Y=-5.23+3.04X		

Table 9. Continued.

Number of fish	Parasite	Sources and Date collected	Length		Weight		Least Squares Formula	F-Value for Slope and df	
			Mean	Range	Mean	Range			
Brook trout 70	with gill louse	Spiegal Pond April 2, 1970	217.7	114-287	106.7	10-258	Y=-5.01+3.00X	2.96	1,136
Brook trout 70	without gill louse	Maxwell Pond March 26, 1970	176.3	101-332	60.6	7-278	Y=-5.51+3.21X		

DISCUSSION

Results of this study indicate that anchor worm, at infestation levels of 1 to 4 worms per fish, gill lice at levels of 1 to 4 lice per trout, and black-spot at 30 to 633 cysts per fish did not increase vulnerability of prey fishes to piscivores. There was no difference in vulnerability to predation of fathead minnow with and without anchor worm (Table 2). Brook trout without gill lice from the Little Plover River were more vulnerable to predation than trout with the parasite from Lawrence Creek (Table 3). The reason for the difference is not known, but trout from the Little Plover River may have been in poorer condition. R.L. Hunt[3] (personal communication), has found brook trout caught from the same area of the Little Plover River from which the experimental fish were taken, to be noticeably thin. Whatever the reason, the experiment provided no evidence that gill lice increase vulnerability.

In experiments in which yellow perch from a single lake were used, there was no difference in vulnerability to predation between perch with light and heavy infestations of black-spot (Table 6) and between normal perch and those

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[3]Group leader - Coldwater Research Group, Bureau of Research, Wisconsin Department of Natural Resources, Hartman Creek Field Station, Waupaca, Wisconsin.

with artificial black spots (Table 7). Evans and MacKiewicz (1958) reported that infections of Neascus metacercariae up to 381 per fish did not affect the vigor or activity of 35 species of New York fish.

Results of experiments in which yellow perch from different lakes infested with Neascus or with artificial black spots were used, although more difficult to interpret, were consistent with results of the temperature tolerance experiment with perch and with observations of the fish during handling and holding.

Even though resistance to high temperature was significantly different for yellow perch from each lake, resistance of Adams Lake perch was much lower than that of perch in Severson and Lions Lakes (Fig. 7). For Adams Lake perch the slope of the line of regression of survival versus time was significantly greater, and the time to 50% dead was an order of magnitude less than for the other two lakes.

Resistance of yellow perch from Severson and Lions Lakes were similar in that the regressions had the same slopes, and the times to 50% mortality were of the same order of magnitude. Yet, those times were significantly different, and Lions Lake perch were more resistant than Severson Lake fish.

These differences could not be related to Neascus since only Lions Lake perch were infested, barring the unlikely possibility that black-spot enhances the ability of fish to withstand high temperature. The differences can be interpreted to indicate state of health of the fish, i.e.

that yellow perch from Lions Lake were healthiest, those from Severson Lake were less healthy, and those from Adams Lake were <u>much</u> less healthy.

The yellow perch could be placed in the same categories on the basis of observations made when the fish were held before experiments. Some of the perch from Adams Lake developed frayed caudal fins, and small hemorrhagic areas appeared on the caudal peduncle. (None of these fish were used in experiments). A few perch died during holding, and the problem seemed sufficiently severe that some of the perch were taken to the Fish Disease Laboratory of the Bureau of Sport Fisheries and Wildlife at Genoa, Wisconsin. The perch were found to have symptoms of a bacterial infection caused by *Aeromonas liquefaciens* (Dennis Anderson, personal communication), but the bacterium could not be isolated. A few Severson Lake perch developed symptoms similar to those of Adams Lake perch, but there was relatively little fin damage and few hemorrhagic areas on these fish. Perch from Lions Lake were easily maintained under laboratory conditions and none developed these signs of bacterial infection.

If the evidence that black-spot had no effect on vulnerability to predation or temperature tolerance of yellow perch (Tables 6, 7, Fig. 7) is valid, the results of predation experiments in which perch from different lakes were used can be interpreted on the basis of the state of health of yellow perch described above. Adams Lake perch, being <u>much</u> less healthy than Lions Lake perch, were more vulnerable to predation (Table 4). Severson Lake perch, being only less healthy than yellow perch from Lions Lake, were more vulnerable to predation in one experiment (Table 8), but not in another (Table 5).

Coble (1970) found that metacercariae of yellow grub, Clinostomum marginatum, at an incidence of 1 to 11 did not increase vulnerability of fathead minnow to largemouth bass predation. The results of this study and that of Coble (1970) differ from those of Herting and Witt (1967) who found largemouth bass infested with Dactylogyrus sp. to be more vulnerable than controls to predation by bowfin, Amia calva. However, they described their infested bass as sluggish whereas in this work and that of Coble (1970) the movement of minnows with parasites was not noticeably different from that of fish without parasites.

Parasites may increase vulnerability of fish to avian predators, however. Van Dobben (1952) found that 30% of roach, Rutilus rutilus, in the diet of cormorants, Phalacrocorax carbo, were infected with Ligula intestinalis whereas only about 6.5% of the general roach population was infected. Also, Holmes and Bethel (1972) found gammarids, Gammarus lacustris, infested with Polymorphus paradoxus, an acanthocephalan cystacanth, to be more vulnerable to mallard ducks, Anas platyrhnchos, than those without the parasite.

Gill lice reduced the resistance of brook trout to high temperature. Of six groups of trout, three with the parasite had lower resistance than three without gill lice (Fig. 5). Also, a trend was evident, albeit not significant at commonly used probability levels, in which, as the number of gill lice increased, time to death decreased (Fig. 6). Fox (1965) found rainbow trout (Salmo gairdneri) infested with the metacercariae of the trematode Bolbophorous confusus, to be less resistant to increasing water temperatures than uninfested controls.

There was a good deal of variation among groups in the survival/time relationships (Fig. 5). The literature does not indicate that so much variation exists. Resistance to high temperature has been found to be affected by acclimation temperature and by season of the year (Brett, 1944; Hart, 1952) in such a manner that fish caught later in a year at higher temperatures are more resistant to high temperature than those taken earlier, even though acclimated before testing.

These sources of variation could not account for most of the differences in resistance among the groups of brook trout. All fish (trout and yellow perch) were acclimated before used in temperature tolerance experiments. Also, 4 of the 6 groups of trout, Buena Vista, Flume, Little Plover and Lawrence 2, were captured on three successive days, April 5 to 7, 1973. Differences in time of capture could account for the differences in resistance of groups Lawrence Creek 1 and 2. The first group of Lawrence Creek trout was captured on March 12, 1973, whereas the second, which has greater resistance, was caught on April 7.

Gill lice at infestation levels ranging up to 28, with a mean of 7.9 copepods per fish did not affect weight-length relationships of brook trout (Fig. 8). Allison and Latta

(1969) also found no effect on condition factor[4] of brook trout with average levels of gill lice as high as 47 parasites per fish.

In this study black-spot at an average incidence level as high as 378 cysts on yellow perch in Lions Lake did not influence the weight-length relationship. Rabideau and Self (1953) did not find the combination of black-spot and yellow grub at incidence levels of 192 and 0.51 cysts per fish respectively, to affect condition of green sunfish, Lepomis cyanellus, and orangespotted sunfish, Lepomis humilis, from an Oklahoma lake. In contrast, Hunter and Hunter (1938) provided evidence that smallmouth bass, Micropterus dolomieui, infested with Crassiphiala ambloplitis at an average incidence level of about 400 metacercariae per fish caused weight loss in a laboratory study.

Other field studies in which no effect on condition factor was found in comparisons of fish with and without a parasite include Elliott and Russert (1949) working with yellow perch with a mean infestation of less than 20 yellow grub cysts per yearling; Lewis and Nickum (1964) working with bluegill infested with white liver grub, Posthodiplostomum minimum, at infestation levels as high as 1035 metacercariae per fish; and Wolfert et al. (1967) working with walleye from Lake Erie infested with Bothriocephalus cuspidatus at incidence levels as high as 94 cestodes per fish. Although these studies indicate no effect of

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[4]Condition factor is calculated by dividing weight by cube of length (Lagler, 1964).

parasites on condition, the possibility remains that, of the fish in each body of water with the parasite, those that originally were affected severely enough to influence condition, would have had a higher mortality rate than others, and therefore would not have been present to be caught.

The existence of such a bias, however, is not supported by some other field studies in which cestodes were found to influence condition or growth of fish. Pitt and Grundmann (1957) reported that *Ligula intestinalis* with infestation levels as low as three cestodes per fish caused stunting of yellow perch in a Utah reservoir. Essex and Hunter (1926) found heavy infestation levels of up to 100 tapeworms to be responsible for poor condition in rainbow trout in Mystic Lake, Montana. Also, Hubbs (1927) found retarded growth and retention of larval characteristics in the cyprinid fish, *Platygobio gracilis*, in a small stream in New Mexico that were infested with *Proteocephalus* sp., trematodes, and nematodes at infestation levels of up to 7.5 parasites per fish. In these studies fish with parasite loads sufficiently high to affect condition or growth were present in the population and were captured.

The effect of the white liver grub on growth of bluegill is not clear from laboratory studies. Smitherman (1964) found mean infestation levels averaging 350 metacercariae or more per fish reduced growth whereas Ramsey (1966), found no effect on growth with incidence levels of 330 to 742 cysts per fish.

This study provided no evidence that gill lice affect reproductive potential of brook trout. There was no relationship between adjusted number of ova and number of parasites on trout (Fig. 9). Fecundity is highly variable in brook trout and other species of fish, e.g. for the 24 brook trout used in this investigation, the number of ova in fish 170 mm long ranged from 223 to 432. Parasites, or anything else, would have to have a very pronounced effect on fecundity for it to be discernible over such variation.

Gall, et al. (1972) did find that the gill copepod, Salmincola californiensis, reduced fecundity of rainbow trout in a California hatchery. Incidence of copepods on the fish was not reported, but was high enough to warrant replacing the fish with uninfested brood stock. Other parasites that have been shown to influence fecundity include Ligula intestinalis, which caused sterility in the common shiner (Dence, 1958), and induced elimination of the gonad stimulating hormone of the pituitary in roach, Rutilus rutilus (Kerr, 1948); and Philonema agubernaculum, which Meyer (1960) reported responsible for elimination of natural spawning of the land-locked Atlantic salmon, Salmo salar sebago.

Many other studies have shown the existence of sublethal effects of parasites on fish, e.g. Fox (1965) found that Bolbophorus confusus reduced stamina of rainbow trout and depressed hematocrit values, Smitherman (1964) reported lowered hematocrit readings in bluegill infested with Posthodiplostomum minimum.

Blindness or impaired vision was shown by Ferguson and Hayford (1941) in fathead minnow infested with the metacercariae of the eye fluke, Diplostomum, and Larson (1965) associated herniation of the bullhead, Ictalurus melas, with Diplostomulum flexicaudum. Exophthalmia has been induced by infesting pumpkinseed, Lepomis gibbosus, with Cercariae bessiae, (Krull, 1934) and the popeye condition has been reported in salmonids infested with Nanophyetus salmincola, (Millerman and Knapp, 1970).

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APPENDIX

Table 1. Occurrence of parasites other than those under study in fish preserved in 10% formalin. Numbers in parentheses are numbers of fish with the parasite[6].

Host	Location	Number Examined	Number With Other Parasites	Trematode	Cestode	Acanthocephalan
Brook trout	Flume Creek	15	1			1(1)
Brook trout	Buena Vista Ditch #4	15	0			
Brook trout	Little Plover River	15	2			2(2)
Brook trout	Lawrence Creek	15	0			
Brook trout	Big Roche a Cri	15	0			
Yellow perch	Adams Lake	15	1	1(1)*		1(1)
Yellow perch	Lions Lake	15	1		1(1)	
Yellow perch	Severson Lake	15	0			
Fathead minnow	Lake Mills Hatchery	15	0			

6 No nematodes or copepods were found in any of the fish examined.

* Cyst

Table 2. Mean length (mm), standard deviation (in parentheses), and differences in mean lengths of fathead minnow with and without *Lernaea cyprinacaea* at the beginning and end of the experiment.

Run	With L. cyprinacaea			Without L. cyprinacaea		
	Beginning	End	Difference	Beginning	End	Difference
1	43.2(5)	41.8(5)	1.4	44.3(7)	54.2(6)	-0.9
2	44.9(5)	44.9(5)	0.0	43.2(6)	42.5(6)	0.7
3	41.7(5)	41.0(5)	0.7	40.5(4)	39.4(4)	1.1
4	46.8(2)	46.3(2)	0.5	45.6(2)	45.7(2)	-0.1
Mean			0.65			-0.20

Table 3. Mean length (mm), standard deviation (in parentheses), and differences in mean lengths of brook trout with (Lawrence Creek) and without (Little Plover River) *Salmincola edwardsii* at the beginning and end of the experiment. A and B are replicate pools.

Run	Pool	With S. edwardsii			Without S. edwardsii		
		Beginning	End	Difference	Beginning	End	Difference
1	A	96.8(4)	100.0(2)	-3.2	97.3(5)	98.8(6)	-1.5
2	A	144.5(8)	143.6(9)	0.9	142.6(9)	142.2(9)	0.4
3	A	85.1(6)	84.8(6)	0.3	85.7(7)	83.6(5)	2.1
	B	145.4(11)	144.6(11)	0.8	143.8(11)	142.0(6)	1.8*
4	A	145.3(17)	145.3(17)	0.0	146.1(14)	149.6(12)	-3.5
Mean				-0.24			-0.62

* If fewer than 3 fish were alive at the end of a run, the difference in mean length from beginning to end was not included in calculating the mean difference for the entire experiment.

Table 4A. Number of brook trout (76-173 mm) with (Lawrence Creek) and without (Little Plover River) *Salmincola edwardsii* eaten by northern pike (358-397 mm) and mean number and standard deviation (in parentheses) of gill lice on each trout. Data herein differ from Table 3 in that trout that were wounded by the pike (Fig. 4) were considered to be in the eaten category. Numbers with same superscripts are significantly different at 0.05 level. A and B are replicate pools.

Run	Pool	Duration of experiment (days)	Initial Number With *S. edwardsii*	Initial Number Without *S. edwardsii*	Number Eaten With *S. edwardsii*	Number Eaten Without *S. edwardsii*	Number of *S. edwardsii* Start With	Number of *S. edwardsii* Start Without	Number of *S. edwardsii* End With	Number of *S. edwardsii* End Without	Change from Start to End With	Change from Start to End Without
1	A	3	10	10	8	6	2.3(0.8)	0	2.0(1.0)	0	0.3	0
2	A	7	10	10	3	7	2.3(1.0)	0	2.9(1.0)	0	-0.6	0
3	A	1	10	10	2	2	2.9(2.0)	0	2.8(2.0)	0	0.1	0
	B	2	10	10	1[a]	10[a]	3.2(3.0)	0	3.4(3.0)	0	-0.2	0
4	A	11	10	10	2	4	2.7(0.5)	0	2.9(0.4)	0	-0.2	0
Total			50	50	16[b]	29[b]						
Mean							2.7	0	2.7	0	0.12	0

Table 4B. Mean length (mm), standard deviation (in parentheses), and differences in mean lengths of brook trout with (Lawrence Creek) and without (Little Plover River) *Salmincola edwardsii* at the beginning and end of the experiment. Trout that were wounded by the pike (Fig. 4) were condidered to be in the eaten category. A and B are replicate Pools.

Run	Pool	With S. edwardsii			Without S. edwardsii		
		Beginning	End	Difference	Beginning	End	Difference
1	A	96.8(4)	99.5(0.7)	-2.7	97.3(5)	100.8(6)	-3.5
2	A	144.5(8)	143.1(9)	1.4	142.6(9)	148.0(2)	-5.4
3	A	85.1(6)	84.8(6)	0.3	85.7(7)	83.6(5)	2.1
	B	145.4(11)	144.5(11)	0.9	143.8(11)	--	--
4	A	145.3(17)	149.8(16)	-4.5	146.1(14)	149.6(12)	-3.5
Mean				-0.48			-2.58

Table 5. Mean length (mm), standard deviation (in parentheses) and differences in mean lengths of yellow perch with (Lions Lake) and without (Adams Lake) the Neascus of *Crassiphiala bulboglossa* at the beginning and end of the experiment. A and B are replicate pools.

Run	Pool	With Neascus			Without Neascus		
		Beginning	End	Difference	Beginning	End	Difference
1	A	119.1(7)	121.1(7)	-2.0	116.8(6)	177.0	-60.2*
2	A	107.6(5)	106.1(6)	1.5	108.4(3)	107.5(1)	0.9
	B	102.6(6)	103.0(4)	-0.4	101.1(6)	106.0(3)	-4.9
3	A	103.4(4)	103.7(4)	-0.3	102.7(6)	105.5(9)	-2.8
Mean				-0.3			-2.27

* If fewer than 3 fish were alive at the end of a run, the difference in mean length from beginning to end was not included in calculating the mean difference for the entire experiment.

Table 6. Mean length (mm), standard deviation (in parentheses), and differences in mean length of yellow perch with (Lions Lake) and without (Severson Lake) the *Neascus* of *Crassiphiala bulboglossa* at the beginning and end of the experiment. A and B are replicate pools.

Run	Pool	With Neascus			Without Neascus		
		Beginning	End	Difference	Beginning	End	Difference
1	A	103.4(15)	107.8(12)	-4.4	102.4(12)	105.7(12)	-3.3
	B	99.3(13)	99.7(14)	-0.4	98.4(7)	98.8(8)	-0.4
2	A	107.7(15)	108.0(16)	-0.3	108.0(16)	110.6(17)	-2.6
Mean				-1.7			-2.1

Table 7. Mean length(mm), standard deviation (in parentheses), and differences in mean lengths of yellow perch from Lions Lake with light and heavy infestations of the *Neascus* of *Crassiphiala bulboglossa* at the beginning and end of the experiment. A and B are replicate pools.

Run	Pool	Light Infestations			Heavy Infestations		
		Beginning	End	Difference	Beginning	End	Difference
1	A	144.6(12)	155.2(16)	-10.6	121.9(11)	121.1(11)	0.8
	B	109.0(6)	110.5(8)	-1.5	120.8(12)	125.0(10)	-4.2
2	A	129.1(17)	129.8(18)	-0.7	130.1(18)	134.1(19)	-4.0
	B	125.1(11)	124.7(12)	0.4	124.3(10)	124.4(8)	-0.1
Mean				-3.1			-1.9

Table 8. Mean length (mm), standard deviation (in parentheses), and differences in mean lengths of yellow perch from Adams Lake with and without artificial black spots at the beginning and end of the experiment.

Run	Pool	With Artificial Black spot			Without Artificial Black spot		
		Beginning	End	Difference	Beginning	End	Difference
1	A	119.1(7)	120.1(7)	-1.0	118.9(8)	121.0(8)	-2.1
2	A	143.0(7)	144.7(7)	-1.7	143.3(7)	143.6(8)	-0.3
3	A	159.8(7)	162.2(5)	-2.4	160.0(4)	160.0(4)	0.0
Mean				1.7			-0.8

Table 9. Mean length (mm), standard deviation (in parentheses), and differences in mean lengths of yellow perch with artificial (Severson Lake) and natural (Lions Lake) infestations of the <u>Neascus</u> of <u>Crassiphiala bulboglossa</u> at the beginning and end of the experiment.

Run	Pool	Artificial			Natural Infestations		
		Beginning	End	Difference	Beginning	End	Difference
1	A	145.3(7)	146.7(4)	-1.4	144.9(7)	144.9(7)	0.0
2	A	138.0(14)	144.0(12)	-6.0	136.0(12)	135.8(15)	0.2
3	A	96.4(6)	97.5(4)	-1.1*	95.9(5)	96.5(5)	-0.6
Mean				-3.7			-0.13

* If fewer than 3 fish were alive at the end of a run, the difference in mean length from beginning to end was not included in calculating the mean difference for the entire experiment.

Table 10. Cumulative percent survival of brook trout at 25 C with and without *Salmincola edwardsii*. Trout acclimated to 20 C. Numbers in parentheses are numbers of fish dying in each five-hour period.

	Salmincola edwardsii					
	With			Without		
Hours to Death	Big Roche a Cri	Lawrence Run #1	Lawrence Run #2	Little Plover	Buena Vista	Flume Creek
5	92.3(1)	100.0(0)	100.0(0)	100.0(0)	100.0(0)	100.0(0)
10	92.3(0)	100.0(0)	100.0(0)	100.0(0)	100.0(0)	91.3(2)
15	84.6(1)	77.8(5)	95.6(1)	88.9(2)	100.0(0)	91.3(0)
20	69.2(2)	55.6(3)	91.3(1)	83.4(1)	100.0(0)	91.3(0)
25	69.2(0)	33.3(4)	78.3(3)	77.8(1)	100.0(0)	91.3(0)
30	46.2(3)	27.8(1)	60.9(4)	72.3(1)	100.0(0)	91.3(0)
35	38.5(1)	16.7(2)	39.1(5)	66.7(1)	100.0(0)	82.6(2)
40	23.1(2)		30.4(2)	61.2(1)	85.0(3)	74.0(2)
45	15.4(1)		26.1(1)		70.0(3)	69.6(1)
Number at start	13	18	23	18	20	23
Number alive at end	2	3	6	11	14	16
Time (hr) to 50% dead	27.6	22.0	32.4	46.3[1]	50.9[1]	85.7[1]

[1] Extrapolated values

Table 11. Mean number (range in parentheses) of *Salmincola edwardsii* on brook trout that died during five-hour periods at 25 C. Trout acclimated to 20 C.

Hours to Death	With Salmincola edwardsii		
	Big Roche a Cri River	Lawrence Creek Run #1	Lawrence Creek Run #2
5	9.0(0)	0.0(0)	0.0(0)
10	0.0(0)	0.0(0)	0.0(0)
15	1.0(0)	10.0(3-37)	1.0(0)
20	3.0(3-3)	5.0(4-7)	9.0(0)
25	0.0(0)	5.2(2-12)	5.3(4-9)
30	3.7(1-6)	1.0(0)	5.0(3-9)
35	4.0(0)	9.5(4-15)	3.0(1-5)
40	5.0(4-6)		4.5(3-6)
45	2.0(0)		1.0(0)

Table 12. Cumulative percent survival of yellow perch at 32 C with and without the *Neascus* of *Crassiphiala bulboglossa*. Perch acclimated to 25 C. Numbers in parentheses are numbers of fish dying in each five-hour period.

Hours to Death	*Neascus* of *Crassiphiala bulboglossa*		
	With	Without	
	Lions Lake	Severson Lake	Adams Lake
5	100.0(0)	100.0(0)	71.0(4)
10	100.0(0)	96.0(1)	42.6(4)
15	100.0(0)	92.0(1)	
20	100.0(0)	92.0(0)	
25	100.0(0)	92.0(0)	
30	100.0(0)	88.0(1)	
35	96.0(1)	72.0(4)	
40	92.0(1)	68.0(1)	
45	84.0(2)	60.0(2)	
50	84.0(0)	60.0(0)	
55	84.0(0)	48.0(3)	
Number at start	25	25	14
Number alive at end	21	12	6
Time (hr) to 50% dead	76.40[1]	56.03	5.8