Observations on the ecology of *Clinostomum marginatum* in largemouth bass (*Micropterus salmoides*)

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Over a fifteen month period, beginning October, 1974, approximately 13 500 centrarchids were examined for evidence of infection with metaceraria of *Clinostomum marginatum*. Species checked included *Lepomis macrochirus*, *L. gulosus*, *L. auritus*, *Pomoxis nigromaculatus* and *Micropterus salmoides*. The study site was Par Pond (South Carolina, U.S.A.), an 1120 ha reservoir receiving thermal effluent from a nuclear production reactor. Except for the largemouth bass, *M. salmoides*, infection percentages among the five species were less than 1%. Among bass, infection varied seasonally, being highest from January to June. From the spring highs of approximately 25%, the percentages dropped to lows of <10% in July and August; there was a jump in September-October to another peak of 30% and then a steady decline through December when infection percentages were again less than 10%. Neither body condition nor length of the bass were related to infection percentage or metacerarial density. Infection percentage could not be related to the influence of thermal effluent. Infection percentages did vary from location to location within the Par Pond system. A significant rank correlation could be established between infection percentage and the amount of littoral zone present in the locality from which the bass were taken. It is suggested that the local 'bay effects' are the result of limited home and foraging ranges of the bass in relation to the amounts of littoral zone present in various locations of the reservoir.

I. INTRODUCTION

*Clinostomum marginatum* is a common, digenetic trematode, having a cosmopolitan distribution. Definitive hosts include several species of herons as well as other fish-eating birds. Intermediate hosts are *Helixoma* spp. and a number of fish species, including the largemouth bass, *Micropterus salmoides*.

The impact of thermal effluent on the population biology of parasites in aquatic ecosystems has been little studied. Over the past three years, Bourque & Esch (1974), Eure & Esch (1974), Eure (1975), Aho, Gibbons & Esch (1976) have all presented evidence that parasite populations and species diversity in bass (*M. salmoides*), turtles (*Chrysemys scripta*) and mosquitofish (*Gambusia affinis*), are altered by thermal effluent in Par Pond, a cooling reservoir located on the Savannah River Plant near Aiken, SC.

In the autumn of 1974, a new study was begun in the Par Pond system to evaluate the impact of thermal loading and other water quality parameters on the epizootiology of red-sore disease (caused by aeromonads and the ciliate) *Epistylis* spp. among various species of centrarchid sunfish (Esch et al., 1976). Metaceraria of *Clinostomum marginatum* were frequently noted among the bass and since the overall programme was aimed at assessing the relationship between thermal effluent and parasitism in aquatic systems, it was decided to include *C. marginatum*. 411
The objectives of this part of the study were:

(i) to compare infection percentages and worm burdens among the various species of Centrarchidae in thermal and ambient parts of the reservoir;
(ii) to compare infection percentages of *C. marginatum* and body conditions of largemouth bass;
(iii) to compare host size with infection percentage;
(iv) to determine seasonal changes in infection percentages among largemouth bass;
(v) to compare infection percentages among bass taken in various localities within the Par Pond reservoir.

II. MATERIALS AND METHODS

Par Pond is an 1120 hectare cooling reservoir which receives heated water from a nuclear production reactor. Floral and faunal characteristics of the reservoir have been described by Parker, Hirshfield & Gibbons (1973). Elevated water (> 10°C above ambient) temperature in Par Pond extends several hundred metres beyond the point of entry of the thermal effluent and then gradually declines to ambient in the more distant parts of the reservoir (Holland et al., 1974).

Largemouth bass (*Micropterus salmoides*), warmouth (*Lepeomis gulosus*), bluegill (*Lepeomis macrochirus*), black crappie (*Pomoxis nigromaculatus*) and red-breast sunfish (*Lepeomis auritus*) were taken throughout the study (1974–75) by a combination of angling and electro-fishing, but mostly the latter. Bass were sampled in all areas on a weekly basis; a few sites (GB, DL, LL and JB; see Fig. 1) were sampled less frequently. In general bass larger than
Fig. 2. Monthly changes in infection percentages of C. marginatum in largemouth bass. ○ represent data for bass from thermal locations; • include data from ambient locations.

20 cm in total length were included while the data for other centrarchids included all sizes longer than 30 mm; exceptions to this pattern are noted in the text. Because of the annual breeding cycle and increase in size of each year's cohort, there was some seasonal variability in size classes of bass examined for C. marginatum; there was, however, no evidence to suggest that size, season and probability of infection were related variables.

Immediately after capture, total, fork and standard length of all bass were measured; the bass were then weighed and visually examined for metacercaria of C. marginatum. The metacercaria are of such size that all, except the most immature forms, could be noted with ease. The entire surface of the bass, as well as the gills and mouth were checked. The location of each metacercaria was noted. During the first 15 months of study, 3439 largemouth bass and in excess of 10,000 of the other four centrarchid species were examined for C. marginatum metacercaria and for evidence of infection with red-sore disease.

III. RESULTS

There is a seasonal periodicity for infection percentages of Clinostomum marginatum among largemouth bass in Par Pond (Fig. 2). Except for the month of October, 1974, the infection percentages among largemouth bass in ambient and thermal locations were very similar; sample sizes during October were small in both areas (N=14 in ambient locations and N=22 in thermal locations), so the differences could be spurious. Otherwise, sample sizes of bass in ambient and thermal locations in other months were approximately the same. The mean densities of C. marginatum per infected bass were low, i.e., ~1.5 per fish (Fig. 3) and they did not follow a marked seasonal pattern. The differences in metacercaria density among bass from ambient and thermal locations were inconsistent and without a distinct pattern.

Body condition, or K-factor is a suitable method for measuring the relative 'fitness' of fish within a given population (Carlender, 1944); a bass with a K-factor of <2.0 would be considered poor body condition and one greater than 2.2 in relatively good condition. Based on data from more than 3400 infected and uninfected bass, there
did not appear to be a correlation between body condition and the density of metacercaria per infected host. However, when infection percentage and body condition were compared, a curious relationship was apparent (Fig. 4). Thus, the lowest infection percentages were noted among bass with the poorest body conditions as well as among individuals with the best body conditions. Such relationships may be spurious, however, since the body condition subclasses with the smallest sample sizes were 1-0-1-2 and 2-6-2-8. To show that body condition may be related to relative ‘fitness’, data for the relationship between body condition and the probability of a given fish being infected with red-sore disease, or not being infected, is superimposed on the *C. marginatum* data in Fig. 4. It is clear, in this case, that the likelihood of a bass being infected with red-sore disease *viz.* *Aeromonas hydrophila* and *Epistyliis* spp. (A-E complex) is much greater for those bass with lower *K*-factors. It should be emphasized that the sample used to generate data for the comparison of red-sore disease and body condition is the same used to compare *K*-factor and *C. marginatum*.

The relationship between length of bass and infection with metacercaria of *C. marginatum* is a curious one (Fig. 5). The infection levels are lowest in bass less than 14 cm, highest in the group between 24-34 cm and then declines as bass increase in size beyond 34 cm in standard length. Again, for comparative purposes, the relationship between infection with red-sore disease and length of bass in the same sampling group is superimposed on the data for *C. marginatum* in Fig. 5. In this case, there is a clear relationship between fish length and infection with red-sore disease.

Since the pattern of infection with *C. marginatum* appeared to be relatively similar in bass from ambient and thermal locations, it was decided to examine and compare infection percentages and worm burdens in bass between various locations, both ambient and thermal. If bass from various areas are separated from each other and
infection percentages then calculated, the levels of infection range from a low of 10.6% in DL to a high of 31.4% in KB (Table 1; see Fig. 1 for comparison of distances separating various areas). The mean worm burdens within each of the locations were low, ranging from 1.27 per host in GB to 1.65 in OB. Employing the rank correlation statistic, infection percentages and mean metacercaria densities were compared between locations (Table 1). The rank correlation was $r_s = 0.196$, which is not significant.
Table I. Infection percentage and mean worm burdens of C. marginatum among largemouth bass and the per cent of littoral zone in each of eleven locations in the Par Pond reservoir.

<table>
<thead>
<tr>
<th>Site</th>
<th>Per cent littoral zone</th>
<th>Per cent bass infected</th>
<th>Mean Worm burden</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>1.9%</td>
<td>15.8%</td>
<td>1.45</td>
</tr>
<tr>
<td>GB</td>
<td>31.0%</td>
<td>19.2%</td>
<td>1.27</td>
</tr>
<tr>
<td>HD</td>
<td>32.4%</td>
<td>16.9%</td>
<td>1.41</td>
</tr>
<tr>
<td>DL</td>
<td>39.5%</td>
<td>10.6%</td>
<td>1.20</td>
</tr>
<tr>
<td>LL</td>
<td>26.1%</td>
<td>24.1%</td>
<td>1.30</td>
</tr>
<tr>
<td>BB</td>
<td>62.0%</td>
<td>21.8%</td>
<td>1.42</td>
</tr>
<tr>
<td>OB</td>
<td>62.6%</td>
<td>22.3%</td>
<td>1.65</td>
</tr>
<tr>
<td>KB</td>
<td>67.7%</td>
<td>31.4%</td>
<td>1.41</td>
</tr>
<tr>
<td>NC</td>
<td>70.8%</td>
<td>17.1%</td>
<td>1.36</td>
</tr>
<tr>
<td>JB</td>
<td>71.7%</td>
<td>22.3%</td>
<td>1.33</td>
</tr>
<tr>
<td>SS</td>
<td>75.3%</td>
<td>31.3%</td>
<td>1.41</td>
</tr>
</tbody>
</table>

Thus, there is not a correlation between infection percentage and worm burdens in bass in various locations of the reservoir.

Evidence from a mark-release-recapture study (Quinn et al., in press) in Par Pond, indicates that bass have reasonably restricted home ranges, with little movement from one location to another; there are, therefore, more or less discrete subpopulations in various locations within the reservoir. Since infection percentage and worm burdens are not significantly correlated it was decided to assess the relationship between each of these parameters and the amount of littoral zone present in each location (Table I). A three meter contour map of the reservoir was used to estimate the amount of littoral zone present in each location sampled. Employing the rank correlation statistic, the amount of littoral zone was compared with the mean worm burdens of bass in each area. The rank correlation (r) was calculated as 0.291, which is not significant. However, when littoral zone and infection percentages were compared, the rank correlation was calculated as 0.591, which is significant at the 5% level of confidence. Thus, there is a significant correlation between the amount of littoral zone and the probability of being infected with C. marginatum. There is a 'bay effect', which results in a differential probability of infection in one location of the reservoir as opposed to another and which can be correlated with the amount of littoral zone present. It should be noted that these results are based on a 15 month sampling period in which some areas were studied more intensively than others during a given season. However, when the data for summer (when sampling was approximately equal in each area of the reservoir) are compared, the results are similar.

IV. Discussion

It is clear, from the observations made on seasonal dynamics of infection percentage and mean worm burdens, that differences in bass from thermal and ambient locations were negligible, except in October, 1974 and 1975 and in July, 1975. Based on small sample sizes, we feel that October, 1974, should be eliminated from any further consideration. In July, 1975 and in October, 1975, infection percentages were nearly twice as high in bass from ambient locations. These differences cannot be attributed to any biotic or abiotic factor.
There was a sharp decline in infection percentage from peak levels in winter and spring months, to lower levels in July and August. Then in September, the levels increased to higher values only to fall again after peaking in October. These seasonal fluctuations follow almost identical patterns in bass from ambient and thermal locations. While the factor(s) which contribute to regulating the cyclic pattern have not been identified, there are several which can be excluded. For example, large numbers of smaller, year-old-of-the-year bass, with significantly lower infection percentages could dilute overall infection percentages during the summer months. However, this can be excluded from consideration since the data shown in Fig. 2 only includes individuals >24 cm. Another factor which must be considered is that of differential predation pressure and the apparent relationship between bass size and infection probability. Thus, if smaller size classes, with presumed greater predation pressure from fish or birds, were included, then one might expect to see seasonal variability in infection percentage. Again, however, smaller size classes were excluded from consideration in the present study. The only predation pressure on bass greater than 24 cm in total length is exerted by the modest alligator population and, in this case, it is also doubtful that predation could influence infection by C. marginatum. Selective fishing pressure by anglers could be a factor in seasonal changes in infection percentage except that the entire reservoir is closed to the public and angling pressure is therefore negligible.

Rather than a “bass-oriented” factor, the cyclic nature of infection in Par Pond is more probably associated with a seasonal change in the density, and/or size structure of snail populations, the first intermediate host for C. marginatum. Such changes in the snail population could, in turn, alter intramolluscan development of the larval stages and/or impact on the release or survivability of cercaria.

The relationship between bass size and probability of infection with C. marginatum is also difficult to assess. Rather than a clear and significant correlation between size and infection, as with red-sore disease in the same bass population, there was nothing positive between host size and probability of infection with C. marginatum. The highest levels of infection by C. marginatum metacercaria occur in mid-size bass with lower infections in bass greater than 34 cm and less than 24 cm in total length. There appears to be no factor in the behaviour, physiology or morphology of bass in the largest and smallest size classes which would permit any speculation regarding the likelihood of a bass being exposed to, or infected with, metacercaria of C. marginatum.

An estimate of body condition, or K-factor, provides a suitable means for measuring the relative health, or “fitness” of fish within a given population (Carlander, 1944). Elliott & Russert (1949) did not observe a significant correlation between K-factor and infection by C. marginatum among some 2200 yellow perch, Perca flavescens, in Buck Lake, Minnesota. Results of the present study show the same trend for C. marginatum (both in terms of metacercaria density and in infection percentage) and largemouth bass in Par Pond. These confirming observations are made even more significant when they are contrasted with the relationship between red-sore disease and body conditions of the same group of fish (see also Esch et al., 1976), i.e., incidence of infection with red-sore disease was always highest among M. salmoides with the lowest body condition. It is therefore apparent that infection with C. marginatum does not induce a reduction in fitness in bass or that individuals in lower body condition are not any more, or less, susceptible to infection with C. marginatum.

The lack of impact of thermal effluent on the population biology of C. marginatum
in Par Pond is not consistent with previous studies on other host-parasite systems in the same reservoir. In 1974, Bourque & Esch reported that the species diversity of helminth parasites in the yellow-bellied turtle, *Chrysemys scripta*, was significantly reduced in hosts taken from thermally altered locations as compared with those from ambient areas. Eure & Esch (1974) and Eure (1976) reported that the density of *Neoechinorhynchus cylindratus* infrapopulations in largemouth bass was significantly higher in bass caught in thermal locations as compared to those in ambient areas. In the case of both turtles and bass, enteric helminths were recruited actively, i.e., by an expenditure of energy on the part of the host. In these host-parasite systems, parasites were obtained through ingestion of infected intermediate hosts. It seems reasonable to assume that bass in heated areas of the reservoir feed more actively because of higher metabolic demands, influenced by the higher temperatures.

Recruitment of *C. marginatum* is passive, in the sense that an expenditure of energy by the host is not needed to acquire the parasite. It is reasonable, therefore, to speculate that the impact of thermal loading on parasite recruitment may be variable according to whether the parasite is actively or passively recruited. This explanation should be viewed cautiously, however, since recently, Aho, Gibbons & Esch (1976) have shown a correlation between temperature and parasitism by *Diplodinium scheuringi* and *Omphaloplatystomum pycholellus* in mosquitofish, *Gambusia affinis*, in Par Pond. In both of these cases, the parasites are acquired by mosquitofish through the direct penetration of cercaria, and hence are passively recruited.

Ecologically, perhaps the most significant aspect of the study rests with the different infection percentages in distinct areas of the reservoir and the significant rank correlation between the level of infection in bass and the amount of littoral zone in each location. The "bay effect", as it is termed, is not surprising when one considers the potential for variability of predator-prey interaction within the different areas of a large reservoir.

Esch (1971) described the differences in parasite faunas of centrarchid fish from oligotrophic and eutrophic ecosystems and attributed the distinctive character of the fauna in each system to "the nature of predator-prey relationships (which) should serve, therefore, as a potential biological index for predicting the structure of a parasite fauna in any given aquatic ecosystem." Evidence to support this hypothesis has since been presented by Kennedy (1975) from Slapton Ley, an eutrophic reservoir in the southwest of England which exhibits a low diversity of parasites, many of which complete their life cycles in fish-eating birds. The results of the present study are also consistent with the trophic hypothesis.

It is clear that the distinct character of the parasite faunas within various aquatic systems is affected, at least in part, by the extent of aquatic-terrestrial interaction (Esch, 1971). For example, in a eutrophic ecosystem, with an extensive littoral zone, there is relatively more aquatic-terrestrial interaction; the system is more open, with greater input from the peripheral, terrestrial component. In an oligotrophic lake, usually the system is more closed, with less aquatic-terrestrial interaction and, hence, is characterized more by parasites which complete their life cycles in tertiary, piscine predators.

Par Pond is a eutrophic ecosystem and, while modified somewhat by thermal effluent from a nuclear production reactor, the parasite fauna in fish is typical of the more open, aquatic-terrestrial interaction. Thus, there is a substantial number of parasite species which complete their life histories in fish-eating birds (*C. marginatum*
is such a parasite). In part because of the size and morphometry of the reservoir, however, there is a number of diverse habitats with some having much more extensive littoral zones than others. If the trophic hypothesis of Esch (1971) is accurate, then one might also expect the parasite fauna in certain host species within different habitats to reflect the magnitude of aquatic-terrestrial interaction. Since the reservoir is eutrophic, the variability in the parasite fauna should be quantitative in nature, not qualitative. The reflection of the habitat variability in the quantitative character of the parasite fauna should, however, only apply to those hosts which have restricted home ranges or which do not forage extensively. Since largemouth bass in Par Pond have relatively restricted home ranges (Quinn et al., in press), then we should expect them to have a parasite fauna which is characteristic of the habitat in which more of their time is spent. Thus, if the home range of a bass includes an extensive littoral zone, then we would expect to see a parasite fauna which also reflects a prominent feature of the home range, i.e., greater aquatic-terrestrial interaction. This is precisely what is observed in Par Pond when the amount of littoral zone in different locations is compared with the infection percentages of C. marginatum in bass.

The "bay effect" conforms to the trophic hypothesis of Esch (1971) and explains the quantitative variability in infection percentages of C. marginatum within distinct locations of the reservoir. Thus, in Par Pond, C. marginatum infection percentages should be variable and reflect the distinctiveness of each habitat; yet, overall, be representative of an ecosystem which is characterised by predator-prey relationships that mirror the extensive aquatic-terrestrial interaction which also should be observed in an eutrophic ecosystem.

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