EFFECTS OF A LARVAL PARASITE ON THE GROWTH AND SURVIVAL OF YOUNG BLUEGILL

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Abstract: Seasonal dynamics of metacercariae of Uvulifer ambloplitis (Hughes 1927), the black spot parasite of centrarchids, were monitored over a 12 month period for bluegill *(Lepomis macrochirus)* $\leq$ 70 mm total length. Prevalence of infection ranged from 8 percent in April to 97 percent in September. Mean parasite density during September was 16 metacercariae per host although individual infections of over 100 per host were not uncommon. Prevalence and density of infection were greatest in bluegill 31 mm to 50 mm total length. Metacercariae were often localized in the caudal peduncle, gular plate, and isthmus of heavily infected fish. Analysis of variance indicated significant differences in weight and body condition (K) of heavily versus lightly infected individuals of the same length class ($P < 0.05$). Body condition was negatively correlated to parasite density ($r = -0.474$, $P < 0.01$). Data indicate that heavily infected hosts ($>$ 50 metacercariae per fish) were most abundant during September, and were eliminated from the population by January. This removal appears to be selective and may involve effects of the parasite on host swimming and/or feeding ability. Infections of *U. ambloplitis* metacercariae may be a factor influencing year class strength and subsequent growth of bluegill in waters where densities exceed 50 per host for individuals less than 50 mm total length.

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Uvulifer ambloplitis is a digenetic trematode of the family Strigeidae. Two intermediate hosts are required for completion of the life cycle, and the parasite is known to be widespread and common. Adult parasites infect kingfishers in North America (Hoffman 1960, Boyd and Fry 1971). Eggs are shed into the water in fecal material and hatch in approximately 3 weeks. The first larval stage penetrates the soft parts of an aquatic snail *(Helisoma trivolvis)* and after 6 weeks a fourth larval stage emerges (cercaria). Contact with an appropriate fish species causes cercariae to attach and penetrate the skin. The cercariae migrate into the deeper layers of dense fiberous tissue, between the myotomes, or into areas surrounding the orbit and brain and transform into metacercariae. The larvae secrete a hyaline cyst about themselves and within 3 weeks the fish responds by producing a black pigmented host cyst. The condition is known as black-spot or black-grub (Krull 1934, Hunter and Hamilton 1941). The life cycle is completed when an infected fish is eaten by a kingfisher. Metacercariae excyst, establish themselves in the intestine, and develop into adults.

Limited data are available on the effects of *U. ambloplitis* metacercariae on centrarchids. Laboratory studies have shown that the parasite is capable of causing reduced weight gain and death in some instances (Krull 1934, Hunter and Hunter 1938). Meyer (1958) and Kakonge (1972) suggested that black-spot infections could regulate host population growth due to the elimination of the most heavily infected fish. However, these studies offer little support based on quantitative data collected from natural fish populations. A majority of the literature giving reference to *U. ambloplitis* is in the form of species surveys (McDaniel and Bailey 1966, 1974, Miller et al. 1973, Barnhart et al. 1976) and studies of seasonal incidence (Voth and Larson 1968, Gash and Gash 1972, Cone and Anderson 1977), with no concern given to effects on the host.

The present study was conducted to establish data on the quantitative effects of *U. ambloplitis* metacercariae on growth and survival of bluegill *(Lepomis macrochirus)* from a natural population $\leq$ 70 mm total length, and to relate these data to the observed prevalence and density of infection.

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METHODS

Bluegill in this study were collected by monthly sampling in the littoral zone of a privately owned 3 hectare impoundment, designated as Lake 150, located in Piedmont, North Carolina. Lake 150 contains only bluegill and largemouth bass *(Micropterus salmoides)*, and the watershed is composed of approximately equal portions of forest, meadow, and livestock pasture. The sampling period extended from April 1979 through March 1980.

Bluegill were taken in seines and minnow traps, the seine samples being used primarily to verify the reliability of trap catches. The entire sample for 1 month was taken to the laboratory and from it, 10 fish from 3 length classes ($\leq$ 30 mm, 31 - 50 mm, 51 - 70 mm) were selected by assigning random numbers (Rohlf and Sokal 1969, Sokal and Rohlf 1969). This process was used each month to assure random sampling and provide equal sample sizes for statistical analyses.

Weight (to the nearest 0.1 g), total length, and standard length (to the nearest millimeter) were recorded for each fish. Five to 10 scales were taken from an area immediately posterior to the pectoral fin and below the lateral line on the left side for age and growth determination. Scale samples were washed in an ammonia solution to remove dried mucous and skin fragments, placed between 2 glass slides, and viewed under a stereomicroscope at 20x to 60x magnification. The age of each fish was determined by counting the number of annuli. Distances between the focus and annuli, and from the focus to the perimeter of the scale were measured along the midline of the anterior field with an ocular micrometer (to the nearest 0.1 mm) for the back-calculation of growth rates (Bagenal and Tesch 1978).

The number of *U. ambloplitis* metacercariae present on each fish was determined by dissection and visual inspection. Locations of individual cysts were noted to establish site preference of the parasite. The bluegill body was divided into 6 regions (upper head, lower head, upper body, lower body, caudal peduncle, fins) and the number of cysts present in each recorded (Fig. 1)

Monthly field measurements of water temperature (°C), pH, and dissolved oxygen (mg/liter) were made in the littoral zone on the same days that bluegill were collected. A 1 liter water sample was taken to the laboratory and tested for turbidity (optical density) and alkalinity (Fisher Scientific Company 1979).

Hile's coefficient of body condition (K) was calculated for each fish based on length-weight relationships. Body condition is determined by the relationship $K = \frac{10^2 w}{l^3}$, where w = body weight (g) and l = standard length (cm). The plumpness of a fish in relation to standard length is indicated by this measurement and should reflect the well being of a fish (Bagenal and Tesch 1978).

A single classification analysis of variance test (one-way ANOVA) was used to determine statistically significant differences in the growth rate, body condition, and weight of heavily versus lightly infected bluegill of each length class. Heavily infected hosts were designated as those bluegill which harbored more than 50 *U. ambloplitis* metacercariae, with lightly infected hosts having fewer than 20 metacercariae. Comparisons were only made of fish taken from the same monthly sample to prevent comparison of weights and body conditions separated by time. Differences in the density of infection between the 6 body regions were also analyzed by single classification ANOVA.

Spearman's coefficient of rank correlation (r_s) was used to relate fish body condition to density of parasite infection (Sokal and Rohlf 1969). The coefficient is expressed as r_s

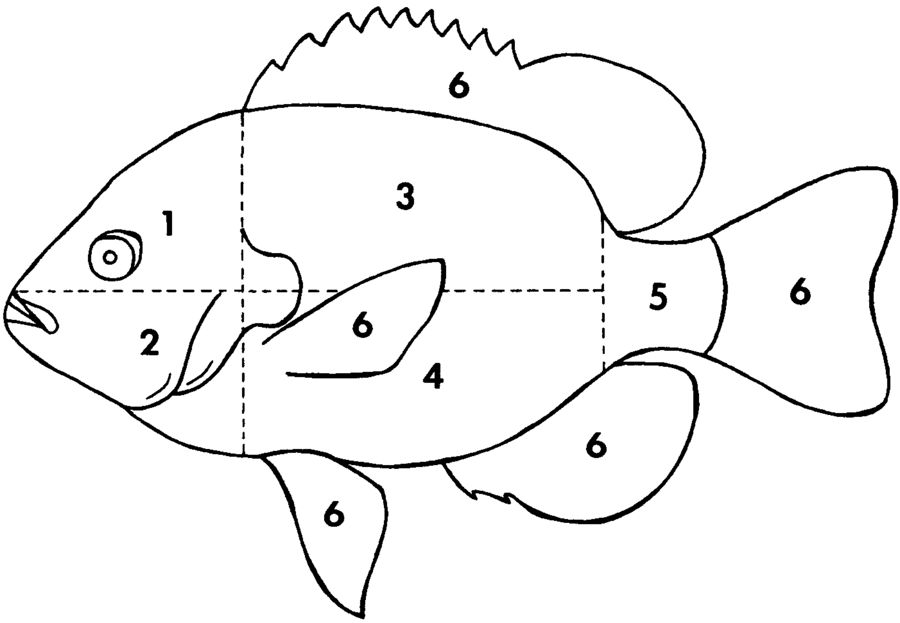

Fig. 1. Divisions used in the determination of site preference of *Uvulifer ambloplitis* metacercariae in bluegill *Lepomis macrochirus*. (1) Upper head region (2) Lower head region (3) Upper body region (4) Lower body region (5) Caudal peduncle region (6) Fins.

$= 1 - \frac{6(\Sigma d^2)}{n(n^2-1)}$, where d = X-rank number subtracted from Y-rank number and n = sample size. Rank correlation operates independently of the assumption of a simple linear relationship in the data and thus has practical application when this relationship is not obvious.

RESULTS

By sampling 10 bluegill from 3 length classes monthly, 360 fish were examined during this study. All fish were less than 2 years old (age class 1+) with 86 percent being young-of-the-year (0+). Prevalence of *U. ambloplitis* infection ranged from 8 percent in April to 97 percent in September (Fig. 2). Parasite density exhibited similar extremes, with many non-parasitized fish present in the April sample, but with individuals which harbored up to 154 metacercariae present in September (Fig. 2). The period of greatest prevalence and density was not similar after September. Prevalence remained high throughout the winter, but maximum density rapidly declined. Mean density of metacercariae during September was 16 cysts per fish although individuals with over 100 cysts were found in July, August, and September. Prevalence and density of metacercariae were greatest in bluegill 31 mm - 50 mm total length throughout the sampling period (Fig. 3). Very few heavily infected individuals were found in the 51 mm - 70 mm length class.

A significant negative correlation was found between body condition (K) and *U. ambloplitis* density (Fig. 4, Table 1). Trends were similar for all 3 length classes of hosts examined although levels of probability were higher with bluegill from the intermediate length class (31 mm - 50 mm).

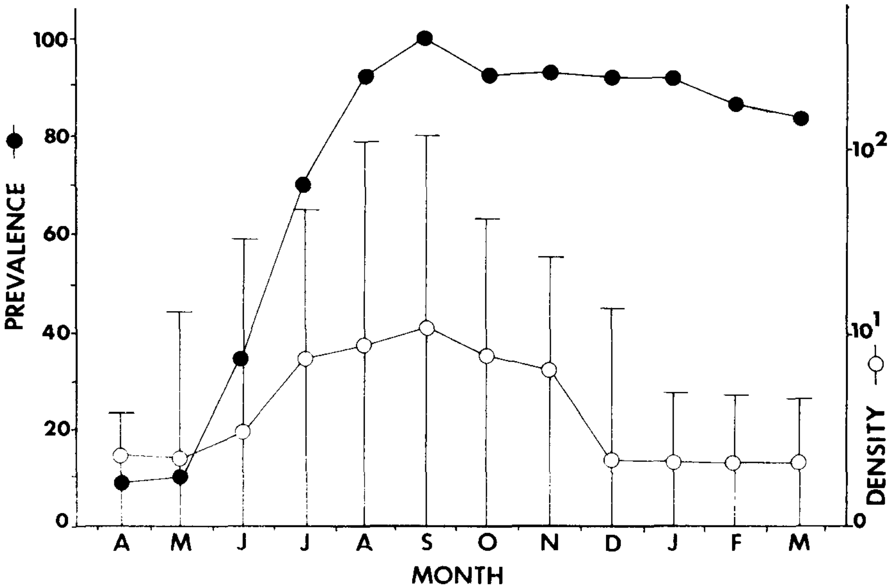

Fig. 2. Mean monthly prevalence and density of *Uvulifer ambloplitis* metacercariae in Lake 150 bluegill *Lepomis macrochirus*, April 1979 through March 1980. Vertical lines on the density curve indicate the range of densities found (N = 30 fish per month).

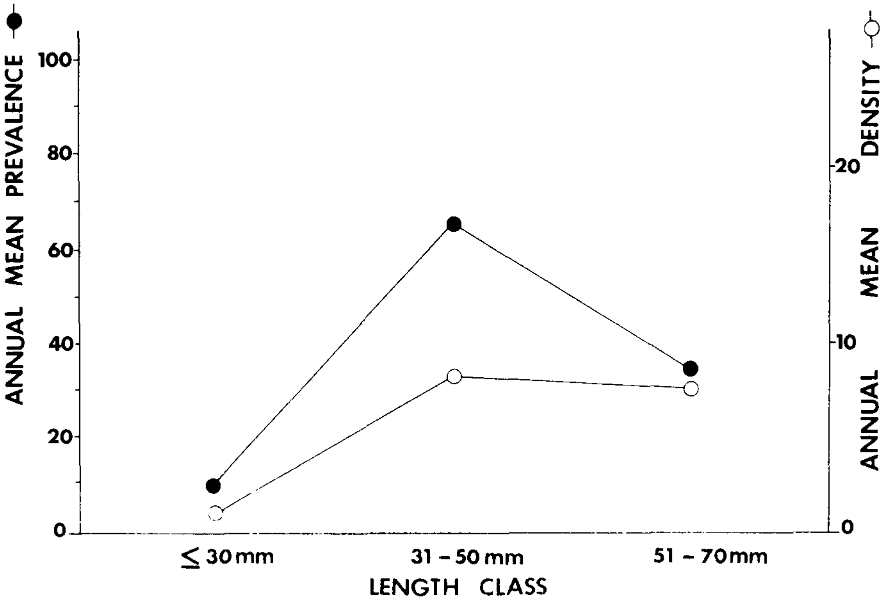

Fig. 3. Mean annual prevalence and density of *Uvulifer ambloplitis* metacercariae in Lake 150 bluegill *Lepomis macrochirus*, April 1979 through March 1980. Sample size for each length class = 120.

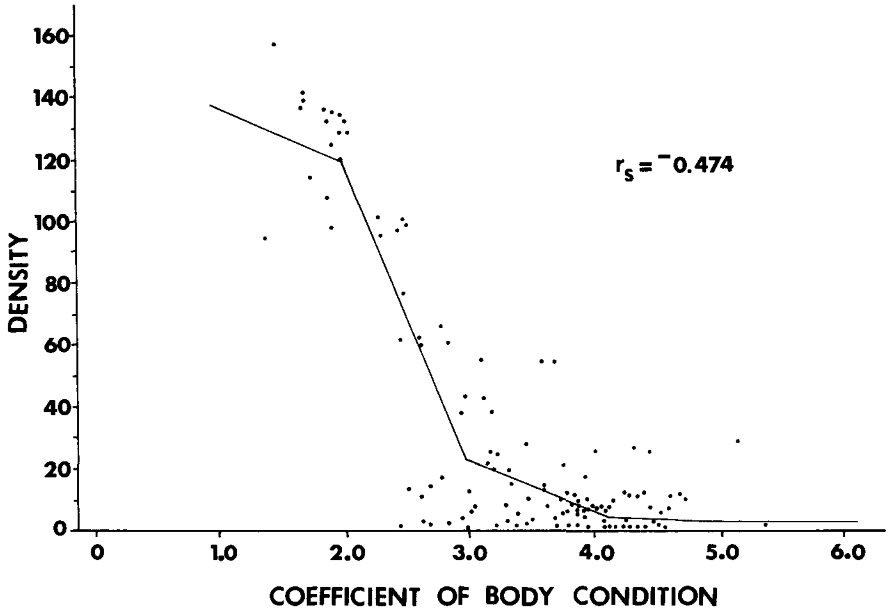

Fig. 4. Relationships between coefficient of body condition (K) and density of *Uvulifer ambloplitis* metacercariae in Lake 150 bluegill *Lepomis macrochirus*, July through October 1979. The correlation coefficient (r_S) is significant at $P < 0.01$, N = 120.

Analysis of variance indicated significant differences in weight and body condition between heavily infected (> 50 metacercariae) and lightly infected (< 20 metacercariae) bluegill (Table 2). Differences were greatest among bluegill 31 mm - 50 mm total length during all months except March and April. Fig. 5 illustrates the difference in overall body size of a heavily infected bluegill as compared with 2 non-infected individuals of the same standard length. Weight and back-calculated growth rates for bluegill age 1+ were not significantly different with respect to parasite density. Most bluegill of this age were greater than 70 mm total length and could not be used in the samples due to the limits of established length classes.

Location of metacercarial cysts indicates that *U. ambloplitis* exhibits some degree of site preference (Table 3), notably the lower head and caudal peduncle regions. The concentrations observed in these body regions were often significantly higher than those found in other regions. This trend was especially evident on the heavily infected bluegill collected during July, August, and September. During these months the lower head and caudal peduncle regions accounted for up to 76 percent of the total number of metacercariae present. Figs. 6 and 7 illustrate a concentration of *U. ambloplitis* metacercariae in the caudal peduncle, isthmus, and gular plate such as was frequently observed on heavily infected bluegill. In lightly infected fish, and during January through April, these 2 body regions did not account for a significantly higher proportion of parasites than did other body regions. Very few bluegill had metacercarial cysts present on the fins, even on individuals harboring high densities of the parasite.

Water quality data for the littoral zone of Lake 150 indicated that pH remained near neutral (6.6 - 7.2) and dissolved oxygen levels were frequently near saturation for existing water temperatures throughout the sampling period. Alkalinity was low (1.6 - 4.1 ppm),

Table 1. Rank correlation coefficients (r_s)[1] of body condition (K) and density of *Uvulifer amblopltitis* metacercaria for bluegill *Lepomis macrochirus* from Lake 150, April 1979 - March 1980.

Month	Length class of fish		
	$\leq$30 mm	31 - 50 mm	51 - 70 mm
April	-0.011	-0.018	+0.040
May	-0.103	-0.219	-0.117
June	-0.634 a	-0.699 a	-0.507
July	-0.930 b	-0.981 b	-0.580
August	-0.988 b	-0.999 b	-0.664 a
September	-0.999 b	-1.000 b	-0.617 a
October	-0.949 b	-0.991 b	-0.449
November	-0.607 a	-0.683 a	-0.312
December	-0.348	-0.620 a	-0.019
January	-0.418	-0.607 a	-0.010
February	-0.400	-0.228	+0.063
March	-0.190	-0.040	+0.013

[1]Each correlation coefficient represents data for 10 fish. Mean r_s = - 0.474, $P < 0.01$.

a Significant at $P < 0.05$.

b Significant at $P < 0.01$.

typical of lakes in the region, and sub-surface temperatures did not exceed 30° C. The degree of turbidity was modest (74 - 90 percent transmittance) although during May, excessive rains apparently caused a brief pulse to occur.

DISCUSSION

It is quite apparent from a review of the data collected in this study that *Uvulifer ambloplitis* metacercariae can have detrimental effects on small bluegill. Significant differences found in weight and body condition of heavily versus lightly infected fish support the laboratory findings of Hunter and Hunter (1938) who stated that the parasite was capable of causing reduced growth and weight gain. Correlation data clearly indicate that heavy infections had negative effects on condition and weight (Table 1).

Rabideau and Self (1953) stated that K-factor (body condition) was not a good indicator of the effects of black-grub on fish hosts. However, their study compared infections and body condition among *Lepomis* spp which ranged from 1 to 4 years old, and included no young-of-the-year fish. With such a broad comparison between species, body length, and age (which would suggest differences in food habits), it would be expected that factors such as overpopulation and food supply would influence body condition as much as parasitism. Data from the present study using bluegill of the same age and length class indicate that body condition and weight may be very effective in quantifying the effect of *U. ambloplitis* metacercariae on small fish (Fig. 4, Table 1).

Seasonal trends show that the prevalence and density of parasitism dropped after building to a peak in September. The reduction in parasite density was sharp but prevalence declined very slowly. A decrease in prevalence could possibly be explained by the introduction of additional bluegill into the population by spawning late in the season,

Fig. 5. Lake 150 bluegill *Lepomis macrochirus* taken from the September 1979 sample. The middle fish is heavily infected with *Uvulifer ambloplitis* metacercariae (> 50 cysts), the other 2 individuals are not infected. Note the differences in body depth and size of the eye in relation to the rest of the head in the infected versus non-infected fish. All 3 fish are the same standard length (38 mm).

Table 2. Summary ANOVA data (F s) on weight and body condition (K) of heavily infected (> 50 cysts / fish) versus lightly infected (< 25 cysts / fish) bluegill *Lepomis macrochirus* from Lake 150, July - October 1979[1].

Parameter	Month[2]			
	Jul	Aug	Sep	Oct
Weight	3.26 a	6.67 b	13.7 c	3.01
Body condition	5.88 b	6.89 b	14.3 c	3.88 a

[1]All fish sampled were 31 - 50 mm total length (N = 10, df = 9).

[2]Months shown were the only ones during which bluegill with more than 50 metacercariae were present in sufficient numbers for analysis.

a Significant at $P < 0.05$.

b Significant at $P < 0.01$.

c Significant at $P < 0.001$.

Table 3. Site preference[1] of *Uvulifer ambloplitis* metacercariae in bluegill *Lepomis macrochirus* from Lake 150, April 1979 - March 1980.

Body region	Month											
of fish	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	16	14	12	18	19	13	14	18	14	20	20	10
2	17	23	30	26	29	40	31	18	12	14	21	19
3	24	20	18	12	8	2	11	19	30	22	19	13
4	29	30	22	10	10	7	14	24	32	31	28	38
5	13	13	17	31	30	36	24	18	11	11	12	18
6	1	0	1	3	4	1	6	1	1	2	0	2

[1]Percentage of total cysts present (N = 30 fish per month).

assuming that production of cercariae by *H. trivolvis* had ceased for the year. However, until data on the seasonal shedding characteristics of *U. ambloplitis* cercariae by *H. trivolvis* are established, this suggestion is speculative.

It is perhaps somewhat more difficult to explain the observed drop in density of infection after September. A certain number of heavily infected bluegill would be expected to be removed through predation by largemouth bass and fish eating birds, independent of the direct effects of the parasite. However, it would also be expected that if heavily infected individuals were removed in proportion to their abundance in the population (i.e. preyed upon randomly) a few could be taken in samples some months after peak infections occurred, assuming the metacercariae are long-lived. Fischthal (1949) conducted experiments on the overwintering ability of *U. ambloplitis* metacercariae and found that the loss during winter was negligible. Hoffman and Putz (1966) maintained bluegill at 12° C and even after 4 years, metacercariae were still alive. Therefore, the observed drop in parasite density appears unrelated to elimination by death of the metacercariae.

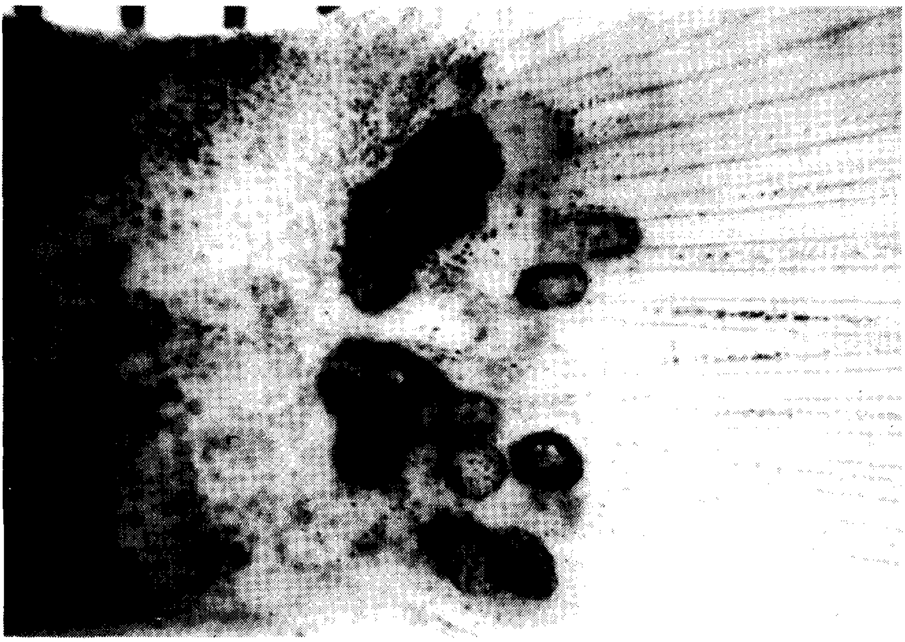

Fig. 6. A concentration of *Uvulifer ambloplitis* metacercariae in the caudal peduncle region (5) of a heavily infected bluegill *Lepomis macrochirus* from Lake 150.

Fig. 7. A concentration of *Uvulifer ambloplitis* metacercariae in the lower head region (region 2, specifically the gular plate and isthmus) of a heavily infected bluegill *Lepomis macrochirus* from Lake 150. Note the differences in cyst depth within the tissues.

Heavily infected bluegill (> 50 metacercariae per fish) were virtually absent from the samples by January, after building to a peak in September (Table 3) suggesting that direct or indirect effects of the parasite were responsible. If predation upon small bluegill was selective toward the more heavily infected individuals, the observed decrease might be explained. It is well known that parasitic infections may alter host populations through effects on survival, growth, and reproduction (Lopukhina et al. 1973, Lanciani 1975, Anderson 1978, 1979a, 1979b). Although apparently no data exist for *U. ambloplitis* in centrarchids, studies have shown that the behavior of parasitized intermediate hosts may be modified in such a way as to increase their vulnerability to predation (Holmes and Bethel 1972, Bethel and Holmes 1977).

Observed localization of *U. ambloplitis* metacercariae in the caudal peduncle of heavily infected bluegill (Fig. 6) suggests that swimming ability may be impaired to the point of making escape from largemouth bass unlikely. Previous studies recording the location of *U. ambloplitis* cysts in host fish have emphasized the fins as a site frequently infected (Evans and Mackiewicz 1958, Rubertone and Hall 1975). Data from the present study indicate that fins were the region least likely to be parasitized (Table 3). Buildup of metacercariae in the gular plate and isthmus (Fig. 7) could lead to the disruption of muscles used in gill ventilation and feeding. Reduced ability to secure food would result in the observed lower body condition and weight of heavily infected fish (Fig. 4, Table 1). Such a retardation of growth might be explained by crowding were it not for the fact that bluegill used for comparison came from the same monthly sample and length class. Krull (1934) noted impairment of swimming ability and feeding efficiency due to *U. ambloplitis* metacercariae in 15 mm to 30 mm pumpkinseed *(Lepomis gibbosus)* in the laboratory.

It was noted that the most heavily infected bluegill were in the 31 mm to 50 mm length class. All samples were collected from shallow littoral areas in 15 cm to 50 cm of water, thus exposure to snails shedding cercariae should have been relatively equal for each length class. Smaller bluegill (< 30 mm total length) may not have been exposed long enough to build up similar infections since approximately 3 weeks are required for pigmentation of cysts to occur. Many fish of this size may be less than 3 weeks old and would not be expected to have any pigmented cysts present. It is not clear why bluegill larger than 50 mm did not exhibit infection densities equal to those in 31 mm to 50 mm fish. One obvious suggestion is that larger individuals have attained some degree of immunity to subsequent infection. However, repeated infections of 40 mm to 80 mm bluegill in the laboratory by Hoffman and Putz (1966) indicated that individuals larger than 50 mm total length were readily infected to high densities. Some field studies have shown that *U. ambloplitis* densities increase in larger individuals of certain *Lepomis* species (Rabideau and Self 1953, Cone and Anderson 1977). Thus, the reason for lower densities in larger bluegill in this study cannot be adequately explained by immunity. Perhaps differences in daily activity and feeding patterns resulted in decreased exposure of larger individuals to areas in the littoral zone where snails were shedding cercariae.

Comparisons with the literature indicate that although the prevalence of infection may be similar (80 percent - 90 percent during late summer), the density of *U. ambloplitis* metacercariae per host during the period of peak infection was high in bluegill from Lake 150. Part of the difference must undoubtedly be due to the fact that other studies often combine data for fish of many different ages, ranging from 1 to 5 years. Other factors may be the number of cercariae to which fish are exposed, and differences in the recruitment of *U. ambloplitis* between *Lepomis* species. Variations in the density of aquatic snail hosts *(H. trivolvis)* between lakes may lead to large differences in cercariae production and subsequent infection of centrarchids. Whether or not the observed infections in bluegill from Lake 150 are as heavy as they appear to be is not clear.

CONCLUSIONS

Bluegill heavily parasitized by metacercariae of *Uvulifer ambloplitis* exhibited significantly lower weight and body condition as compared to lightly infected individuals of the same length class. Heavily infected individuals were absent from samples taken soon after peak infections occurred. Based on these data, it is suggested that heavily parasitized fish were eliminated due to direct effects of the parasite or as a result of selective predation by largemouth bass. Selective predation by fish eating birds may also have occurred, but observations made on sampling days do not indicate such predation to have been significant. Heavily infected bluegill may have impaired swimming and feeding ability when metacercariae become concentrated in the caudal peduncle, gular plate, and isthmus. Seasonal trends in infection densities and body condition indicate that mortality may have occurred in bluegill less than 50 mm total length which harbored more than 50 metacercariae. It appears that infections such as those observed in Lake 150 may affect your class strength to the extent that growth beyond 70 mm is improved and potential for overcrowding reduced. Studies are presently underway to establish data on cercariae shedding characteristics of the snail intermediate host *(Helisoma trivolvis)* as well as determine how infections in young-of-the-year centrarchids vary between species and lakes.

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