Population Dynamics of the Monogenea (Platyhelminthes) on the Bluegill, Lepomis Macrochirus, in Southern Louisiana.

Leon F. Duobinis-gray

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POPULATION DYNAMICS OF THE MONOGENEA (PLATYHELMINTHES) ON THE BLUEGILL, LEPOMIS MACROCHIRUS, IN SOUTHERN LOUISIANA

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Population Dynamics of the Monogenea
(Platyhelminthes) on the Bluegill, *Lepomis macrochirus*, in Southern Louisiana

A Dissertation
Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in

The Department of Zoology and Physiology

by
Leon F. Duobinis-Gray
B.S., East Tennessee State University, 1971
M.S., East Tennessee State University, 1976
May, 1986
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ABSTRACT

Seven species of Monogenea of the subfamily Ancyrocephalinae were collected from 700 Lepomis macrochirus from two eutrophic localities in southern Louisiana. Host specimens were collected monthly from May 1982 through April 1984 from Pat's Bay and Spanish Lake. The relative densities of nonlarval Onchocleidus ferox, Actinocleidus fergusoni, Haplocleidus acer, H. dispar, Anchoradiscus triangularis, Cleidodiscus robustus, and C. nematocirrus were analysed for correlation with water temperature, significant differences in locality, temporal and spatial dynamics, and effect of host sex on population densities. The three more abundant species, O. ferox, A. fergusoni, and H. acer, were warm-water forms, whereas H. dispar and A. triangularis were cold-water species. C. robustus favored warm water while C. nematocirrus did not show a preference. Significantly (P < .001) more specimens of O. ferox and H. acer were recovered from Spanish Lake than Pat's Bay. The second gill arch was preferred (P < .0001) by the three more abundant species, whereas the fourth arch was least preferred (P < .0001). Significant (P < .0001) differences in densities between gill arches two and four were observed for all the less abundant species, but densities on the second and fourth arches were not necessarily significantly different from the densities on gill arches one or three. All species
preferred the anterior hemibranch of each gill arch (P < .0001). The medial section of the anterior hemibranch was most preferred by the majority of the species.

Monthly gill arch and gill section distributional patterns of the more abundant species were consistent over the entire 24-month period with the exception of January and February, whereas monthly variations occurred among the less abundant species. Significantly more specimens of the more abundant species were found on female hosts. Distributional patterns of these worms on the gills of the host were not affected by the sex of the host.
Chapter I

General Overview of the Monogenea on Bluegill, 
*Lepomis macrochirus* Raf., in 
Southern Louisiana
INTRODUCTION

Monogeneans are a group of parasitic platyhelminths most often found on the gills and skin of freshwater or marine fishes. These parasites have direct life cycles which consist of monoecious adults mating while on the host, deposition of eggs into the aquatic environment, hatching of the eggs, which release free-swimming, ciliated larvae known as onchomiracidia, which attach to appropriate sites on selected hosts and shed their locomotor cilia upon attachment and after a sufficient period of time, usually days, the larval onchomiracidia develop into post-onchomiracidia and finally into the adult form.

Seven species of Monogenea parasitize the bluegill sunfish, *Lepomis macrochirus*, in southern Louisiana (Duobinis-Gray and Corkum, 1985). They are *Actinocleidus fergusoni* Mizelle, 1938; *Anchoradiscus triangularis* (Summers, 1937); *Cleidodiscus nematocirrus* Mueller, 1937; *C. robustus* Mueller, 1934; *Haplocleidus acer* (Mueller, 1936); *H. dispar* (Mueller, 1936); and *Onchocleidus ferox* (Mueller, 1934).

The purpose of this chapter is to provide a brief, general, comparative overview of each species of Monogenea found on bluegill in southern Louisiana. Discussion of the separate species, coupled with illustrations, is provided to facilitate in the analyses of their population
dynamics, which are provided in subsequent chapters.
MATERIALS AND METHODS

As part of a survey of Monogenea in southern Louisiana between August 1981 and October 1982, 276 host specimens of Lepomis macrochirus were collected by electroshocking at or near the shoreline from various freshwater localities in southern Louisiana. For permanent preparations of monogeneans, the gills were removed from the hosts and placed in a 1:4000 formalin solution for approximately 1.5 hr in order to relax the worms and facilitate their removal. The worms were placed in vials of 10% formalin and allowed to remain in the fixative for at least 24 hr. Subsequently, the parasites were mounted in glycerin jelly and identified. Another method employed to relax and kill the parasites involved freezing the parasite-ladened gills for approximately 24 hr. The worms were pipetted into 10% formalin and allowed to remain for at least 24 hr. They were mounted in glycerin jelly and identified. The last method involved removing live monogeneans from the gills, placing them into water on slides, and applying coverslip pressure for viewing with both phase and light microscopy.

All measurements are in micrometers. Illustrations were drawn with the aid of a microprojector.
RESULTS

Actinocleidus ferausoni Mizelle, 1938

This species was one of the most abundant forms found on bluegill during this study. Its prevalence was high (99%), occurring on 273 of 276 hosts examined. The mean length of this species was approximately 270 \( \mu \)m. The anchors are of similar size and comparatively large for the size of the worm (Fig. 1).

Anchoradiscus triangularis (Summers, 1937)

This species was not as abundant as A. ferausoni. It occurred on 99 of 276 hosts (36%). The mean length was approximately 500 \( \mu \)m. It is unusual among the monogeneans occurring on bluegill in that the haptor of this species is large and composed of four triangular anchors (Fig. 2).

Cleidodiscus nematocirrus Mueller, 1937

This species was the least abundant of all seven species encountered on bluegill. Only 43 of 276 hosts (16%) harbored this species. The average length was approximately 400 \( \mu \)m. The anchors are similar in size and shape but are small in relation to the size of the worm (Fig. 3).

Cleidodiscus robustus Mueller, 1934

This species was observed with a similar frequency to that of C. nematocirrus. Only 48 of 276 (17%) hosts were infested. C. robustus was the largest worm encountered with a mean length of approximately 1350 \( \mu \)m. The anchors
were similar in size and shape but were extremely small in comparison to overall body size (Fig. 4). It was also noted that the haptor of this species was often embedded in the gill tissue with what appeared to be a granuloma surrounding this attachment organ.

**Haplocleidus acer** (Mueller, 1936)

*H. acer* was quite abundant on bluegill. 235 of 276 hosts (85%) harbored this worm. The mean length was approximately 340 μm. The anchors are of similar size and shape. Each anchor possesses a "spur" on the inner curvature (Fig 5).

**Haplocleidus dispar** (Mueller, 1936)

The abundance *H. dispar* appeared to be less than that of *H. acer*. This species occurred on 161 of 276 hosts (58%). The mean length was approximately 400 μm. The anchors of this species are dissimilar in size but similar in shape (Fig. 6).

**Onchocleidus ferox** (Mueller, 1934)

This was the most abundant species encountered. It occurred on 263 of 276 hosts (95%). The mean length of these worms was 380 μm long. The anchors are similar in size and shape (Fig. 7).
DISCUSSION

Based upon the results of this study, three species of Monogenea appear to be abundant on the bluegill. They are *O. ferox*, *A. fergusoni*, and *H. acer*. These species are followed in decreasing order by *H. dispar*, *A. triangularis*, *C. robustus*, and *C. nematocirrus*.

Prevalence is higher for the three more abundant species.

The three smallest species observed also tended to be the more abundant forms i.e., *O. ferox*, *H. acer*, and *A. fergusoni*. Whether small size has any bearing on population densities of these worms is open for question. If available gill surface is a limiting factor, then more individuals of the smaller versus larger monogenean species could occupy areas of similar size.

This basic information is necessary to provide an overall understanding of community dynamics of monogenean populations.
LEGEND FOR FIGURES

Figures 1-7. Illustrations of Actinocleidus fergusoni, Anchoradiscus triangularis, Cleidodiscus nematocirrus, Cleidodiscus robustus, Haplocleidus acer, H. dispar, and Onchocleidus ferox, respectively. Ventral views.
Figure 2
LITERATURE CITED
Chapter II

Temporal Dynamics of the Monogenea on Bluegill, 
*Lepomis macrochirus* Raf., from Two Localities 
in Southern Louisiana
INTRODUCTION

A majority of the research on North American Monogenea has been taxonomic or systematic. Far less work has been done on the ecology of these parasites, especially population dynamics.

Studies of various species of Monogenea in the subfamily Ancyrocephalinae have been conducted by Crane and Mizelle (1968); Rawson and Rogers (1972a, 1972b); Mizelle and McDougal (1974); and Hanek and Fernando (1978a, 1978b, 1978c). Generally, the duration of these studies has been approximately one year or less. Reports by Hanek and Fernando (1978a, 1978b, 1978c) are the only ones which examined parasite populations from the same host species from two localities. These localities were, however, of two limnologically different regimes (eutrophic vs. oligotrophic).

The present study was designed to monitor the population dynamics of all seven species of Monogenea on Lepomis macrochirus (Rafinesque) from two eutrophic localities in southern Louisiana over two years. In addition to the trophic characteristics of the study sites, they are unique in that they were part of the Mississippi River distributary system and were thus interconnected until the mid-1920's. At that time the U.S. Army Corps of Engineers completed the levee system section that effectively isolated Spanish Lake from Pat's
Bay. As the water system now exists, movement of fish and monogenean populations between these localities is thwarted by both a levee system and a saltwater barrier, the Gulf of Mexico. The question of whether detectable differences in worm populations from similar but isolated localities was developed. Therefore, a long-term collection of data was initiated, and analysed by extensive computer-assisted methods.
MATERIALS AND METHODS

Fish were collected monthly from May 1982 through April 1984 from two near localities: (a) Pat's Bay (30°11'36"N, 91°22'04"W), which is west of the Mississippi River and (b) Spanish Lake (30°17'32"N, 91°02'10"W), which is east of the Mississippi River. With the exception of December 1982, 15 L. macrochirus were randomly collected by electroshocking at or near the shoreline of the two study sites. Due to inundation during December 1982 only six and four fish were collected from Pat's Bay and Spanish Lake, respectively. Water temperature was recorded near the shoreline at approximately the same depth from where the fish were taken (30 cm).

The fish were transported to the laboratory and killed by severing the vertebral column. They were then weighed, total and standard length recorded, and sexed. Mean standard lengths during the study period ranged from 3.7-11.4 cm for Pat's Bay and 3.5-10.5 cm for Spanish Lake. Gill arches were separated, placed individually in water-filled Petri dishes, and numbered I-IV anteroposteriorly. No distinction between right or left gill arches was made. Each hemibranch of a gill arch was designated as either anterior or posterior, and each hemibranch was divided into 3 subequal sections (dorsal, medial, and ventral); thus 24 gill arch sections per fish
were examined. Monogenea were removed and placed in water on slides under slight coverslip pressure for identification. The number of specimens of each species and their precise location were then recorded.

The data were determined to be heteroscedastic when subjected to tests of probability distributions. Transformation of the data prior to further analyses (log transformation) was necessary to meet the assumptions of normality required by parametric statistical tests. Data were analyzed using Pearson product-moment correlations and analysis of covariance. These tests are supported by the SAS Institute, SAS Circle, P.O. Box 8000, Cary, N.C. The experimental design incorporated a split plot arrangement of factors. Main plot factors were the time periods and locations, sex of the fish, and covariable standard length. Subplot factors were gill arch and gill section.

All references to density will be considered relative density, which was defined by Margolis et al. (1982) as the total number of individuals of a particular parasite species in a sample of hosts divided by the total number of individuals of the host species (infected + uninfected) in the sample.
RESULTS

Seven species of Monogenea were recovered from 700 L. macrochirus from the two localities in southern Louisiana. They were Actinocleidus ferqusoni Mizelle, 1938; Anchoradiscus triangularis (Summers, 1937); Cleidodiscus robustus Mueller, 1934; C. nematocirrus Mueller, 1937; Haplocleidus acer (Mueller, 1936); H. dispar (Mueller, 1936); and Onchocleidus ferox (Mueller, 1934).

The population dynamics of each species of parasite will be presented in decreasing order of density followed by a combined presentation of all species of Monogenea considered during this study. All species showed a significant, positive correlation of increasing density with increasing standard length of the host; hence, length was entered as a covariable in the experimental design.

"High" and "low" temperatures are considered = or > 20°C or < 20°C, respectively. These values were chosen because, in general, notable changes in the trends of density dynamics for the majority of the species of worms were observed in response to changes in an approximate range of 16-20°C.

Onchocleidus ferox

Totals of 8142 and 11623 adult specimens of O. ferox were recorded from Pat's Bay and Spanish Lake, respectively. The combined totals (19765) comprised 41.11% of the monogenean community on L. macrochirus
from these two localities. The relative density was 28.2 individuals per fish for the two-year period (Fig. 1). Significantly (P < .001) more *O. ferox* were present in Spanish Lake than Pat's Bay. The presence of *O. ferox* was positively correlated (P < .01) with high water temperature.

**Actinocleidus fergusoni**

Totals of 8992 and 10002 adult specimens of *A. fergusoni* were recorded from Pat's Bay and Spanish Lake, respectively. Combined totals of 18994 composed 39.5% of the monogenean community on bluegill in these localities. The relative density was 27.1 specimens of *A. fergusoni* per host (Fig. 2). Locality differences were not significant. *A. fergusoni* was positively correlated (P < .0001) with high water temperature.

**Haploclidus acer**

Totals of 2746 and 3389 nonlarval specimens of *H. acer* were collected from Pat's Bay and Spanish Lake. Combined totals (6135) were 12.76% of the monogenean community, and the relative density was 8.8 individuals per fish (Fig. 3). Significantly more specimens of *H. acer* were collected from Spanish Lake (P < .001). The density of *H. acer* was not significantly correlated high or low water temperature (P = .32).

**Haploclidus dispar**

Totals of 939 and 997 adult specimens of *H. dispar*
were recorded from Pat's Bay and Spanish Lake with combined totals of 1936 or 4% of the monogenean community. The relative density was 2.8 individuals per host (Fig. 4). Locality differences were not significant. H. dispar was negatively correlated (P < .01) with high water temperature.

Anchoradiscus triangularis

Totals of 380 and 319 adult specimens of A. triangularis were recorded from Pat's Bay and Spanish Lake, respectively. A combination of these totals (699) constituted 1.48% of the monogenean community with a relative density of 1.0 individual per host (Fig. 5). Locality differences were not significant. A. triangularis was negatively correlated (P < .001) with high water temperature.

Cleidodiscus robustus

Totals of 127 and 235 adult specimens of C. robustus were collected from Pat's Bay and Spanish Lake for a total of 362 or 0.75% of the monogenean community. The relative density was 0.5 per fish for the two-year period (Fig. 6). Locality differences were not significant. C. robustus was not significantly (P = .10) correlated with water temperature; however, a trend for a positive relationship with warm temperature was observed.

Cleidodiscus nematocirrus

Totals of 75 and 122 adult individuals of C.
nematocirrus were recorded from Pat's Bay and Spanish Lake for a combined total of 197 or 0.4% of the monogenean community. The relative density was 0.3 per host during the 24 month study (Fig. 7), and locality differences were not significant. C. nematocirrus was not significantly correlated to water temperature, and no trend for high or low temperatures was observed.

An overview

From 700 L. macrochirus, 48088 monogeneans were collected during the 24-month period (21401 from Pat's Bay and 26687 from Spanish Lake). The species composition was identical in both localities. A prevalence of 99.4% was recorded from both localities combined (99.7% from Pat's Bay and 99.1% from Spanish Lake). A. fergusoni was the predominant parasite in Pat's Bay, whereas O. ferox was predominant in Spanish Lake. The least abundant species in both localities was C. nematocirrus.

In general terms, if the populations of the seven species of worms comprising the monogenean community on bluegill from the two localities are treated collectively, the community density was positively correlated (P < .0001) with increased standard lengths of the hosts and warmer water temperature. Locality differences were significantly different for two of the seven species in that more O. ferox and H. acer (P < .001) were recovered from Spanish Lake than Pat's Bay.
A comparative overview of the density dynamics of each species of monogenean from each locality is provided in Fig. 8.
DISCUSSION

Combined totals from both localities indicated that *O. ferox* was the predominant species during this two-year study of the population dynamics of the Monogenea on bluegill from two localities in southern Louisiana. *O. ferox* was followed, in decreasing order of relative density, by *A. fergusoni*, *H. acer*, *H. dispar*, *A. triangularis*, *C. robustus*, and *C. nematocirrus*.

The three more abundant species showed similar patterns of dynamics but varied in mean relative densities. *O. ferox* and *A. fergusoni* (Figs. 1-2) were at high levels from March through December with the lowest levels occurring during January and February. A similar pattern was noted for *H. acer* (Fig. 3) but at more moderate levels.

*H. dispar* and *A. triangularis* (Figs. 4-5) were at low to moderate levels throughout most of the study with the highest levels occurring in October through December for *H. dispar* and December only for *A. triangularis*.

*C. robustus* and *C. nematocirrus* (Figs. 6-7) were at low density levels during the entire study. *C. robustus* was more abundant than *C. nematocirrus*, but neither of these species showed other than irregular oscillations throughout the study period.

Although specific comparisons with other studies concerning the population dynamics of Monogenea may be
made, there is no assurance that the comparisons will be valid due to the variables considered during each study. At best, broad concepts or trends may be ascertained.

*O. ferox* was predominant in Spanish Lake, whereas *A. fergusoni* was predominant in Pat's Bay. Crane and Mizelle (1968), Hanek and Fernando (1978a), and Mizelle and McDougal (1974) showed that *O. ferox* was the most abundant species encountered. On the other hand, Rawson and Rogers (1972a) determined that *A. fergusoni* was the most abundant monogenean on bluegill. These results tend to indicate that both these species may actually be codominant forms on *L. macrochirus* and that the dictating factors which result in this codominance have yet to be determined.

A significantly higher relative density was noted for *O. ferox* and *H. acer* in Spanish Lake as compared to Pat's Bay. Specific factors responsible for these locality differences may include effective geographic isolation, inherent genetic variation of host and worm populations, water quality disparities, different water flow rates, etc. Whatever the case may be, the results clearly indicate that differences do exist in what appear to be closely related host/parasite systems.

When correlation analyses between the relative densities of the monogeneans and water temperature were performed, three broad categories were apparent. These
were: (a) species positively correlated with increasing water temperature, i.e., O. ferox, A. fergusoni, and C. robustus; (b) species negatively correlated with increasing temperature, i.e., H. acer, H. dispar, and A. triangularis, and; (c) a species density not correlated with water temperature, i.e., C. nematocirrus. Notable changes in density for most species were detected when the water temperature fluctuated above or below approximate range of 16-20°C. Variation from this range may provide an environmental cue which influences the reproductive rates of the Monogenea on bluegill. A lag period between increased egg production by the parasites and the appearance of adult individuals on the hosts is to be expected. Based upon field and laboratory observations, the lag period is estimated to be 10-14 days at approximately 29-30°C for the species considered during this study. Hence, it is apparent that temperature does have an affect on monogenean cycling, but variation rather than an absolute temperature value may be the triggering mechanism.

Another factor which may influence density levels and population trends is that optimum monogenean reproduction may coincide with reproductive patterns of the host. Bluegill assemble on spawning beds near shore and begin reproduction when the water temperature rises to approximately 19.4°C (67°F; Morgan, 1951). The populations of O.
ferox and A. fergusoni, which collectively comprised 80.6% of the monogenean community, have relative densities that are positively correlated (P < .01 and P < .0001, respectively) with increasing water temperature. One would therefore expect a concomitant rise in worm and fish activity when this temperature range is achieved. Similarly, Rawson and Rogers (1972a) observed that increased levels of O. ferox, A. fergusoni, H. acer, and H. dispar coincided with the temperatures at which spawning of bluegill appeared to be at maximum. Furthermore, they noted a decline in the Fall that coincided with a decrease in temperature below this range. There is little question that host aggregation associated with breeding would enhance the probability of infection.

In a broad sense, the most abundant monogeneans tend to have high population levels during periods of warm water temperature followed by a decline when temperatures start to decrease. A subsequent increase in the population occurs when the temperature approaches its minimum value followed by a second, more obvious decline in relative density until the water temperature rises again. The increase in parasite density previous to the obvious decline in January and February may be due to an extension of the lag period for egg maturation at low water temperatures that results in delayed appearance of
adult worms on the host.

Species that have negative correlations of density with high water temperature, e.g. *H. acer*, *H. dispar*, and *A. triangularis*, also showed distinct changes in the density patterns at the 16-20°C temperature range. This may indicate that although the temperature range is an important environmental cue for the parasite, the response is species-dependent.

Undoubtedly other factors, both endogenous and exogenous, influence population dynamics of monogeneans, but to determine what these factors are and their degree of role will require far more work on the ecology of these parasites.
LEGENDS FOR FIGURES

Figure 1. Mean locality temperatures and mean relative densities per fish of *Onchocleidus ferox* versus time for Pat's Bay and Spanish Lake.

Figure 2. Mean locality temperatures and mean relative densities per fish of *Actinocleidus fergusoni* versus time for Pat's Bay and Spanish Lake.

Figure 3. Mean locality temperatures and mean relative densities per fish of *Haplocleidus acer* versus time for Pat's Bay and Spanish Lake.

Figure 4. Mean locality temperatures and mean relative densities per fish of *Haplocleidus dispar* versus time for Pat's Bay and Spanish Lake.

Figure 5. Mean locality temperatures and mean relative densities per fish of *Anchoradiscus triangularis* versus time for Pat's Bay and Spanish Lake.

Figure 6. Mean locality temperatures and mean relative densities per fish of *Cleidodiscus robustus* versus time for Pat's Bay and Spanish Lake.

Figure 7. Mean locality temperatures and mean relative densities per fish of *Cleidodiscus nematocirrus* versus time for Pat's Bay and Spanish Lake.
Figure 2
MEAN *A. triangularis* DENSITY / FISH

Figure 5

TEMPERATURE (°C)

TIME

MAP JAN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR

TEMP

PB
Figure 6
Figure 7

MEAN C. nematocirrus DENSITY/FISH

TEMPERATURE (°C)

TIME
LEGEND FOR FIGURE

Figure 8. Mean relative densities of seven species of Monogena versus time for Pat's Bay and Spanish Lake.
## MEAN DENSITY OF MONOGENEA/FISH VS. TIME
FOR PATS BAY AND SPANISH LAKE

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**Figure 8**
LITERATURE CITED


Chapter III

Spatial Distribution of the Monogenea on Bluegill,
*Lepomis macrochirus* Raf., in Southern Louisiana
INTRODUCTION

It has been observed that various species of Monogenea exhibit a gill arch preference on their respective fish hosts and may prefer particular sites on each arch. Cerfontaine (1896, 1898) was the first to describe these affinities while working with Diclidophora denticulata on Pollachius virens. Suydam (1971) statistically analyzed the spatial distribution of Diclidophora maccallumi on Urophycis regius and reviewed other reports of spatial distribution (Akazaki 1965; Frankland 1955; Ktari 1969; Llewellyn 1956; Llewellyn and Owen 1960; Owen 1963; Slinn 1963; Wiles 1968). Most of these studies involved marine, polyopisthocotylid monogeneans. More recently, Mizelle and McDougal (1974) and Hanek and Fernando (1978a, 1978b, 1978c) contributed information on spatial distribution patterns regarding ancyrocephalinaen monogeneans on freshwater fishes.

The question of whether spatial distribution patterns of Monogenea remain constant or are variable over time has been an enigma. This, in part, is due to the lack of detailed, long-term studies which provide sufficient data for extensive computer-assisted analyses. The present study focuses on distributional patterns of ancyrocephalinean Monogenea on the gills of Lepomis macrochirus in southern Louisiana over a 24-month period and involves the examination of 700 hosts, 48,088 specimens of Monogenea consisting of seven species, and
16800 observations of site specificity on the hosts. Extensive, computer-assisted analyses allowed the distributional pattern of each monogenean population to be examined, in detail, within the context of the overall monogenean community.
MATERIALS AND METHODS

Fish were collected monthly from May 1982 through April 1984 from two near localities: (a) Pat's Bay (30°11'36" N, 91°22'04" W), which is west of the Mississippi River and (b) Spanish Lake (30°17'32" N, 91°02'10" W), to the east of the Mississippi River. With the exception of December 1982, 15 L. macrochirus were randomly collected by electroshocking at or near the shoreline of the two study sites. Due to inundation during December 1982 only six fish from Pat's Bay and four from Spanish Lake were collected (see Duobinis-Gray and Corkum 1986).

The fish were transported to the laboratory and killed by severing the vertebral column. They were then weighed, measured, and sexed. Mean standard lengths ranged from 3.7-11.4 cm for Pat's Bay and 3.5-10.5 cm for Spanish Lake. Gill arches were separated, placed individually in water-filled Petri dishes, and numbered I-IV anteroposteriorly. No distinction between right or left gill arches was made; however, each hemibranch of a gill arch was designated as either anterior (A) or posterior (P), and each hemibranch was divided into 3 subequal sections (dorsal, medial, ventral). Anterior hemibranch sections were designated as 1, 2, or 3 to correspond to dorsal, medial, and ventral, respectively. Posterior hemibranch sections were defined as 4, 5, or 6, which also corresponded to dorsal, medial, and ventral.
Consequently, data were collected from 24 gill arch sections per fish (Fig. 1). Monogenea were identified and their precise location was then recorded.

The data were determined to be heteroscedastic when subjected to tests of probability distributions. Transformation of the data prior to further analyses (log transformation) was necessary to meet the assumptions of normality required by parametric statistical tests. Data were analyzed using Pearson product-moment correlations and analysis of covariance. These tests are supported by the SAS Institute, SAS Circle, P.O. Box 8000, Cary, N.C. The experimental design used incorporated a split plot arrangement of factors. Main plot factors were the time periods and locations, sex of the fish, and covariable standard length. Subplot factors were gill arch and gill section.

All references to density will be considered relative density which was defined by Margolis et al. (1982) as the total number of individuals of a particular parasite species in a sample of hosts ÷ total number of individuals of the host species (infected + uninfected) in the sample.
RESULTS

Seven species of Monogenea were recovered from 700 *L. macrochirus* in southern Louisiana: *Actinocleidus fergusoni* Mizelle, 1938; *Anchoradiscus triangularis* (Summers, 1937); *Cleidodiscus robustus* Mueller, 1934; *C. nematocirrus* Mueller, 1937; *Haplocladus acer* (Mueller, 1936); *H. dispar* (Mueller, 1936); and *Oncholeidus ferox* (Mueller, 1934).

The spatial distribution of each species on its fish host will be presented in decreasing order of density followed by a comparative presentation of the distribution concerning all the species encountered during this study. Data from both localities are combined and normalized in order to provide an overview of the worm populations.

A coding system for spatial distribution which adheres to the following format will be used in the remainder of this paper: I-A-2 = gill arch I, anterior hemibranch, medial section; IV-P-6 = gill arch IV, posterior hemibranch, ventral section; etc. Numbers in parentheses, other than probability values, denote that no significant differences at the .05 level were observed.

*Oncholeidus ferox*

*O. ferox* was most abundant on II-A-2 and least abundant on IV-P-6. The abundance of *O. ferox* was significantly (*P < .0001*) different on each gill arch. In decreasing order, the preferences for gill arches were II,
Ill, I, and IV and gill sections were 2, 1, 3, 4, 5, and 6 (P < .0001). During two years, the distribution of O. ferox showed little variation with the exception of January and February, which both showed a pattern unlike the other 20 months (Figs. 2, 3).

**Actinocleidus fergusoni**

*A. fergusoni* was most abundant on II-A-2 and least abundant on IV-P-6. Analyses revealed that the abundance of *A. fergusoni* on gill arches II and IV was significantly (P < .0001) different from arches I and III; however, arches I and III were not significantly (P = .07) different from each other. In decreasing order of density, the arch preferences were II, (I and III), and IV. Densities on gill sections were all significantly (P < .0001) different from each other. The decreasing order of gill section preference was 2, 1, 3, 4, 5, and 6. The distribution of *A. fergusoni* showed slight monthly variation and was similar to O. ferox in overall patterns (Figs. 2, 4).

**Haploclidus acer**

*H. acer* was most abundant on II-A-2 and least abundant on IV-P-6. The relative densities on gill arches II and IV were significantly (P < .0001) different from each other and arches I and III. However, like *A. fergusoni*, arches I and III were not significantly (P = .12) different from each other. In decreasing order of density, the arch preferences were II, (I and III), and
IV. Densities on all gill sections were significantly (P < .001 or less) different from each other with the exception of sections 5 and 6, (P = .0543). The decreasing order of gill section preference was 2, 1, 3, 4, 5, and 6. Variation in the spatial distribution of *H. acer* on gill arches and sections was minimal during the study period and was similar in overall configuration to that of *O. ferox* and *A. fergusoni* (Figs. 2,5).

**Haplocleidus dispar**

*H. dispar* was most abundant on I-A-2; however, densities on gill arches I and II were not significantly (P = .50) different from each other. *H. dispar* was least abundant on IV-P-6 but the density on that section was not significantly (P = .31) different from IV-A-2. Although the densities on arches I and II were not significantly different from each other, both were significantly (P < .0001) different from arches III and IV, which were significantly (P < .0001) different from each other. In decreasing order of density, the arch preferences were (I and II), III, and IV. Densities on gill sections were significantly (P < .001 or less) different from each other with the exceptions of 3 and 1 (P = .22) and 5 and 6 (P = .31). The decreasing order of gill section preference was 2, (3 and 1), 4, and (5 and 6). The monthly distribution of *H. dispar* on gill arches and sections for the two-year period was more variable than for the three
previously mentioned species (Figs. 2, 6). This shows that two cogeners may not exhibit similar degrees of site specificity on the same host.

**Anchoradiscus triangularis**

*A. triangularis* was most abundant on II-A-2; however, the density of that section was not significantly different from II-A-6 (*P* = 0.15). *A. triangularis* was least abundant on IV-P-6. The relative densities on gill arches II and IV were significantly (*P* < 0.0001) different from each other and arches I and III; however, arches I and III were not significantly (*P* = 0.12) different from each other. In decreasing order of density, the arch preferences were II, (I and III), and IV. The decreasing order of gill section preference was (2 and 3), (1, 5, and 4), and 6. The monthly distribution of *A. triangularis* on gill arches and sections was variable during the study period (Figs. 2, 7).

**Cleidodiscus robustus**

*C. robustus* was most abundant on II-A-2; however, there were no significant (*P* = 0.60) differences between densities on the arches I and II. In addition, density differences of the anterior medial section versus the anterior dorsal section were not significant (*P* = 0.17). *C. robustus* was least abundant on the IV-P-6; however, no significant (*P* = 0.06) density differences were evident between arches IV and III. Furthermore, density on the
posterior ventral section was not significantly different from the posterior dorsal or medial sections (P = .28 and P = .66, respectively). Densities on arches (I and II) and on arches (III and IV) were not significantly different from each other (P = .60 and .06, respectively), but arch I was significantly different from arches III and IV (P < .01 and P < .0001, respectively). Density on arch II was significantly different from arches III and IV (P < .001 and P < .0001, respectively). In decreasing order of density, the arch preferences were (II and I) and (III and IV). The decreasing order of gill section preference was (2 and 1), 3, and (4, 5, and 6). The monthly distribution of C. robustus on gill arches and sections for the two-year period was variable (Figs. 2, 8).

Cleidodiscus nematocirrus

C. nematocirrus was most abundant on II-A-1; however, densities on gill arches II and III were not significantly different (P = .06) nor were gill sections 1 and 2 (P = .53). C. nematocirrus was least abundant on IV-P-5; however, densities on arches I and IV were not significantly different from each other (P = .06), nor were gill sections 3, 4, 5, and 6 significantly different from each other (P > .05). In decreasing order of density, the arch preferences were (II and III) and (I and IV). The decreasing order of gill section preference was (1 and 2) and (3, 4, 5, and 6). The spatial distribution of C.
nematocirrus on gill arches and sections for the study period was variable (Figs. 2,9).

An overview

Gill arch II was significantly (P < .0001) preferred by the three most abundant species, i.e. *O. ferox*, *A. fergusoni*, and *H. acer*, whereas gill arch IV was least preferred (P < .0001). On the other hand, significant (P < .0001) differences in densities between gill arches II and IV were observed for all the less abundant species, i.e. *H. dispar*, *A. triangularis*, *C. robustus*, and *C. nematocirrus*, but densities on arches II and IV were not necessarily significantly different from the densities on arches I or III. A preference for the anterior hemibranch of the gill arches was evident for all seven species encountered (P < .0001). Section 2 of the anterior hemibranch was most preferred (P < .0001) by the majority of the species. Monthly gill arch and section distributional patterns of the three more abundant species were consistent over the entire 24-month period with the exceptions of January and February, when notable variations occurred. When compared to the three more abundant species, the four less abundant species showed greater monthly and yearly variation in both gill arch and section distribution (Figs. 2-9).
DISCUSSION

Cerfontaine's (1896, 1898) original observations that certain Monogenea prefer particular gill arches and sites on those arches have been corroborated by other workers. For example, Frankland (1955) indicated that *Dactylocotyle denticulata* was most abundant on gill arch I of *Gadus virens*, whereas Llewellyn (1956) found that *Diclidophora merlangi* occurred most frequently on gill arch I of *Gadus merlangus* but was more prevalent on arches II and III of *G. luscae*.

During the present 24-month study, all species of parasites were most abundant on gill arch II with the exception of *H. dispar*, which was most abundant on gill arch I. However, densities on arches I and II were not significantly (*P = .50*) different for this species. All species in this study were least abundant on arch IV. In contrast, Hanek and Fernando (1978a), working with monogenea on *Lepomis gibbosus* (L.) and *Ambloplites rupestris* (Raf.) in Canada, noted a well-defined preference for arches which was, in decreasing order, II, III, I, and IV. Mizelle and McDougal (1974), during the months of June and July in 1972, found that the largest percentages of worms occurred, in decreasing order, on arches II, I, III, and IV.

Although discrepancies exist regarding detailed and specific patterns of monogenean distribution on gill
arches, there is an overall affinity for gill arches other than arch IV. This may, in part, be explained by Paling's (1968) observation that the glochidia of *Anodonta cygnea*, when allowed passively to flow over the gills with the respiratory current, attached most often to gill arches II and III of *Salmo trutta* L. Fewer glochidia attached to gill arch I and the fewest on gill arch IV. This observation may indicate that infestation levels of Monogenea on the gills of their respective hosts may, similarly, be correlated to the volume and pattern of water flow over the gills. Mizelle and McDougal (1974) measured the branchial surface area by planimetric methods in square centimeters of *Lepomis cyanellus* Raf. and found that the order of decreasing size from gill arch I-IV was 8.22, 7.54, 6.08, and 4.33. These combined observations indicate that both the ventilating pattern and available gill surface area influence the levels of monogenean infestation on the gills of fishes. Other factors e.g., differences in mobility of larvae and species of the host, may affect the levels of infestation by monogeneans on particular gill arches and the patterns of their distribution.

More monogeneans were recorded from the anterior versus posterior hemibranch during the present study. Mizelle and McDougal (1974) noted a preference by monogeneans for the anterior row of "gill filaments"
(hemibranchs) during their study of *O. ferox*, *H. dispar*, and *Gyrodactylus macrochiri* on *L. cyanellus*.

It is evident that the majority of the monogenean species examined during this study prefer the anterior, medial section (2) of gill arch II and least prefer the posterior, ventral section (6) of arch IV. Hanek and Fernando (1978a) noted that levels of monogenean infestations on the medial sections of gill arches were significantly different from other sections during their study. Suydam (1971) found that higher numbers of *Diclidophora maccallumi* occurred on the "middle region" (medial section) of the gills of fishes examined.

Short-term studies have been unable to demonstrate whether distributional patterns of monogenean populations are constant or variable over time. The gill arch distributional patterns of the three more abundant species in this study were consistent throughout the two-year period with the exception of January and February, when worm density levels were lower than the remainder of the year (Fig. 2). The gill arch distributional patterns of the four less abundant species were, however, variable to different degrees (Fig. 2). This variability may be attributable to low levels of these parasites. On the other hand, these light infestations may be indicative of low population stability which is reflected in their distributional patterns. There is yet another possibility that *L. macrochirus* is not the primary host
but is serving in an auxiliary capacity. Alternatively, these less abundant forms may exist at low levels on all hosts which they parasitize. Many other factors that remain to be explored may influence distributional patterns of monogeneans which include physiological, behavioral, and reproductive activities of both the parasite and the host.
LEGEND FOR FIGURE

Figure 1. Illustration of gill arch showing anterior and posterior hemibranchs and arbitrary divisions of gill sections.
Figure 1
LEGEND FOR FIGURE

Figure 2. Graph showing the normalized percent distribution of Monogenea versus time on all four gill arches of Lepomis macrochirus. From left to right, the closed circles within each month correspond to gill arches I-IV.
Figure 2
LEGEND FOR FIGURES

Figures 3-9. Graphs showing the normalized percent distribution of *O. ferox*, *A. fergusoni*, *H. acer*, *H. dispar*, *A. triangularis*, *C. robustus*, and *C. nematocirrus* respectively, versus time on gill sections of gill arches of *Lepomis macrochirus*. From left to right, the closed circles within each month correspond to gill sections 1-6.
NORMALIZED PERCENT DISTRIBUTION /FISH OF O. FERAX ON GILL SECTIONS
NORMALIZED PERCENT DISTRIBUTION OF A. FERGUSONI ON GILL SECTIONS

Figure 4
NORMALIZED PERCENT DISTRIBUTION OF H. ACER ON GILL SECTIONS

Figure 5
NORMALIZED PERCENT DISTRIBUTION //FISH OF A. TRIANGULARIS ON GILL SECTIONS

Figure 7

GILL ARCHES
NORMALIZED PERCENT DISTRIBUTION OF C. ROBUSTUS ON GILL SECTIONS

GILL ARCHES
LITERATURE CITED


____. 1978c. Seasonal dynamics and spatial distribution of Cleidodiscus stentor Mueller 1937 and Ergasilus.


Chapter IV

Effects of Host Sex on the Population Dynamics of the Monogenea on Bluegill, *Lepomis macrochirus* Raf., in Southern Louisiana
INTRODUCTION

Whether the sex of the fish host has an effect on the population dynamics of monogeneans has been examined by few authors. Mizelle and McDougal (1974), during their study of three species of Monogenea on Lepomis cyanellus Raf. in California, indicated that there was no apparent sexual selection of hosts by the parasites, but a lack of sufficient males in the lower size classes and a lack of sufficient females in the upper size classes precluded a reliable analysis of sexual selection by parasites in their study. Hanek and Fernando (1978a, 1978b) stated that host sex was not statistically significant for Monogenea, Copepoda, or glochidia on Lepomis gibbosus (L.) and Ambloplites rupestris (Raf.) in Canada.

As part of a more inclusive work (see Duobinis-Gray and Corkum 1986a, 1986b), the present study focuses on the open question of whether the sex of the fish host affects the population dynamics of Monogenea. By examining 700 specimens of L. macrochirus over a 24-month period, sufficient data were obtained to permit detailed, computer-assisted analyses of the role of host sex in monogenean population dynamics.
MATERIALS AND METHODS

The materials and methods are the same as for Duobinis-Gray and Corkum (1986b).
RESULTS

A total of 48088 monogenean specimens comprising seven species were recovered from 700 L. macrochirus in southern Louisiana: Actinocleidus fergusoni Mizelle, 1938; Anchoradiscus triangularis (Summers, 1937); Cleidodiscus robustus Mueller, 1934; C. nematocirrus Mueller, 1937; Haplocleidus acer (Mueller, 1936); H. dispar (Mueller, 1936); and Onchocleidus ferox (Mueller, 1934).

A total of 242 female hosts with a mean standard length of 6.5 cm and 458 male hosts with a mean standard length of 6.6 cm were collected. The effects of host sex on the population dynamics of these Monogenea will be presented in decreasing order of parasite density.

Mean density values of each species of worm on female and male hosts over the entire study period are provided in Figures 1-7 in addition to the mean standard lengths of female and male hosts.

Significant differences in gill arch and gill section distribution patterns for all seven species of monogeneans between host sexes were not evident.

Onchocleidus ferox

Significantly ($P = .0006$) more O. ferox were found on female hosts during the study period. A total of 19765 worms from both sexes with a mean density of 31.40 on females and 26.57 on males was recorded (Table 1).
Density levels of *O. ferox* increased as host size increased during March and April, and density levels declined with decreasing host size during January and February (Fig. 1).

**Actinocleidus fergusoni**

More specimens of this species were found on female hosts to a significant degree (*P* = .0011). 18994 specimens of this species were recorded from all hosts examined with a mean density of 30.92 on females and 25.13 on males (Table 1). The density levels of *A. fergusoni* increased and decreased on female and male hosts in a similar manner to *O. ferox* (Fig. 2).

**Haplocleidus acer**

More specimens of *H. acer* were found on female hosts to a significant degree (*P* = .007). 6135 individuals of this species were recorded with mean densities of 9.85 on female hosts and 8.19 on males (Table 1). Although densities of *H. acer* increased during March and April, a more substantial increase was not realized until May, especially on female hosts (Fig. 3). Patterns of density decline were similar to those of *O. ferox* and *A. fergusoni*.

**Haplocleidus dispar**

*H. dispar* occurred more frequently on female hosts but the difference was not statistically significant (*P* = .098). A total of 1936 worms were recovered with mean
densities of 3.06 on females and 2.61 on males (Table 1). In contrast to the three previous species, the density levels of *H. dispar* increased most substantially during November and December (Fig. 4). Subsequent declines in density levels were observed in January and February.

**Anchoradiscus triangularis**

More *A. triangularis* were found on female hosts but the difference was not statistically significant (*P* = .12). 699 worms were recovered for a mean density of 1.30 on females and 0.84 on males (Table 1). *A. triangularis* appears to be a cool weather species with notable density increases occurring on both host sexes during November and December (Fig. 5).

**Cleidodiscus robustus**

The occurrence of *C. robustus* was more frequent on male hosts. However, this finding was not statistically significant (*P* = .23). 362 individuals of this species were recorded. The mean density on female hosts was 0.48 and on males was 0.53 (Table 1). The density of *C. robustus* increased during March after which irregular oscillations were observed on both host sexes through December (Fig 6).

**Cleidodiscus nematocirrus**

Female hosts harbored more *C. nematocirrus* than males but the difference was not statistically significant (*P* = .88). 197 specimens of this parasite were recovered.
Mean densities of 0.33 on females and 0.25 on males were recorded (Table 1). Density levels fluctuated irregularly on both host sexes throughout the study period (Fig. 8).
DISCUSSION

The results of the present study indicate that the more abundant monogeneans on _L. macrochirus_ have significantly higher relative densities on females of this host. These increased densities on females are not consistent from month to month and vary from species to species. The distributional patterns of all seven species of Monogenea on gill arches and hemibranch sections are unaffected by the sex of the host.

Mizelle and McDougal (1974) indicated that intensities of infestations of monogeneans on _L. cyanellus_ varied directly with the standard length of the host for the major segment of the sample (5.1-11 cm). A positive correlation of increasing density of Monogenea with increasing standard length of bluegill sunfishes, _L. macrochirus_, was indicated by Duobinis-Gray and Corkum (1986a). The lack of sufficient males in the first five size classes and females in the upper five size classes was thought to have precluded a reliable analysis of sexual selection by parasites during Mizelle and McDougal's (1974) study. Although fewer female than male hosts (242 versus 458) were collected during the present study, the difference in mean standard length between sexes (6.5 versus 6.6 cm) was not significant. An analysis of covariance utilizing standard length as the covariable in the experimental design removed the variation due to length from the results regarding
relative densities of parasites during this study.

In ecological studies which deal with population interactions within communities, it is difficult to assess what effect any single factor has upon community dynamics without examining other factors which may alter dynamics patterns. Although host length may be an important factor for consideration during studies of this type, ecological and behavioral differences between host sexes must be examined. Population densities of the more abundant monogenean species on L. macrochirus are known to increase at times which coincide with the host's spawning activities (see Duobinis-Gray and Corkum 1986a). Male bluegills are known to create the nests on the spawning beds and "lure" the females to the nests (see Morgan 1951). These large fish start to appear near shore during March-April and commence breeding in April-May in southern Louisiana. Schooling is apparent when bluegills are actively breeding. Morgan (1951) indicated one angler caught 130 bluegills, mostly gravid females, in two hours over spawning beds. While males disperse from the schools to excavate nests, females apparently congregate at or near the margins of nesting areas. This type of behavior would concentrate mature, infested females and result in higher infestations on females due to a spatial relationship of the hosts. Eggs released by monogeneans on both male and female bluegills at this time would be
responsible, upon hatching, for the primary infestations of larval bluegills.

Increased densities of the three more abundant monogenean species on larger bluegill appear to be closely linked to the behavioral activities of the host. As large fish congregate near shore to spawn, monogenean levels rise. This is followed by oscillations through December and a subsequent decline in January and February. If host size was the only factor involved in determining density levels, one would not expect increased levels of *H. dispar* and *A. triangularis* during November and December when hosts are smaller than in April and May.

An additional factor is one of a hormonal nature between the host sexes. Onchomiracidia may be attracted to female hosts more frequently due to differences between female and male hormonal secretions.

Experimental laboratory studies with selected monogenean species may elucidate how host sex affects the population dynamics of these worms.
LEGEND FOR TABLE

Table 1. Abundance and probability values of Monogenea on female versus male *Lepomis macrochirus*.
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Table 1
LEGEND FOR FIGURES

Figures 1-7. Graphs showing the mean relative densities of *O. ferox*, *A. fergusoni*, *H. acer*, *H. dispar*, *A. triangularis*, *C. robustus*, and *C. nematocirrus*, respectively, per female and male fish over 24 months. Also included on each graph is the mean standard length (cm) of female and male fish over 24 months.
Figure 4

MEAN H. DISPAR DENSITY/FISH

MEAN STANDARD LENGTH (CM) OF FISH

TIME

1982

1983

1984
Figure 5

**MEAN A. TRIANGULARIS DENSITY/FISH**

**MEAN STANDARD LENGTH (CM) OF FISH**

<table>
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<th>Month</th>
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</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0.5</td>
<td>10 cm</td>
</tr>
<tr>
<td>Feb</td>
<td>1.2</td>
<td>12 cm</td>
</tr>
<tr>
<td>Mar</td>
<td>0.9</td>
<td>11 cm</td>
</tr>
<tr>
<td>Apr</td>
<td>1.5</td>
<td>15 cm</td>
</tr>
</tbody>
</table>

Male and female densities and lengths are indicated by different symbols.

1982-1984 timeline shown.
Figure 7

MEAN C. NEMATOCIRRUS DENSITY/FISH

MEAN STANDARD LENGTH (CM) OF FISH

TIME

1982
1983
1984


0 0.5 1.0 1.5

0 4 8 10 12

Figure 7
LITERATURE CITED


VITA

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Leon F. Duobinis-Gray

Major Field: Invertebrate Zoology (Parasitology)

Title of Dissertation: Population Dynamics of the Monogenea (Platyhelminthes) on the Bluegill, Lepomis macrochirus, in Southern Louisiana

Approved:

[Signatures]

Major Professor and Chairman
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination: May 2, 1986