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DISTRIBUTION PATTERNS OF *POSTHODIPLOSTOMUM MINIMUM CENTRARCHI* METACERCARIAE AMONG JUVENILE AND MATURE BLUEGILL SUNFISH, *LEPOMIS MACROCHIRUS*

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ABSTRACT—The intensity and pattern of distribution of *Posthodiplostomum minimum centrarchi* metacercariae among juvenile (≤7 cm) and mature (>7.0 cm) bluegill sunfish, *Lepomis macrochirus* collected from Beaver Lake, an impoundment in Shelby Farms, an urban park located in Memphis, Tennessee, were compared. Partial correlation coefficient analysis between fish weight and parasite infrapopulation size, controlling for fish length, was conducted to determine the degree to which infrapopulation size alters the relationship between fish weight and length. Prevalence of infection for the entire population ranged from 80–100%. With the exception of the September 1994 collection, metacercaria abundance in mature fish was higher than juveniles. The distribution of metacercariae was overdispersed in mature and juvenile fish, with mature fish having higher variance/abundance ratios. As expected, the correlation between fish weight and fish length was statistically significant. There was a significant positive correlation between fish weight and parasite infrapopulation, suggesting that detrimental effects of mature metacercariae on field populations of bluegill sunfish were negligible. This lack of detrimental effects may be an adaptation for *P. minimum* overwintering survival because the definitive hosts, herons, are migratory, and the first intermediate host, physid snails, are annual.

Posthodiplostomum minimum centrarchi is a strigeid trematode whose metacercariae live in the visceral organs of bluegill sunfish, *Lepomis macrochirus*. Field studies have shown that prevalence of *P. minimum* among centrarchids quickly approaches 100% and that metacercariae become established in visceral organs when fish are extremely young, appearing in fish as small as 15 mm (Fischer and Kelso, 1990). Laboratory studies have shown that the infection process will cause violent fin-fanning, brushing against aquarium walls and extensive hemorrhaging (Bedinger and Meade, 1967), and it can be lethal (Hoffman, 1958).

Metacercariae become fully developed and resistant to the effects of pepsin between 26 and 44 days, and it is probable that worms become infective to the definitive host at this time (Hoffman, 1958). Spall and Summerfelt (1970) state that metacercariae become infective 21 to 30 days post-exposure.

Field studies have yielded conflicting results in determining whether harmful or lethal effects of *P. minimum* metacercariae observed in laboratory studies also occur in nature. Bluegills infected with large numbers of grubs show decreased growth rates (Smitherman, 1964), or reduced mass for a given length (i.e., condition) (Hugghins, 1959). In contrast, infrapopulation size does not correlate with condition among bluegills (Lewis and Nickum, 1964), and the severity of white grub infection has no impact on hematocrit, relative weight, or growth in largemouth bass (Grizzle and Goldsby, 1996). Spall and Summerfelt (1970) concluded that most serious debilitating effects, which may result in death of the host, occur in the first three weeks following cercarial penetration.

The goals of this study were to compare the abundance, as defined by Margolis (1982), and distribution patterns of *P. minimum* metacercariae among juvenile and mature bluegill sunfish, to determine whether parasite presence has a significant effect on fish weight, and to suggest a reason why the apparent lack of detrimental effect caused by the metacercariae may be an evolutionary adaptation for survival of this parasite species.

MATERIALS AND METHODS

Fish were collected from Beaver Lake, one of several lakes at Shelby Farms, an urban park located in Memphis, Tennessee.

During each of 15 monthly sampling dates between October 1993 and December 1994, a minimum of 40 fish were collected with a 50-foot bag seine, and surface water temperature was measured. Upon return to the laboratory, fish were preserved in 10% formalin. Length and weight of each fish were measured, and livers were dissected to remove and count the metacercariae. Although other visceral organs are infected, the liver is the single most heavily parasitized and easily sampled organ in bluegills (Grizzle and Goldsby, 1996).

Prevalence of the parasite and the number of mature (>7.0 cm) and juvenile (≤7.0 cm) fish were determined. Descriptive statistics, such as abundance, variance and ratio of variance/abundance were calculated. For each sampling date, abundance and ratio of variance/abundance for juvenile (≤7 cm) and mature (>7 cm) bluegills were compared.

Statistical analysis determined the correlation between fish length and infrapopulation size, and the partial correlation between fish weight and infrapopulation size, controlling for fish length (SPSS Inc., 1997).

TABLE 1. Prevalence, abundance, and ratio of variance/abundance of *Posthodiplostomum minimum* metacercariae among bluegill (*Lepomis macrochirus*) of Beaver Lake, Shelby Farms, Memphis, Tennessee.

Sampling date	Prevalence (% infected)	Fish ≤ 7 cm			Fish > 7 cm		
		No. in sample	Abundance	Variance/Abundance	No. in sample	Abundance	Variance/Abundance
1993 Oct	80	42	3.90	6.14	8	18.75	57.58
Nov	94	40	5.33	5.97	10	54.40	36.74
Dec	96	34	8.44	6.20	16	34.94	27.86
1994 Jan	100	18	11.44	12.05	36	37.44	40.04
Feb	94	15	8.27	4.62	38	31.87	31.16
Mar	98	18	10.44	4.83	37	34.24	19.94
Apr	100	5	15.00	7.57	45	69.58	29.66
May	100	12	23.08	19.73	38	58.03	29.73
Jun	100	31	15.68	11.78	9	41.67	15.59
Jul	100	14	30.71	12.49	36	100.61	89.34
Aug	93	38	10.32	11.63	16	129.56	55.42
Sep	81	41	8.54	7.64	3	0	
Oct	100	52	12.67	9.74	0		
Nov	96	56	10.32	9.97	0		
Dec	98	49	10.78	15.82	1	38	

RESULTS

A total of 810 fish was collected. Prevalence of *P. minimum* metacercariae was extremely high, ranging from 80–100% (Table 1). The number of mature bluegill was higher than of that of juveniles in collections between January 1994 through May 1994 and again in July 1994 (Table 1). Mature fish tended to have higher parasite intensities than juveniles. The decrease of intensity to 0 observed in September 1994 among the mature fish was due to the small number of mature fish collected (n = 3), all of which were uninfected (Table 1). With onset of colder water temperatures in September 1994, mature bluegills probably retreated to deeper water, thus accounting for their disappearance in subsequent sample dates. Ratios of variance/abundance were consistently high, well exceeding one, particularly among mature bluegills (Table 1).

As expected, there was a significant positive correlation between fish weight and fish length (Table 2). The partial correlation between fish length and parasite infrapopulation size, controlling for fish length, was both significant and positive (Table 3).

TABLE 2. Non-parametric correlations between fish length and weight among bluegills, *Lepomis macrochirus*, collected from Beaver Lake, Shelby Farms, Memphis, Tennessee.[1]

			Fish length (cm)	Fish weight (g)
Kendall's tau b	Correlation Coefficent	(cm)	1.000	0.864**
		(g)	0.864**	1.000
Spearman's rh	Correlation Coefficient	(cm)	1.000	0.962**
		(g)	0.962**	1.000

[1] n = 810.

** Correlation is significant at the $P < 0.01$ level (2-tailed).

DISCUSSION

The most surprising finding in this study is the significant, positive correlation between fish weight and infrapopulation size. This is not to suggest that the parasite presence promotes weight gain or plumpness as an index of relative health (Lewis and Nickum, 1964) or that *P. minimum* releases a growth factor as reported for other helminths such as *Diphyllobothrium mansonoides* (Mueller, 1974). Instead, healthier fish are more likely to survive invasion and migration of numerous cercariae within various visceral organs, especially when such a low percentage of cercariae succeed in developing into the metacercarial form. This observation may have significant implications regarding the life cycle strategy of *Posthodiplostomum minimum.* First, if mortality caused by *P. minimum* among fish occurs when the cercariae are migrating through internal organs, and ceases when those cercariae develop into infective metacercariae, then perhaps the reduced morbidity of fish that are heavily infected with metacercariae is an adaptation that enables the parasite to survive overwintering conditions. Esch and Fernandez (1993) refer to a residual effect in helminth life cycles, in which a helminth species can survive and continue their life cycle in an aquatic habitat without the presence of a migratory definitive host. In the case of *P. minimum,* the definitive host is a migratory piscivorous bird, the great blue heron. The first intermediate hosts for *P. minimum* are members of the genus *Physa,* which are annual (Hoffman, 1958). Therefore, the only remaining stage that can survive on a year-round basis in an aquatic habitat may be the metacercaria. Evidently, the formation of the numerous cysts in visceral tissue does not cause sufficient cellular or physiological responses to deplete the energy stored by infected fish for surviving the winter. Hoffman (1958) does report that metacercariae,

TABLE 3. Partial correlation coefficients between fish weight and parasite infrapopulation size, controlling for fish length.

		Fish weight (g)	Parasite infrapopulation size
Fish weight (g)	Correlation	1.0000	0.4094
	d.f.	(0)	807
	2-tailed significance	—	$P < 0.005$
Parasite infrapopulation size	Correlation	0.4094	1.000
	d.f.	(807)	(0)
	2-tailed significance	$P < 0.005$	—

d.f. = degrees of freedom.

in fish collected in the field and maintained in the laboratory for at least 16 months, were normal and alive.

Second, the reduced lethality of individual metacercariae allows for the accumulation of large parasite infrapopulations, thus increasing the likelihood of definitive hosts becoming infected with the ingestion of any intermediate host. This strategy is quite different than that described by Holmes and Bethel (1972), where each infected intermediate host (gammarids) has no more than a single intermediate stage of the acanthocephalan *Paradoxus polymorphus*. When that intermediate stage has matured within the gammarid to become infective to ducks, the definitive host for the parasite, the parasite alters the behavior of the infected gammarid, thus making it more likely to be captured and ingested by the definitive host.

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