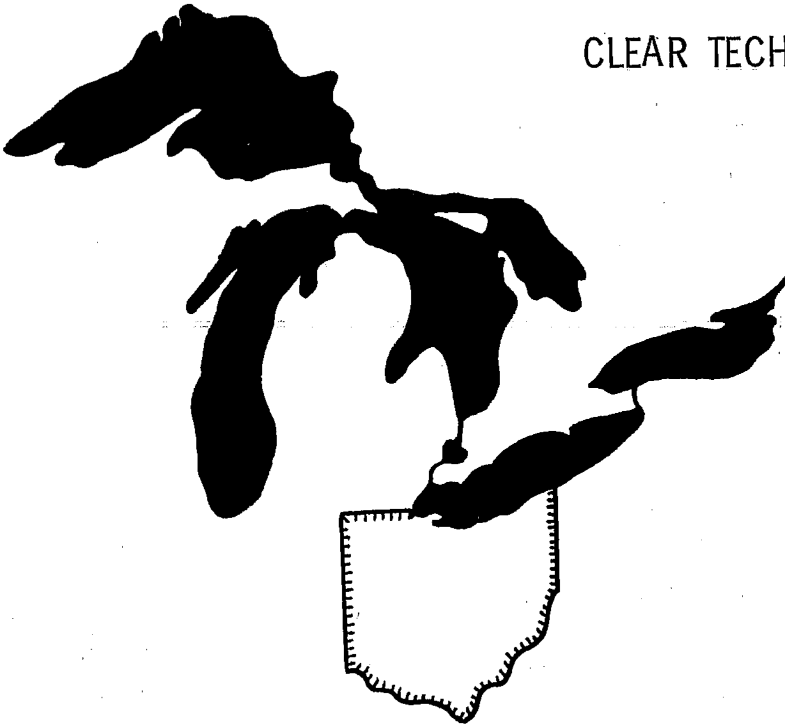

CLEAR TECHNICAL REPORT NO. 180

IMPACT OF THE NEMATODE PARASITE _EUSTRONGYLIDES TUBIFEX_ ON YELLOW PERCH IN LAKE ERIE

Second Project Segment
1 July 1979 - 30 June 1980
Project No. 3-298-R-2

Prepared by

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Prepared for

Ohio Department of Natural Resources
Division of Wildlife

and

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service

THE OHIO STATE UNIVERSITY
CENTER FOR LAKE ERIE AREA RESEARCH
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Period Covered: July 1, 1979 - June 30, 1980

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ABSTRACT

A total of 2,691 yellow perch from Lake Erie were examined during 1979. The majority of yellow perch, 63.1%, were 2+ age class (1977 year class). Eighty percent of the yellow perch in the samples were infected with one of the three parasites involved in this contract; 46.4% were infected with the nematode parasite *Eustrongylides tubifex*, 42.9% with the nematode *Philometra cylindracea* and 57.4% with the plerocercoid of the tapeworm *Trianopharus modulosus*. The greatest number of infected yellow perch were in the 2+ age class. Again in 1979, as in 1978, the highest percentages of infection with *E. tubifex* occurred in older yellow perch. The populations of parasites maintained themselves and increased in the populations sampled of yellow perch in 1979. Most perch infected with *E. tubifex* were also infected with one of the other parasites.

Seasonal distribution percentages of samples for *E. tubifex* in 1979 were generally similar to 1978. *P. cylindracea* and *T. nodulosus* showed patterns different from 1978, but these patterns were similar to one another in both years. The mean worm burden of *E. tubifex* increased significantly in perch from 1978 through 1979.

The use of an abundance index (A-index) shows that again in 1979 the parasites were more abundant in the Western Basin than in the Central Basin, and this was correlated with the larger size of yellow perch in the Central Basin. The A-index was also used to show the abundance of *E. tubifex* and *P. cylindracea* in samples throughout the season and to show distributional trends. The index indicated a high degree of variability for *E. tubifex* in sampled perch. This may be because we were sampling

migrating subpopulations of yellow perch. As mean worm burden increased there was a trend in weight loss within the 2+ age class. As mean worm burden increased during the first two years of the life of a perch, there was a weight loss, and this may be maintained in older fish. However, this has not been shown to be statistically significant due to the high degree of variability between samples.

The size at which E. tubifex entered the coelem of perch, the size at which they molted in the capsules and the maximum size they attained in yellow perch were ascertained this year. The position and character of E. tubifex chemoreceptors (amphids) were determined by scanning-electron microscopy. The mesenteric capsules which surround the developing E. tubifex larvae were sectioned and their histopathology studied. It was illustrated that these capsules are much more complex than the usual primary tissue response which occurs in fishes. The wall of mesenteric capsules is composed of at least five different kinds of tissue and is highly vascularized. Experimental transfers of E. tubifex from one yellow perch to another were accomplished, demonstrating that cannibalism may be one means of infection of older perch.

The implications of this information for the development of effective management strategies are still preliminary in nature.

STUDY OBJECTIVE

To specify the impact of pathological damage to yellow perch caused by the parasite Eustrongylides tubifex on growth and survival in the perch populations of the Western and Central Basins of Lake Erie and to develop management recommendations.

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JOB 1a

PREVALENCE OF *EUSTRONGYLIDES TUBIFEX* IN LAKE ERIE YELLOW PERCH

Objective

To determine the seasonal prevalence of the nematode parasite *Eustrongylides tubifex* in yellow perch by size and age class in the Western and Central Basins of Lake Erie.

Procedures

Samples of yellow perch (2,146 fish) were taken weekly, June through October, from the Western Basin of Lake Erie by otter-trawl from the Motor Vessel *Bio-Lab* in the vicinity of Green and Rattlesnake Islands. These samples furnished a data base for comparison with other samples from other areas of Lake Erie. The sampling interval was shortened to weekly data collections to better identify changes in the parasite burden. Samples (514 fish) were collected by otter trawl from other areas within the Central (July) and Western (June and July) Basins of the lake from the Motor Vessel *Explorer* and were provided by the staff of the Lake Erie Fisheries Research Station, Ohio Department of Natural Resources, at Sandusky, Ohio. To increase the reliability of the statistical tests, trawling continued on each date, at each station, until at least 100 fish were collected. A minimum of 1000 yellow perch were to be examined from all collections combined.

All yellow perch were iced immediately after removal from the trawl while on board the boats, and they remained on ice until they were measured, weighed, and necropsied in the laboratory.

The following parameters were measured and the following data recorded for each yellow perch: total length in millimeters; standard length in millimeters; height in millimeters; a first weight, measured in grams to one-tenth of a gram; and a second weight (after the yellow perch had been eviscerated) of only flesh, bone, and gills. Scales were removed from each yellow perch, pressed into plastic, and read to determine the age, which was recorded.

The viscera of each yellow perch was removed and placed in a dish of "Ringer's Cold" salt solution, and the body cavity was rinsed with salt solution into the same dish. The viscera were examined with a stereoscopic binocular dissection microscope. The number of *Eustrongylides tubifex* and the number of other parasites considered to be pathogenic to yellow perch were noted, and the following data were recorded: the number of *Eustrongylides tubifex* larvae removed from capsules or free in the body cavity (the body wall was always examined for larvae); the number of *Philometra cylindracea* adults present, and the number of partial adult, female *P. cylindracea* encapsulated; and the extent of liver infected with the plerocercoid stage of the tapeworm, *Triaenophorus nodulosus* (this infection was scored light (1-5), medium (6-10), and heavy (10 or more)).

Two separate sets of computer cards were prepared by two separate operators for each yellow perch. The two sets of cards were checked against one another for accuracy. The data concerning lengths, heights, weights, ages, and numbers of different parasites were punched into each card. All data and analyses were stored on a computer disc. The data were analyzed on an AMDAHL 470 computer using the Statistical Analysis System, SAS (SAS, User's Guide, Barr et al., 1979).

Findings

Overall Prevalence of Infection (Parasites Combined - Entire Season)

In this section we will examine the overall, combined prevalence or incidence of parasitism by the three parasites involved in this contract. The numbers and percentages of parasitized yellow perch include any yellow perch infected with one or a combination of the following parasites: *Eustrongylides tubifex*, *Philometra cylindracea*, and *Triaenophorus nodulosus*.

First to be considered will be the combined prevalence of these parasites from all sampling stations during 1979 (Tables 1-3), and secondly, the prevalence at the sampling station between Green and Rattlesnake Islands (GR Station, Tables 4-6). In later sections we will consider the prevalence of the individual species of parasites and their seasonality.

In 1979, we examined 2,691 yellow perch from all sampling sites and 2,146 (80.0%) of these were parasitized, 544 were uninfected.

In 1978, 63.6% of all yellow perch sampled were in the 1+ age class. Then in 1979, 1,698 of 2,691 or 63.1% of all the yellow perch sampled were of the 2+ age class (Table 1). In 1978, the majority of infected yellow perch (63.2%) were distributed in the large 1+ age class; in 1979, 1,447 of 2,146 infected yellow perch, 67.3%, were of the 2+ age class (Table 2). Table 3 presents the percentage or rate of infection within each age class of yellow perch examined from all sampling sites in 1979 combined.

TABLE 1

NUMBERS AND PERCENTAGES OF ALL AGE CLASSES
OF YELLOW PERCH FROM ALL SAMPLING SITES COMBINED, 1979

Age Class	N	% of Total Catch
YOY	303	11.60
1+	166	6.17
2+	1,698	63.10
3+	330	12.20
4+	153	5.60
5+	33	1.23
6+	8	0.30
	2,691	

TABLE 2

AGE CLASS DISTRIBUTION OF INFECTED YELLOW PERCH FROM ALL SAMPLING SITES, 1979

Age Class	N	% of 2,146 Infected Perch	% of the Entire 2,691 Perch Examined
YOY	120	5.59	4.46
1+	109	5.08	4.05
2+	1,447	67.43	53.78
3+	285	13.28	10.60
4+	144	6.71	5.35
5+	33	1.54	1.23
6+	8	0.34	0.30
	2,146		

TABLE 3

THE PERCENTAGE OR RATE OF INFECTION OF EACH AGE CLASS OF YELLOW PERCH EXAMINED FROM ALL SAMPLING SITES, 1979

Age Class	Number of Perch Examined	Number of Perch Infected	% of Each Age Class Infected
YOY	303	120	39.60
1+	166	109	65.66
2+	1,698	1,447	85.52
3+	330	285	86.36
4+	153	144	99.12
5+	33	33	100.00
6+	8	8	100.00
	N = 2,691	N = 2,146	

TABLE 4

NUMBERS AND PERCENTAGES OF ALL CLASSES
OF YELLOW PERCH SAMPLED FROM THE GR STATION, 1978 AND 1979

Age Class	N		% Composition	
	1978	1979	1978	1979
YOY	270	303	13.10	13.92
1+	1,303	134	63.40	6.16
2+	158	1,302	7.60	59.81
3+	192	294	9.30	13.50
4+	85	123	4.10	5.63
5+	33	18	1.60	0.83
6+	13	3	0.63	0.14
7+	1	0	0.05	0.00
	2,055	2,177		

TABLE 5

COMPARISON OF THE AGE CLASS DISTRIBUTION OF INFECTED YELLOW PERCH SAMPLED FROM THE GR STATION 1978 AND 1979

Age Class	N 1978	N 1979	% of 1,577 Infected Yellow Perch 1978	% of 1,732 Infected Yellow Perch 1979	% of Entire 2,055 Yellow Perch Examined 1978	% of Entire 2,177 Yellow Perch Examined 1979
YOY	126	120	8.00	6.93	6.10	5.52
1+	1,002	92	65.50	5.31	49.80	4.23
2+	140	1,130	8.90	65.24	2.00	51.91
3+	183	255	11.60	14.72	8.90	11.71
4+	82	114	5.20	6.58	3.90	5.24
5+	31	18	2.00	1.04	1.50	0.83
6+	12	3	0.80	0.17	0.58	0.14
7+	1	0	0.60	0.00	0.05	0.00
	1,577	1,732				

TABLE 6

THE PERCENTAGES OR RATES OF INFECTIONS OF EACH
OF THE AGE CLASSES OF YELLOW PERCH
EXAMINED FROM THE GR STATION 1978 AND 1979

	1978			1979		
Age Class	N Examined	N Infected	%	N Examined	N Infected	%
YOY	270	126	46.7	303	120	39.6
1+	1,303	1,002	76.9	134	92	68.7
2+	158	140	88.6	1,302	1,130	86.8
3+	192	183	95.6	294	255	86.8
4+	85	82	96.6	123	114	92.7
5+	33	31	93.9	18	18	100.0
6+	13	12	92.3	3	3	100.0
7+	1	1	100.0	0	0	0.0
	2,055	1,577		2,177	1,732	

The samples taken from collection sites other than the GR Station were of value when compared with samples taken at approximately the same time from the GR station. Samples from other collection stations were not comparable between 1978 and 1979 if they did not match in time and location. The samples taken weekly throughout the collecting seasons of 1978 and 1979 from the GR Station were comparable between these years.

The comparative data for 1978-1979 from the GR Station are similar to the data already presented for all sampling stations combined. The greatest actual numbers and percentages of yellow perch from this station were 1+ class in 1978 and 2+ class in 1979 (Table 4). Table 5 presents data showing that the actual numbers and highest percentages of infected yellow perch in the entire sample for each year were in the 1+ class in 1978 and in the 2+ class in 1979. Table 6 presents the comparative percentages or rates of infection within each of the age classes for both years at the GR station. Table 7 compares the mean rate of infection for all three parasites during 1978 and 1979 at the GR Station and for all stations.

Prevalence of *Eustrongylides tubifex*

First to be considered will be the prevalence of *E. tubifex* at all sampling sites combined during 1979 (Figures 1-4 and Appendix Tables 14 and 15), and secondly, the prevalence at the station between Green and Rattlesnake Islands in the Western Basin of Lake Erie (Figures 5-8 and Appendix Tables 16 and 17).

The comparative data for the GR Station for any yellow perch infection with *E. tubifex* from the 1978 and 1979 sampled populations are presented in Figures 5 through 8 and Appendix Tables 16 and 17. These are yellow perch infected with one or more *E. tubifex*, and they may also have been infected

TABLE 7

COMPARISON OF MEAN PERCENTAGES OF INFECTION OF YELLOW PERCH FOR THE ENTIRE 1978 AND 1979 SAMPLING SEASONS

	Green and Rattlesnake Island Station		All Sampling Sites	
	1978	1979	1978	1979
<u>Eustrongylides</u> <u>tubifex</u>	45.80	44.9	45.30	46.38
<u>Philometra</u> <u>cylindracea</u>	35.80	42.11	35.60	42.95
<u>Triaenophorus</u> <u>nodulosus</u>	46.70	56.66	46.90	57.42
Infection with any one of the three parasites	76.70	79.80	76.60	80.50
N	2055	2167	2275	2691

Figure 1

Age Class Distribution of 1230 Yellow Perch Infected With Eustrongylides tubifex from All Sampling Sites Combined, 1979 (% of infected perch only).

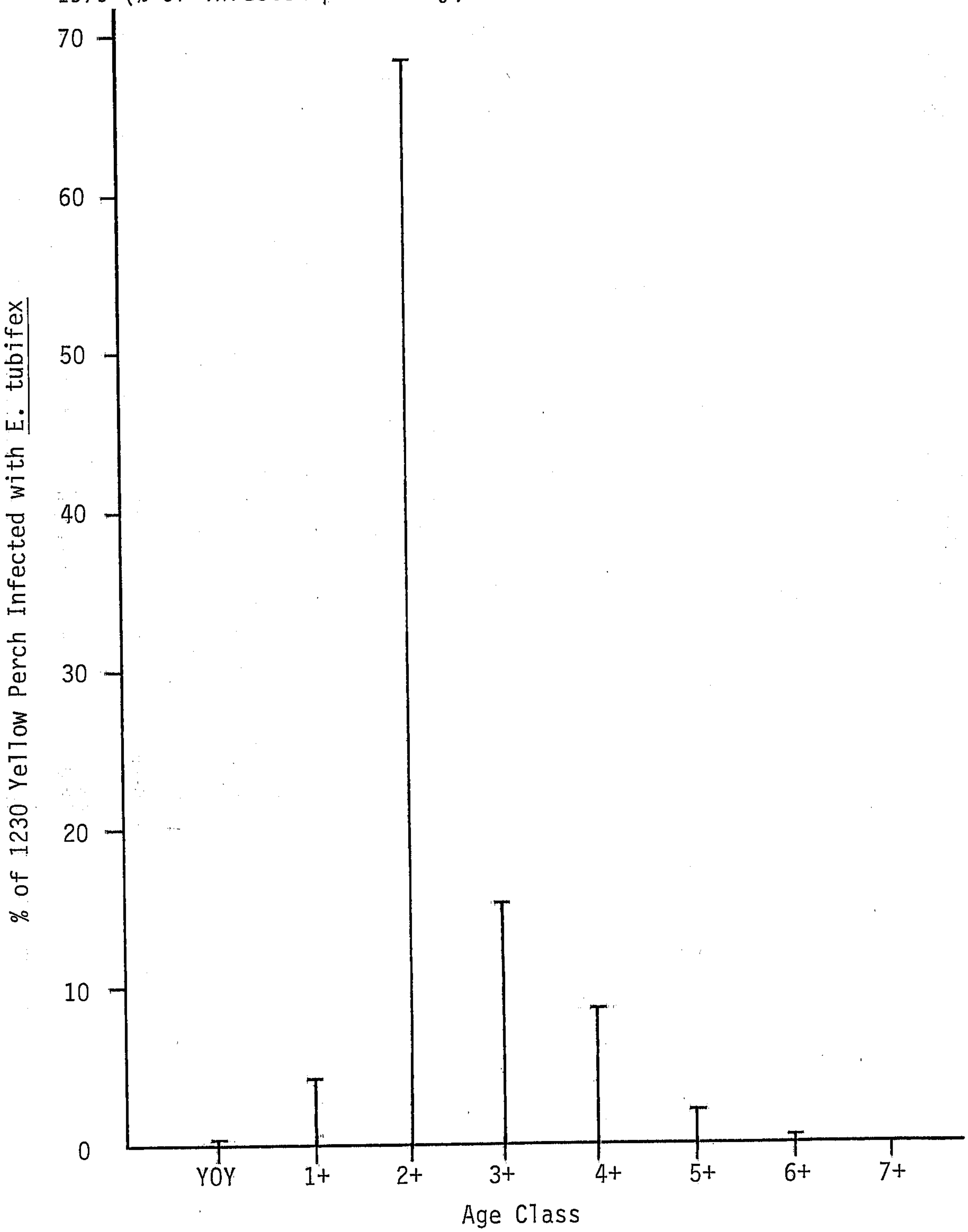


Figure 2

Age Class Distribution of Yellow Perch Infected With *Eustrongylides tubifex* from All Sampling Sites Combined, 1979 (% of entire sample).

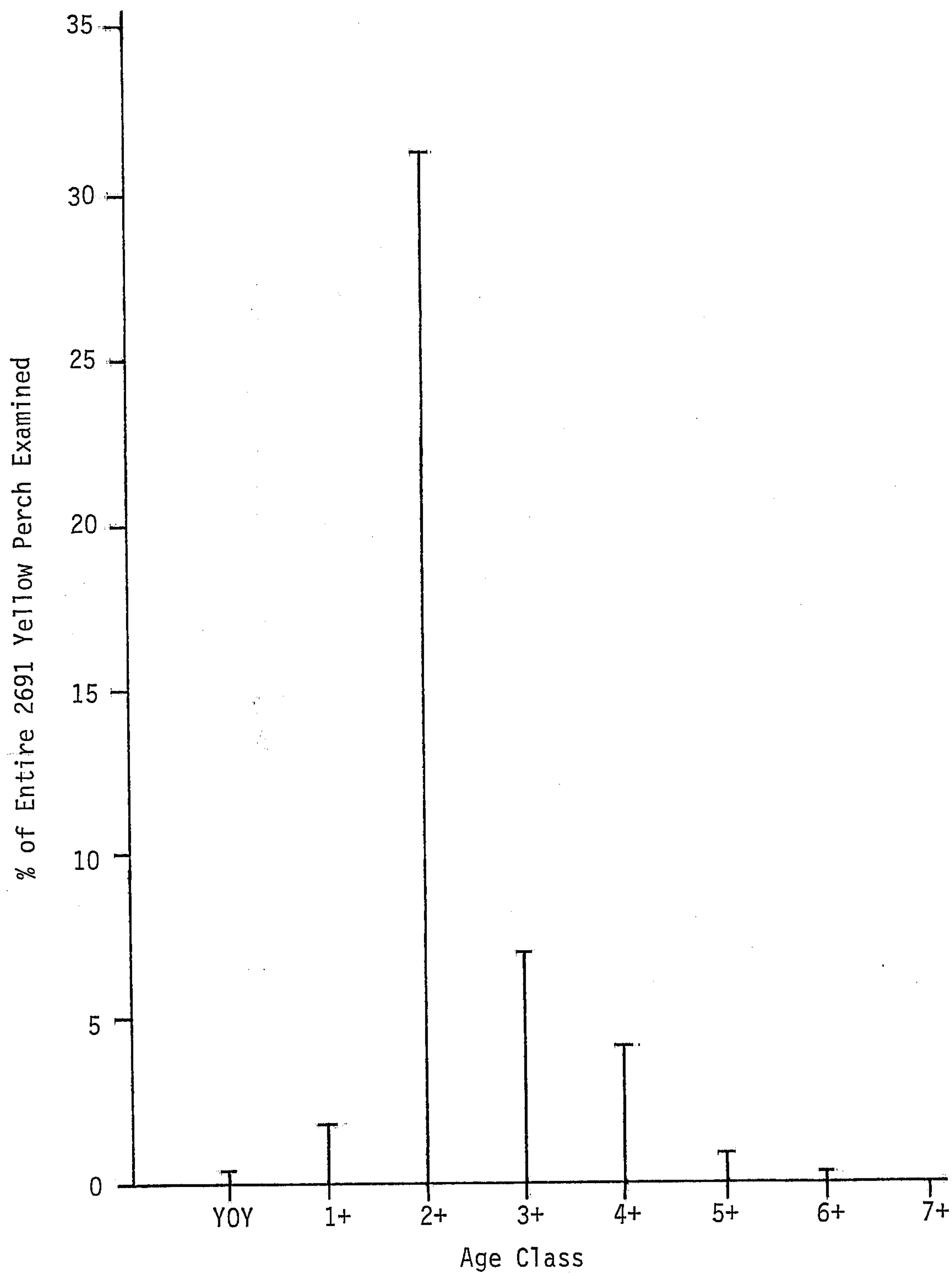


Figure 3

Percentage or Rate of Infection of Each Age Class of Yellow Perch Infected With Eustrongylides tubifex from All Sampling Sites, 1979.

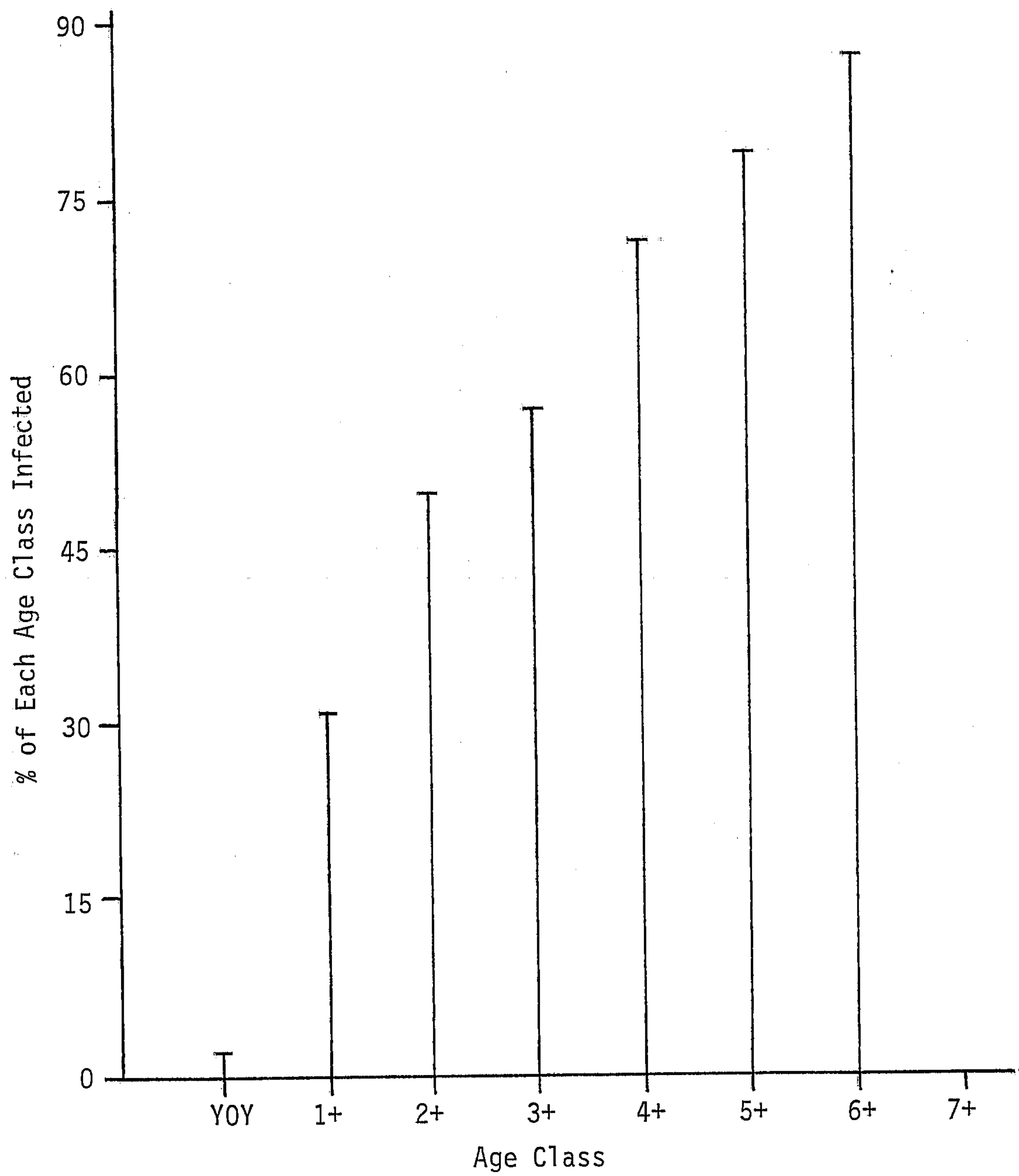


Figure 4

Numbers in Each Age Class of Yellow Perch Examined from All Sampling Sites, 1979 vs. Numbers in Each Age Class of Yellow Perch Infected With E. tubifex from All Sampling Sites, 1979.

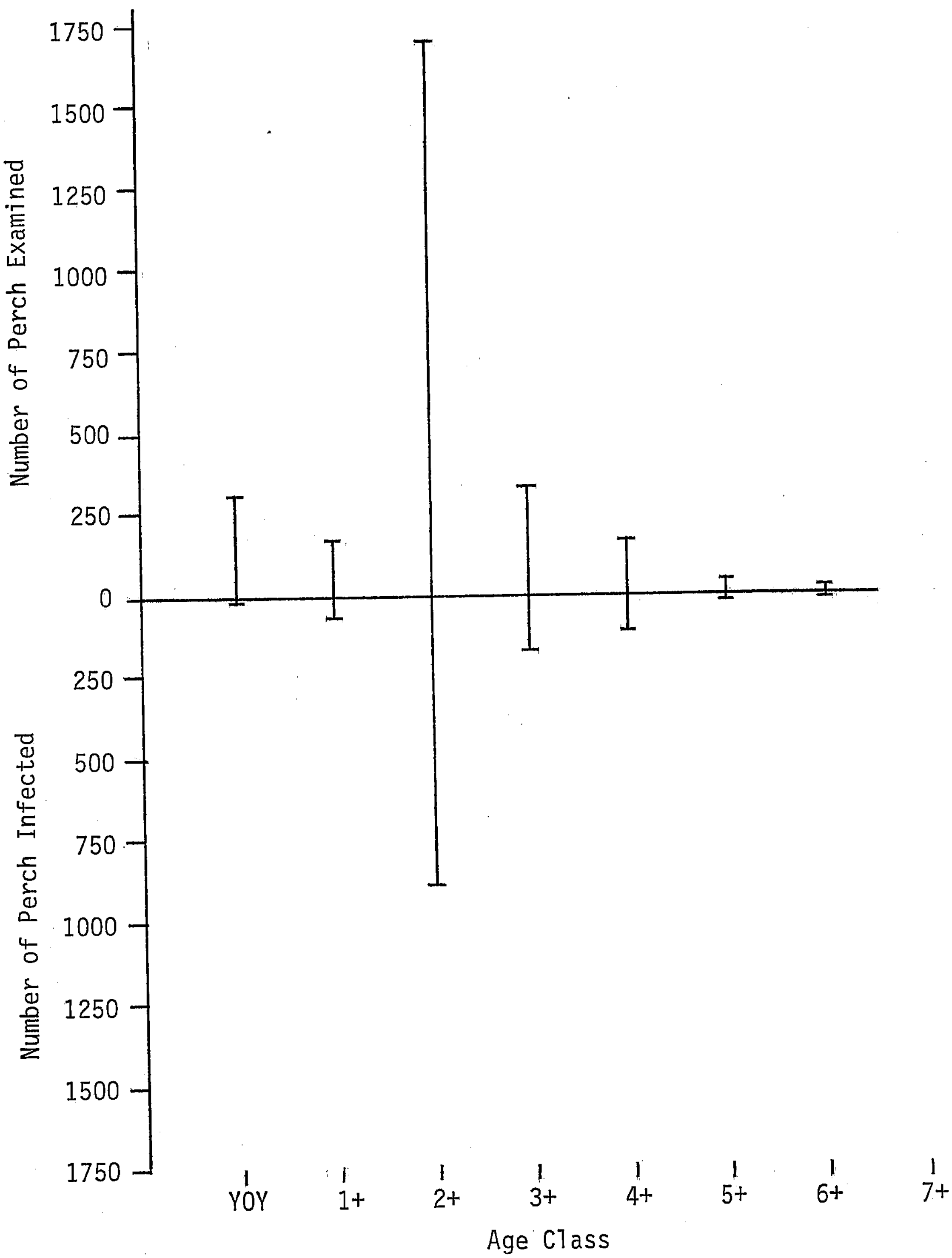


Figure 5

Numbers in Each Age Class of Yellow Perch Infected With <u>Eustrongylides tubifex</u> from the GR Station 1978 and 1979.

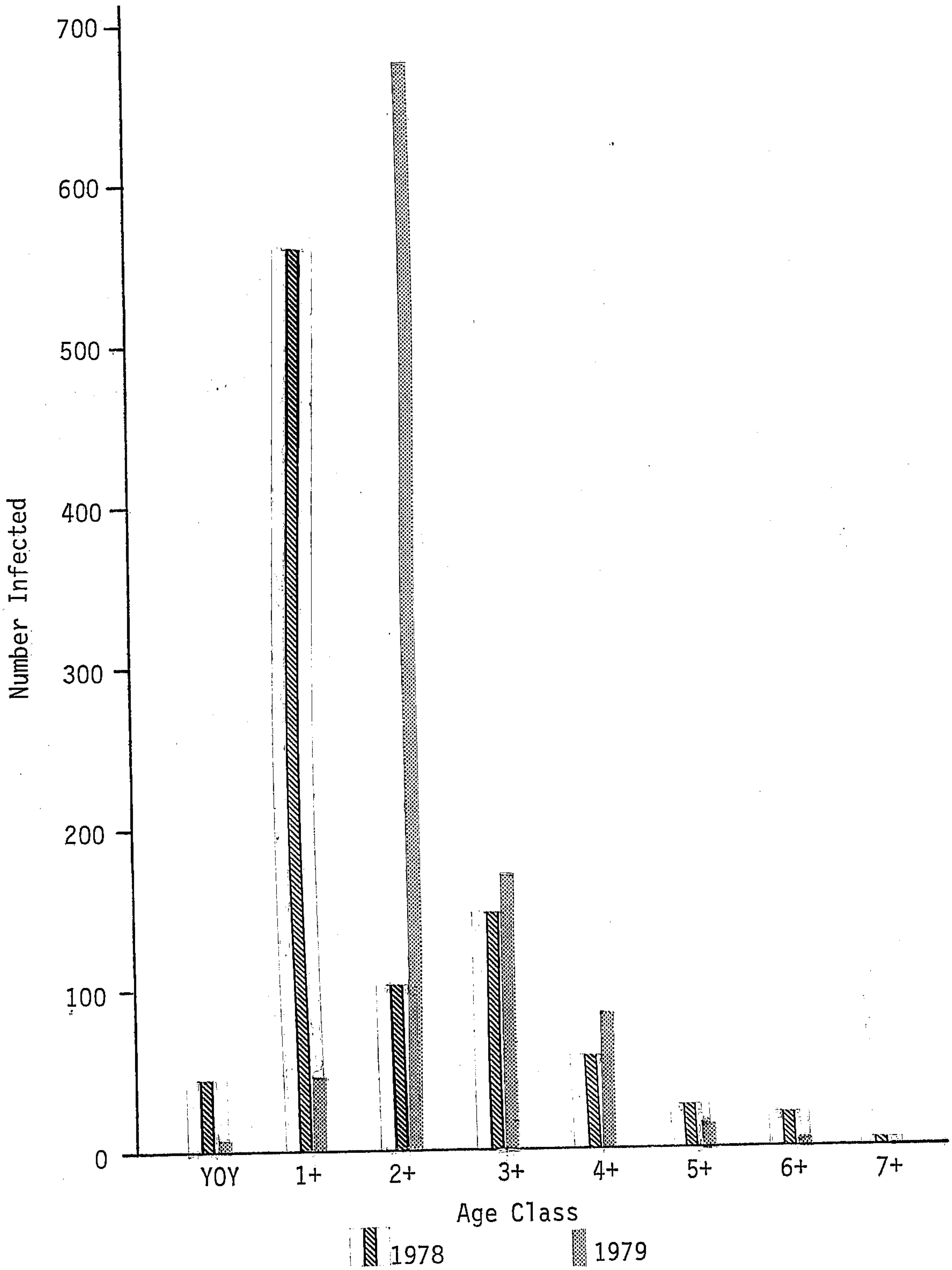


Figure 6

Comparison of the Age Class Distribution of Yellow Perch Infected With Eustrongylides tubifex from the GR Station 1978 and 1979 (% of infected perch only).

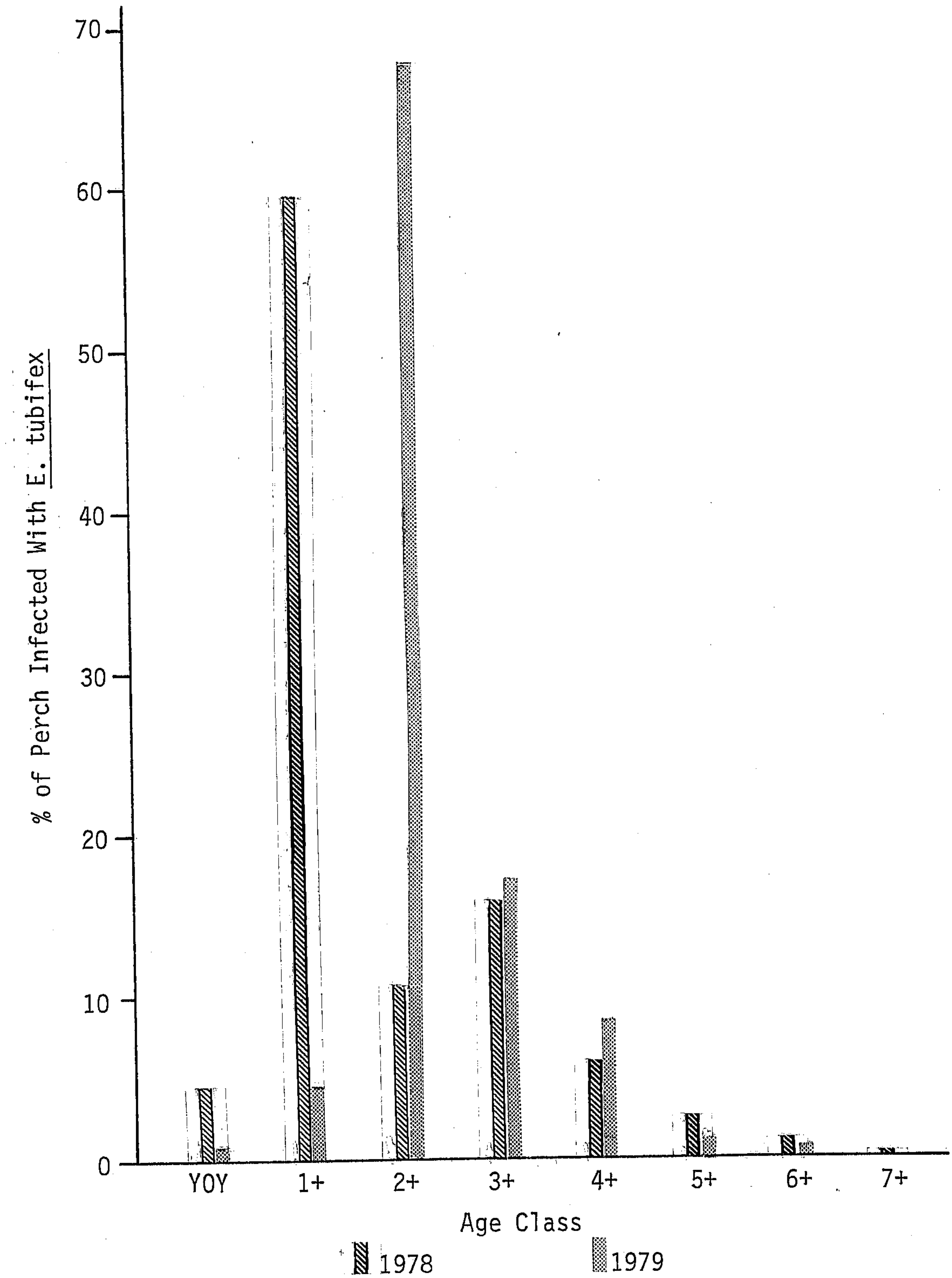


Figure 7

Comparison of the Age Class Distribution of Yellow Perch Infected With <u>Eustrongylides tubifex</u> from the GR Station 1978 and 1979 (% of entire sample).

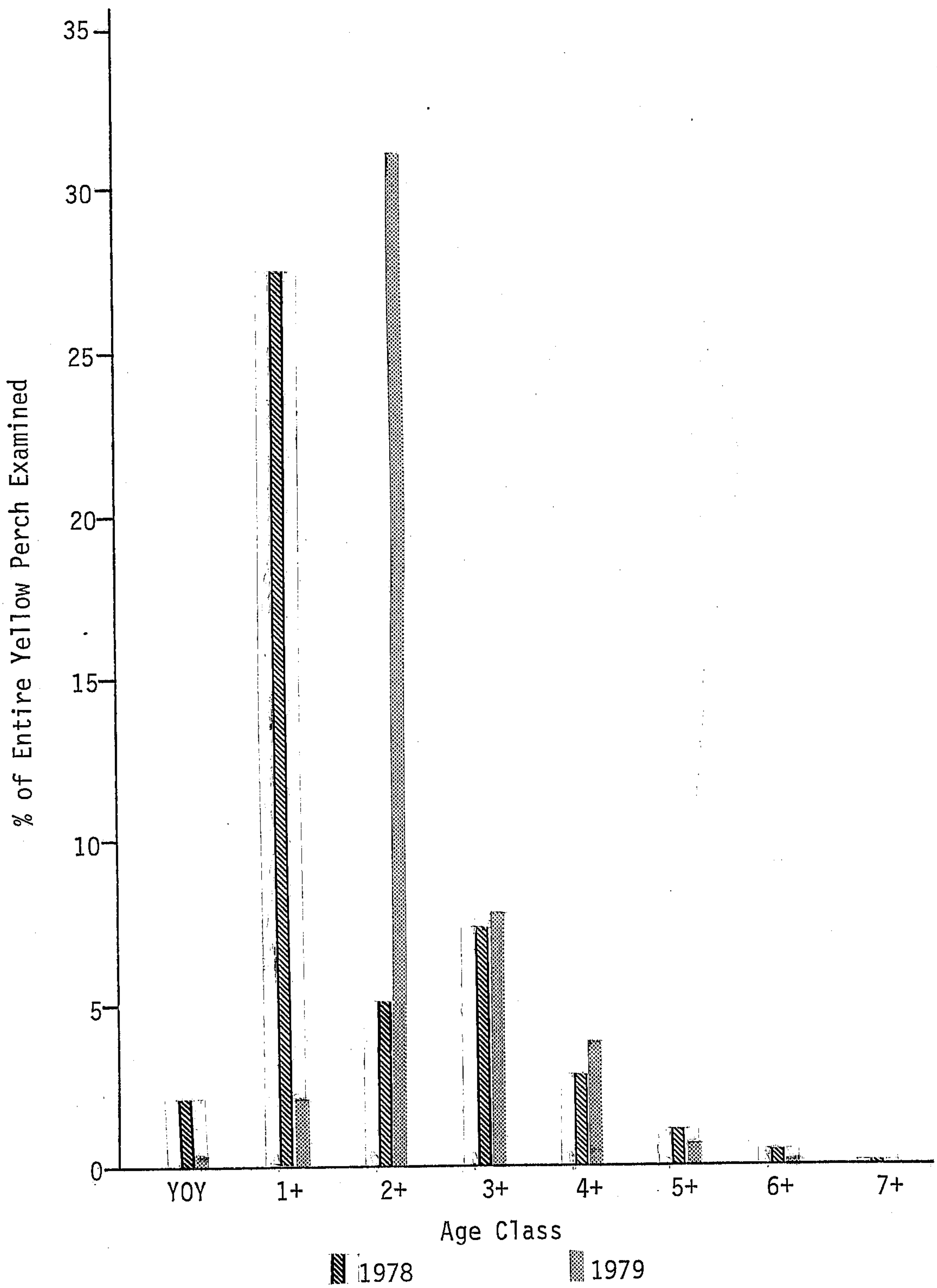
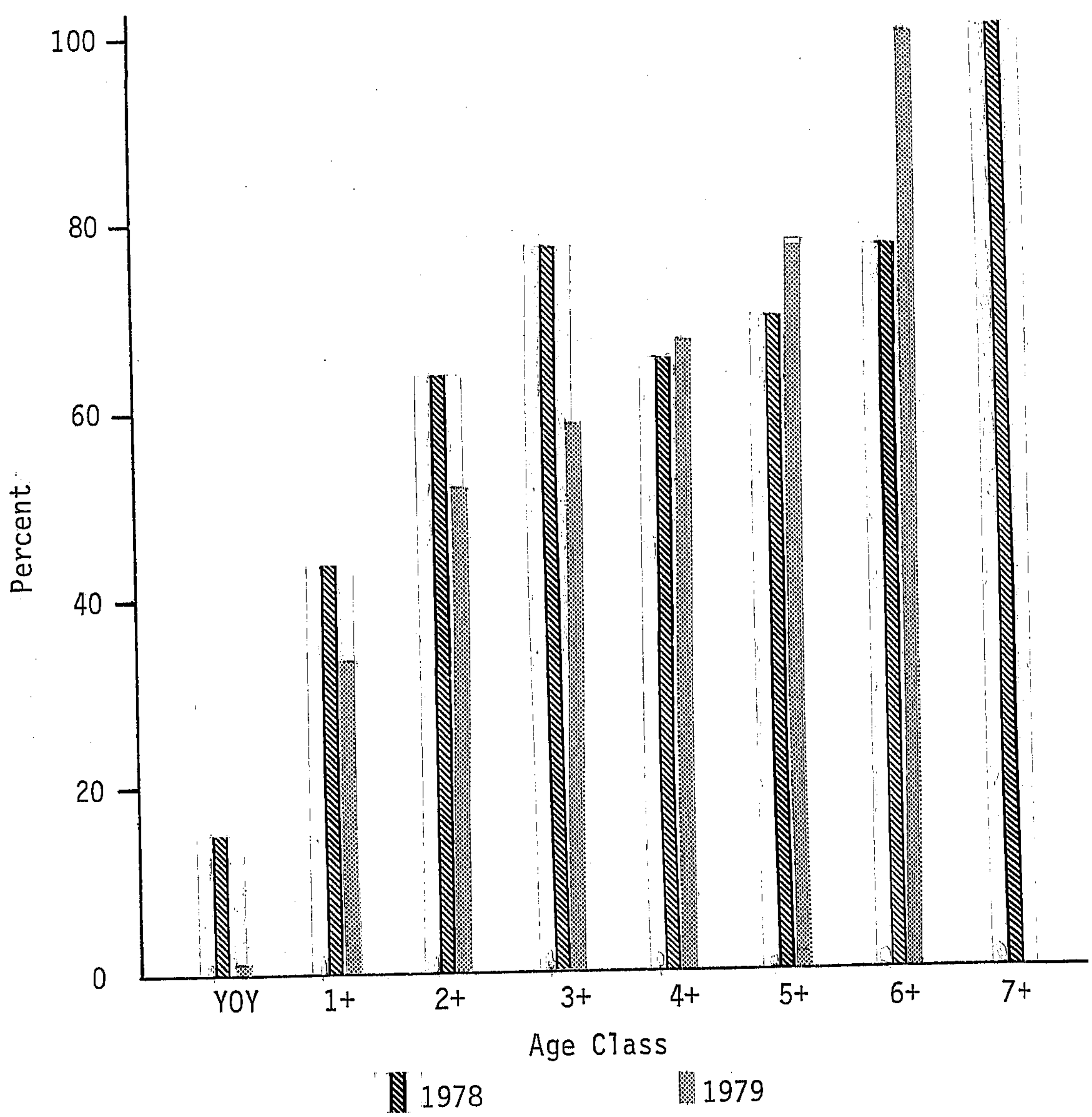


Figure 8

The Percentage or Rates of Infection of Each Age Class of Yellow Perch Infected With E. tubifex Examined from the GR Station 1978 and 1979.



with one or both of the other parasites considered in this study. Figures 5 through 7 and Appendix Table 16 present data showing that the highest actual numbers and highest percentages of the total number of infected yellow perch from the GR Station were 1+ age class in 1978 and 2+ age class in 1979.

Figure 8 and Appendix Table 17 present the comparative data on the rate of infection of each age class of yellow perch infected with *E. tubifex* for both years at the GR Station. Again, these data demonstrate that older yellow perch had higher rates of infection with *E. tubifex* in both 1978 and 1979.

The comparative 1978-1979 data for yellow perch parasitized *only* with *E. tubifex* (neither of the other two parasites present) are presented in Tables 8 and 9. The data presented in the first three columns of Table 8 exhibit a similar pattern to the data mentioned above.

Seasonal Prevalence of *Eustrongylides tubifex*

Seasonal percentages of infection of yellow perch with *E. tubifex* alone or in any combination during 1979 from the GR Station are shown graphically in Figure 9. These data include any yellow perch with an *E. tubifex* infection taken at the GR Station. The rate of *E. tubifex* infection during 1979 decreased irregularly from June until July and then increased irregularly until mid-September; it decreased into October. Figure 10 shows a graphical comparison of the seasonal rates of infection at the GR Station in 1978 and 1979. The patterns of seasonal infection percentages were surprisingly similar in the two years. These data correlate with data presented earlier and indicate that the population of *E. tubifex* maintained itself seasonally.

TABLE 8

COMPARISON OF THE AGE CLASS DISTRIBUTION OF YELLOW PERCH INFECTED WITH EUSTRONGYLIDES TUBIFEX ONLY. EXAMINED FROM THE GR STATION 1978 AND 1979

AGE CLASS	N 1978	N 1979	% OF 339 YELLOW PERCH INFECTED WITH E. TUBIFEX ONLY 1978	% OF 213 YELLOW PERCH INFECTED WITH E. TUBIFEX ONLY 1979	% OF THE ENTIRE 2055 YELLOW PERCH EXAMINED 1978	% OF THE ENTIRE 2177 YELLOW PERCH EXAMINED 1979
YOY	22	4	6.5	1.88	1.07	0.18
1+	219	13	64.6	6.10	10.66	0.60
2+	32	144	9.4	67.61	1.56	6.61
3+	26	37	7.6	17.37	1.27	1.70
4+	21	12	6.1	5.63	1.02	0.55
5+	15	2	4.4	0.94	0.72	0.09
6+	3	1	0.9	0.47	0.14	0.05
7+	1	0	0.3	0.00	0.05	0.00
	339	213				

TABLE 9

THE PERCENTAGES OR RATES OF INFECTIONS OF EACH AGE CLASS OF YELLOW PERCH INFECTED WITH E. TUBIFEX ONLY. EXAMINED FROM THE GR STATION 1978 AND 1979.

AGE CLASS	1978 N EXAMINED	1978 N INFECTED WITH E. TUBIFEX ONLY	1978 %	1979 N EXAMINED	1979 N INFECTED WITH E. TUBIFEX ONLY	1979 %
YOY	270	22	8.1	303	4	1.3
1+	1303	219	16.8	134	13	9.7
2+	158	32	20.2	1302	144	11.1
3+	192	26	13.5	294	37	12.6
4+	85	21	24.7	123	12	9.8
5+	33	15	45.5	18	2	1.1
6+	13	3	23.1	3	1	3.3
7+	1	1	100.0	0	0	0.0
	2055	339		2177	213	

Figure 9. Rate of Infection of Yellow Perch with _Eustrongylides_, Alone or in Combination with _Triaenophorus_ and/or _Philometra_. Examined from the GR Station 1979.

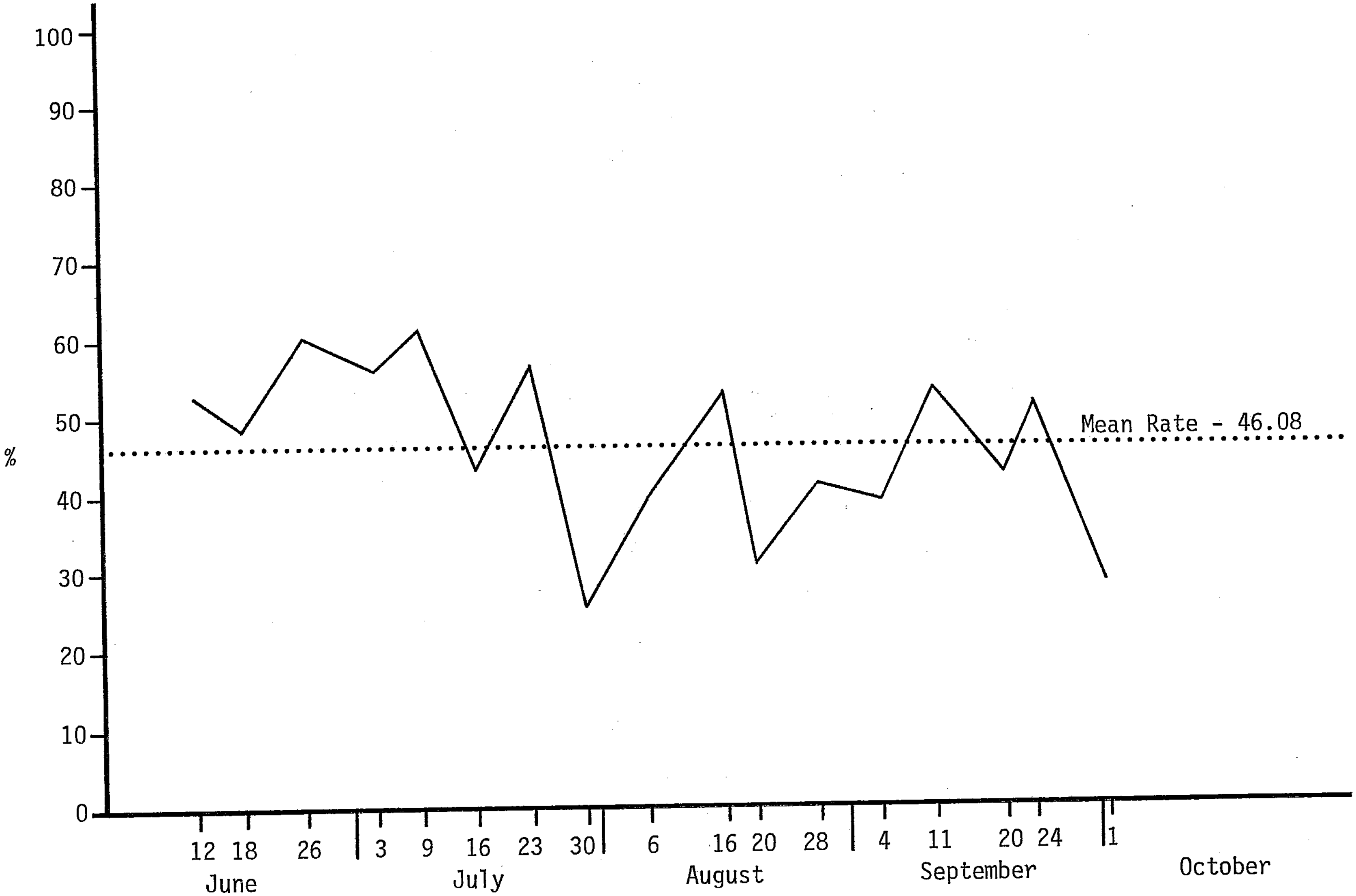
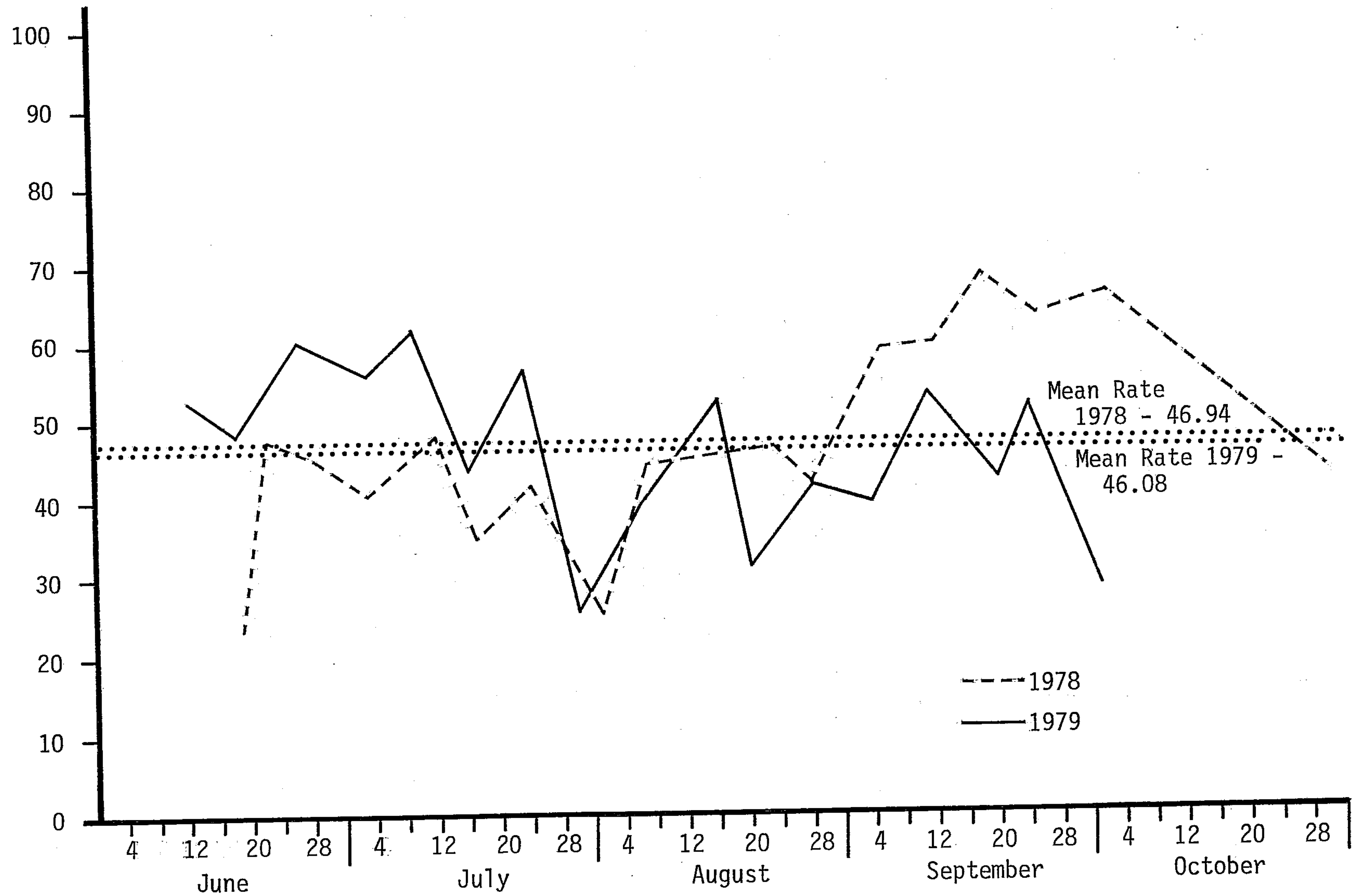


Figure 10. A Comparison of the Rates of Infection of Yellow Perch with _Eustrongylides_, and/or _Triaenophorus_ and/or _Philometra_ Sampled from the GR Station 1978 and 1979.



Seasonal Prevalence of Philometra cylindracea

The data presented in Table 10 include any yellow perch with an infection of P. cylindracea taken from GR Station during 1979. Figure 11 compares the 1978 and 1979 seasonal rates of infection for P. cylindracea for yellow perch. In 1979, the highest rates of infection with P. cylindracea occurred irregularly during June and July. The lowest percentages occurred during August. P. cylindracea has an annual life cycle and this August period marked the end of a generation. The adult female worms at that time were large and filled with larvae. The female worms released the larvae and died. The males had died earlier.

The seasonal pattern of infection for 1979 was different from 1978, but in both years there was a rise in the infection during the late summer months. We have no good explanation for the seasonal differences in the infection rates for the two years, but we can infer that they were related to two things: (1) lake temperature and (2) the changing age of the perch population. Copepods are the known intermediate hosts for P. cylindracea.

There were fewer forage-age yellow perch in the 1979 sampled populations, fewer 1+ and more 2+ age class yellow perch. There was less variation between seasonal rates in 1979 than in 1978 and the mean rate of infection for the entire season was slightly higher in 1979 (42.8% vs. 38.8% in 1978). The rise of the rates of infection during September represented a new generation of Philometra entering the yellow perch.

Seasonal Prevalence of Triaenopharas nodulosus

The data presented in Table 11 include any yellow perch collected from the GR Station during 1979 which were infected with the plerocercoid stage of the tapeworm, Triaenophorus nodulosus. Figure 12 graphically compares

TABLE 10

RATE OF INFECTION OF YELLOW PERCH EXAMINED FROM THE GR STATION 1979

DATE	% OF INFECTION WITH PHILOMETRA (ANY STAGE) ALONE OR IN COMBINATION WITH EUSTRONGYLIDES and/or TRIAENOPHORUS	N
June 12	55.63	142
June 18	40.95	105
June 26	61.95	113
July 3	43.00	100
July 9	59.13	115
July 16	38.05	113
July 23	48.63	183
July 30	31.11	135
August 6	34.69	196
August 16	36.00	125
August 20	30.91	110
August 28	47.22	180
September 4	37.29	118
September 11	45.05	111
September 20	32.50	120
September 24	41.58	101
October 1	44.55	110
	$\bar{X}$ = 42.84	2177

Figure 11. A Comparison of the Rates of Infection of Yellow Perch with Philometra (Any Stage) Alone or in Combination with Eustrongylides and/or Triaenophorus Sampled From the GR Station 1978 and 1979.

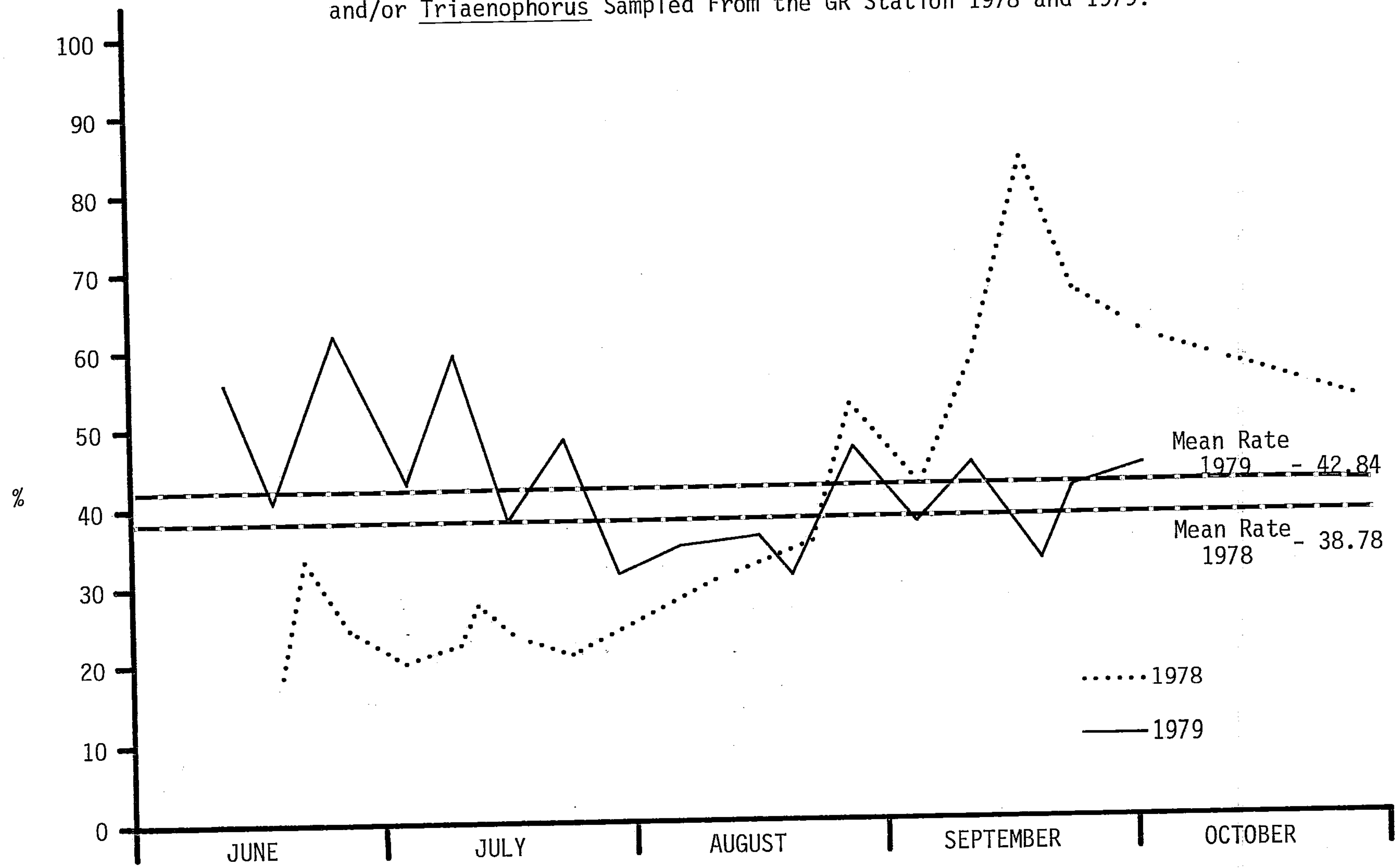
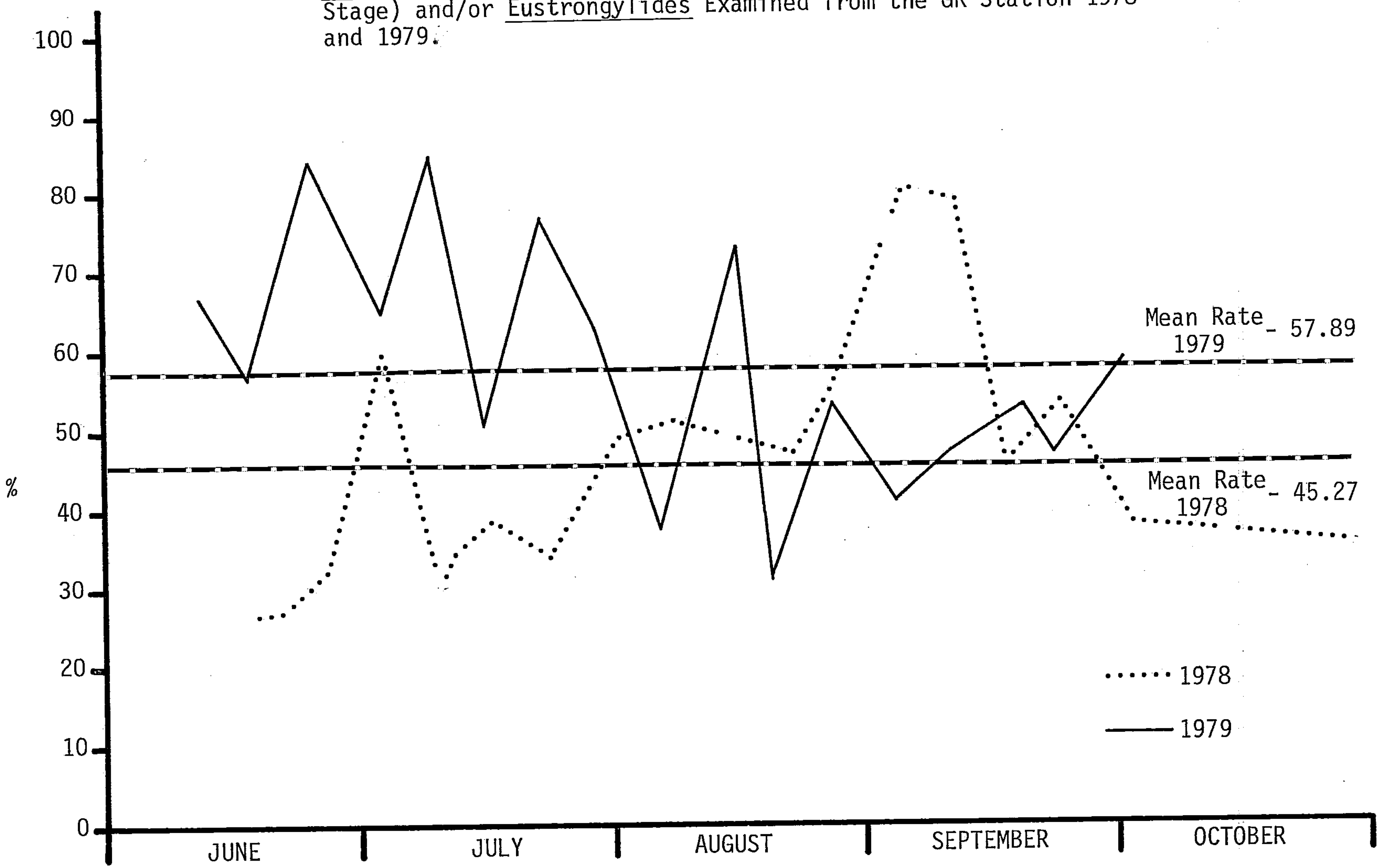


TABLE 11

RATE OF INFECTION OF YELLOW PERCH EXAMINED FROM THE GR STATION 1979

DATE	% OF INFECTION WITH TRIAENOPHORUS ALONE OR IN COMBINATION WITH PHILOMETRA (ANY STAGE) and/or EUSTRONGYLIDES	N
June 12	66.90	142
June 18	56.19	105
June 26	84.07	113
July 3	65.00	100
July 9	84.35	115
July 16	50.44	113
July 23	76.50	183
July 30	62.22	135
August 6	37.24	196
August 16	72.80	125
August 20	30.91	110
August 28	52.78	180
September 4	40.68	118
September 11	46.85	111
September 20	52.50	120
September 24	46.53	101
October 1	58.18	110
	$\bar{X}$ = 57.89	2177

Figure 12. A Comparison of the Rates of Infection of Yellow Perch with *Triaenophorus*, Alone or in Combination with *Philometra* (Any Stage) and/or *Eustrongylides* Examined from the GR Station 1978 and 1979.



the seasonal rates of infection of yellow perch with T. nodulosus for 1978 and 1979. In 1979, the percentage of infection for T. nodulosus was highest during June and July, lowest in August, and rose again in the autumn. The mean rates of infection across the entire collecting season were quite different, 57.9% for 1979 and 45.72% for 1978. In 1978, the highest rate of infection occurred in the autumn but in 1979 the highest rate of infection occurred in the early summer.

The interspecific distributional patterns for T. nodulosus and P. cylindracea in the two seasons, 1978 and 1979, were somewhat different (Figures 11 and 12). However, when the interspecific distributional patterns for T. nodulosus were compared with those of P. cylindracea, they were found to be similar in both years (Figures 11 and 12).

Abundance Index

We suggested in last year's annual report that an abundance index has value, as it includes consideration of the percentage of infection and the mean worm burden. We have used the A-index for comparison of entire samples during this past year. The A-index is calculated by multiplying the percent of perch in a sample infected with a given species of parasite times the mean worm burden of that parasite in infected perch in the sample. For example:

$$\left(\begin{array}{c}\text{Percent Infection}\\ \text{E. tubifex}\end{array}\right)\left(\begin{array}{c}\text{Mean Worm Burden}\\ \text{of Infected Perch}\\ \text{E. tubifex}\end{array}\right) = \text{A-Index of E. tubifex}$$

The A-index was used for comparisons of samples from different locations, of samples from different years, and of samples from the same site at different times of the year.

Table 12 is an example of comparisons of stations within the same year. In each case the sample was compared with the index station between Green and Rattlesnake Islands in the Western Basin of Lake Erie. This station was sampled every week throughout the collecting season. We demonstrated last year that it was necessary, when gathering data about parasites which will be used as a basis for management strategies, to have a station which was sampled often and regularly to obtain accurate comparisons. In Table 12, the West and Middle Sister Islands sample represents a sample taken the farthest west and the Vermilion sample was taken on the edge of the Central Basin of Lake Erie.

Figures 13 and 14 present the abundance indices for *E. tubifex* and *P. cylindracea* at the GR Station during the entire 1979 season (Appendix Table 18). The comparison and variations in the abundance of the two parasites can readily be ascertained. The low indices for both parasites occurred in July and early August.

Worm Burden Versus Weight

We ascertained the mean worm burden in the 1977 year class, the 1+ age class in 1978 and presented data to show that uninfected yellow perch weigh more than infected perch. During 1979, we again determined worm burden of the same year class of fish, now the 2+ age class. Table 13 presents the mean weight in grams for 2+ age class yellow perch harboring 1 through 8 *E. tubifex* larvae as generated by computer. Figure 15 is a computer-generated plot showing the weight of yellow perch of the 2+ age class with increasing numbers of *E. tubifex* larvae. One can note the weight loss as the worm burden increases. It appears that when the perch enter their first full

TABLE 12

STATION TO STATION COMPARISONS USING AN ABUNDANCE INDEX

Location	Date	*Eustrongylides tubifex*	*Philometra cylindracea*
GR Station	18 June	91.40	97.15
West Sister	19 June	138.20	121.80
Vermillion	07 July	110.21	84.28
GR Station	09 July	126.87	98.24
GR Station	16 July	61.55	7.96
Sandusky Bay	17 July	86.02	16.78

FIGURE 13. Abundance Indices for _Eustrongylides tubifex_, Trawls Between Green & Rattlesnake Islands, Lake Erie, 1979.

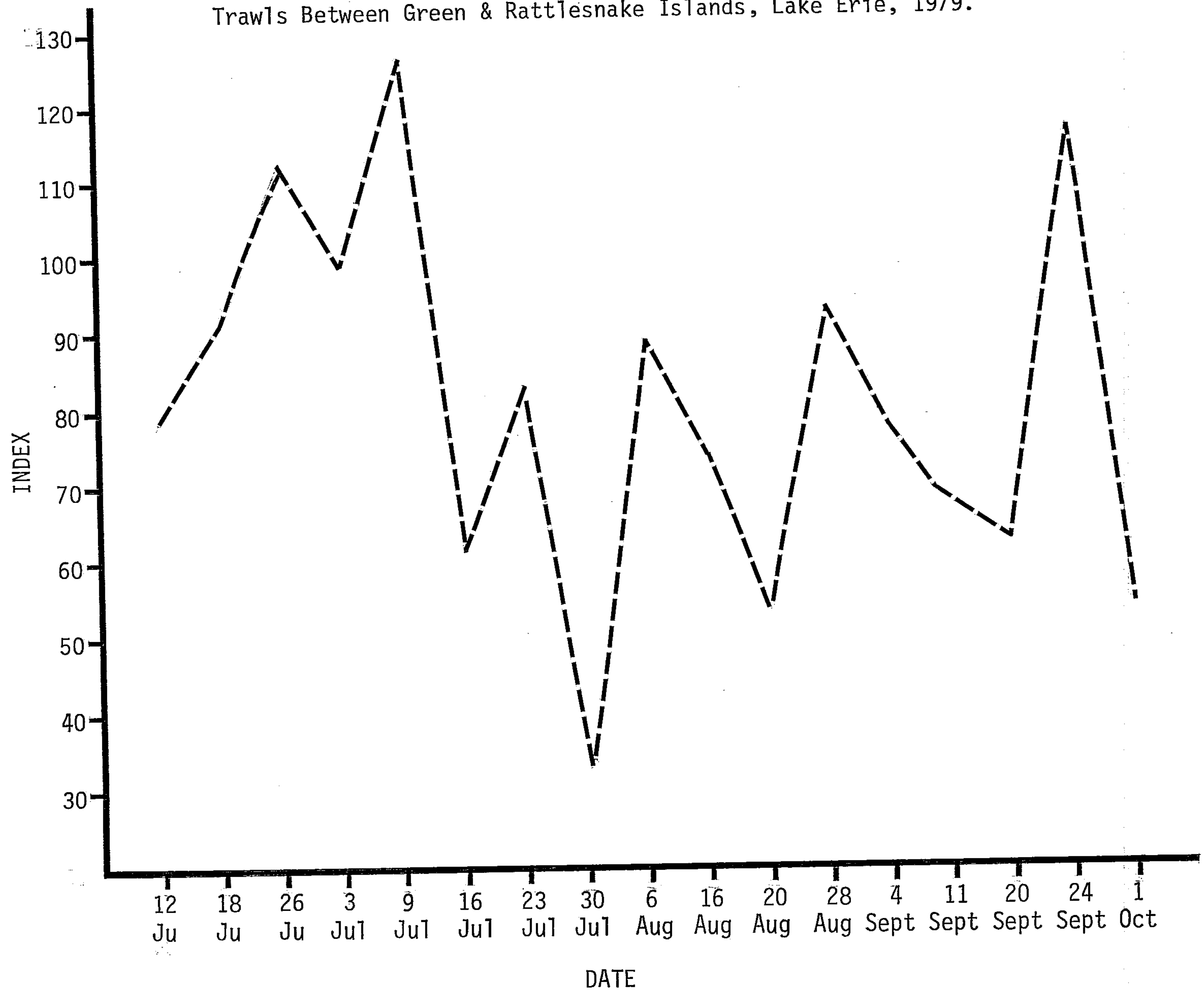


FIGURE 14. Abundance Indices - Philometra cylindracea, Trawls Between Green and Rattlesnake Islands, Lake Erie, 1979.

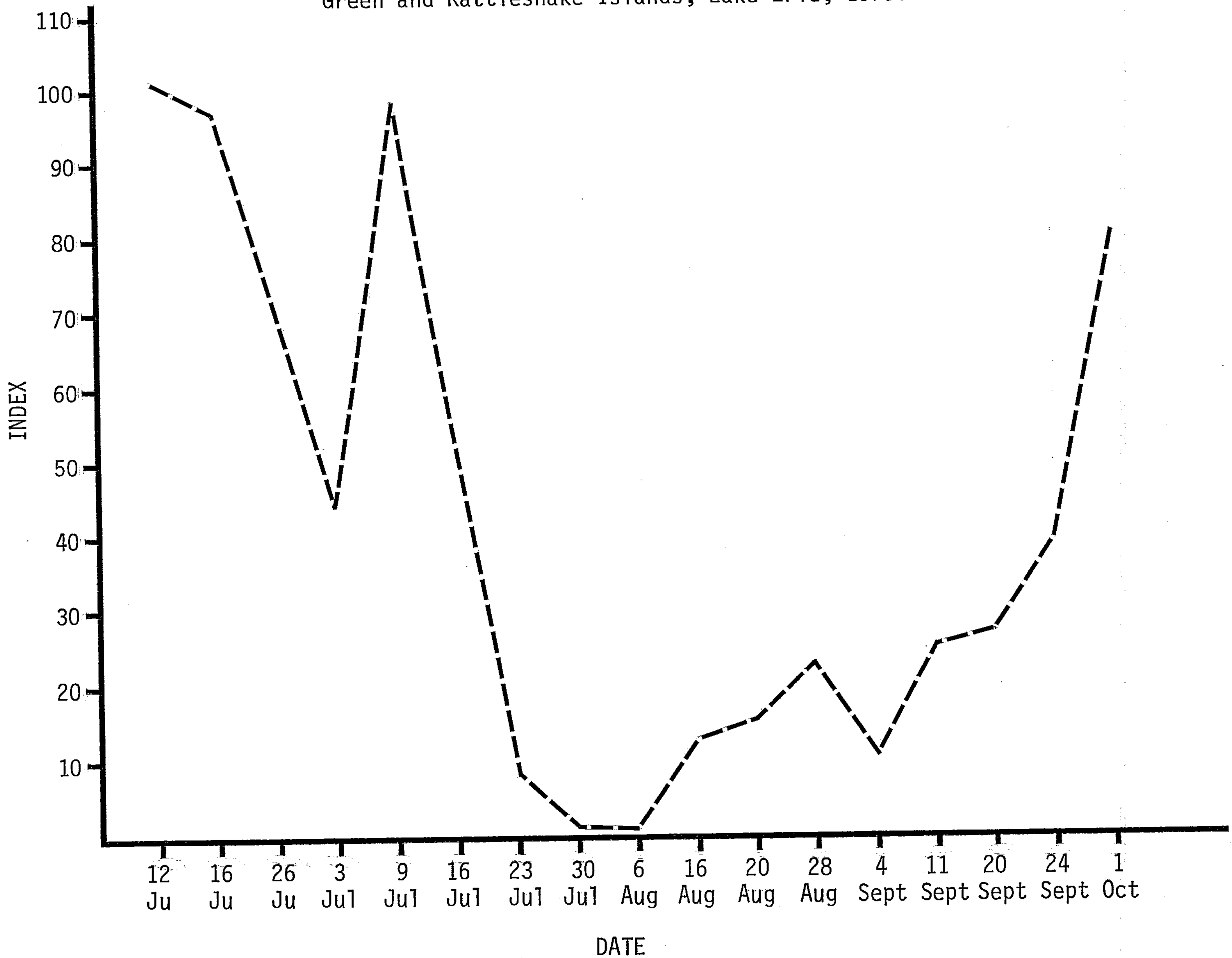


TABLE 13

EUSTRONGYLIDES WORM BURDEN VS. WEIGHT OF 2+

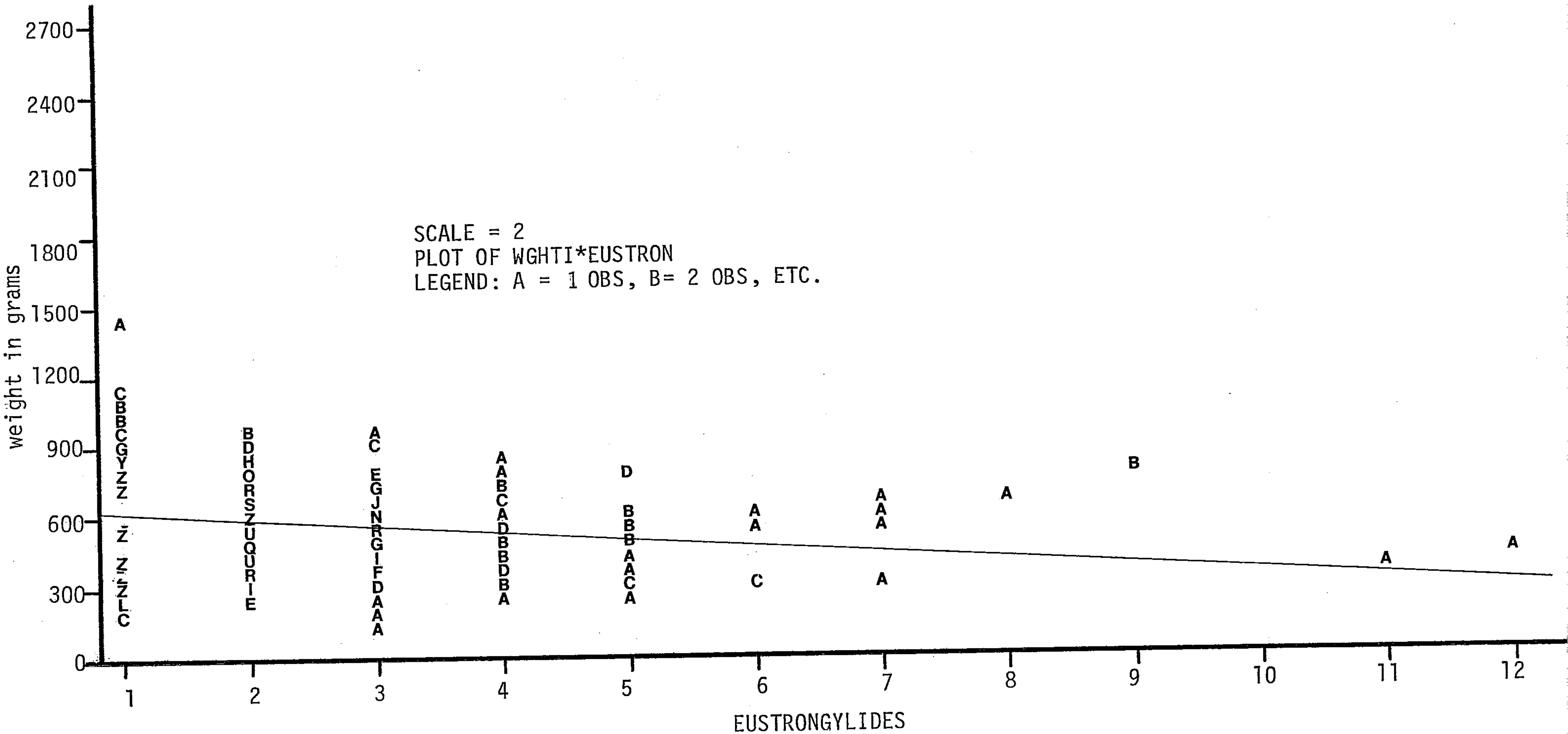
AGE CLASS YELLOW PERCH - 1979

E. tubifex Worm Burden	N Yellow Perch	Weight (1) Grams (Mean)	Weight (2) Grams (Mean)
0	856	60.22	53.82
1	510	57.80	51.75
2	193	56.73	509.8
3	82	56.59	50.69
4	23	51.46	46.57
5	16	50.88	44.96
6	7*	45.31*	39.89*
7	4*	53.37*	48.03*
8	1*	64.70*	56.60
	1692		

*Sample Size not Significant

FIGURE 15.

PLOT OF FISH WEIGHT 1 WITH INCREASING NUMBER <u>EUSTRONGYLIDES</u>



Note: 2 OBS had missing values 228 OBS Hidden year (1+ age class) the worm burden (1-5 _E. tubifex_ larvae) has little effect on their initial weight (Figure 16). However, during this year of growth, worm burden appears to play a very important role, as uninfected fish weigh more than twice as much as infected fish (5 worms) by the end of the 1+ year (Figure 16). When this same year class is followed through their 2+ year, one notes that the differences in weight associated with worm burden observed at the end of their 1+ year are carried through the 2+ year, but that the difference in weight versus worm burden does not increase significantly during the 2+ year (Figure 17). This means that in the 2+ year, worm burden may determine weight, but does not appear to significantly affect growth, as it did during the 1+ year.

Recommendations

Trawls should be continued on a weekly basis during 1980 to add to the two years of accumulated data from sampled yellow perch populations. The 1980 data will be used as a basis for comparison of uninfected and infected yellow perch, for comparison of different age classes, for data on seasonal variation, for comparisons between different years, and for comparison of different collecting sites. We need more samples from other collecting sites in Lake Erie. We should also give specific attention to the 3+ age class during 1980, as we predict that this will be the largest age class, being the 1977 year class. This has been the strongest year class during the past two years, and its relationship to the parasites being studied is of particular interest. It now appears that it would be of definite value to follow this year class into its 4+ year, as it will be reaching the 8-inch length in the spring of 1980 in the Central Basin, and this may be

Figure 16. Weight per Collection Date vs Worm Burden for 1+ Age Class of Yellow Perch Infected with E. tubifex (0 - 5 worms) for the 1978 Season.

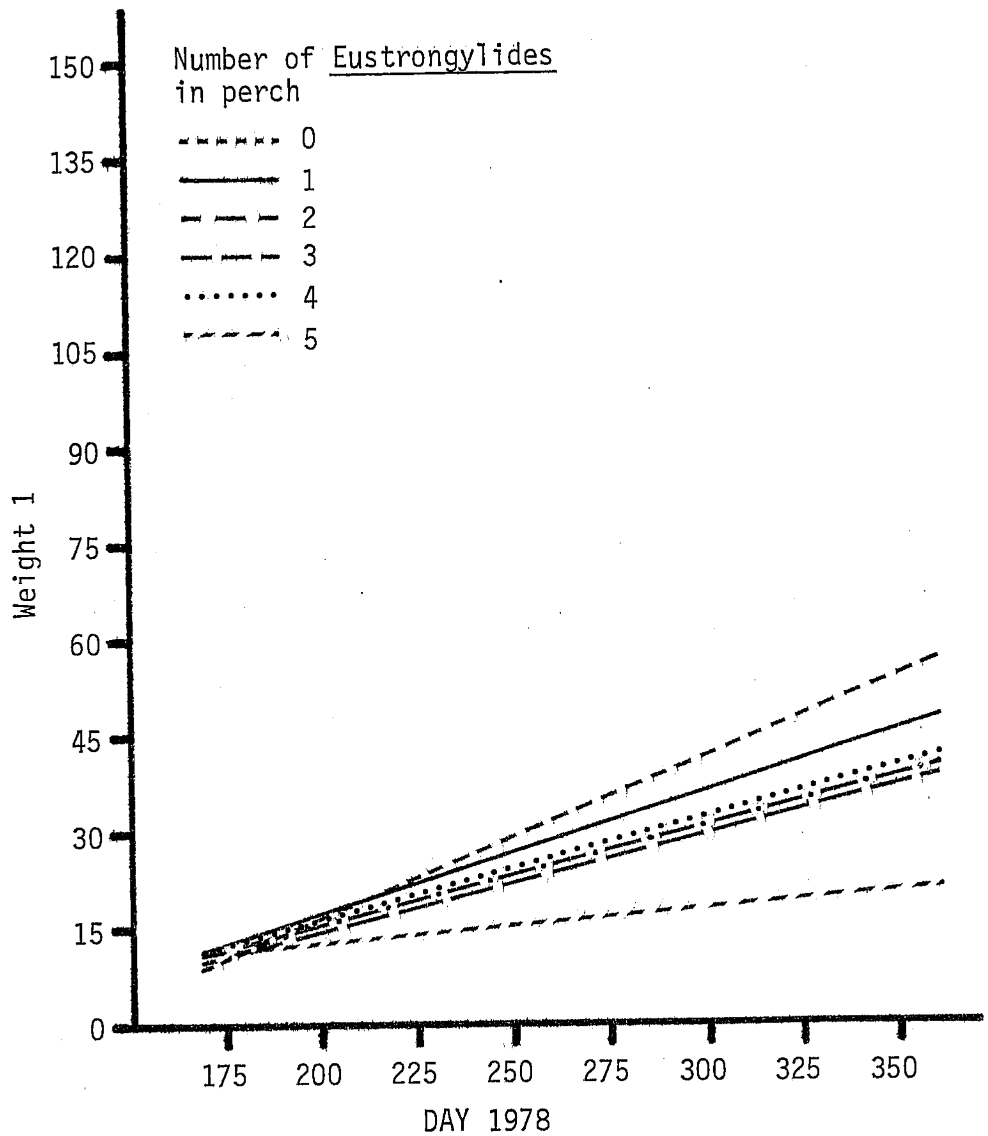
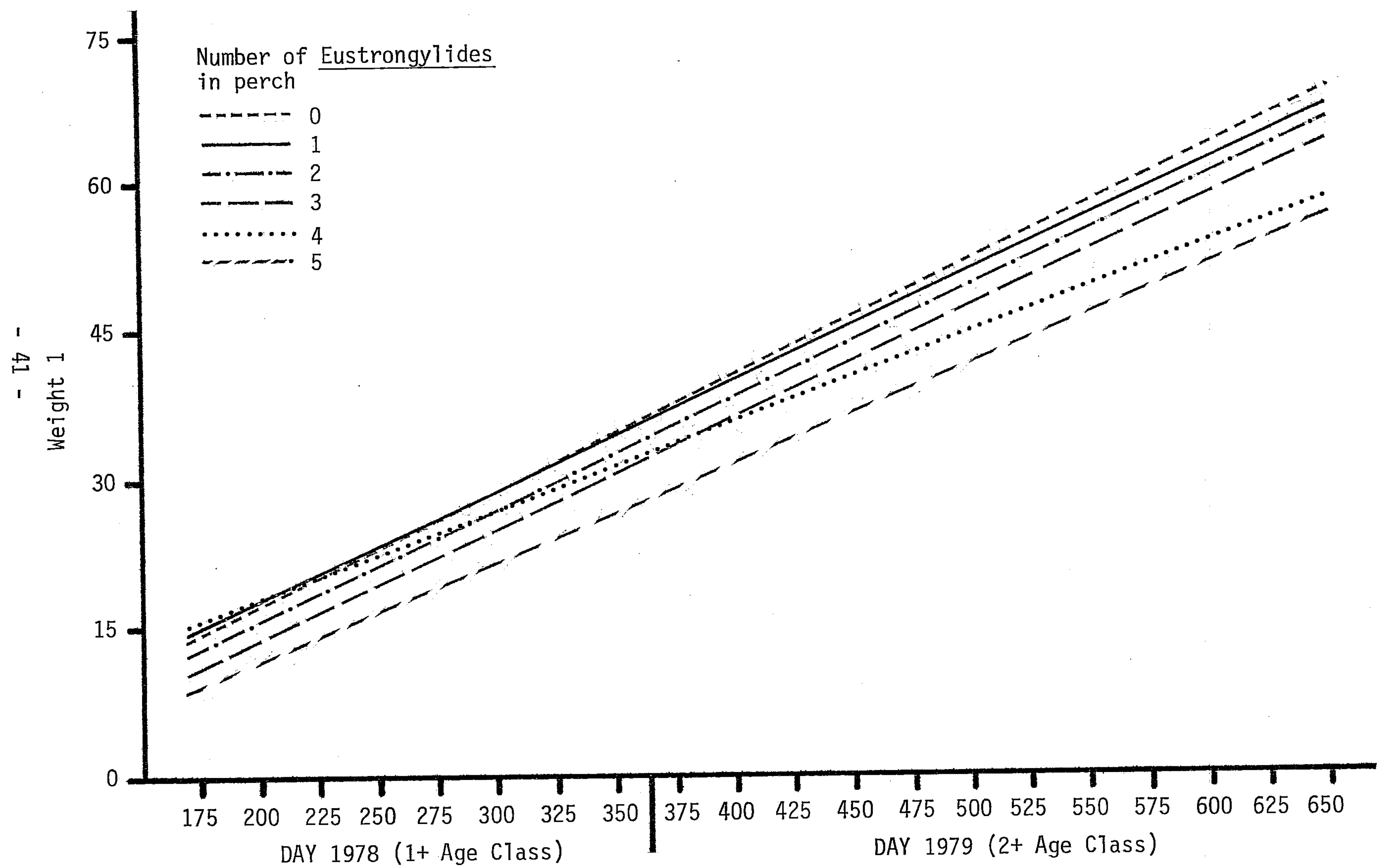


Figure 17. Weight per Collection Date vs Worm Burden for the 1977 Year Class of Yellow Perch in 1978 and 1979 Infected with _E. tubifex_ (0 - 5 worms).



attained in the Western Basin in the autumn of 1980. The 8-inch length may be taken by commercial fishermen.

JOB 1b

DESCRIPTION OF PATHOLOGY OF EUSTRONGYLIDES TUBIFEX IN YELLOW PERCH

Objectives

Define through anotomical investigations the pathological impact of *Eustrongylides tubifex* upon the growth and survival of western and central Lake Erie yellow perch.

Procedures

All yellow perch were iced immediately after removal from the trawl while on board the boat and remained on ice until examined in the laboratory.

Samples of tissues and capsules containing parasitic worms were removed from yellow perch at necropsy and fixed in alcoholic Bouin's solution. Capsules were also injected with fixative to assure fixation of inner cells. Fixed tissues were embedded in paraplast parafin and sectioned with a microtome at 8-10 micrometers. The tissues were dehydrated and stained with modified Mallory's Triple stain or haemotoxylin and eosin, and cleared with xylene.

The nematodes *E. tubifex* and *P. cylindracea* were removed from the viscera of perch and processed in different ways. Some were studied alive and photographed using light microscopy. Some nematodes were fixed immediately with Alcohol-Formalin-Acetic Acid (AFA) solution. These nematodes were later placed in glycerine alcohol and dehydrated until all alcohol was removed. They were then mounted in pure glycerine for study. Some third- and fourth-stage larvae of E. tubifex were killed by dipping them in glacial acetic acid and fixed with either AFA or Tris-buffered gluteraldehyde. These specimens were later prepared for scanning-electron microscopy. They were dehydrated, free-dried in a critical point dryer, coated with gold, and mounted on stubs. The nematode larvae so prepared were examined and photographed using a Hitaschi S-500 stereo-electron-microscope.

Findings

Eustrongylides tubifex are usually encountered by fishermen free in the body cavity or flesh of yellow perch. This is not the natural situation. While very small specimens, third-stage larvae, are occasionally found free in the coelom, most specimens occur in granulomatous, tumor-like tissue capsules. The nematodes migrate from these capsules only when the body temperature of yellow perch is raised above 17°C. The longer the fish are held at these temperatures or at higher temperatures, the farther the larvae migrate from their capsules, often into the body wall. All of our samples were immediately iced as soon as the perch were removed from the trawl nets aboard the boat and held on ice until they were necropsied. The nematodes do not migrate from their capsules under these conditions.

Gross Pathology

The first cause of pathology which should be noted was the migration of third-stage larvae across the wall of the alimentary canal. Larvae first entered the body cavity of yellow perch by migrating from the lumen through the wall of the alimentary canal, usually through the wall of the stomach or the anterior one-fifth of the intestine. The means by which the third-stage larvae pentrated the tissues has not yet been determined, but it was probably by the secretion of cytolysins from the esophageal glands. While this penetration by the parasite may have caused an opening which could have been secondarily invaded by bacteria, we could find no serious pathology associated with it.

The smallest E. tubifex in the coelem were found wandering free. They were delicate nematodes 8.9 mm long, whitish pink in color. Since it was inferred that these larvae had entered the perch in some invertebrate first intermediate host before pentration of the alimentary canal, we designated them third-stage larvae following Karmanova (1968). The early third-stage larvae penetrated some of the visceral organs and their presence evoked tissue responses on the part of the yellow perch host. The larvae coiled in a flattened spiral and became encapsulated by the tissues of the organs they had penetrated (Figure 18).

The larvae continued to grow and develop within the capsules. Larvae 9.2-31.0 mm long were found in small, slightly flattened, thin-walled capsules 0.15 to 1.5 cm in diameter (Figure 18). These were third-stage larvae. Once the larvae reached a length of 31.0 to 34 mm they became enclosed in molted cuticle -- at this point we designated them fourth-stage larvae. The fourth-stage larvae continued to grow and reached lengths up to 93.37 mm within the perch host. As the larval nematodes grew the capsules also enlarged and their walls thickened.

We found encapsulated E. tubifex larvae most prevalent in four tissue sites: (1) in mesenteries; (2) in the liver; (3) in the gonads and (4) in

Figure 18. Early capsule in mesentary

Figure 19. Granulomatous capsule open to show E. tubifex inside

the body wall. The great majority of capsules (85%) were found in the mesenteries. The mesenteric capsules started as epithelial tissue. They were clear or pinkish in color soon after formation, but they became more opaque as they increased in size. Figure 19 is a photograph of an older, well-developed capsule opened to show the fourth-stage nematode larva inside. Well-developed mesenteric capsules ranged from 1.5 to 5 cm in diameter, most being 2.5 to 3.5 cm. The older mesenteric capsules were tumor-like, yellowish-browh in color and granular in appearance, resembling a melanomatous granuloma. The capsules in the liver (10% of all capsules) were brownish-red and less granular in external appearance. Most often they were near or on the surface of the liver (Figure 22). The capsules in the gonads were usually clear and transparent, but some larger ones were more opaque. These gonadal capsules were rare, accounting for about 3% of the capsules seen. The largest capsules, up to 5 cm in diameter, were found on the body wall. These large tumor-like capsules were also less granular than the mesenteric capsules. They were dark reddish brown and pulpy in appearance, and they crowded into the coelem. There is evidence that these body wall capsules continue to grow and enlarge. They form a pressure on the viscera and may castrate or even kill infected perch.

In gross aspect, blood vessels were easily observed entering the capsule walls except for those in the liver.

Histopathology

During 1979, we sectioned several more mesenteric capsules. Figure 20 shows a mid-cross section of a mature, mesenteric capsule with the

Figure 20. Cross-section of the capsular wall

Figure 21. Cross-section of capsular wall showing tissues and blood vessel

nematode removed. We determined from study of these sections that the mesenteric capsules were more complex in structure than the capsules of a primary tissue response which occurs in the tissues of many fishes and consists for the most part of fibrous connective tissue. The central lumen of a mesenteric capsule is filled with lymph which bathes the nematode. The innermost portion of the capsule wall is composed of a thin layer of disintegrating connective tissue. The middle, thicker portion of the mesenteric capsular wall is composed primarily of liver cells and aggregations of pancreatic cells; small numbers of smooth muscle cells and connective tissue cells are also present. The mid-wall of mesenteric capsules is laced with small blood vessels and capillaries. Each capsule has a strong blood supply. The outer portion of the mesenteric capsule wall is comprised primarily of fat cells and modified mesenteric epithelial cells (Figure 21).

The characteristics described here for the mesenteric capsules are more typical of a tumorous granuloma than a simple primary tissue response.

The capsules formed within liver tissue have fewer cell types and are more typical of a primary tissue response. There is a thick layer of fibrous connective tissue surrounding a fluid-filled lumen containing the larva and there is some leucocytic infiltration (Figure 22). If these capsules break through the surface of the liver, the outer capsule wall in the area of the break become granular and yellowish-brown if there is contact with the mesentery.

Reinfection and Longevity

The question arose, could yellow perch be reinfected with E. tubifex larvae? Perch with multiple infections of this nematode had both small and

Figure 22. Capsule in liver

large capsules and this indicated that they could be reinfected. In five separate experimental attempts, we removed third-stage larvae from capsules in one perch and fed them by gavauge to a second yellow perch. In each case the larvae pentrated the intestinal wall of the second perch and began to become encapsulated.

We have established that E. tubifex larvae can live for a long time in their capsules -- at least as long as a year and a half. When necropsied, yellow perch held 18 months in captivity showed mesenteric capsules containing viable, well-developed E. tubifex larvae. There was usually only one nematode per capsule, but there were occasionally two. This may result from the merging of two closely adjacent capsules during their development.

During this year we have continued to study the larvae of E. tubifex with scanning-electron microscopy. We have been elucidating the structure of the amphids (chemo-receptors) and their relationship to other sensory structures. Study of these structures is important, for they are used in identification of species of Eustrongylides.

Recommendations

We have now demonstrated the gross- and histopathology caused to yellow perch by E. tubifex larvae during their migration and in the reaction of the perch host in the formation of mesenteric and hepatic capsules. One reviewer of last year's report questioned whether or not the mesenteric capsules were truly granulomas. We believe that we have now demonstrated that they are granulomas. We intend during the coming year to have our interpretations and our tissue sections checked by an impartial board-certified veterinary pathologist.

If possible during the coming year, we should attempt to section and study the tumorous capsules which develop on the body wall. Because of their size these capsules may be difficult to handle, fix and section. We should also study the more rare situation in which the larvae enter the gonads.

We have now identified the anterior papillae and other sense organs of the third- and fourth-stage larvae by scanning electron microscopy. These are important taxonomic characters at the generic level. In the coming year we should concentrate more on the posterior ends of the male and female third- and fourth-stage larvae. We can then emphasize the differences between the two sexes of larvae which occur in the perch host.

We would also recommend that line drawings now be prepared from cleared, whole mounted specimens of third- and fourth-stage larvae and that a formal, conventional description of the larval stages be completed. These descriptions and drawings would then be available for use by other investigators in fisheries studies.

Job 1c

DEVELOPMENT OF MANAGEMENT STRATEGIES WHICH WOULD OPTIMIZE THE YELLOW PERCH FISHERIES IN LAKE ERIE

Objective

Develop feasible management recommendations that would optimize the benefits from western and central Lake Erie yellow perch by analysis of seasonal pathological variances.

Procedures

Compilation and analysis of 1978 and 1979 prevalence and pathology data as it relates to seasonal pathological variances was continued and reported under Jobs 1a and 1b in this performance report. Initiatives were again undertaken through the Great Lakes Fishery Commission to continue development of yellow perch management strategies. The preliminary findings reported in this report were forwarded to the appropriate scientific advisory personnel with the Ohio Division of Wildlife.

Findings

Management recommendations have not been developed, as yet, due to the preliminary nature of the study findings under Jobs 1a and 1b.

Recommendations

None.

STUDY ANALYSIS

Since pathological analyses have peculiar aspects which lend themselves more readily to presentation with the pathological findings the analyses of gross pathology and histopathology were presented in the "Findings" section of Job 1-b. In this analysis they will be referred to when they fit with other material or briefly described as they fit in a manner not discussed previously.

This year we continued to gather basic data and for the first time they were comparable to another year, 1978. We ordered, organized and computerized these data and considered hypotheses which we believed might be important in the management of yellow perch in Lake Erie.

This year we were able to confirm that yellow perch become infected with these parasites as young-of-the-year. Young-of-the-year (YOY) perch first became infected with *Triaenophorus* and *Philometra*, and, later in the collecting season, became infected with *E. tubifex*. This probably reflected their feeding habits, at first feeding on plankton and then on plankton along with benthos. The YOY class yellow perch did not enter our trawls in the island region of the Western Basin until July 17 in 1978 (Figure 23) and July 22 in 1979 (Figure 24). Young-of-the-year were continuously infected with *E. tubifex* and both the percentage of infection and the mean worm burden increases throughout their first year. Most *E. tubifex* larvae removed from YOY perch were third-stage larvae. This means

Figure 23

Plot of Total Length of Yellow Perch by Sample Date 1978.

Legend: A = 1 fish, B = 2 fish, etc.

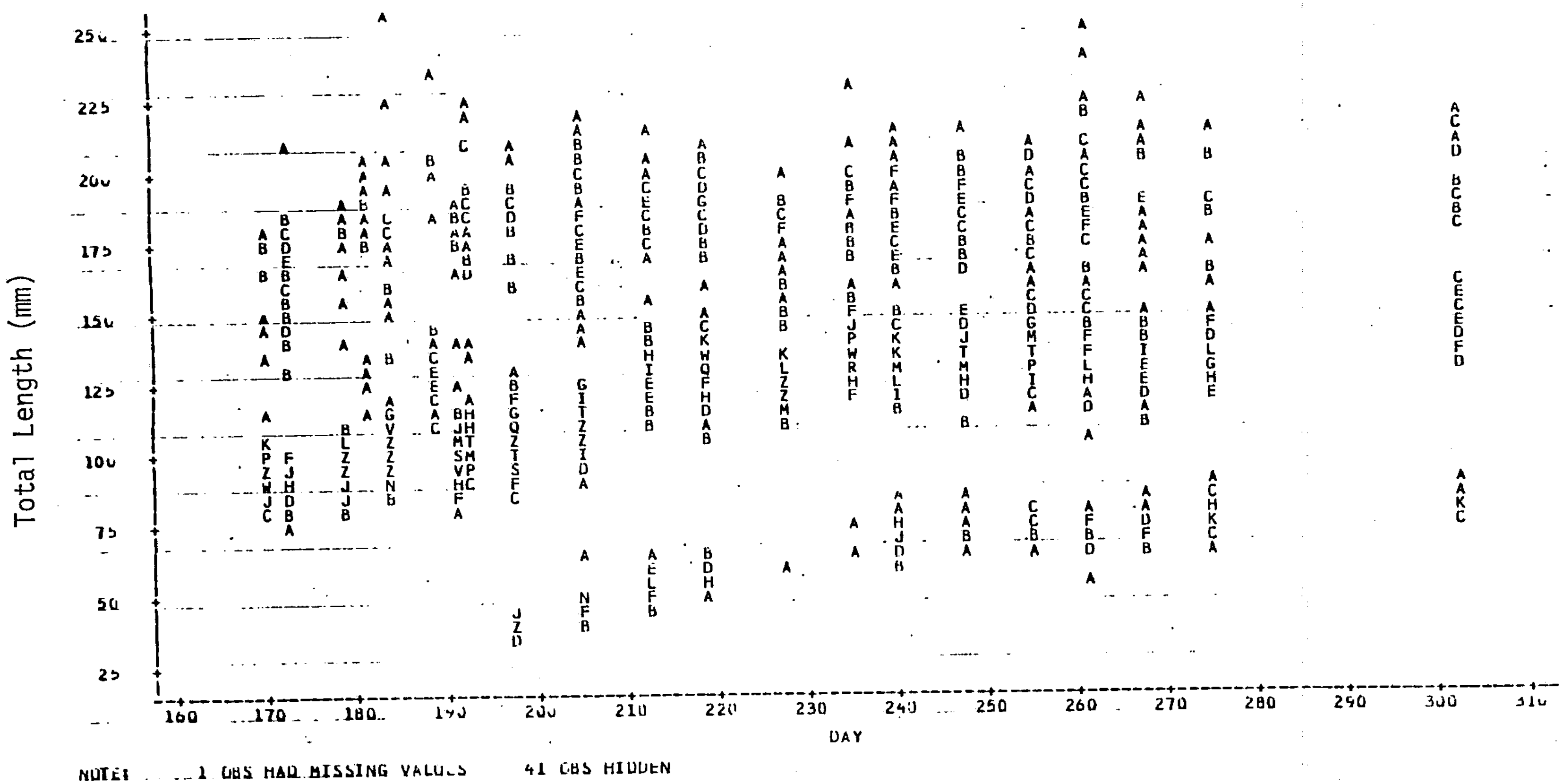
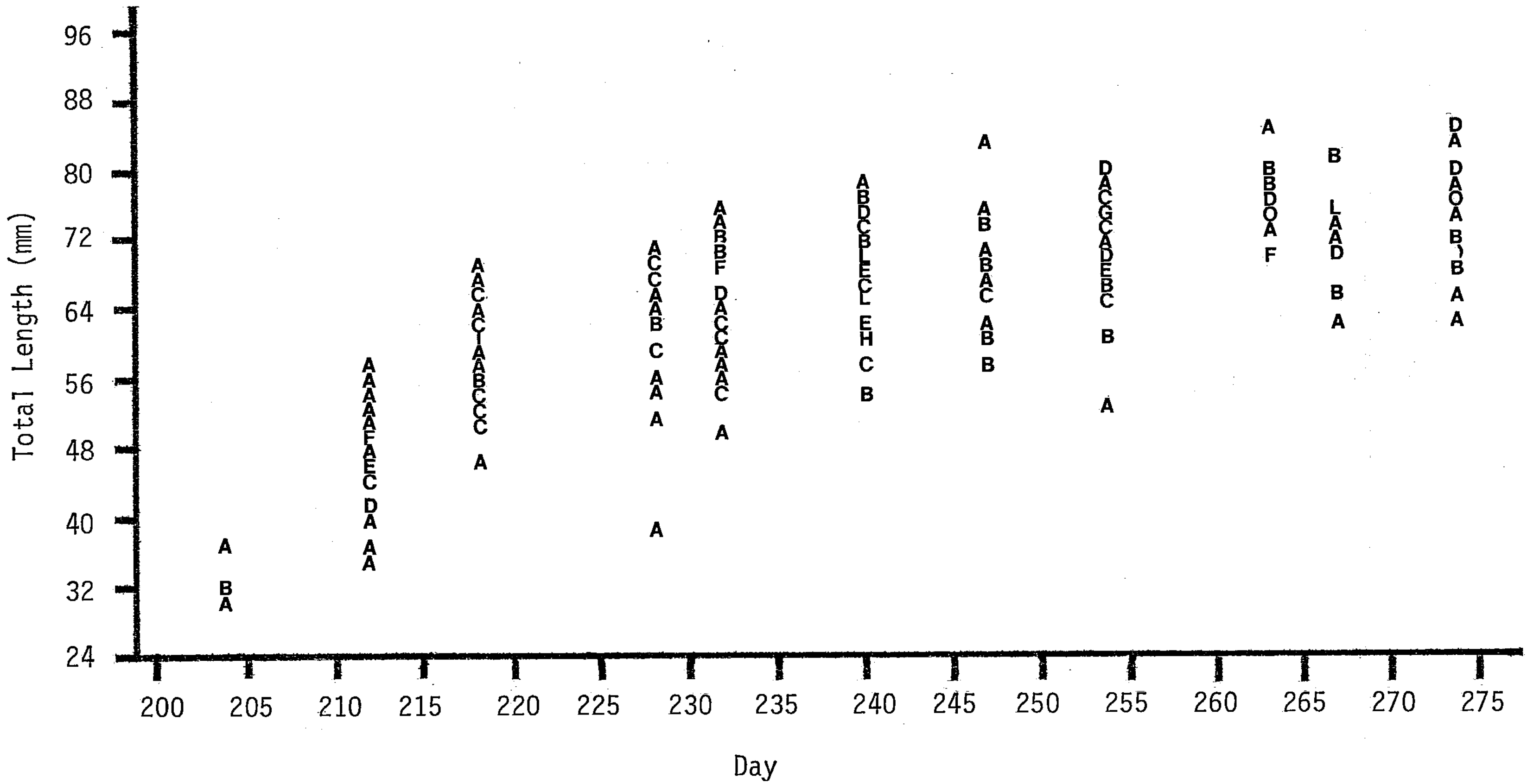


Figure 24. Plot of Length of YOY Class Yellow Perch by Sample Date 1979.



that the nematode had not had time to molt. This does not mean that older yellow perch do not become infected or that perch cannot become reinfected. Our data clearly show that yellow perch can become infected at any age. As noted earlier our experiments have demonstrated that the worm can transfer when a small fish is eaten by a larger one. We have taken E. tubifex larvae from small thin-walled capsules and from large granulomatous capsules in individual perch, age class 1+ through 5+.

Prevalence of Infection for the Entire Season, Parasites Combined

We determined the combined prevalence of parasitism for the three pathogenic parasites found in extraintestinal sites which were the target of this study. The numbers and proportions of parasitized yellow perch include those infected with one or more or combinations of the parasites, E. tubifex, P. cylindracea and T. nodulosus. In 1979 we examined 2,691 yellow perch from all sampling sites and 2,146 (80%) were infected with one of the parasites, 544 were uninfected. Some age classes were more infected than others. Of the yellow perch sampled in 1978, 63.6% were 1+ age class. In 1979, 63.1% or 1,698 of 2,691 yellow perch sampled were in the 2+ age class (Table 1). As we predicted, there was a definite shift in age class structure of the sampled population of yellow perch from 1+ in 1978 to 2+ in 1979. These data correlated with that of the Lake Erie Fisheries Unit, which recorded the same shift in their sampling Districts I, II and III (ODNR, 1980).

In 1978, the majority of infected yellow perch (63.2%) were distributed in the large 1+ age class; in 1979, 1,447 of 2,146 infected yellow perch, 67.3% were of the 2+ age class (Table 2). The percentage of infection had been maintained and had slightly increased as these fish aged. Of the entire number of yellow perch sampled in 1979, the 2+ age class contained 53.78% of the infected fish (Table 2). Table 3 presents the percentage or rate of infection within each age class of yellow perch examined from all sampling sites in 1979 combined. In 1978 we pointed out that older yellow perch had higher rates of infection. This was true again in 1979, regardless of collection sites. In 1979, the greatest actual numbers of infected yellow perch were in the 2+ age class, but older yellow perch had the highest rates of infection. However, there were fewer actual numbers of these older perch (Table 3).

The comparative data for 1978-1979 from the GR Station somewhat mirror the discussion already presented for all sampling stations combined. The greatest actual numbers and percentages of yellow perch from this station were 1+ class in 1978 and 2+ class in 1979 (Table 4). Table 5 presents data showing that the actual numbers and highest percentages of infected yellow perch in the entire sample for each year were in the 1+ class in 1978 and in the 2+ class in 1979. This was also the case in weekly samples each year. Table 6 presents the comparative percentages or rates of infection within each of the age classes for both years at the GR Station. Again, these data demonstrate that older yellow perch had higher rates of infection in both 1978 and 1979.

The shift in proportions of infection with numbers in an age class, and with rate of infection with age, prompted us to compare the "mean percentages" of infection for the entire sampling season of each of the two years, 1978 and 1979. We compared the seasons for each of the parasites and for yellow perch with any infection. The comparisons are presented in Table 7. Although there was some seasonal variation (Figures 9, 11 and 12) there was a surprising similarity when the "mean percentages" were calculated over the entire season.

Mean percentages of infection for E. tubifex were very close, 0.9% being the greatest difference. Differences between years for Philometra cylindracea and Triaenophorus nodulosus were greater but not nearly as different as expected. The differences in overall infection were also less than expected. All differences were tested with Chi Square tests and none were significant.

What does this mean? It means that the populations of these parasite species were able to maintain themselves in the population of yellow perch at high and somewhat stable levels from 1978 to 1979. The populations of the parasites were maintained although there were changes in the age class structure of the perch population and differences in the lake temperatures between the two years. This raises several interesting questions and the answers to some of these questions could have management applications.

Prevalence of Eustrongylides tubifex

Of the 2,691 yellow perch examined from all sampling sites in 1979, 1230 (48.8%) were infected with E. tubifex larvae. The majority of E. tubifex infected perch (68.5%) from all sampling sites in 1979 were 2+ age class (Figures 1, 2 and 4 and Appendix Table 14). Again in 1979 as in 1978, the older yellow perch had higher rates of infection with E. tubifex at all stations.

Comparative data for any yellow perch infected with E. tubifex from the GR Station in 1978 and 1979 demonstrate that of the total number of yellow perch examined from that station, the greatest actual numbers of infected perch and highest percentage of infected perch occurred in the 1+ class in 1978 and the 2+ class in 1979. This was also the situation for each of the weekly samples. It is worth noting that 59.4% of the E.

tubifex infected yellow perch were in the 1+ class in 1978 and 67.4% were in the 2+ class in 1979 (Figure 5). In both years the majority of infected yellow perch were in the most abundant year class, but during a one-year period a higher percentage of this year class became infected with E. tubifex. Whether this increase is associated with a particular age span of yellow perch or whether it is a trend which may continue cannot be determined at this time. We will gain further information as we follow the 1977 year class for one more year. This information could be of significance in the management of yellow perch in Lake Erie.

In 1979, as in 1978, the older age classes of yellow perch had higher rates of infection than did younger yellow perch (Table 4 and Figure 8). Yellow perch which were infected only with E. tubifex comprised a small percentage of the entire population (Table 9). Most perch infected with E. tubifex were also infected with one or both of the other two parasites. Table 9 shows a comparison of the rates of infection of the different age classes of yellow perch infected with only E. tubifex during 1978 and 1979. Here the older yellow perch do not appear to have higher rates of infection. This means that older fish generally have double or triple infections, i.e., one or both of the other two species of parasites are present with E. tubifex in these older perch (Table 11). They are seldom infected with it alone. A strategy for the management of yellow perch which considered only E. tubifex infections would not be completely effective.

Seasonal Prevalence of Eustrongylides tubifex

There were seasonal variations in the percentage of infections in both 1978 and 1979. The rate of E. tubifex infection from the GR Station during 1979 decreased irregularly from June until late July and then increased until mid-September (Table 10 and Figure 9). We believe that the decrease of both the percentage of infection (Figure 9) and the abundance index (Figure 13) discussed later was caused by an influx of new, uninfected young-of-the-year perch during July recruitment which diluted the percentage of the infected population. We would suggest that during 1980 the percentages of infection be studied without the young-of-the-year being included and compared with percentages where they are included to see if there is a dilution effect. The mean rate of infection for the entire season during each of the two years varies only by 0.867 (46.08%, 1979; 46.94%, 1978). This data correlated with the data presented earlier and indicated that the population of E. tubifex yearly maintained itself in the population of yellow perch, even though the majority of perch aged from 1+ in 1978 to 2+ in 1979.

Seasonal Prevalence of Philometra cylindracea

The seasonal rates of infection for any yellow perch infected with P. cylindracea during 1979 from the GR Station is presented in Table 10. The comparative rates of infection for 1978 and 1979 are shown graphically in Figure 11. In 1979, the highest rates of infection occurred during June and July, but the rates were irregular. The lowest percentage occurred in August. The data upon which this graph is based include both living worms and encapsulations. The dips in July, 1978 and in August, 1979 were caused by the death of one generation of P. cylindracea. They released their larvae into the water of the lake and died. The dip here is also caused by dilution from percentages of uninfected YOY class perch entering the trawled samples for the first time. A more practical view of the seasonal variation of *P. cylindracea* was attained by the use of an "abundance index" (Figure 14) and will be discussed later. The slight variation in the lowest points of infection in the two years probably reflects the water temperatures, 1979 having been a cooler year. In 1979, the mean rate of infection was higher, 42.8%, compared to 32.8% for 1978.

Seasonal Prevalence of *Triaenophorus nodulosus*

Figure 12 graphically compares the seaonal rates of infection of yellow perch with the plerocercoid larvae of the tapeworm, *Triaenophorus nodulosus*, for 1978 and 1979. Different patterns of prevalence and rates of infection are shown for the two years. In 1978, the rate of infection was 45.72% and in 1979 it rose 59 57.9%. In 1978, the highest rate of infection occurred in August, but in 1979 the highest rate of infection occurred in the early summer. The seasonal distribution pattern for *T. nodulosus* is very similar in each respective year to that for *P. cylindracea* (Figures 11 and 12). Both of these parasites require copepod intermediate hosts for their transmission. The changing age of the perch host population and the resultant shift in feeding habits in the largest year class of the sampled population may have contributed to the similarities of seasonal occurrence of these two parasites. In both parasites there was an increase in the YOY class perch during the late summer. Management strategies involving these two parasites would require consideration of the ages and the foraging habits of the yellow perch in the Western and Central Basins of Lake Erie.

Abundance Index

Recommendations in last year's annual report included the suggestion that this year (1979-1980) there should be more emphasis placed on the use of an abundance index. The A-index includes not ony the percentage of each parasite species in each sample, but it also included the mean worm burden of each species in the infected yellow perch of that sample. It provides more accurate comparisons for management considerations.

Table 12 presents the abundance indices for three different locations and the A-index for the closest dated sample from the GR Station. Samples from the West Sister-Middle Sister Island area were the farthest west and north locations taken during 1979, and they had the highest abundance indices for *E. tubifex* and *P. cylindracea*. The Sandusky Bay sample had higher A-indices for both of these parasites than the GR Station. When one considers the date of the Sandusky Bay sample its A-index was really quite high. We have hypothesized that Sandusky Bay, which has a large population of tubificid annelids, might be a geographic location where infection with *E. tubifex* occurs. The ODNR Lake Erie Fisheries Unit Staff believes however, that the population in the Sandusky Bay may be a resident one. A sample from off Vermilion, Ohio on the edge of the Central Basin showed the lowest of the comparative A-index values of any of the stations sampled in 1979. Yellow perch from that station were larger in size and had fewer parasites. This finding fits well with the data reported last year indicating that yellow perch were larger and had fewer parasites the farther east in Lake Erie they were collected. This also agrees with data compiled by the ODNR Lake Erie Fisheries Unit Staff which indicated that yellow perch in the Central Basin were larger in size (ODNR, 1980).

Abundance indices were also of value in comparing seasonal distributions of given species of parasites in our samples. The abundance indices for the entire 1979 season for E. tubifex are presented in Appendix Table 16 and they are graphed in Figure 13. The highest A-index occurred on July 9, 1979 and the lowest A-index occurred on July 30, 1979, only 21 days later. We believe that this may be an artifact in the data, the percentage of infection figures are for the entire samples, and the YOY class perch which were at first completely uninfected entered our samples in mid-July. These YOY perch lowered both the percentage of infection and mean worm burden figures used in calculating the indices. When we calculated an A-index for July 30, 1979 using only the 1+ and older perch the index was 9.3. This is low, but not nearly as low as when the YOY perch were included. The indices rose in the late summer and autumn as the young-of-the-year perch and older perch became infected wtih E. tubifex larvae.

The use of an abundance index for each sample emphasized the differences between samples and the variations which occurred throughout the 1979 season (Figure 13). It is our opinion that those variations between samples were real and represent the sampling of different subpopulations of yellow perch moving through the sampling area between Green and Rattlesnake Islands. The variation between the A-indices of these samples indicates that the perch in this area were not a resident population and that they were infected with E. tubifex elsewhere. If this inference is proven to be true there would be management implications.

Appendix Table 18 also lists the abundance indices for Philometra cylindracea for the 1979 season from the GR Station and these A-indices are graphically presented in Figure 14. The encapsulations of parts of spent, dead adult female P. cylindracea are not included in these data. Only the numbers of living P. cylindracea were considered in calculating the percentages used in the computation of the A-index of each sample. The indices for living P. cylindracea decline rapidly during July to a period in early August when almost no living stages occur in yellow perch. This is followed by a gradual rise in the indices during August, September and October. These data fit almost perfectly with our studies of the life cycle and biology of P. cylindracea. During the early spring the adult female of P. cylindracea which have overwintered in the coelom of the perch grow in size, and thousands of larvae develop in their uteri. These larvigerous females penetrate the body wall of the perch and release their larvae into the water during July, completing this behavior in 1979 by July 30. Some of the larvae are ingested by copepods and develop to a stage which is infective for foraging yellow perch. This occurs during early August. Yellow perch which ingest copepods containing these larvae become infected with a new generation of P. cylindracea. As this occurred the abundance indices rose during late August and during September (Figure 14).

From the standpoint of developing management strategies which consider the occurrence and effects of these parasites, the use of an abundance index is of more value than considering either the percentage of infection or the mean worm burden separately. The use of abundance indices here points to a seasonal period in late July when both of these nematodes have their lowest occurrence, almost concurrently. This low abundance period may be affected by temperature, but its timing will probably not vary greatly from year to year. If this period correlates well with other management practices and schedules, it might be one of the better times for removing yellow perch from Lake Erie to stock other waters. There would be less probability of transferring parasites. These two nematodes have their greatest prevalence in the spring and the autumn when fishing pressures are the greatest.

Weight versus Mean Worm Burden

Our studies of the pathology caused by E. tubifex larvae indicate that they are harmful to yellow perch. The buildup of a tumorous capsule composed of different tissues around each larva deprives the fish of some nutritional materials which would be used in growth and reproduction. The fish provides the materials for growth and development of the worms. The more vigorous yellow perch and those most successful in feeding may be the perch most likely to be infected. While these inferences may seem evident they have not proved to be easy to demonstrate on a strict statistical basis related to length or weight loss because of the great variability in samples.

Computer calculations were made of the mean weights (1 and 2) for all 2+ age class yellow perch infected with from 0 to 8 Eustrongylides tubifex larvae from all sampling sites across the entire 1979 season. The data from these computations are listed in Table 13. The data show that when the worm burden (number of worms/fish) increases the mean weight of yellow perch decreases. Figure 15 is a computer-generated graph illustrating the same data and indicating weight loss.

The reader might well ask, did the worm burden of E. tubifex increase as the large 1+ class of perch in 1978 became the 2+ class in 1979? The answer is yes, it did. The mean worm burden increased from 1.4 in 1978 to 1.7 in 1979, in the same year class of yellow perch. By inspection we did not consider this a significant increase, however, we tested this difference and it was significant. The T-statistic for 1978 was -5.867 and for 1979 it was -5.30. The mean worm burdens were significantly different, $p < 0.001$. These long lived E. tubifex larvae tend to build up in their perch hosts and exert their effects.

Figure 16 illustrates that reduced growth rates correlated with worm burden occurred while the yellow perch were in their 1+ age class. Figure 17 illustrates that the resulting differences in weight of fish with worm burdens 0-5 worms at the beginning of their 2+ year remained relatively constant throughout the 2+ year. This means that growth rates are affected by worm burden during the 1+ age class, but growth appears to be uneffected in the 2+ year although the weights of infected fish are lower than the weights of uninfected fish. We could show no significant differences in the slope of the lines in Figure 17. We tested for significant differences with a battery of statistical tests including some non-parametric methods. Again, we attribute this to the great variability between samples. We could sometimes demonstrate statistically significant differences in weight between infected and uninfected 2+ age class yellow perch of some samples taken on the same date from the same location. In 1980, we plan to do pre-analyses of fit before we run weight correlations on samples across the entire season. We sincerely believe that there is a harmful effect of biological significance to yellow perch, and it will be of importance to follow these effects in the 1977 year class as it becomes the 3+ age class in 1980.

STUDY RECOMMENDATIONS

The study should continue through the 1980 field season with particular attention paid to the job recommendations. Furthermore, it is strongly recommended that the study be continued for 1 to 2 years after the 1980 field season to allow the 1977 year class to be observed as it reaches the 4 and 5 year age classes. It would be susceptible to commercial harvest during this entire period, whereas, to date it has been below legal length for commercial harvest. It should also be noted that the 1980 year class appears to be quite strong, and, consequently, would provide an excellent comparison to the 1977 year class which has been the only strong year class observed.

It is also recommended that results from this study be compared to results from a study by Ohio Sea Grant which is, in part, attempting to determine how yellow perch become infected with _Eustrongylides tubifex_.

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APPENDIX

TABLE 14

AGE CLASS DISTRIBUTION OF YELLOW PERCH INFECTED WITH
EUSTRONGYLIDES TUBIFEX FROM ALL SAMPLING SITES COMBINED, 1979

AGE CLASS	N	% OF 1230 YELLOW PERCH INFECTED WITH E. TUBIFEX	% OF ENTIRE 2691 YELLOW PERCH EXAMINED
YOY	6	0.49	0.22
1+	52	4.23	1.93
2+	842	68.46	31.29
3+	188	15.28	6.99
4+	109	8.86	4.05
5+	26	2.11	0.97
6+	7	0.57	0.26
7+	0	0.00	0.00

TABLE 15

THE PERCENTAGE OR RATE OF INFECTION OF EACH AGE CLASS OF YELLOW PERCH INFECTED WITH EUSTRONGYLIDES TUBIFEX FROM ALL SAMPLING SITES, 1979

AGE CLASS	NUMBER OF PERCH EXAMINED	NUMBER OF PERCH INFECTED WITH E. TUBIFEX	% OF EACH AGE CLASS INFECTED
YOY	303	6	1.98
1+	166	52	31.32
2+	1698	842	49.59
3+	330	188	57.00
4+	153	109	71.24
5+	33	26	78.79
6+	8	7	87.50
7+	0	0	0.00
	2,691	1,230	

TABLE 16

COMPARISON OF THE AGE CLASS DISTRIBUTION OF THE YELLOW PERCH INFECTED WITH EUSTRONGYLIDES TUBIFEX FROM THE GR STATION 1978 AND 1979

AGE CLASS	N 1978	N 1979	% OF 942 YELLOW PERCH INFECTED WITH E. TUBIFEX 1978	% OF 998 YELLOW PERCH INFECTED WITH E. TUBIFEX 1979	% OF ENTIRE 2055 YELLOW PERCH EXAMINED 1978	% OF ENTIRE 2177 YELLOW PERCH EXAMINED 1979
YOY	43	6	4.5	0.60	2.1	0.28
1+	560	45	59.4	4.51	27.5	2.07
2+	101	676	10.7	67.74	4.9	31.05
3+	148	171	15.7	17.13	7.2	7.85
4+	56	83	5.9	8.32	2.7	3.81
5+	23	14	2.4	1.40	1.1	0.64
6+	10	3	1.06	0.30	0.48	0.14
7+	1	0	0.11	0.00	0.05	0.00
	942	998				

TABLE 17

THE PERCENTAGES OR RATES OF INFECTION OF EACH AGE CLASS OF YELLOW PERCH INFECTED WITH E. TUBIFEX EXAMINED FROM THE GR STATION 1978 AND 1979

AGE CLASS	1978 N EXAMINED	1978 N INFECTED WITH E. TUBIFEX	1978 %	1979 N EXAMINED	1979 N INFECTED WITH E. TUBIFEX	1979 %
YOY	270	43	15.9	303	6	1.98
1+	1303	560	42.9	134	45	33.58
2+	158	101	63.9	1302	676	51.92
3+	192	148	77.1	294	171	58.16
4+	85	56	65.9	123	83	67.47
5+	33	23	69.7	18	14	77.78
6+	13	10	76.9	3	3	100.00
7+	1	1	100.0	0	0	0.00
	2055	942		2177	998	

TABLE 18

ABUNDANCE INDICES FOR NEMATODE PARASITES IN

1979 SAMPLES OF YELLOW PERCH

GREEN AND RATTLESNAKE STATION

Date	Eustrongylides tubifex	Philometra cylindracea
1. 12 June	78.96	100.71
2. 18 June	91.40	97.15
3. 26 June	112.21	127.34
4. 3 July	99.00	44.00
5. 9 July	126.87	98.24
6. 16 July	61.55	7.96
7. 23 July	83.36	6.00
8. 30 July	32.77	0.74
9. 6 August	88.71	0.51
10. 16 August	73.86	12.80
11. 20 August	53.61	15.78
12. 28 August	93.41	22.21
13. 4 September	77.91	10.17
14. 11 September	69.48	25.23
15. 20 September	62.52	27.41
16. 24 September	116.37	39.49
17. 1 October	53.63	86.62
	$\overline{x}$ = 80.91	$\overline{x}$ = 42.49
Other Stations		
West Sister Island 19 June	138.20	121.80
Vermilion 7 July	110.21	84.28
Sandusky Bay 17 July	86.02	16.78