OCCURRENCE AND DISTRIBUTION OF HELMINTH PARASITES OF FISHES FROM LAKE CARL BLACKWELL, OKLAHOMA

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PREFACE

In the past much attention has been given the host-parasite relationship, but usually for medical and economic reasons the emphasis was placed on evaluating the harmful effects of the parasite upon its host. The design of the present study was to investigate ways in which the host influences the success of its parasites. The emphasis has been placed on consideration of the host-variables of age, sex and degree of sexual maturity, and feeding and spawning behavior. Evaluation of environmental-related variables was also done.

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CHAPTER I

INTRODUCTION

The purpose of this study was to survey the endoparasitic helminths of fishes of Lake Carl Blackwell, Oklahoma, and determine to what degree certain environmental factors can be correlated with variations in the prevalence and intensity of parasitism. This purpose is in keeping with the contemporary emphasis of fisheries research on the ecological relationships between stocks of fishes and their environment. Van Cleave and Mueller (1934) regarded the habits of the host and environmental conditions under which it lives foremost in determining the kinds and numbers of parasites which it contains. Ward (1910) regarded the parasitic fauna of any animal to be a primary function of its habitat.

The environment of fishes, by virtue of its dynamic state in terms of both the physical and biological components, imposes many interrelating and reciprocating influences on their parasitocenoses, the community of parasites which they harbor. The spectrum of variables which may influence the kinds and abundance of parasites in fishes include intrinsic host factors such as age and size, sex and degree of sexual maturity, food habits and migratory behavior, and extrinsic factors such as availability of suitable diet, changing seasons with attendant changes in photoperiod and water temperature, water levels, and such activities of man as exploitation of the fishery stocks and pollution. Parasite-factors such as interspecific synergism and antagonism also influence the incidence and severity of parasitism.

Objectives and Scope of Study

The design of this study was to investigate the ways in which the host and its changing environment influence the success of certain parasites. The objectives were fourfold: (1) to describe the endoparasitic helminth fauna of fishes from this lake, their prevalence and intensity of infection; (2) to evaluate seasonal changes and differences in the hosts' macroenvironment on the occurrence of parasitism; (3) to evaluate the effect of the hosts' age (size) or sex on the degree of parasitism; and (4) to determine the degree of host-specificity of certain helminths for fishes of the same and different familial groups. Season, depth of capture, age and sex of the host are not presumed to be the most important variables with respect to the occurrence of parasitism, but they are those for which data were collected.

This survey began in June, 1967, and continued through mid-May, 1968. Eleven species of fishes were collected from six sampling areas within the lake. Two species, channel catfish (Ictaluras punctatus) and white crappie (Pomoxis annularis), because of their availability in all areas and in all seasons, were selected for analysis regarding changes in the helminthocenoses due to seasonal and environmental differences. They were sampled continually throughout the experimental period. The other fishes, carp (Cyprinus carpio), river carpsucker (Carpiodes carpio), white bass (Roccus chrysops), freshwater drum (Aplodinotus grunniens), bluegill (Lepomis macrochirus), longear sunfish (L. megalotis), largemouth bass (Micropterus salmoides), flathead catfish

(*Pylodictis olivaris*) and gizzard shad (*Dorosoma cepedianum*) were collected mostly during the summer months, although a few individuals were taken as late as February, 1968.

Necropsies were performed in the laboratory; the viscera were removed and examined, and the endoparasitic helminths enumerated, fixed and stored. Prominent macroscopic ectoparasites were noted during necropsy but were not subjected to critical counts or included in the analyses. In addition to the parasitological survey, the general physical and biological features of the lake are described.

Historical Review

The literature concerning the helminth parasites of fishes in North America is quite extensive and only a few examples will be cited here. The synopsis is arranged chronologically within general areas of emphasis.

Early morphologic and taxonomic studies of helminth parasites were made by Leidy, 1851 to 1888 (as described by Bangham and Hunter, 1939), Linton (1893, 1901) and Ward (1894 to 1918). Intensive taxonomic studies on restricted groups of fish parasites include works by LaRue (1914) on the Proteocephalidae, Cooper (1919) on the Pseudophyllidea, Van Cleave (1919) on the Neoechinorhynchidae, Manter (1926) on the Azygiidae, Essex (1927) on *Corallobothrium*, Holl (1929) on the phyllodistomes, Hughes (1927 to 1929) on the Strigeidae, Hunter (1930) on the Caryophyllaeidae, and Hopkins (1934) on the Allocreadiidae. Later works include those of Dickerman (1934, 1945, 1946) on the Azygiidae, Fischthal (1942, 1943, 1952) on *Phyllodistomum*, Mizelle and associates (1936 to 1964) and Price (1936 to 1962) on the Monogenea (cited in

Hoffman, 1967), Choquette (1948, 1951) on Metabronema and Rhabdochona, Erickson and Wallace (1959) on Sanguinicola, Hoffman (1960) on the Strigeids, and Mackiewicz (1961 to 1964) and Mackiewicz and McCrae (1965) on the Caryophyllaeidae.

Concurrent with interest in the morphology and classification of helminths from fishes was an era of parasitological surveys and life-cycle studies. Among these were the surveys of Bangham (1925) in Ohio; Essex and Hunter (1926) in the Midwestern states; Hunter and Hunter (1929 to 1934; cited by Hoffman, 1967), Mueller and Van Cleave (1932), Van Cleave and Mueller (1932, 1934) and Mueller (1934) in New York; Wardle (1932a, b) and Lyster (1939, 1940) in Canada; Bangham and Venard (1942) in Tennessee; Fischthal (1947a, b, 1950) in Wisconsin; Haderlie (1954) in California; Fritts (1959) in Idaho; Hugghins (1959) in South Dakota and Meyer (1962) in Maine. Some life cycle studies pertinent to the present survey and not mentioned elsewhere include those by Hedrick (1935), McMullen (1935), Crawford (1937), Thomas (1937), Gustafson (1939), Coil (1954), and others. Studies of an ecological nature include those of Ward (1912), Linton (1914), Van Cleave (1916), Holl (1932), Van Cleave and Mueller (1934), and the later works of Van Cleave and Lynch (1950), Connor (1953) and Bogitsh (1958).

More recent reports indicate an interest in host-parasite relationships and the pathogenesis of helminth parasites. Publications with this emphasis include those of Cross (1934), Ferguson (1943), Elliott and Russert (1949), Rabideau and Self (1953), Venard and Warfel (1953), Morrison (1957), Pitt and Grundeman (1957), Fox (1962), Bullock (1963), Chubb (1964), Lewis and Nickum (1964), Avault and Smitherman (1965), Calentine (1965), Kellogg (1965), Needham and Behnke (1965), Osborn and

Self (1966) and others. A review of the pathogensis of helminth infections in fishes was given by Williams (1967).

Helminthological studies relevant to the present survey, on fishes of reservoirs and inland waterways in the south-central United States, include the works of Caruthers (1935), Harwood (1935), Loewen (1935), Seamster (1938, 1961), Steelman (1938), Sneed (1950), Bynum (1951), Sparks (1951), Cook (1952), Van Cleave and Timmons (1952), Beilfuss (1954), Self (1954), McIntosh and Self (1955), Self and Timmons (1955), Self and Campbell (1956), Roberts (1957), Wilson (1957), Harms (1959, 1960), Minckley and Deacon (1959), Branson and Amos (1961), Delco (1962), Houghton (1963), Klaas (1963), McDaniel (1963), Self, Peters, and Davis (1963), Holmes (1964), Mackiewicz (1964), Holmes and Mullan (1965), Becker, Heard and Holmes (1966), Hopkins (1966), McDaniel and Bailey (1966), Allison (1967), Allison and McGraw (1967), Casto and McDaniel (1967), Hopkins (1967), Lawrence and Murphy (1967), McGraw and Allison (1967), Meade and Bedinger (1967), and Nowlin, Price and Schlueter (1967). A taxonomic list of the parasites and their hosts described in these surveys is presented in Appendix A.

An additional survey in this region by Chandler (1935) described the helminth fauna of twenty-three Texas Gulf Coast fishes. Other studies of the parasites of Texas coastal fishes include those by Pearse (1952), Causey (1953, 1955), Hopkins (1954), Sparks (1954, 1957, 1960), Koratha (1955a, b), Bullock (1957a, b), Ho (1967) and Schlict and McFarland (1967).

CHAPTER II

METHODS AND DESCRIPTION OF SAMPLING AREA

Fish were collected primarily by use of sinking 150 foot experimental gillnets with one, two and three-inch bar mesh. They were also taken by use of rotenone, frame nets (modified fyke net), barrel traps, and by electrofishing. The average net-set was 24 hours. Fish collected by rotenone and electrofishing were taken immediately from the water while those caught in nets may have been in the net for several hours prior to removal. Except for a few fish collected in gillnets in the summer, all the fish were alive upon removal from the collection gear.

Such varied collecting gear may increase the variability of results. It is not known what effect the stress of netting or short periods of fasting have on the helminthocenoses of fishes but Burlingame and Chandler (1941), Reid and Ackert (1941) and Reid (1942; as reviewed by Read, 1960) found that starvation periods from 24 to 96 hours completely removed certain helminth populations from laboratory rats and chickens.

Sampling Area

This study was conducted on Lake Carl Blackwell, a thirty-year-old, 3300 acre impoundment[1] located in Payne County in north-central Oklahoma (Figure 1). The reservoir began filling in 1937 and reached spillway levels in 1945. At spillway elevation the reservoir has nearly 100 miles of shoreline. The flood plain of the reservoir is quite level with few irregularities except for the former stream channels which form narrow, steeply sloping trenches through the middle of the lake and the larger coves. The channel bottoms lie one to two meters below the flood plain.

The reservoir lies in the Redbeds Plains physiographic region and soils were formed chiefly from Permian clays and shale (Cooper, 1965). The watershed is composed of gently rolling and partially wooded land used primarily for grazing, although some sections are planted with small-grain crops. The watershed was approximately 20 times the surface area of the lake during the interim of this study but is only about 11 times at maximum storage levels (Norton, 1968).

Fish were collected from six major sampling areas within the lake, each assumed to represent a different habitat type (Figure 1). Area A was on a transect located thirty meters west and parallel to the earth-and-rockfill dam. Area A represented the deepest part of the lake with an average depth, during this study, of eight meters. Area B was located in an open water, moderately deep (average four meters) part of the lake having a wind swept north shore and a rocky, irregular south

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[1]At spillway level (elevation 288 m). Water levels during the course of this study were about four meters below the spillway with a resulting surface area of only about 1800 acres.

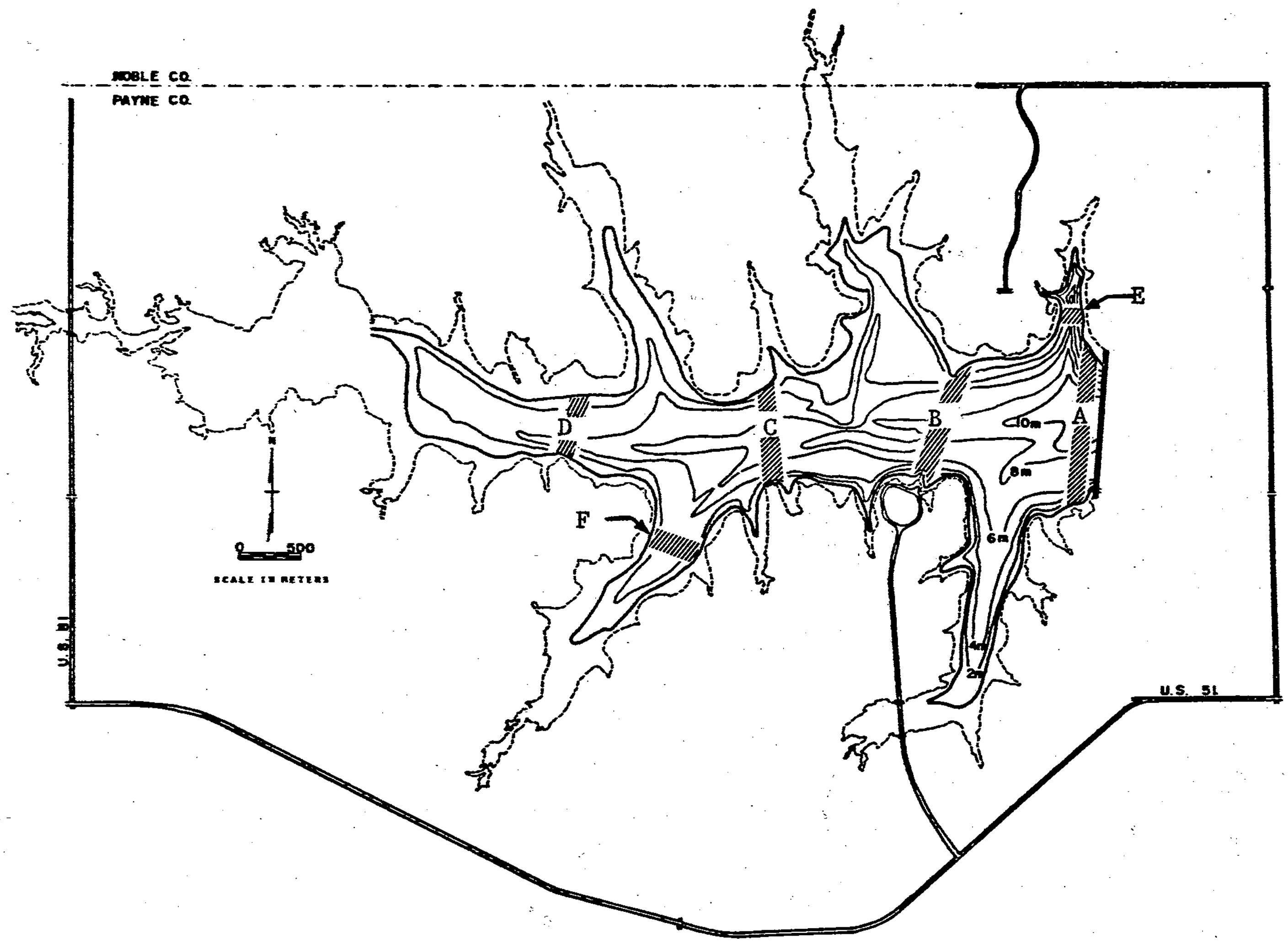

Figure 1. Contour Map of Lake Carl Blackwell with 6 Collection Sites (adapted from Norton, 1968)

shore. Area C had a somewhat irregular bottom with an average depth of three meters. This area had a dense stand of large trees and snags left when the land was inundated. Neither shoreline was indented or irregular. Area D was less than two meters deep except in the stream channel and lacked the heavy cover of dead trees found in Area C. Further west from this area the lake became very shallow, forming wide mud flats. Area E was a moderately deep, narrow cove, with relatively steep sides. Average depth was five meters. Area F was a wide, shallow cove with little bottom relief. Average depth here was two meters.

Fish collected from areas A, B, C and D were sampled along north-south transects extending from shore to shore; those from areas E and F were sampled along east-west transects running across the cove mouths or from within the coves.

Abiotic Features of the Reservoir

The relatively shallow water depth and low surrounding landscape permitted prevailing strong, southwesterly winds to keep the lake circulating almost continually throughout the sampling period. This mixing resulted in uniform physical and chemical conditions, such as temperature and dissolved oxygen, from the surface to the bottom. Another consequence of this continuous mixing was the suspension of a high concentration of colloidal clay particles. The turbidity, inversely related to water depth, increased appreciably going from east to west. Transparency, measured by a Secchi disc, was usually less than one meter in the deeper, east areas (A and E) and graded downward to twenty centimeters or less in the western end of the lake (Area D).

Midwater temperatures varied from 31 C in July to 1 C in January. Surface temperatures showed a wider range varying from 35 C on quiet summer afternoons to 0 C in the winter. The lake was frozen for one week in January, 1968. Dissolved oxygen was generally 70% saturation or greater throughout the sampling period. Thermal stratification was observed only in Area A for a short period during July, 1967. No apparent decrease occurred in the catch rate of fishes during stratification, although there was greater mortality in the gillnets, probably due to oxygen depletion in the lower hypolimnion.

Bottom sediments are composed chiefly of fine montmorillonite clay particles. The depth of sediment was found to vary from approximately 0.3 to 1.0 meters on the flood plain and from 1.0 to 2.3 meters in the stream channel. The pH of the water remained quite constant throughout the sampling period at 8.4 (Norton, 1968).

Biological Factors and Feeding Ecology of Hosts

The lake was devoid of rooted vegetation thus reducing suitable habitat for many possible invertebrate intermediate hosts. This lack of submergent and emergent macrophytes was apparently due to the very turbid water conditions and unstable bottom. A result of the low water conditions present during this survey was a widened vegation-free perimeter around the reservoir. Only in certain restricted areas on the south shore of the reservoir and within Area E were the terrestrial macrophytes (other than short grasses) close enough to the water to be an apparent direct influence on the ecology of helminth parasitism in fishes. Sunfishes collected from these inshore areas were observed to have fed upon terrestrial invertebrates, especially flies, ants and beetles, and upon semiaquatic spiders.

Some filamentous algae were observed attached to rocks in the splashzone at the water's edge. Small channel catfish invariably contained much of this algae during the summer and fall, indicating a movement into the shallow shoreline areas to feed. According to Cooper (1965) there are 33 species of algae in the lake, the most abundant being in the families Zygnemataceae, Desmidiaceae, Hydrodictyaceae and Oscillatoriaceae. The presence of certain of these algae, especially planktonic forms, may influence the numbers of certain pelagic crustacea which can serve as intermediate hosts for helminth parasites.

Sixteen species of fishes were found in the reservoir. In addition to the eleven species included in this study were these five: green sunfish (Lepomis cyanellus), orangespotted sunfish (L. humilis), redear sunfish (L. microlophus) and the minnows Notropis lutrensis and Pimephales notatus. Others possibly occur but were not observed during this study.

Resident and migratory waterfowl and other birds known to serve as definitive hosts of helminth parasites of fishes observed at various times about the lake include: the double-crested cormorant (Phalacrocorax auritus), belted kingfisher (Megaceryle alcyon), white pelican (Pelecanus erythrorhynchus), red-breasted merganser (Mergus serretor), American merganser (M. merganser), great blue heron (Ardea herodius), black-crowned night heron (Nycticorax nycticorax), and the Franklin's gull (Larus pipixcan). In addition to the above the lake supports many other waterfowl at various times of the year which no doubt also directly or indirectly influence helminth parasitism in fishes. Other vertebrates observed within the lake include watersnakes (Natrix), various turtles (Pseudemys, Chelydra), frogs (Rana, Acris), and the beaver (Castor canadensis) and muskrat (Ondatra zibethica).

Norton (1968) found an average of 83 benthic macroinvertebrates per m^2 in the bottom mud (maximum 1076) during June, 1967, and an average of 256 (maximum 3186) during October, 1967. The most abundant insect families were Chironomidae, Culicidae (Chaoborus), Ephemeridae (Hexagenia), Ceratopogonidae and Sphaeriidae. Oligochaetes of the Tubificidae were also abundant. His June samples were dominated by the Chironomidae and Tubificidae; in October the Culicidae were more abundant. The Ephemeridae, while of major significance in terms of biomass, were found to be lower in numbers than the Chironomidae, Tubificidae and Culicidae during both sampling periods. Heptogenia (Heptogeniidae) and damselfly nymphs (Coenagrionidae) were collected by this worker from beneath rocks along the dam.

The freshwater mussel, Anodonta, is apparently abundant as evidenced by their shells found along the shore. Quadrula and Musculium were found in Areas B and E respectively. Snails of the genus Physa were found sparingly in the splashzone in Areas E and F. Crayfish of the genus Procambarus and probably others have been observed in the lake. Zooplankters were abundant during most seasons in spite of the very thin phototrophic zone. Amphipods were observed along shoreline areas, especially on attached algae. Ostracods were also found in the lake.

The importance of these forms as they relate to the helminth fauna of fishes is discussed later under the listings of individual parasites.

A summary of observations of the food habits of the fishes under study is presented here. Stomachs of centrarchids examined in this study showed a high utilization of copepods and cladocerans from late summer through the fall and winter. Ostracods were observed in the stomach contents of carpsuckers and small channel catfish, especially during the late summer and fall. The inclusion of microcrustacea in the diets of these fishes reflected a decrease in the utilization of benthic macroinvertebrates, especially dipterans and tubificids, which formed their major diet during the late winter, spring and early summer months. Aquatic beetles, hemipterans, (Notonectidae, Saldidae, and others) and larval damselflies were observed in the stomachs of the centrarchids, channel catfish and white bass during the summer and fall. The most abundant food items of the drum were bivalve molluscs, crayfish and mayfly larvae. The dependence of the flathead catfish and largemouth bass on invertebrates is very short-lived and they apparently become piscivorous at a relatively small size. Occasionally large crayfish were observed in the intestinal contents of these latter two fishes.

The utilization of terrestrial invertebrates by small centrarchids and the channel catfish was observed in the late summer and fall. The general food habits of the fishes under study are outlined in Table I. This summary is based on observations made during this study but it should be representative of the general food habits of these fishes.

Laboratory Methods

Necropsies of fishes were conducted in the laboratory within 24 hours after collection, usually within 4 hours. In retrospect, the same considerations which were expressed in reference to helminth

TABLE I

GENERAL FOOD HABITS OF HOST FISHES OF LAKE CARL BLACKWELL

Host	Age or Size Group Fingerling	Immature	Adult
Carp and carpsucker	Planktophagous and detritophagous	Benthophagous: omnivorous, feeding chiefly on detritus, insect larvae (chironomids, culicids; and others), tubificids, zooplankters especially ostracods, and algae.	
Gizzard shad	Planktophagous	Planktophagous: zoo- and phytoplankton, detritus.	
Channel catfish	Benthophagic: omnivorous, feeding chiefly on benthic macroinvertebrates, detritus, algae.	Similiar to fingerlings but including larger insects such as _Hexagenia_, small molluscs, crayfish, some terrestrial insects.	Largely piscivorous: (chiefly gizzard shad), diet still includes crayfish and other larger invertebrates.
Flathead catfish	Zooplanktophagous; also rely on insect larvae.	Piscivorous (minnows and shad); few crayfish also included in diet.	Piscivorous (principally shad).
White bass and largemouth bass	Zooplanktophagous (Cladocera and Copepoda).	Piscivorous (gizzard shad and minnows) and some insects.	Piscivorous (principally shad).
Drum	Benthophagous: algae, snails.	Benthophagous: molluscs, especially _Musculium_, few aquatic Coleoptera.	Carnivorous: bivalve molluscs, rarely small fish; crayfish.
White crappie	Chiefly zooplanktophagous: (Cladocera and Copepoda) few macroinvertebrates.	Carnivorous and planktophagous: insect larvae, Cladocera and Copepoda.	Carnivorous: insect larvae, small fish.
Bluegill and longear sunfish	Zooplanktophagous	Carnivorous and planktophagous: insect larvae, especially Diptera and Ephemeroptera, terrestrial invertebrates, copepods.	

losses from fish in the collecting gear may apply here also. However no helminths were observed in containers used to hold the fish until necropsy, although Camallanus oxycephalus was observed protruding from the anus of white crappie and white bass. Those fish which were not examined immediately after being brought into the laboratory were refrigerated.

Length, weight, sex and gonad weight were recorded for each fish and scales or pectoral spines taken for age determination. Cursory examinations of the mouth, nares and branchial cavity were made. The fish were opened and the entire viscera placed in finger bowls containing Locke's solution (0.65% NaCl). The organs were isolated and examined separately under a wide-field, binocular microscope. The parenchyma of the liver, spleen and kidneys was teased apart and examined. To facilitate counting heavy infections of encysted parasites, the livers were minced and then digested for 20 minutes at 37 C in a 1% pepsin solution in 1% HCl. This method is similiar to that described by Avault and Smitherman (1965) and Hoffman (1955).

An abbreviated pepsin digestion method (10 minutes) was useful for separating small helminths from the silt-laden chyme of the alimentary tracts of gizzard shad and carpsuckers. Digestion techniques have previously been used to recover intestinal nematodes from ruminants (Herlich 1956) and encysted nematodes from salmon (Stern, et al., 1958). It caused no apparent deformation or damage to nematodes, although a few caryophyllidean tapeworms were killed by this treatment. After digestion the residue was strained through a standard 60-mesh sieve (pore size 240 microns). The helminth fauna of these two fishes was found to be quite low in both numbers and kinds, but this digestionscreening technique appeared to be more efficient than direct observation in recovery and enumeration of parasitic nematodes of the alimentary canal.

Another technique employed in the recovery of intestinal helminths from some of the larger piscivorous fishes, such as the basses and catfish, was to shake the opened intestine and its contents in a jar containing a dilute detergent solution and strain through a 60-mesh sieve. The detergent liquified the gelatinous mucous strings found in the chyme of these post-mortem fish and thereby aided in separating small helminths from the intestinal contents.

All helminths recovered were fixed in hot (70 - 85 C) 10% formal-saline. After 24 hours the specimens were transferred to fresh formal-saline and stored. Representative specimens were selected and prepared in the following manner to aid in identification. Tapeworms and flukes were stained with either Delafield's hematoxylin or Semichon's aceto-carmine. Specimens were dehydrated with ethanol, cleared in xylene and mounted in Permount[2]. Further contrast in mounted specimens was obtained by using a green filter during microscopic examination. Nematodes and acanthocephalans were mounted unstained in glycerine-jelly, or temporary mounts were prepared using lacto-phenol as a clearing agent. *En face* views were obtained by decapitation or by the technique of Lee (1964). Large tapeworms, which were stretched and gently pressed between damp paper towels before and during fixation, and during dehydration prior to clearing and mounting, gave the best results with regard to ease in handling and microscopic examination of the completed

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[2] Fisher Scientific Co., Fairlawn, New Jersey.

mount. Attempts to relax flatworms before fixation by refrigeration and other methods were generally unsuccessful and thus were abandoned. Flukes and small tapeworms were gently pressed between glass slides during fixation.

Taxonomic keys used in this study include those of Wardle and McLeod (1952), Yamaguti (1958, 1959, 1961, 1963), Dawes (1946), Yorke and Mapleston (1926) and Hoffman (1967). The names used in the text follow those prescribed by Yamaguti. Fixing, storing, staining and mounting of helminths, as well as histological sectioning techniques, followed the procedures outlined by Humason (1962) or as recommended by Besch.[3]

Statistical Tests

Where the data for a particular parasite were numerous enough to support an extensive analysis, the following nonparametric tests were used. The Fisher exact probability test was applied to evaluate the differences in the incidence of infection for a given parasite between sexes of the respective host. The use of this test is recommended by Seigal (1956: 96-104) for small ($N < 20$ for each test), independent, two-sample cases where the level of measurement is nominal or classificatory.

The processing of enumeration data which are classified by two variables, in this case by sex and presence or absence of the helminth in question, was easily obtained by the use of 2 X 2 contingency tables. The hypothesis of independence implies that the ratio of numbers of

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[3]Besch, E. D. 1967. Dean, College Vet. Med., Louisiana State Univ. Personal communication.

infected individuals, within random sampling errors, is the same for each sex. To insure homogeneity within each contingency table, each fish was placed in its respective age, locality and seasonal group. The Fisher test gives the exact probability of the data occurring by chance for each cell. When this probability was less then the chosen level of significance ($P < .05$), the null hypothesis of no difference between the sexes was rejected.

If the above tests gave no significant value, then the data was tested further for differences due to age, locality or season. Should the influence of sex be found significant, then it becomes less meaningful to test the data further. The effects of sex may overshadow or interact with the other variables and nonparametric tests can not suitably explain or test for specific interaction. However, as will be shown later, this did not occur with any of the helminths analysed from the white crappie and channel catfish and therefore the following tests were completed.

After combining the fish from both sexes, sample size was usually sufficient to test the data by use of chi-square analysis for differences due to season, locality or age. This test is recommended (Seigal, 1956: 174-179) for the same type of data as that outlined for the Fisher test but has the added capability of being able to analyze any number of independent variables. Restrictions employed with chi-square include a total $N > 20$ with no more than 20% of the expected frequencies < 5; (no expected frequencies may be < 1).

CHAPTER III

RESULTS AND DISCUSSION

The composition of the parasitic fauna of fishes is dependent on the geographical location of the habitat (and attendant climatic factors), season of the year, bottom type, water characteristics and the fauna present in and around the habitat (Dogiel, et al., 1961: 1). The biology and behavior of the host must also be given consideration. The interplay of these factors on the host-parasite association are little understood and have only rarely been subjected to investigation and analysis. The following results are offered with emphasis on an ecological interpretation. Only facets of the parasites' macroenvironment, that is, the environment of the host, will be evaluated. It was beyond the scope of this study to directly examine the microenvironment of the parasites under discussion. However, the indirect influences of the microenvironment such as the hosts' age, sex and food habits are considered. A summary of the results appears in Table II.

The terms incidence or rate of infection are equated with the concept of prevalence of infection, that is, they are used to depict the number of infected individuals in a population of fishes at a given instant. The term intensity of infection is used to indicate the degree of parasitism, that is, the number of particular worms of a species in a host or group of hosts.

TABLE II

PREVALENCE AND INTENSITY OF INFECTION WITH ENDOPARASITIC HELMINTHS IN FISHES FROM LAKE CARL BLACKWELL

Taxon	Prevalence (%)			Mean Intensity		
	M	F	Total	M	F	Total
CHANNEL CATFISH (67 males; 82 females)						
Digenea:						
Phyllodistomum lacustri	26.9	28.0	27.5	1.1	1.3	1.2
Crepidostomum ictaluri	9.0	2.4	5.4	3.0	3.0	3.0
Alloglossidium corti	0	1.2	0.7	0	11.0	11.0
Eucestoda:						
Corallobothrium fimbriatum and *C. giganteum*	71.6	77.0	71.6	10.2	13.4	11.9
Proteocephalus spp.	19.4	32.9	26.8	3.5	4.0	3.8
Nematoda:						
Contracaecum spiculigerum[1]	28.4	20.7	24.2	1.8	3.4	2.5
Camallanus oxycephalus	17.9	17.1	17.4	1.8	2.8	2.3
Rhabdochona decaturensis	47.8	56.2	52.4	4.8	4.6	4.7
Spinitectus carolini	14.9	18.3	16.8	1.9	1.9	1.9
Dacnitoides robusta[1]	3.0	6.1	4.7	1.5	3.2	2.7
Spiroxys sp.[1]	1.5	0	0.7	2.0	0	2.0
Spiruroidea[1]	1.5	0	0.7	3.0	0	3.0
Acanthocephala:						
Leptorhynchoides thecatus	1.5	0	0.7	1.0	0	1.0
Others:[2]						
Dactylogyrus sp. (Monogenea)	-	-	-	-	-	-
Ergasilus versicolor (Copepoda)	-	-	-	-	-	-
Argulus sp. (Branchiura)	-	-	-	-	-	-
Illinobdella sp. (Hirudinea)	-	-	-	-	-	-
Piscicolaria sp. (Hirudinea)	-	-	-	-	-	-
Henneguya sp. (Protozoa)	-	-	-	-	-	-

[1] Immature or larval form.

[2] External or incidental parasites not included in the analysis and discussion.

TABLE II (Continued)

Taxon	Prevalence (%)			Mean Intensity		
	M	F	Total	M	F	Total
FLATHEAD CATFISH (13 males; 23 females)						
Digenea:						
Phyllodistomum lacustri	0	4.3	2.8	0	1.0	1.0
Eucestoda:						
Proteocephalus spp.	92.3	69.5	77.8	6.0	5.3	5.6
Corallobothrium fimbriatum and C. giganteum	84.6	91.3	88.9	15.6	16.1	16.0
Nematoda:						
Contracaecum spiculigerum[1]	77.0	73.9	75.0	4.2	8.6	7.0
Camallanus oxycephalus	23.1	4.3	11.1	1.3	1.0	1.2
Spinitectus sp.	7.7	0	2.8	1.0	0	1.0
Rhabdochona decaturensis	7.7	0	2.8	23.0	0	23.0
Others:[2]						
Lernaea sp. (Copepoda)	-	-	-	-	-	-
Argulus sp. (Branchiura)	-	-	-	-	-	-
BLUEGILL (10 males; 27 females)						
Digenea:						
Posthodiplostomum minimum[1]	100.0	96.2	97.2	283.4	78.5	135.4
Uvulifer ambloplitis[1]	10.0	3.7	5.4	-	-	-
Eucestoda:						
Proteocephalidea[1] including Proteocephalus ambloplitis	30.0	26.0	27.0	2.3	2.1	2.2
Nematoda:						
Contracaecum sp.[1]	20.0	0	5.4	2.0	0	2.0
Spinitectus carolini	50.0	40.8	43.3	1.8	1.8	1.8
Rhabdochona decaturensis	10.0	11.1	10.6	1.0	4.0	3.3
Others:[2]						
Lernaea sp. (Copepoda)	-	-	-	-	-	-

TABLE II (Continued)

Taxon	Prevalence (%)			Mean Intensity		
	M	F	Total	M	F	Total
LARGEMOUTH BASS (13 males; 18 females)						
Digenea:						
Posthodiplostomum minimum[1]	76.9	55.5	64.5	23.7	19.2	21.5
Clinostomum marginatum[1]	7.7	0	3.2	1.0	0	1.0
Eucestoda:						
Proteocephalus ambloplitis[1]	46.2	50.0	48.4	3.7	8.1	6.3
Nematoda:						
Contracaecum spiculigerum[1]	100.0	89.9	93.5	8.3	6.4	7.2
Camallanus oxycephalus	30.8	22.2	25.8	6.8	7.8	7.3
Rhabdochona decaturensis	0	16.7	9.7	0	3.0	3.0
Spiroxys sp.	15.4	0	6.5	1.0	0	1.0
Philometra nodulosa	7.7	0	3.2	1.0	0	1.0
LONGEAR SUNFISH (12 males; 14 females)						
Digenea:						
Posthodiplostomum minimum[1]	58.3	28.6	42.3	14.8	13.5	14.0
Eucestoda:						
Proteocephalidea[1] including *Proteocephalus ambloplitis*[1]	50.0	28.6	38.7	1.5	1.3	1.4
Bothriocephalus sp.[1]	12.5	0	3.9	1.0	0	1.0
Nematoda:						
Camallanus oxycephalus	41.7	7.1	23.1	1.2	1.0	1.2
Rhabdochona decaturensis	0	28.6	15.8	0	1.8	1.8
Spinitectus carolini	0	21.4	11.5	0	1.7	1.7
Others:						
Dactylogyrus sp. (Monogenea)	-	-	-	-	-	-
Urocleidus sp. (Monogenea)	-	-	-	-	-	-

TABLE II (Continued)

Taxon	Prevalence (%)			Mean Intensity		
	M	F	Total	M	F	Total
WHITE CRAPPIE (76 males; 100 females)						
Digenea:						
Posthodiplostomum minimum[1]	85.5	72.0	77.8	14.6	17.0	15.8
Eucestoda:						
Proteocephalidea[1] including *Proteocephalus ambloplitis*[1]	10.5	3.0	6.3	1.0	1.0	1.0
Nematoda:						
Camallanus oxycephalus	64.5	66.0	65.4	3.6	3.4	3.5
Spinitectus gracilis	3.9	6.0	5.1	1.0	1.3	1.2
Rhabdochona cascadilla and *R. decaturensis*	11.8	13.0	12.5	1.7	2.5	2.2
Spiroxys sp.[1]	2.6	0	1.3	2.5	0	2.5
Contracaecum sp.[1]	9.2	13.0	11.4	1.4	1.4	1.4
Ascaroidea[1]	2.6	1.0	1.7	2.5	1.0	2.0
Spiruroidea[1]	1.3	0	0.6	1.0	0	1.0
Others:						
Dactylogyrus sp. (Monogenea)	-	-	-	-	-	-
Ergasilus versicolor (Copepoda)	-	-	-	-	-	-
CARP (1 male; 11 females)						
Digenea:						
Clinostomum marginatum[1]	0	9.1	8.3	0	1.0	1.0
Cestoda:						
Khawia iowensis	0	18.2	16.7	0	2.5	2.5
Atractolytocestus huronensis	100.0	45.5	50.0	9.0	18.0	16.5
Proteocephalus sp.[1]	0	9.1	8.3	0	2.0	2.0
Nematoda:						
Rhabdochona decaturensis	100.0	72.7	75.0	19.0	28.9	27.8
Camallanus ancylodirus	0	9.1	8.3	0	3.0	3.0

TABLE II (Continued)

Taxon	Prevalence (%) M	Prevalence (%) F	Prevalence (%) Total	Mean Intensity M	Mean Intensity F	Mean Intensity Total
DRUM (9 males; 21 females)						
Eucestoda:						
Proteocephalus sp.[1]	0	4.8	3.3	0	1.0	1.0
Nematoda:						
Rhabdochona decaturensis	66.7	80.9	76.7	25.2	16.4	18.7
Contracaecum sp.[1]	0	19.0	13.3	0	4.0	4.0
Spinitectus carolini	11.1	9.5	10.0	1.0	2.5	2.0
Camallanus oxycephalus	11.1	4.8	6.7	1.0	1.0	1.0
GIZZARD SHAD (14 males; 21 females)						
Nematoda:						
Ascaroidea[1]	7.1	9.5	8.6	4.0	3.5	3.7
RIVER CARPSUCKER (14 males; 24 females)						
Cestoda:						
Spartoides wardi	7.1	12.5	10.5	2.0	1.7	1.8
Biacetabulum sp. nov.	21.4	8.3	13.2	1.3	3.0	2.0
Proteocephalus sp.[1]	7.1	0	2.6	1.0	0	1.0
Nematoda:						
Contracaecum sp.[1]	7.1	0	2.6	2.0	0	2.0
Spiroxys sp.	14.3	20.8	18.4	1.5	2.0	1.9
Rhabdochona decaturensis	7.1	4.2	5.3	1.0	7.0	4.0
Ascaroidea	7.1	0	2.6	1.0	0	1.0
WHITE BASS (16 males; 23 females)						
Eucestoda:						
Proteocephalus sp.[1]	0	8.7	5.1	0	1.0	1.0
Nematoda:						
Camallanus oxycephalus	56.3	47.8	51.3	3.9	4.9	4.5
Rhabdochona decaturensis	12.5	30.4	23.0	5.5	1.9	2.7
Contracaecum sp.	0	8.7	5.1	0	1.0	1.0
Ascaroidea[1]	6.2	8.7	7.7	1.0	1.0	1.0

Trematoda

Only the endoparasitic flukes (Digenea) are considered in this report, although the monogenetic genera Dactylogyrus from channel catfish and white crappie and Urocleidus from longear sunfish have occasionally been noted on the gills of these fishes. Six species of digenetic flukes were recovered during the course of this study, three as adults and three as encysted metacercariae. Except for Posthodiplostomum minimum both the rate and severity of infections of digenetic flukes were quite low. The paucity of Digenea in Lake Carl Blackwell would appear to result from a lack or insufficient numbers of suitable molluscan intermediate hosts.

This scarcity of snails is undoubtably correlated with the unstable bottom and low transparency of this reservoir. These conditions limit suitable substrate for both the snail and periphyton upon which it may feed. Phyllodistomum lacustri, which uses a filter-feeding, bivalve mollusc as first intermediate host, appeared to be somewhat more successful in Lake Carl Blackwell than other digenetic flukes. The exception was P. minimum which was highly prevalent in this reservoir, although its snail host, Physa, had been only rarely collected. This indicates that even a few suitable intermediate hosts are sufficient to transmit heavy infections of some digenetic flukes.

The indirect influences of the habitat as they relate to parasitism must also be considered. Bangham (1958) reported that "soft-water" lakes produced fewer species and numbers of digenetic trematodes (and acanthocephalans) than "hard-water" lakes. Soft-water lakes presumably are low in calcium salts useful for shell building and this in turn may play an important role in limiting the numbers of molluscs. Cross

(1933) reported that encysted trematodes were virtually absent from fishes of a small softwater lake in Wisconsin. After calcium and phosphorous were added selected fishes were found to be 6% infected with strigeid metacercariae. Considerable numbers of Clinostomum marginatum reportedly also appeared in fishes after enrichment of this Wisconsin lake.

Conversely, Kastak (1964) reported that the abundance of the snail Galba truncatula was negatively correlated with "permanent" water hardness. However, Kastak also reported a positive correlation with increasing alkalinity which complicates our understanding of the relationship between molluscs and their environment.

The calcium carbonate content of Lake Carl Blackwell was about 80 mg/1 which would not seem to be limiting for molluscs. Since the lake affords little protection for snails because of a lack of aquatic macrophytes, predation by fishes may limit their abundance.

Posthodiplostomum minimum (MacCallum, 1921)

Posthodiplostumum minimum metacercariae (larval genus Neascus) have been described from at least 97 species of fishes (Hugghins, 1959). However, host records show it to predominate in the Centrarchidae and Cyprinidae. Two subspecific strains were recognized by Ferguson (1943) based on host preferences and apparent physiological differences. These were later name P. m. minimum and P. m. centrarchi by Hoffman (1958), minimum being found primarily in cyprinids and centrarchi being found in the sunfishes. Hoffman (1967: 176) expressed the belief that other subspecies are probable. The first intermediate host has been given as Physa spp. (Avault and Smitherman, 1965; Miller, 1954). Hugghins (1959) lists the great blue heron and black-crowned night heron as definitive hosts. Ulmer (1960) has experimentally infected robins and red-winged blackbirds to a limited degree with metacercariae, and Avault and Smitherman (1965) and others have used unfed chicks as experimental definitive hosts.

These small strigeids were recovered as metacercariae from only the four species of centrarchids. It therefore seems that P. m. centrarchi is the only strain present in the lake. However, as the carp was the only cyprinid examined the possibility that P. m. minimum coexists in the lake cannot be ruled out. They were most abundant in the livers of the centrarchids but were commonly found in the kidney, spleen, heart and pericardium and less commonly under the serosa of the gut.

Observations of bluegill liver sections prepared with analin-blue collagen stain (Mallory's triple) suggested that encystment by the parasite rather than encapsulation occurs. Further, cysts containing worms are easily removed and retain their structural integrity for several days in saline at 4 C. Hoffman (1967) characterizes the whole larval genus Neascus (in which P. minimum is placed) as generally possessing true cysts. There was only a faint indication of a walling off process by host tissues which would support the view of a long-evolved and successful host-parasite relationship. In apparent contradiction to this latter concept, Miller (1954) and Meade and Bedinger (1967) found that experimental infection of sunfishes, including the bluegill, by P. minimum cercariae resulted in great stress and trauma to the host, sometimes resulting in the death of the fish.

The incidence of infection varied from a high of 97.2% for bluegill to a low of 42.3% for longear sunfish. White crappie and largemouth bass were 77.8 and 64.5% infected respectively. Meade and Bedinger (1967) reported an incidence of 66.7% for bluegill, 80.0% for longear sunfish, 80.0% for largemouth bass and only 6.2% for white crappie. McDaniel and Bailey (1966) reported a prevalence of 96.4% for longear, 100% for bluegill (only two fish examined) and negative for a single white crappie. The greatest variation in the prevalence of infection found in these and other selected studies was reported in white crappie, and bluegill generally had the highest incidence of infection (Table III). The variability found in these surveys indicates that the success of _P. minimum_ in fish is more dependent on environmental factors external to the host rather than host-specific factors. A helminth with a three-host life cycle might be expected to occur erratically in areas where the ranges of all three do not overlap to a high degree.

Males had a higher incidence of infection than females in all four host species (Table IV). This difference between the sexes was significant for crappie from the summer and fall samples ($X^2 = 3.88$; where $X^2_{.05,1d.f.} = 3.84$) and was highly significant for largemouth bass ($X^2 = 7.17$; where $X^2_{.01,1d.f.} = 6.63$). All centrarchids combined also showed a significant difference in infection rate between the sexes ($X^2 = 4.17$). However, when the crappie data for the entire year were analyzed, after stratifying the fish by age, season and location of capture (Table V), no significant variation between the sexes could be detected at the 5% level (Fisher exact probability test). Apparently interaction occurs between the sex of the host and some other variable.

TABLE III

COMPARISON OF THE PREVALENCE OF INFECTION OF *POSTHODIPLOSTOMUM MINIMUM* IN FOUR CENTRARCHIDS FROM SELECTED STUDIES IN THE SOUTHCENTRAL UNITED STATES

Study and Investigator	Percent Infected (Number of Fish)			
	Bluegill	White crappie	Largemouth bass	Longear sunfish
Present Survey	97.2(37)	77.8(176)	64.5(31)	42.3(26)
Benbrooke Lake, Texas (Lawrence and Murphy, 1967)	89.4(66)	0 (191)	17.6(17)	-
Navasota River, Texas (Allison and McGraw, 1967)	94.7(19)	0 (27)	72.7(11)	83.3(18)
Leavenworth Co. Lake, Kan. (Wilson, 1957)	100.0(3)	84.6(13)	100.0(2)	-
Little River, Texas (McGraw and Allison, 1967)	63.3(30)	0 (7)	25.0(8)	56.0(25)
White River, Arkansas	-	-	96.4(55)[1]	-
Three Hatcheries (Mean), Ark. (Becker, et al., 1966)	-	-	76.0(79)	-
Lake Texoma, Oklahoma (McDaniel, 1963)	32.4(114)	-	-	40.6(74)
Little River, Oklahoma (McDaniel and Bailey, 1966)	100.0(2)	0 (1)	-	96.4(55)
Eastern Texas (Meade and Bedinger, 1967)	66.7(24)	6.2(16)	80.0(5)	80.0(5)

[1]One fish examined for external parasites only.

The intensity of infection paralleled the rate of infection among all four centrarchids (Table IV). Bluegill had the greatest numbers of metacercariae, and crappie, bass and longear sunfish followed in decreasing order. Also, the difference in intensity of infection between the sexes was similiar to the rate of occurance. Thus, male bass, bluegill and longear sunfish had a higher average number of metacercariae than females.

TABLE IV

PREVALENCE AND INTENSITY OF INFECTION WITH *POSTHODIPLOSTOMUM MINIMUM* METACERCARIAE IN FOUR LAKE CARL BLACKWELL CENTRARCHIDS (JUNE, 1967 THROUGH NOVEMBER, 1967)

Host	Prevalence (%)			Average Intensity		
	Males	Females	Total	Males	Females	Total
Bluegill	100.0	96.2	97.2	88.1[1]	78.5	79.7[1]
White crappie[2]	82.8	62.5	70.2	15.9	29.6	23.5
Largemouth bass	76.9	55.5	64.5	23.7	19.2	21.5
Longear sunfish	58.3	28.6	42.3	14.8	13.5	14.0

[1]Does not include a single individual containing 2,041 metacercariae; inclusion of this value changes the average to 135.4 for all bluegill and 283.4 for males.

[2]Values for crappie correspond to collections made during the same seasons (summer and fall, 1967) as the other centrarchids.

TABLE V

PREVALENCE OF INFECTION WITH POSTHODIPLOSTOMUM MINIMUM METACERCARIAE IN WHITE CRAPPIE FROM DIFFERENT AGE CLASSES AND SEASONS (JUNE, 1967 THROUGH MAY, 1968)

	Percent Infected (Number of Fish)				
	I and II	III	IV and V	VI and Older	All Ages
			SUMMER		
Males	75.0 (4)	100.0 (7)	100.0 (5)	-	93.7 (16)
Females	72.7 (11)	69.1 (13)	50.0 (2)	100.0 (2)	71.4 (28)
Combined	73.4 (15)	80.0 (20)	85.7 (7)	100.0 (2)	79.5 (44)
			FALL		
Males	50.0 (2)	83.3 (6)	80.0 (5)	-	76.9 (13)
Females	37.5 (8)	60.0 (5)	50.0 (6)	100.0 (1)	50.0 (20)
Combined	40.0 (10)	72.7 (11)	63.6 (11)	100.0 (1)	60.6 (33)
			WINTER		
Males	66.7 (6)	100.0 (6)	87.5 (8)	100.0 (1)	85.7 (21)
Females	50.0 (4)	87.5 (8)	33.3 (6)	100.0 (2)	65.0 (20)
Combined	60.0 (10)	92.8 (14)	64.3 (14)	100.0 (3)	75.6 (41)
			SPRING		
Males	-	72.7 (11)	92.3 (13)	100.0 (2)	84.6 (26)
Females	87.5 (8)	85.7 (14)	100.0 (6)	100.0 (4)	90.6 (32)
Combined	87.5 (8)	80.0 (25)	94.7 (19)	100.0 (6)	87.9 (58)
			ALL SEASONS		
Males	66.7 (12)	86.7 (30)	90.4 (31)	100.0 (3)	85.5 (76)
Females	64.5 (31)	77.5 (40)	60.0 (20)	100.0 (9)	72.0 (100)
Combined	65.2 (43)	81.5 (70)	78.4 (51)	100.0 (12)	77.8 (176)

The average numbers of metacercariae in white crappie (both sexes combined) was greater in the summer months than in the other seasons (Figure 2). The maximum monthly averages reached 80.5 in August and dropped to a low of 6.2 in January. The reasons for this sharp decline in intensity are not clear. Meade and Bedinger (1967) suggested on the basis of laboratory observations that significant mortality might occur in natural waters due to infections with P. minimum. Starrett and Fritz (1957) as reported by Bennett (1962: 201) found that most of the annual natural mortality of crappie in Chautauga Lake, Illinois, occurred in the summer months (which they attributed to "old age"). The death and removal of crappie from Lake Carl Blackwell during the summer due to heavy infection with P. minimum might account for the decrease in the average intensity of infection observed during this season.

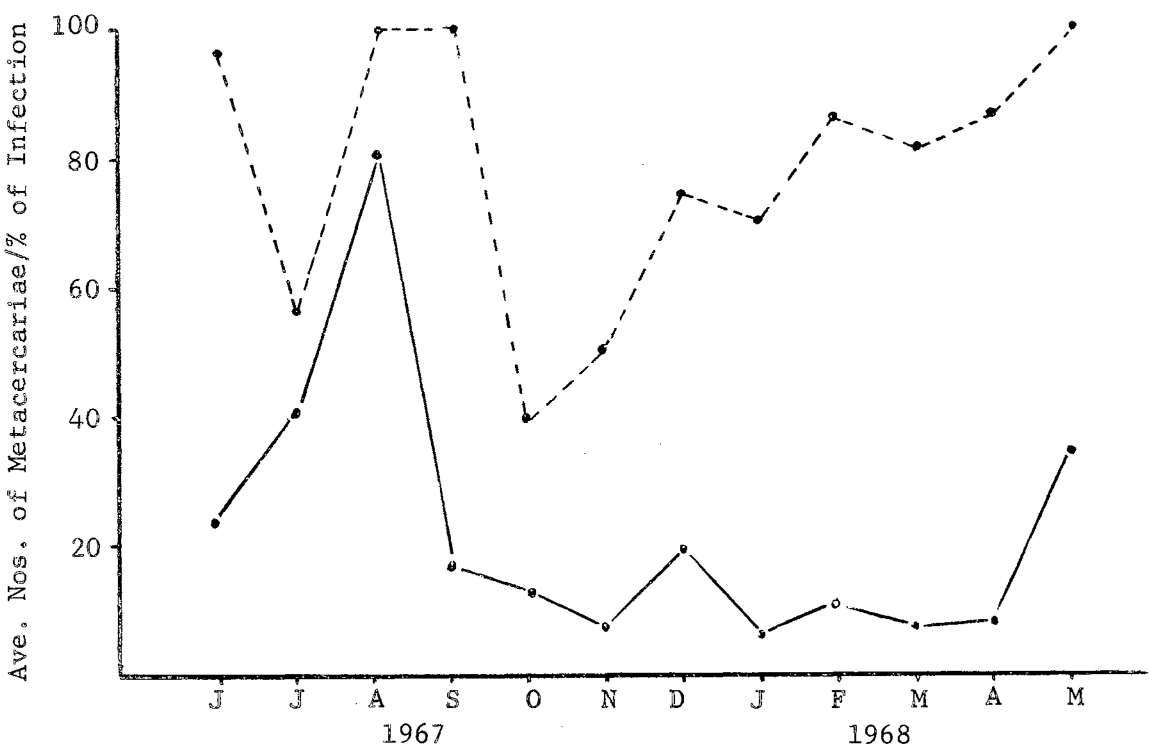

Figure 2. Monthly Variation in the Prevalence (broken line) and Intensity (solid line) of Posthodiplostomum minimum in White Crappie

A similiar sharp decline in the prevalence of infection occurred during the early fall, although a month later than the decline observed in the average intensity of infection. Unlike the latter, the drop in prevalence was followed by a gradual increase through the late fall, winter and spring (Figure 2). This seasonal pattern may have resulted from summer mortality followed by a gradual rise in the incidence of new infections due to the continuous presence of low numbers of cercariae throughout the year. The establishment of an equilibrium between the numbers of successful invasive cercariae and degenerating metacercariae was indicated by the stability found in the average intensity through the fall and winter.

A rise in the intensity of infection was observed during the spring and early summer. Environmental changes such as rapidly increasing water temperatures could result in an increase in the rate of maturation and liberation of cercariae from snails. Therefore fish would be exposed to more infective larvae during this period. Also, as a possible aftermath of physiological changes during spawning, the fish may be more susceptible to cercarial penetration at this time.

The viability as well as numbers of metacercariae appeared to lessen during the winter. The cysts from fish collected during this period appeared to be smaller in size, more opaque and the larvae less active when compared with those collected during the summer and fall. A hypothesis of an annual life cycle for this parasite is suggested from the changes in the condition and size of the cysts. The presence of both old and degenerated and fresh and viable cysts in the livers of fishes from the late spring collections lends credence to the aforementioned concept of a recurring seasonal infection.

The incidence of infection in white crappie increased with increasing age (Table V). The increases among the age groups of crappie were significant ($X^2 = 8.20$; where $X^2_{.05,3d.f.} = 7.81$). The rate of infection of *P. minimum* in longear sunfish increased with age also, and bluegill were heavily infected in all age classes. Variation in the prevalence of *P. minimum* in largemouth bass did not show definite age relationships (Table VI). The rate for all centrarchids combined increased slightly with increasing age of the host. Variations in numbers of metacercariae (intensity) do not appear to be correlated with the age of the host.

TABLE VI

PREVALENCE AND INTENSITY OF INFECTION WITH *POSTHODIPLOSTOMUM MINIMUM* IN VARIOUS AGE CLASSES OF FOUR CENTRARCHIDS FROM LAKE CARL BLACKWELL

	Percent Infected of Number Examined (Mean Number of Metacercariae)			
	I and II	III	IV and V	VI and Over
White crappie	65.2 of 43 (17.1)	81.5 of 70 (16.2)	78.4 of 51 (11.2)	100.0 of 12 (21.2)
Bluegill[1]	91.6 of 12 (65.8)	100.0 of 21 (69.4)	100.0 of 1 (2,041)	-
Largemouth bass	66.7 of 15 (12.8)	85.7 of 7 (16.7)	42.8 of 7 (62.0)	50.0 of 2 (17.0)
Longear sunfish	33.3 of 6 (5.0)	35.7 of 14 (19.2)	66.7 of 6 (12.0)	-
Centrarchidae	67.1 of 76 (26.2)	79.5 of 112 (29.0)	73.8 of 65 (14.5)[2]	92.8 of 14 (20.8)

[1]Estimates of age only, based on average growth data of Houser and Bross (1963); all others determined by scale analysis.

[2]Value for bluegill ignored in computing mean no. of metacercariae.

Thus, previous exposure apparently did not inhibit reinfection, and older fish, by reason of their longevity, had an increasingly greater prevalence of infection. However, since the average numbers of metacercariae remained fairly constant with respect to increasing age in the general population of sunfishes, it appears that an equilibrium is reached where the numbers of new metacercariae encysting in the fish equals those dying or being destroyed by the host. Hoffman (1967: 177) reported that P. minimum metacercariae persisted at least 4 years in the tissues of fish at 12 C.

Variations in the prevalence of P. minimum in white crappie from the six collection sites (p. 7) varied from 71.0% to 88.8% (Table VII). These differences were not significant. Pooling data from the three deeper (A, B, and E) and more shallow (C, D, and F) areas also revealed no significant differences.

TABLE VII

PREVALENCE AND INTENSITY OF INFECTION WITH POSTHODIPLOSTOMUM MINIMUM IN WHITE CRAPPIE FROM SIX COLLECTION SITES IN LAKE CARL BLACKWELL

Area	Prevalence (%)	Average Intensity
A (Deep)	77.8	13.2
B (Deep)	75.4	9.0
E (Deep Cove)	73.9	36.2
C (Shallow)	71.0	22.9
D (Shallow)	88.8	9.9
F (Shallow Cove)	83.3	17.7

The differences in intensity of infection among the four collection sites are also thought to be not significant. These differences were tested by a rank-correlation test (Kruskall-Wallis; Seigal, 1956: 184-193) and the statistic H was less than chi-square at the 5% level of significance. However, the use of this test with nominal data may invalidate assumptions concerning the distribution of the dependent variable. But since the results of the test were not significant, the apparent error, if any, was increased conservatism in making probability estimates.

Phyllodistomum lacustri (Loewen, 1929)

The genus Phyllodistomum includes distome flukes known to parasitize both marine and freshwater fishes and amphibia. It primarily inhabits the urinary bladder but has also been reported from the hepatic bile duct (Meyer, 1958; in Hoffman, 1967: 129). P. lacustri is apparently host specific and only infects the catfishes of North America. The life cycle for P. lacustri is unknown. It is presumed that an arthropod second intermediate host is utilized and the rout of infection into the definitive host is per os.

Beilfuss (1954) reported the life cycles for P. lohrenzi and P. caudatum. The cercariae of P. lohrenzi develop after two sporocyst generations in Musculium transversum and are eaten by caddisfly larvae (Oecestis spp., Leptocella sp.). The life cycle is completed when the infected trichopteran is eaten by the fish host (Lepomis cyanellus). The first intermediate host of P. caudatum is Musculium elevatum and cercariae may leave the clam or encyst within daughter sporocysts. The fish host (Ictaluras melas) may be infected by eating the clam or presumably by active penetration by free cercariae for no second intermediate host was found by Beilfuss. The life cycle for P. solidum has been given by Olsen (1967: 242). He reported the first intermediate host was the fingernail clam Pisidium; the second are odonatan naiads such as Ischnura and Argia.

P. lacustri was found in 27.5% of the channel catfish examined. The numbers of worms per fish varied from one to five but one or two was the usual number. Sexually mature worms appeared throughout the sampling period. Immature worms occurred only in the samples from February through May, 1968, and in June, 1967. The average number of immature worms (3.7) was slightly higher than the overall average (1.1) indicating some mortality, possibly due to crowding and competition for nutrients in the urinary bladder. A single specimen was recovered from the flathead catfish from a total of 39 fish examined. The low incidence in the flathead could be attributed to their food habits, very few invertebrates appear in the diets of the size groups included in this study.

The difference in the rate of infection between the sexes was not significant (Fisher test). The data did show considerable differences among the different age groups (Table VIII).[4] The immature fish (I and II) were negative for P. lacustri; the maturing and newly matured fish (III and IV) were 17.0% infected; older fish (V and VI) were 37.8% infected; and the oldest group (over VI) were 30.0% infected. The differences among the latter three groups were not significant however.

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[4]Estimates of age only, based on the total length of each fish. The judgements are founded on data of Finnell and Jenkins (1954) given by Miller (1966) for a turbid, old reservoir with greater than 500 acres of surface.

The youngest age group could not be included because of insufficient sample size. When the data for the one through four-year-old fish was pooled the age differences were significant but only at the 10% level for the two-tailed test ($X^2 = 6.18$; where $X^2_{.05,2d.f.} = 5.99$).

TABLE VIII

PREVALENCE OF INFECTION WITH PHYLLODISTOMUM LACUSTRI
IN FOUR AGE GROUPS OF CHANNEL CATFISH
(JUNE, 1967 THROUGH MAY, 1968)

Season	Sex	Percent Infected (Number of Fish)				
		I, II	III, IV	V, VI	Over VI	All Ages
Summer	M	-	50.0(2)	33.3(3)	0 (4)	22.2(9)
	F	0(2)	0 (5)	44.5(9)	20.0(5)	23.8(21)
	T	0(2)	14.3(7)	41.7(12)	11.1(9)	23.3(30)
Fall	M	-	22.2(9)	0 (1)	0 (4)	14.3(14)
	F	0(1)	28.6(7)	40.0(5)	0 (1)	28.6(14)
	T	0(1)	25.0(16)	33.3(6)	0 (5)	21.4(28)
Winter	M	-	33.3(6)	25.0(4)	33.3(9)	31.6(19)
	F	-	0 (6)	16.7(6)	25.0(8)	15.0(20)
	T	-	16.7(12)	20.0(10)	29.4(17)	23.2(39)
Spring	M	-	21.4(14)	40.0(5)	50.0(6)	32.0(25)
	F	-	0 (10)	75.0(4)	45.2(13)	33.3(27)
	T	-	12.5(24)	55.5(9)	47.4(19)	32.7(52)
All Seasons	M	-	25.8(31)	30.8(13)	26.1(23)	26.9(67)
	F	0(3)	7.1(28)	41.7(24)	33.3(27)	25.6(82)
	T	0(3)	17.0(59)	37.8(37)	30.0(50)	26.2(149)

Considering the ontogenic changes in food habits of channel catfish and presuming an arthropod intermediate host in the life cycle of P. lacustri, an explanation for this variance may be found. An increasing number of larger arthropods such as Hexagenia larvae appeared in the diets of these fish with increasing size until a length of about 35 cm was reached. Fish 35 cm and larger characteristically changed to piscivorous feeding habits, although not exclusive of invertebrate food items, until a very large size (several pounds) was attained. The rise and decline in the incidence of this parasite appeared to parallel the usage of benthic macroinvertebrates.

No significant differences could be detected to indicate any seasonal changes in infection rate. The slightly higher value for the spring samples corresponds to the period when immature worms were observed in greatest numbers (Table VIII).

The hypothesis of a difference in incidence of infection between fishes captured from the three upper, shallow areas and the lower, deeper parts of the lake was also tested for _P. lacustri_ but the difference observed was not significant.

Crepidostomum ictaluri (Surber, 1928)

These small distome flukes were rare in occurance and found only in channel catfish. It appeared to show a host preference for male channel catfish. Seven of 67 males were infected while only 1 of 82 females harbored this parasite. The intensity of infection was low (mean was 3). It is difficult to explain the low infection rate of this parasite since both the first (sphaerid clams) and second intermediate hosts (mayfly naiads eg. _Hexagenia_; Hopkins, 1934) are probably abundant in most areas of the lake. _C. ictaluri_ was found in catfish collected during all four seasons and no variation among the seasons was apparent.

Aside from 11 worms recovered from 2 male catfish in shallow water (Area D) during April, these parasites were limited to fishes collected from the deeper areas of the lake (Areas A and B). Assuming the hypothesis of a deep water relationship to be true, the two infected fish collected in the shallow, upper portion of the lake may have migrated there after becoming infected in deeper water. Catfish may be expected to move within the reservoir during the spring in search of suitable spawning sites. However, Norton (1968) showed that the abundance of mayfly naiads was negatively correlated with increasing depth in Lake Carl Blackwell. Craven (1958) found in nearby Boomer Lake (Payne Co.) that Hexagenia, spp. were more abundant in deeper water (4.5 - 5.5 m) in summer and fall, and were more abundant in shallow water (1.8 - 2.7 m) in the winter and spring. The bivalve first intermediate host is probably restricted to the shallow, inshore areas in Lake Carl Blackwell.

If as suspected, the definitive hosts show seasonal and diurnal movement in and out of deep water areas then the distribution of intermediate hosts becomes less limiting in the transmission of this parasite. Apparently, other factors besides transmission must be limiting its success. It has previously been reported only once from the south-central United States (Harms, 1959).

Alloglossidium corti (Lamont, 1921)

Alloglossidium corti was found during only one necropsy. Eleven worms were recovered from the hindgut of a four-year-old female channel catfish from Area A during the winter. It has previously been reported from two separate studies in this region (Harms 1959, 1960; Houghton, 1963).

A. corti may be limited in Lake Carl Blackwell by the scarcity or absence of the pondsnail, *Helisoma*, which according to Crawford (1937) serves as first intermediate host. This mollusc has not been collected in the lake proper although several recoveries have been made from storage ponds in the watershed above the lake. Dragonfly and mayfly naiads, crayfish, and other "small arthropods" may serve as second intermediate hosts (Crawford, 1937; McCoy, 1928, in Crawford, 1937; McMullen, 1935).

Clinostomum marginatum (Rudolphi, 1819)

Only two specimens of *C. marginatum* metacercariae were collected, one each from the largemouth bass and carp. Both specimens were found beneath the integument of the medial surface of the gill cover.

The first intermediate host is the snail *Helisoma* and the definitive host is the great blue heron. The cercariae are probably capable of infecting any North American freshwater fish (Hoffman, 1967). The ecology of this parasite has been examined by Klass (1963) in Kansas. He found a higher incidence in fishes from ponds known to contain *Helisoma* spp. than from those in which the snail could not be found. No relationships could be detected between *C. marginatum* infections, size and abundance of fish or physical features of the ponds.

As with *Alloglossidium corti*, the absence or rarity of *Helisoma* in Lake Carl Blackwell apparently precludes heavy infections of *C. marginatum* in spite of the frequent presence of the definitive host in all seasons. *Helisoma* is abundant elsewhere in the watershed and infected fish from upland ponds may be able to reach the lake during temporary high runoff periods. Metacercariae have been reported to survive for at least two years in the flesh of fish (Hoffman, 1967: 182). Infected snails or cercariae could be transported into the lake in like manner.

Uvuliver amboplites (Hughes, 1927)

Metacercariae of *U. amboplites* were found encysted within the dermis and body muscles of a single bluegill taken from Area E. It also must be considered as only an occasional parasite of Lake Carl Blackwell fishes. The number of metacercariae was high (over 25) in this single host. It therefore appears that it was infected elsewhere and subsequently introduced into this lake. Such an introduction is possible from storage ponds above the lake during high runoff periods. Also, sport fishermen are known to transport and release bait fishes, including some small sunfishes, into the lake which have been captured elsewhere. Sunfishes from farm ponds in Payne County often show the same or similiar metacercariae encysted under the skin of the body and fins.

According to Hoffman (1967: 177) the snail *Helisoma* is the first intermediate host; the definitive host is the belted kingfisher. The metacercariae have been reported from a variety of fishes in North America but it appears to show a host preference for the Centrarchidae.

Cestodaria

Four caryophyllidean tapeworms, which Yamaguti (1959) assigns to the Cestodaria, were collected during this study. *Spartoides wardi* and *Biacetabulum* sp. were collected from the river carpsucker; *Atractolytocestus huronensis* and *Khawia iowensis* were collected from the carp. There is some disagreement as to the separation of these forms from the

Eucestoda which follow (Cheng, 1964; Hoffman, 1967; and others) but to be consistant, the classification is allowed to stand. All four caryophyllaeids exhibited pronounced seasonal variation, occuring principally in the winter samples. The relative lack of occurance during the summer may account for the fact that these four helminths have been infrequently reported from this region (Appendix A). Previous helminthological surveys generally have been conducted during the summer months.

Spartoides wardi Hunter, 1929

These small monozoic tapeworms were recovered only from the foregut of the river carpsucker. They were found in 7.1% of the males and 12.5% of the females. The low incidence in both sexes may be misleading for, like the other caryophyllideans, the incidence of infection appeared to increase substantially in the late fall and winter. Three of the four hosts containing this helminth were collected after mid-December. The infection rate for fish collected during the months from June through November was 3.2% and was 42.8% for fish collected during December and January. Quantatative data was not recorded for fish taken after January but it appeared that the rate of infection diminished during March and April.

The intensity of infection of carpsuckers with S. wardi was quite low for both sexes (Avg. 2.0 for males and 1.7 for females).

The life cycle for this genus is unknown but it may be similiar to other caryophyllideans such as Caryophyllaeus in which the intermediate host is an aquatic oligochaete (Hoffman, 1967). Adults have been reported only from catostomid fishes.

Biacetabulum sp. nov.[5]

Like Spartoides wardi, Biacetabulum was recovered from only the forepart of the intestine of the river carpsucker. The incidence of infection was 21.4% and 8.3% for males and females, respectively. As in infections with Spartoides, the incidence apparently increased during the winter months. Four of the five infected hosts were collected after mid-December. This represented an infection rate of only 3.2% for all fish collected from June through November, and a rate of 57.2% for fish collected in December and January. The number of worms per host remained low (mean 2.0) for infected individuals. The life cycle is unknown. Adults have been reported from both the Cyprinidae and Catostomidae.

Atractolytocestus huronensis Anthony, 1958

These small-to-medium sized monozoic cestodes were found only in the carp, attached to the foregut. The total incidence of infection was 50.0% (the only male examined was positive for this helminth). This relatively high incidence, when compared to caryophyllaeids from the carpsucker, may have resulted from more winter samples (ten) than summer (two). The two fish examined from the summer samples were both negative. Other carp taken during September, for which no data were recorded, were also negative for A. huronensis.

The intensity of infection of A. huronensis was much higher than the other caryophyllaeids; the average number of worms was 16.5 for

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[5]The description for this species is currently being prepared by J. S. Mackiewicz of the University of New York, Albany, and the University of Tennessee, Knoxville.

infected individuals. The life cycle is unknown but adults are apparently restricted to the Cyprinidae.

Khawia iowensis Calentine and Ulmer, 1961.

These medium-sized caryophyllaeids were recovered from the foregut of the carp. Only two fish (females) were found with this helminth for an infection rate of 16.7%. The average intensity of infection was 2.5. Both of these fish were captured during February. Calentine and Ulmer (1961) reported that the heaviest infections of this parasite in carp from Iowa occurred during the summer and fall. The life cycle for this parasite is apparently unknown. Adults have been reported from the carp (Cyprinidae) and the bigmouth buffalo, Ictiobus cyprinellus (Catostomidae; Calentine and Ulmer, 1961), but only from the carp in this region (Appendix A).

Eucestoda

Five taxa of polyzoic tapeworms were found in fishes of Lake Carl Blackwell. The presence of others is probable since a variety of immature forms were recovered.

Proteocephalidea Mola, 1928

Larval proteocephalid tapeworms of uncertain classification were readily recovered from the liver, ovaries and lumen of the intestine and pyloric caecae of the centrarchids and less commonly from the white bass, drum, carp and carpsucker. It has been suggested that all larval proteocephalids from the largemouth bass be considered as Proteocephalus *ambloplites*[6] and those encysted in the viscera of many of the other fishes, especially the centrarchids, are probably *P. ambloplites* as well. Certain facts suggest that at least some of the plerocercoids were not this species however for they lacked the fifth apical sucker and calcareous bodies generally ascribed to it. Without further experimental work it is impossible to ellucidate their identity any closer. It is plausible to consider many of them larval forms of *Corallobothrium* spp. and *Proteocephalus* spp. discussed below.

Some of the plerocercoids found in the intestine of host fishes, such as the largemouth bass, drum, carp and carpsucker, appeared to be far advanced and strobilization had begun. Those from the latter three hosts were considered as *Proteocephalus* sp. based on scolex morphology. However, no adult polyzoic tapeworms were recovered from the above list of fishes.

Corallobothrium spp. Fritsch, 1886

Corallobothrium giganteum and *C. fimbriatum* were both found in the alimentary tracts of flathead and channel catfish. Descriptions for these two species were given by Essex (1928). Hopkins[7], however, has expressed doubts that these two taxa should be separated from each other. He reported that supposed differences in morphology between the two were present in the same or similiar worms from Lake Carl Blackwell,

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[6] Self, J. T. 1967. Dept. Biological Sciences, Oklahoma Univ. Personal communication.

[7] Hopkins, S. H. Texas A & M University, College Station. Personal letter; June, 1968.

and that certain measurements given by Essex were in error. For present purposes, they are considered separate species.

C. fimbriatum was the most prevalent species in the flathead and smaller channel catfish, while C. giganteum was dominant in older channel catfish. The above generalizations apply to mature specimens only. It is impossible to separate immature Corallobothrium with certainty. For this reason both species are treated together in the analysis and discussion. In addition, undifferentiated larval cestodes, which could not be placed in either Corallobothrium or Proteocephalus (discussed below), were occasionally found in these catfishes.

Essex's studies (1927, 1928) of the life cycle of Corallobothrium indicated that various Cyclops spp. could be infected with eggs of either or both C. fimbriatum and C. giganteum. Notropis blennius was found to be a suitable second intermediate host. The Ictaluridae are apparently the only definitive hosts. Essex (1927) reported that the minnows might not be necessary in the transmission of Corallobothrium by showing that catfishes could be infected directly by copepods containing procercoids. Catfish probably do not feed on microcrustacea except as fingerlings, and rely heavily upon small fish in their adult lives, thus establishing the minnow as ecologically, if not biologically, necessary in the natural transmission to catfish.

Corallobothrium spp. were recovered from 88.8% of the flathead catfish and 71.8% of channel catfish. Elsewhere in the southcentral United States, Houghton (1963) reported C. fimbriatum from channel catfish in Lake Fort Smith, Arkansas. Wilson (1957) found C. giganteum in 20% of the channel catfish samples from Leavenworth County State Lake, Kansas. Harms (1959) found both C. fimbriatum and C. giganteum in channel catfish from northeastern Kansas. Sneed reported C. *fimbriatum* from the flathead catfish and *C. fimbriatum* and *C. thompsoni* from the channel catfish in Lake Texoma, Oklahoma. Lawrence and Murphy (1967) reported an infection rate of 52.4% for either or both *C. fimbriatum* and *C. giganteum* in Benbrook Lake, Texas.

Differences in the rate of occurrence of *Corallobothrium* between the sexes of both catfishes from Lake Carl Blackwell were generally slight (Tables III, IX). No significant differences were found between male and female channel catfish after stratifying the data for age, season and depth of capture (Fisher test). Similarily, no significant differences were found between channel catfish collected from the deeper and more shallow portions of the lake (Chi-square test).

The prevalence of infection in channel catfish sharply increased in the fall and continued at a high level through the spring months (Table X). The differences due to these seasonal changes were highly significant ($X^2 = 44.7$; where $X^2_{.01,3d.f.} = 11.3$). The increased prevalence during the fall and winter corresponded to the maturation period of the greatest numbers of *Corallobothrium* spp., indicating an annual life cycle. Large, fully mature specimens were regularily collected during December through February. Fragmentation and apparent loss of these tapeworms was most evident during the late winter and spring. However, the average intensity of infection did not decrease substantially until May. Plerocercoids were evident during all seasons but their numbers were greatest during the fall. Essex (1928) reported that adult *Corallobothrium* were more abundant from spring to fall in Mississippi, Illinois and Rock River channel catfish.

TABLE IX

PREVALENCE OF INFECTION WITH CORALLOBOTHRIUM SPP. IN FOUR AGE GROUPS OF CHANNEL CATFISH FROM LAKE CARL BLACKWELL (JUNE, 1967 THROUGH MAY, 1968)

Season	Sex	Percent Infected (Number of Fish) I, II	III, IV	V, VI	Over VI	All Ages
Summer	M	-	50.0(2)	0 (3)	0 (4)	11.1(9)
	F	50.0(2)	0 (5)	33.3(9)	40.0(5)	28.6(21)
	T	50.0(2)	14.3(7)	25.0(12)	22.2(9)	23.3(30)
Fall	M	-	77.8(9)	100.0(1)	75.0(4)	78.5(14)
	F	100.0(1)	71.4(7)	80.0(5)	0 (1)	71.4(14)
	T	100.0(1)	75.0(16)	83.3(6)	60.0(5)	75.0(28)
Winter	M	-	66.7(6)	75.0(4)	100.0(9)	84.2(19)
	F	-	100.0(6)	83.3(6)	87.5(8)	90.0(20)
	T	-	83.3(12)	80.0(10)	94.1(17)	87.2(39)
Spring	M	-	64.3(14)	100.0(5)	100.0(6)	80.0(25)
	F	-	80.0(10)	100.0(4)	100.0(13)	92.5(27)
	T	-	70.8(24)	100.0(9)	100.0(19)	86.5(52)
All Seasons	M	-	67.7(31)	69.2(13)	78.2(23)	71.6(67)
	F	66.7(3)	67.8(28)	66.7(24)	81.5(27)	72.0(82)
	T	66.7(3)	67.8(59)	67.6(37)	80.0(50)	71.8(149)

TABLE X

SEASONAL CHANGES IN THE PREVALENCE AND INTENSITY OF INFECTION WITH CORALLOBOTHRIUM SPP. IN CHANNEL CATFISH (JUNE, 1967 THROUGH MAY, 1968)

Season	Prevalence (%)	Average Intensity
Summer	23.3	10.0
Fall	75.0	10.0
Winter	87.2	10.8
Spring	86.5	14.0

Bogitsh(1958) reported that both the prevalence and individual size of pseudophyllidean tapeworms in bluegill increased in the winter and spring from summer low values. Similiar results for other tapeworms have been reported by Chubb (1963), Connor (1953) and Haderlie (1953). They also reported that the highest infection rates in fishes were attained just prior to ecdysis and/or the death of these worms. This was generally followed by a period of low prevalence.

The prevalence of Corallobothrium in channel catfish was not significantly affected by the hosts' size (Table IX). However, the intensity of infection did increase with increasing size. Age group I and II averaged 2.0 worms, III and IV averaged 3.8, V and VI averaged 5.4, and fish older then VI averaged 20.9 worms per infected host. No size relationships in either incidence or intensity of infection were apparent with flathead catfish but only two fingerlings and one intermediate sized fish were included in the samples. The majority of flathead catfish examined were large (40 to 80 cm) and probably shared common feeding habits. Thus they should not be expected to differ with respect to their proteocephalid tapeworms, which infect per os.

Proteocephalus Weinland, 1858

Proteocephalid tapeworms, exclusive of those previously discussed, were common in occurrence in both catfishes. They were assigned to the genus Proteocephalus based on scolex morphology. Two different species of Proteocephalus occurred in both catfishes, but their identity is unknown at this time. Species identification was impossible because reproductive structures were not clearly evident, even though strobilization was far advanced in many cases, particularily with those specimens collected from flathead catfish.

Proteocephalus spp. were found throughout the alimentary tracts of these two fishes, but more mature worms were usually found in the posterior half of the intestine. However, as Haderlie (1954) and others have found, considerable migration of large tapeworms occurs when fish are held in captivity or after the death of the host. Like *Corallobothrium*, the first intermediate hosts for *Proteocephalus* are copepods, and the second intermediate hosts are small fishes (Hoffman, 1967: 221).

The intestinal wall, particularily the anterior third, of winter-caught flathead catfish, contained numerous dark-pigmented, nodular lesions. Dissection of the lesions revealed the presence of small (<2 mm) proteocephalid plerocercoids, probably *Proteocephalus* sp. Although these worms were not demonstrated *in situ* in stained sections, their presence between lamina propria and submucosa was indicated by a formed space there, sometimes filled with red blood cells. The lesions were composed mostly of fibrous connective tissue. Quantatative data were not recorded but these lesions appeared from January through March. About 80% of the flathead showed lesions during this period, and the average number of lesions was about 20.

The rates of infection of *Proteocephalus* spp. were 26.8% for channel catfish and 77.8% for flathead. The differences between these two fishes may possibly result from differences in food habits. Large channel catfish, which presumably are piscivorous, had a slightly higher rate of infection then smaller channel catfish, which feed primarily on invertebrates (Table XI). Flathead, of the sizes included in this study, are piscivorous.

TABLE XI

PREVALENCE OF INFECTION WITH PROTEOCEPHALUS SPP.
IN FOUR AGE GROUPS OF CHANNEL CATFISH
(JUNE, 1967 THROUGH MAY, 1968)

Season	Sex	Percent Infected (Number of Fish)				
		I, II	III, IV	V, VI	Over VI	All Ages
Summer	M	-	0 (2)	0 (3)	25.0(4)	11.1(9)
	F	0(2)	60.0(5)	44.4(9)	20.0(5)	38.1(21)
	T	0(2)	42.8(7)	33.3(12)	22.2(9)	30.0(30)
Fall	M	-	11.1(9)	0 (1)	50.0(4)	21.4(14)
	F	0(1)	0 (7)	60.0(5)	0 (1)	21.4(14)
	T	0(1)	6.2(16)	50.0(6)	40.0(5)	21.4(28)
Winter	M	-	16.7(6)	0 (4)	44.4(9)	26.3(19)
	F	-	50.0(6)	33.3(6)	50.0(8)	45.0(20)
	T	-	33.3(12)	20.0(10)	47.1(17)	35.9(39)
Spring	M	-	14.3(14)	20.0(5)	16.7(6)	16.0(25)
	F	-	30.0(10)	25.0(4)	23.1(13)	25.9(27)
	T	-	20.8(24)	22.2(9)	21.0(19)	21.2(52)
All Seasons	M	-	12.9(31)	7.7(13)	34.8(23)	19.4(67)
	F	0(3)	32.1(28)	41.6(24)	29.6(27)	32.9(82)
	T	0(3)	22.0(59)	29.7(37)	32.0(50)	26.8(149)

The differences in infection rate between the sexes of channel catfish (Table XI) were found to be not significant after stratifying the data for age and season. Similarily, the rate of infection did not vary significantly among channel catfish from the six different collection sites. The general increases found in the prevalence of *Proteocephalus* with increasing age of channel catfish were not significant. The average number of worms in fish older than six (5.4) was about double that observed in fish six years and younger.

Bothriocephalus sp. Rudolphi, 1808

A single immature specimen of Bothriocephalus sp. was recovered from a male longear sunfish. This parasite may be more widespread than the present study indicates as two additional infected sunfishes (bluegill, longear) were observed in the spring. No quantatative data are available for these two hosts however. The first intermediate host is a copepod and Hoffman (1967) states that small fish may act as "carriers." Presumably this means that they serve as paratenic or transfer hosts and that development within these fishes is limited. Adults have been described from a variety of fishes.

Nematoda

The nematodes were the most abundant and widespread endoparasites found in this study, both in kinds and numbers. Ten distinct species from seven genera were found. In addition three other taxa, all immature, were collected but remain unidentified. The nematodes showed the least host specificity of the major groups of helminths.

Contracaecum spiculigerum (Rudolphi, 1809)

These relatively large ascarids were recovered from both catfishes and all the centrarchids except the longear sunfish. Also they were occasionally found in the larger drum, the carpsucker and the white bass. All were immature and were found encysted within the mesenteries or beneath the serosa surrounding the gut. It is therefore evident that Contracaecum possesses little host specificity, although host preference was evident as seen by the wide difference in the prevalence and intensity of infection (Table XII). Although positive identification was impossible with specimens from all the hosts, it is likely that they are all *C. spiculigerum*.

TABLE XII

PREVALENCE AND INTENSITY OF INFECTION WITH *CONTRACACUM SPICULIGERUM* IN FISHES OF LAKE CARL BLACKWELL

Host	Prevalence (%)			Average Intensity		
	M	F	T	M	F	T
Flathead catfish	77.0	73.9	75.0	4.2	8.6	7.0
Channel catfish	26.9	19.5	22.8	1.8	3.4	2.5
Largemouth bass	100.0	89.9	93.5	8.3	6.4	7.2
White crappie	9.2	13.0	11.4	1.4	1.4	1.4
Bluegill	20.0	0	5.4	2.0	0	2.0
Drum	0	19.0	13.3	0	4.0	4.0
River carpsucker	7.1	0	2.6	2.0	0	2.0
White bass	0	8.7	5.1	0	1.0	1.0

C. spiculigerum is a cosmopolitan species and adults have been reported in many piscivorous birds including gulls, mergansers, pelicans and cormorants (Hoffman, 1967). According to Thomas (1937), small fish are the first and apparently the only intermediate hosts although, as shown below, larger predatory fishes may serve as transfer hosts.

Thomas found that the larvae underwent two molts within the egg and that third-stage larvae, upon hatching, were infective to small fishes which ate them. It has been proposed by Olsen (1967) that natural transmission occurs when various small fishes eat the infective larvae (which migrate through the gut wall and encyst or become encapsulated within the mesenteries). Larger, predatory fishes become infected when they eat these small fish, and the definitive host receives the infection upon eating either of these hosts, provided the larvae are sufficiently developed. The larvae apparently undergo no maturation in the second fish and so this host suitably fits the description of a paratenic host as proposed by Baer (1952: 12).

The rate and intensity of infection was observed to be positively correlated with the size of the individual fish. This is somewhat unexpected because smaller fish would be most likely to receive the primary infection due to their feeding habits and thus should exhibit high infection rates. Small fish of the species examined in this study were apparently refractile to infection by the free-living larvae of C. spiculigerum, while older members of the same species were commonly infected, apparently the result of eating encysted larvae within food fishes. For example, they rarely were observed in the smaller-sized catfish or centrarchids while larger fish often harbored many individuals. This increased prevalence of C. spiculigerum with increasing host-size was seen both among and within the various host species.

Interspecies variation was strongly suggestive of a positive host-size correlation with the prevalence and intensity of infection (Table XII). The flathead catfish sampled were consistantly larger than most channel catfish and had a higher incidence of infection at 75.0%. Channel catfish were only 22.8% infected. Largemouth bass, the largest centrarchid examined, were 93.5% infected; white crappie, a medium to small-sized fish, were 13.5% infected; and the smaller bluegill were only 5.4% infected. Longear sunfish, the smallest centrarchid, did not contain any of these worms.

Intraspecies variation observed in both catfishes, the largemouth bass and the crappie showed a similiar relationship. Bass less than 400 g generally contained fewer than 5 worms, while those greater than this size contained as many as 47 (Figure 3). Although it is doubtful that the intensity of infection is actually linearly related with size in any host species, the regression line was computed for largemouth bass because the data tend toward a straight-line relationship. It indicates that the expected number of worms in largemouth bass from Lake Carl Blackwell is equal to 1.50 plus 0.7676 times the weight of the fish in hundreds of grams. For comparative purposes, estimates of the regression line for the two catfishes are also shown in Figure 3.

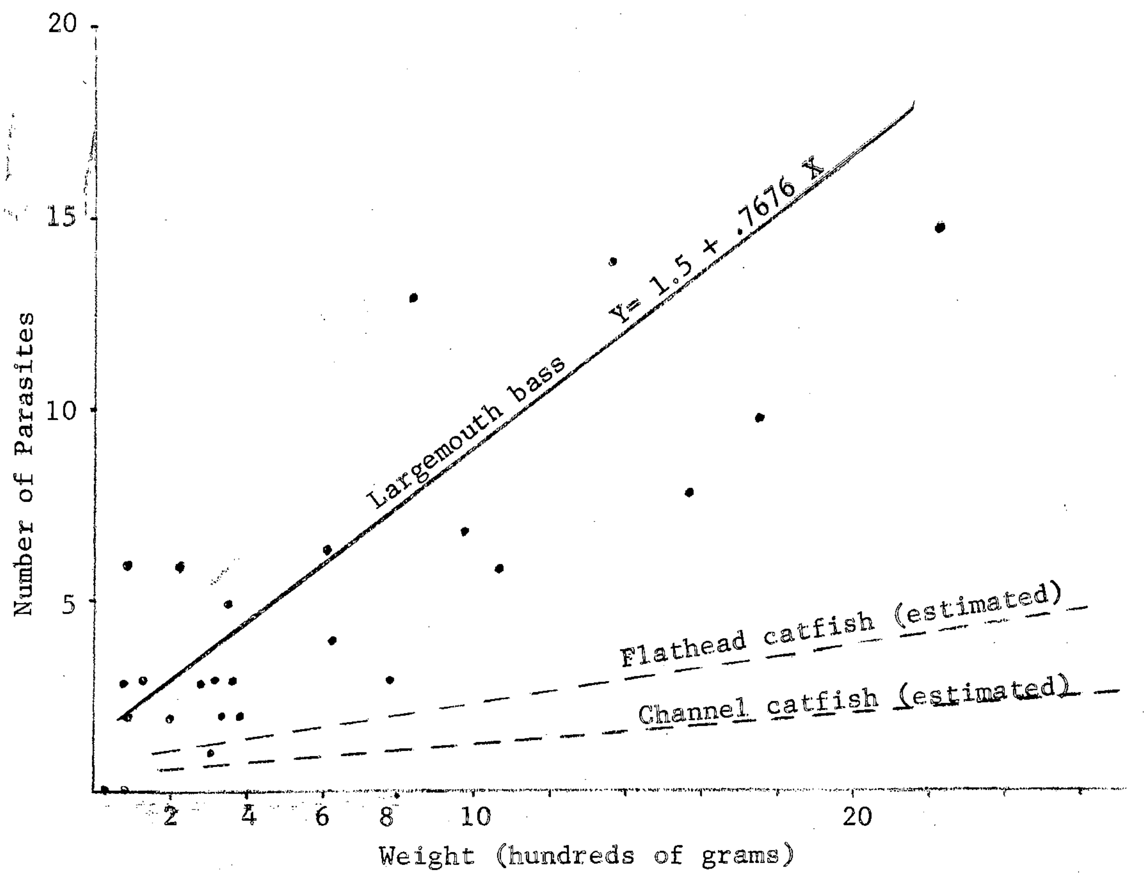

Figure 3. Relationship of Numbers of Contracaecum and Body Weight of Three Host Fishes.

Further evidence for a positive correlation between the rate and severity of infection and the size or age of the host is seen in the data for white crappie, flathead and channel catfish (Table XIII). The prevalence of infection increased substantially in older white crappie and channel catfish. The differences observed in the rate of infection was not significant for white crappie but was highly significant for channel catfish ($X^2 = 15.2$; where $X^2_{.01,3d.f.} = 11.3$).

TABLE XIII

PREVALENCE AND INTENSITY OF INFECTION WITH *CONTRACAECUM SPICULIGERUM* IN VARIOUS AGE CLASSES OF SELECTED FISHES FROM LAKE CARL BLACKWELL

Percent and No. of Fish Examined (Mean No. Parasites)			
	WHITE CRAPPIE[1]		
I and II	III	IV and V	VI and Older
9.3 of 43 (1.5)	8.6 of 70 (1.2)	11.8 of 51 (1.5)	33.3 of 12 (1.5)
	LARGEMOUTH BASS[1]		
0 and I	II	III and IV	V and VI
71.4 of 7 (3.6)	100.0 of 8 (3.3)	90.0 of 10 (9.4)	100.0 of 6 (13.0)
	FLATHEAD CATFISH[2]		
III and Younger	IV	V	VI and Older
62.5 of 8 (4.0)	100.0 of 10 (7.6)	54.5 of 11 (7.2)	85.7 of 7 (8.2)
	CHANNEL CATFISH[3]		
I and II	III and IV	V and VI	Over VI
0 of 3 (0)	15.3 of 59 (1.2)	16.2 of 37 (1.3)	42.0 of 50 (3.3)

[1]Age determined by scale analysis.

[2]Age estimated from data of Houser and Bross (1963).

[3]Age estimated from data of Finnell and Jenkins (1954) in Miller (1967).

The rate of infection did not increase in a similiar fashion for the bass and flathead but remained high for all age classes, reflecting a change to piscivorous food habits at a very young age. On the other hand, the crappie and channel catfish do not begin eating small fishes until their fourth and fifth years of life and appropriately the data show that few fish of either species less than four years are infected with C. spiculigerum

The higher incidence of C. spiculigerum in large fish appears to reflect a transfer of infective larvae through the food chain of these predatory fishes. Large, non-predatory fish such as the carp or carpsucker were only rarely infected or not at all. The accumulation of high numbers of this nematode in older fish appears to indicate that it is long-lived in the fish intermediate host. Since the definitive hosts would be limited to eating smaller fish, the accumulation of this nematode in larger fish has no apparent adaptive value for its transmission to the final host.

The size and appearance of cysts, and the viability of the worms within, appeared to greatly differ within and between the various hosts, indicating a degree of senility in older infections. Some were observed to be only weakly encysted and contained very active worms; others were heavily covered with a dark, nodular, fibrous capsule and contained lifeless worms much reduced in size. This latter condition was particularily evident in older fish.

The hypothesis of a difference in the incidence of infection between the sexes was tested (Fisher test) for C. spiculigerum in channel catfish after stratifying the fish by age and season. No significant differences could be detected, although data in the younger age groups were scanty because, as shown above, this worm rarely occurred in the smaller fish. Chi-square analysis did not reveal any significant differences in the incidence of infection among the different sampling areas which cannot be explained in terms of the host's size. Also, no significant seasonal differences could be detected at the 5% level.

Camallanus oxycephalus Ward and Magath, 1916

These small-to-medium sized spirurids were taken from both catfishes, drum and white bass, and all the centrarchids except the bluegill.[8] Both immature and adult specimens were regularily recovered from white crappie, even from the same fish. They were found both free in the lumen of the gut and attached to the mucosa. This species is viviparous and sexually mature, larvae-bearing females were generally recovered more posterior in the alimentary tract than immature or male worms. Mature females were frequently observed protruding from the anus. Female worms appeared to outnumber males in all hosts examined which suggests either a differential or an earlier mortality such as seen with the nematode Trichinella spiralis in man and swine. Hoffman (1967: 253) lists copepods and possibly other crustacea as intermediate hosts.

C. oxycephalus appears to have an annual life cycle. Although maturation was rarely completely uniform in any population or season, the majority of mature females occurred during the spring and early summer, while those individuals recovered during the fall and winter were largely immature. This maturity coincided somehwat with the

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[8]Recent collections of bluegill from Lake Carl Blackwell show them to also be infected with Camallanus oxycephalus.

sexual cycle of the host; female worms were observed to gradually increase in size through the spring, the uteri becoming filled with eggs during April, and these eggs hatching in utero during May. Larvated females were observed to remain throughout the summer but their numbers became fewer after July. Tornquist (1931; in Dogiel, et al., 1961: 16) reported an annual life cycle for C. lacustris.

Except for white crappie, all host species did show a slightly higher incidence of infection in males (Table XIV). The difference between the sexes was not significant in crappie and channel catfish after stratifying the fish collections by age, locality and season.

TABLE XIV

PREVALENCE AND INTENSITY OF INFECTION WITH CAMALLANUS OXYCEPHALUS IN LAKE CARL BLACKWELL FISHES

Host	Prevalence (%)			Average Intensity		
	M	F	T	M	F	T
Channel catfish	17.9	17.1	17.4	1.8	2.8	2.3
Flathead catfish	23.1	4.3	11.1	1.3	1.0	1.2
White crappie	64.5	66.0	65.4	3.6	3.4	3.5
Largemouth bass	30.8	22.2	25.8	6.8	7.8	7.2
Longear sunfish	41.7	7.1	23.1	1.2	1.0	1.2
Drum	11.1	4.8	6.7	1.0	1.0	1.0
White bass	56.3	47.8	51.3	3.9	4.9	4.5

The incidence of C. oxycephalus in fishes collected from the upper, shallow areas did not vary significantly from those caught from the deeper parts of the lake when the variables of age and season were held constant. Data from both sexes and all areas was combined and the influence of the host's age or size on the incidence of infection was tested for both white crappie and channel catfish (Table XV). No significant differences could be found for white crappie but the incidence of C. oxycephalus in channel catfish did vary significantly among three selected age groups ($X^2 = 10.01$; where $X^2_{.01, 2d.f.} = 9.21$). The winter and spring samples (combined) seemingly contributed the greatest amount to this significance ($X^2 = 9.37$). The percent infection for these age groups of catfish was respectively 6.5%, 18.9% and 30.0%. Fish sampled during the summer and fall showed no significant difference due to increasing age in the rate of C. oxycephalus infections.

TABLE XV

PREVALENCE AND INTENSITY OF INFECTION WITH CAMALLANUS OXYCEPHALUS IN VARIOUS AGE GROUPS OF WHITE CRAPPIE AND CHANNEL CATFISH

Season	Percent and No. of Fish Examined (Mean No. Parasites)			
	WHITE CRAPPIE			
	I and II	III	IV and Older	All Ages
Summer-Fall	68.0 of 25 (3.1)	61.3 of 31 (2.7)	57.1 of 21 (4.0)	62.3 of 77 (3.2)
Winter-Spring	50.0 of 18 (2.1)	61.6 of 39 (2.6)	76.2 of 42 (5.4)	65.7 of 99 (2.6)
All Seasons	60.4 of 43	61.5 of 70	69.8 of 63	64.2 of 176
	CHANNEL CATFISH			
	IV and Younger	V and VI	Over VI	All Ages
Summer-Fall	7.7 of 26 (1.0)	5.6 of 18 (3.0)	21.4 of 14 (2.0)	10.3 of 58 (2.0)
Winter-Spring	5.6 of 36 (2.0)	31.6 of 19 (1.3)	33.3 of 36 (3.2)	22.0 of 91 (2.1)
All Seasons	6.5 of 62 (1.7)	18.9 of 37 (1.6)	30.0 of 50 (2.9)	17.5 of 149 (2.4)

The reasons for an increase in the infection rate in older catfish, but not in the crappie was apparently due to differences in their food habits. White crappie were observed to utilize copepods to a high degree, especially in the colder months, whereas the catfish apparently fed little on these microcrustacea. The diets of one through four-year-old catfish consisted primarily of macroinvertebrates, whereas fish in the older age classes were piscivorous. If C. oxycephalus is aided in its transmission by a paratenic host, as has been suggested for Camallanus spp. by Kupriyanova (1954; in Dogiel, et al., 1961: 162), then crappie probably become infected by eating infected copepods (the first intermediate host) and catfish by eating small fish (the paratenic host). Crappie eat copepods intermittently during all their first four or five years of life; thus the rate of infection should remain high and not vary significantly within these age classes. On the other hand, channel catfish, beyond the fingerling stage, eat few copepods but do not begin to consume small fish until after their fourth or fifth year of life (35 cm). Thus they should show an increase in the incidence of infection at this point. Crappie older than five or six years are also primarily piscivorous.

These same two fishes were tested for differences in the infection rate for C. oxycephalus due to season. A greater percentage of winter-caught catfish were infected than those caught during other seasons (due to the December sample). These differences were not significant, however. Catfish collected in May (1968) and June (1967) were not infected at all (Figure 4).[9] This absence is perhaps related to gonadal

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[9] Sampling through June, 1968, indicated a continued absence of C. oxycephalus in channel catfish until June 28.

development of the catfish and the onset of reproduction which occurs at this time. However, no influence of this type was noted in crappie at their time of spawning. Sadun (1948) found that moderate doses of sex hormones (testosterone propionate, alpha-estradiol) in immature male and female chickens increased their natural resistance against the establishment of the nematode Ascaridia galli. He expressed the opinion that gonadal hormones may be related to antibody release via the pituitary-/adrenal cortex-/lymphocyte chain of action. The absence of infection in catfish during June, 1967, and May, 1968, may simply be the result of annual mortality; however no similiar phenomena or significant seasonal differences were seen in the white crappie.

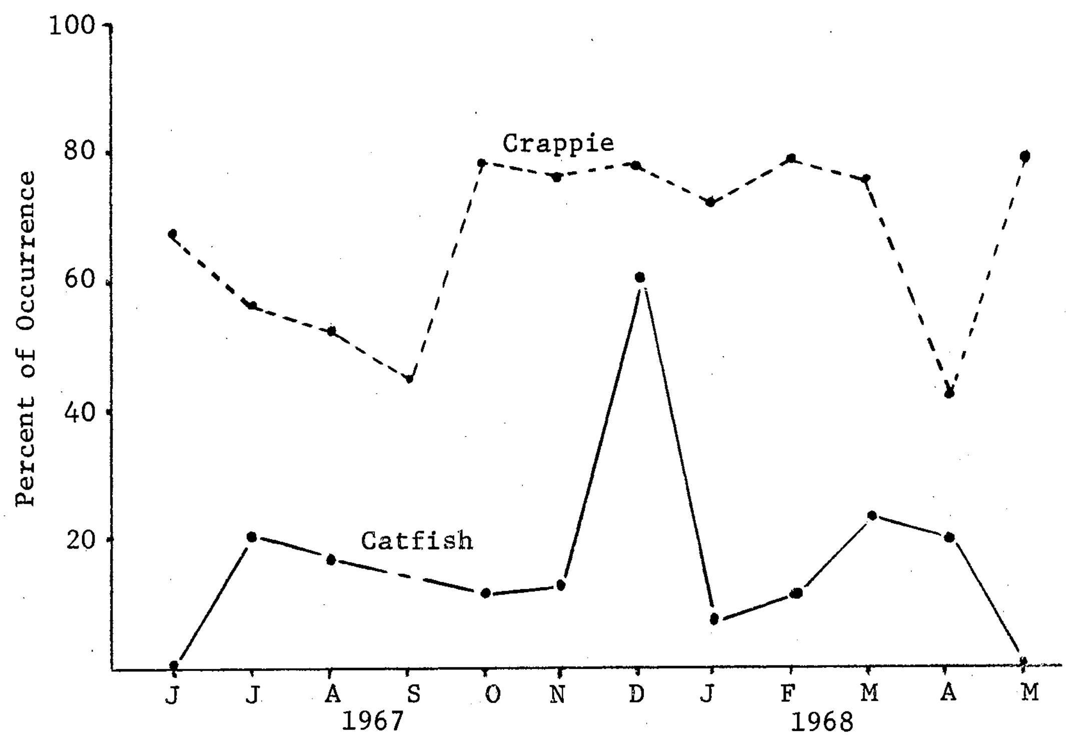

Figure 4. Monthly Variation in the Prevalance of Camallanus oxycephalus in Channel Catfish and White Crappie.

Camallanus ancylodirus Ward and Magath, 1916

Three specimens of C. ancylodirus were collected from a single female carp. These resembled C. oxycephalus but were distinguished by possessing a recurved anterior end, by being somewhat longer and wider, and by possessing a thicker cuticle. The life cycle is probably similiar to that described for C. oxycephalus. This parasite apparently has a preference for cyprinid and catostomid fishes. It has previously been reported from this region in fishes from Lake Texoma (Bynum, 1951; Roberts, 1957; Self and Campbell, 1956).

Rhabdochona cascadilla Wigdor, 1918, and R. decaturensis Gustafson, 1949

The Rhabdochona spp. showed the least host specificity of any helminths recovered in this study, although host preferences were indicated for channel catfish, freshwater drum and winter-caught carp (Table XVI). These apparent host preferences may be due to the feeding behavior of these fishes rather than to physiological mechanisms. These three fishes were observed to commonly feed on the intermediate host, Hexagenia sp. The gizzard shad was the only fish included in this study not found to be infected with Rhabdochona spp.

R. decaturensis were recovered from the intestine of all four centrarchids, both catfishes, white bass, river carpsucker, carp and freshwater drum. R. cascadilla was only rarely recovered from a single host species, white crappie. The above list of fishes, except for channel catfish and the freshwater drum, all represent new host records for R. decaturensis. This is also the first report of this species from the southcentral United States. R. cascadilla has previously been reported from a variety of hosts elsewhere but only once from this region, in white bass (Bynum, 1951). Female R. decaturensis were smaller in the carp and carpsucker and egg maturation was not observed to be as advanced as in the other hosts. This may be a reflection of the season in which they were collected (winter) rather than an indication of the inability to mature in these two fishes. Males were of a similiar size as those observed in the other hosts and possessed the long left spicule (about 850 μ) characteristic of this species. For purposes of analysis, R. cascadilla and R. decaturensis are considered as one in the white crappie where they occur together.

TABLE XVI

PREVALENCE AND INTENSITY OF INFECTION WITH RHABDOCHONA SPP. IN LAKE CARL BLACKWELL FISHES

Host	Prevalence (%)			Average Intensity		
	M	F	T	M	F	T
Channel catfish	47.8	56.2	52.4	4.8	4.6	4.7
Flathead catfish	7.7	0	2.8	23.0	0	23.0
White crappie	11.8	13.0	12.5	1.7	2.5	2.2
Bluegill	10.0	11.1	10.6	1.0	4.0	3.3
Largemouth bass	0	16.7	9.7	0	3.0	3.0
Longear sunfish	0	28.6	15.8	0	1.8	1.8
River carpsucker	7.1	4.2	5.3	1.0	7.0	4.0
Carp	100.0	72.7	75.0	19.0	28.9	27.8
Drum	66.7	80.9	76.7	25.2	16.4	18.7
White bass	12.5	30.4	23.0	5.5	1.9	2.7

After stratifying the fish for age or size and season, the hypothesis of a difference in infection rate between the sexes of both white crappie and channel catfish was tested. A single significant value was obtained for the cell containing catfish older then age VI collected during the spring months (p= .049). In this particular case females showed the higher incidence of infection. This disparity probably should be ignored as no other significant cells could be detected.

The effects of the hosts' habitat on the incidence of infection were also tested. To increase sample size, the three upper areas (C, D, F) were grouped together as were the three lower areas (A, B, E). No significant values between upper and lower were found for either channel catfish or white crappie. Fish collected from coves (E, F) also did not vary significantly in the rate of infection with Rhabdochona from those collected from the central pool of the reservoir (A, B, C, D).

It appears that the overall effects of season on the establishment of Rhabdochona in fishes of this lake is negligable. No significant seasonal changes were detected in either channel catfish or crappie. However, in channel catfish the incidence decreased with increasing host size, and differences were significant for the one-tailed test ($X^2 = 6.65$; where $X^2_{.05, 2d.f.} = 5.99$). This difference was most evident during the winter and spring months ($X^2 = 7.62$); the summer and fall collections (combined) were found to be not significant. The data does not show a similiar decrease in white crappie (Table XVII).

The inverse relationship between prevalence of infection and host size may be explained by considering the feeding habits of channel catfish. Mayfly nymphs (Hexagenia sp.) have been described by Gustafson (1949) as the intermediate hosts of Rhabdochona spp. Smaller catfish are largely benthophagous and feed heavily on these forms, whereas fish larger than 35 cm are primarily piscivorous. Burrowing mayfly larvae are widespread throughout the lake in the bottom sediments (Norton, 1968). Why this inverse relationship is most prominent in the winter and spring is unknown. It might be speculated that a seasonal increase in gonadatropic hormones in mature fishes works to the disadvantage of the parasite. Immature fish could not affect their parasites in this manner.

TABLE XVII

PREVALENCE AND INTENSITY OF INFECTION WITH RHABDOCHONA SPP. IN VARIOUS AGE CLASSES OF WHITE CRAPPIE AND CHANNEL CATFISH

Season	Percent and No. of Fish Examined (Mean No. Parasites)				
			WHITE CRAPPIE		
	I and II	III	IV and V	VI and Older	All Ages
Summer-Fall	12.0 of 25 (1.3)	6.5 of 31 (1.0)	5.6 of 18 (1.0)	33.3 of 3 (3.0)	9.1 of 77 (1.5)
Winter-Spring	16.7 of 18 (2.3)	7.7 of 39 (2.0)	18.2 of 33 (3.3)	33.3 of 9 (1.7)	15.2 of 99 (2.6)
Combined	13.9 of 43 (1.8)	7.1 of 70 (1.8)	13.7 of 51 (3.0)	33.3 of 12 (2.0)	12.5 of 176 (2.1)
			CHANNEL CATFISH		
	I and II	III and IV	V and VI	Over VI	All Ages
Summer-Fall	66.7 of 3 (4.1)	52.2 of 23 (9.2)	55.6 of 18 (3.4)	42.8 of 14 (4.0)	51.7 of 58 (5.9)
Winter-Spring	-	66.7 of 36 (4.7)	63.2 of 19 (3.3)	36.1 of 36 (2.7)	53.8 of 91 (3.8)
Combined	66.7 of 3 (4.1)	61.0 of 59 (6.2)	59.5 of 37 (3.4)	38.0 of 50 (3.1)	53.0 of 149 (4.6)

The benthophagous feeding habits of the carp and freshwater drum, especially the smaller drum, might explain the high incidence and intensity of infection of Rhabdochona spp. in these fishes. Predatory fishes such as the flathead catfish, largemouth and white bass showed a lower rate and intensity of infection.

Spinitectus carolini Holl, 1928 and S. gracilis Ward and Magath, 1916

These small spirurids also showed low host specificity. Spinitectus gracilis was found in the white crappie and drum. S. carolini was recovered from the channel catfish, bluegill, longear sunfish and probably from the freshwater drum. Immature Spinitectus sp. were found in the flathead catfish (Table XVIII). It is likely that these two species occur together in at least some of the fishes, but owing to their small size and gross similarities, the necropsy techniques employed failed to distinguish them. Spinitectus spp. were recovered primarily from the lumen of the gut but occasionally they were found in the parenchyma of the liver. Like Rhabdochona, the intermediate hosts are mayfly larvae (Hoffman, 1967: 262).

TABLE XVIII

PREVALENCE AND INTENSITY OF INFECTION WITH SPINITECTUS SPP. IN LAKE CARL BLACKWELL FISHES

Host	Prevalence (%)			Average Intensity		
	M	F	T	M	F	T
Flathead catfish	7.7	0	2.8	1.0	0	1.0
Channel catfish	14.9	18.3	16.8	1.9	2.0	1.9
White crappie	3.9	6.0	5.1	1.0	1.3	1.2
Bluegill	50.0	40.8	43.3	1.8	1.8	1.8
Longear sunfish	0	21.4	11.5	0	1.7	1.7
Drum	11.1	9.5	10.0	1.0	2.5	2.0

Spinitectus sp. has apparently not been recovered previously from the flathead catfish and so this finding represents a new host record. However, it appears from the low occurrence and immature condition of the specimen that this fish is an abnormal host. Also, flathead do not normally feed on mayfly nymphs, except possibly as fingerlings, and so the chance of becoming infected is probably slight. *S. carolini* has previously been reported in a number of studies from this region while *S. gracilis* has been less commonly found (Appendix A). This study reports a new locality record for *S. gracilis* for the two hosts, white crappie and freshwater drum.

The extent of the infections with *Spinitectus* were generally quite limited except in the bluegill where 50.0% of the males and 40.8% of the females experienced an infection. The incidence of infection did not vary significantly with sex in either the channel catfish or white crappie. Similarily, the analysis showed no significant differences in the incidence of infection between the upper and lower areas of the lake, or among the various age groups, or among the seasons in either of these fishes.

Spiroxys sp. Schneider, 1866

These spirurids were only rarely recovered as larvae from the intestinal serosa and mesenteries of the channel catfish, largemouth bass, river carpsucker and white crappie. In all but the carpsucker only males were infected. *Spiroxys* sp. may be more widespread than this study indicates because, owing to its small size and location in the host, it may be frequently overlooked. The definitive hosts are turtles (*Pseudemys*, *Chrysemys*); the first intermediate hosts (experimental) are given as the copepod (Cyclops spp. and others). Amphibians (Rana, Trituris), dragonfly naiads and others may serve as alternate second intermediate hosts for S. contortus (Hedrick, 1935). Spiroxys sp. has not previously been reported from the southcentral United States.

Dacnitoides (Neocucullanus) robusta Van Cleave and Mueller, 1932

This short, relatively stout spirurid was found only in the channel catfish and only in fish sampled from the deeper portion of the reservoir. Further, except for a single specimen recovered in October all the worms were found in June and July. The disappearance of this worm after the summer months is difficult to explain. The life cycle is unknown but presumably an arthropod intermediate host is required. This helminth had not reappeared in the spring samples but two small, apparently immature, worms were collected on June 3, 1968, in a female catfish from Area A.[10] Because of its limited nature no analysis could be made concerning differences in intensity or rate of infection due to age or sex. Of the seven fish infected, five were females. The average parasite count was also slightly higher in females. All age groups were infected.

This species has been previously reported twice (as Dichelyne robusta) from the southcentral United States, (Harms, 1959; Lawrence and Murphy, 1967). Both reports were for channel catfish. In addition, Chandler (1935) reported this species from fish of the Texas Gulf Coast.

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[10]Continued sampling through June, 1968, indicated a high rate of infection of D. robusta in channel catfish from Areas A and E.

Philometra nodulosa Thomas, 1929

A single specimen was recovered from the inner opercle of a largemouth bass. The intermediate host is the copepod *Cyclops* (Thomas, 1929). *P. nodulosa* has been previously reported once from this region. This record was also from largemouth bass (Lawrence and Murphy, 1967).

Nematodes of Uncertain Classification

Certain larval nematodes occasionally appeared in the samples from a disparant list of hosts. One very small form, recognized as being in the Order Ascaroidea by the three prominent lips, was recovered from the intestinal wall, liver and other viscera of gizzard shad, river carpsucker, white bass and white crappie. This ascarid was rare in occurrence in all host species.

A single channel catfish had three small larval spirurids coiled and encysted in the liver. These were removed by partial pepsin digestion and were unlike other worms found in this study. Another apparent spirurid was recovered from the white crappie.

Acanthocephala

A single specimen of an acanthocephalan was found in this study and they must therefore be regarded as rare in Lake Carl Blackwell fishes. This specimen, *Leptorhynchoides thecatus*, was found in a male channel catfish from Area A. The variety of fishes and suitable intermediate hosts (copepods, amphipods, ostracods) in the reservoir would seem to favor the success of the Acanthocephala. It seems necessary to conduct further surveys to discover what factors limit the survival of these worms.

Interspecific antagonism may have limited the Acanthocephala because of the high incidence and intensity of certain nematodes and cestodes in fishes from this reservoir. Scheuring (1923; in Dogiel, et al., 1961: 47) reported that acanthocephalans were usually absent from the intestines of fish severely infected with the pseudophyllidean cestode Triaenophorus nodulosus. Cross (1933, 1934) found an antagonistic relationship between tapeworms and acanthocephalans in fish of northern Wisconsin. Holmes (1959) reported a possible mechanism of antagonism between acanthocephalans and tapeworms in rats. He found that Hymenolepis diminuta and Moniliformis dubius competed with one another for carbohydrates in the gut of the host.

Seven acanthocephalans have previously been reported from the southcentral region (Appendix A). They were generally reported as being fairly abundant in these surveys. Neochinorhynchus cylindratus appears to be the most widespread. These records of Acanthocephala are comparable with other geographic regions in North America.

CHAPTER IV

SUMMARY

The incidence and intensity of infection of fishes with helminth parasites varied considerably among the different hosts. These variables were discussed in conjunction with each helminth species. The relationship of age or size, sex, food habits, season and area of capture of the host to their helminthocenoses is summarized below. It appears that the age of the host and season of the year are far more important in determining the helminthocenoses of fishes from this warm, turbid reservoir than the variable of sex or locality of capture. It was assumed that any population of helminths is independent of the presence or density of other species in the same host. This assumption may be erroneous because the progressive and regressive influences that helminths have on each other may markedly limit or enhance one another's success. This was suggested as a possible factor limiting the Acanthocephala in Lake Carl Blackwell fishes.

Influence of Gross Habitat Differences

Certain habitat features common to the lake such as high turbidity and the absence of aquatic macrophytes probably limited many of the Trematoda. On the other hand, features attendant to constant circulation of the water mass, such as a lack of thermal stratification and oxygen depletion in the bottom water, may have appreciably enhanced the success of the Nematoda by insuring the success of their aerobic intermediate hosts. Also, continuous mixing seemingly would aid continuing success of planktonic crustacea and consequently proteocephalid tapeworms by transporting a constant supply of nutrients to the euphotic zone at all times rather than seasonally as seen in dimictic lakes of temperate North America. Pearse (1924, as reported by Holl, 1932) found that a stratified Wisconsin lake, Lake Mendota, had fewer species of parasites than Lake Pepin, a sandy bottomed, warm water lake which did not stratify. Pearse also reported that greater diversity in habitats of Lake Michigan resulted in the greatest overall percentage of helminth parasitism in its fishes.

Alloglossidium corti were recovered only from the deeper part of the lake. Van Cleave and Mueller (1934) also found A. corti to be limited to fishes from deeper water. Van Cleave and Mueller also found, as was shown by this study, that the occurrence of Clinostomum marginatum and Uvulifer (Neascus) ambloplites was related to areas having a protected shoreline.

The variation in abundance of helminths with a high prevalence, such as Posthodiplostomum minimum, Contracaecum spiculigerum, and Corallobothrium spp., was not related to characteristics of the habitat. Perhaps the selected sampling areas did not differ enough, to have appreciable effect on the helminthocenoses of fishes. The channel catfish and white crappie which were selected for analysis of differences in infection due to habitat changes, were apparently sufficiently mobile to mask any habitat differences which may actually occur. Van Cleave and Mueller found Corallobothrium fimbriatum to have a general distribution in Oneida Lake. The local distribution of intermediate hosts probably has an added influence on the success and range of helminth parasites. The habitat of many of the intermediate hosts may be more homogeneous than one might expect from looking at the gross habitat differences. Their chances of success may be nearly equal throughout the lake, thus assuring a relatively uniform distribution of many of the helminths.

Influence of the Host's Size or Age

The age of the host appears to have far-reaching effects on parasitism in natural infections. Physiological and immunological changes in fishes resulting from the aging process appeared to influence their helminthocenoses. The most obvious changes of this nature are those associated with gonadal development and sexual maturity. However, data from this survey seem to show that ontogenic changes in the feeding behavior of the host are perhaps even more important. The most striking changes in the abundance of helminth parasites occurred in fish which changed from an invertebrate to a vertebrate (fish) diet such as the basses and catfish. The carp and carpsucker, although attaining large size, showed little dietary changes throughout their lives and likewise showed little ontogenic diversity in their helminth fauna.

Parasites which mirrored the greatest increases in abundance due to increasing age or size of the host were *Contracaecum spiculigerum* and *Corallobothrium* spp. *C. spiculigerum* typically increased in both rate and intensity of infection, whereas the *Corallobothrium* spp. were most significantly different with respect to incidence only. Also, *Corallobothrium* increased significantly in prevalence, but only in the winter and spring. Both parsites are found as larvae in small fishes and the change in their infectivity is believed correlated with a change in the food habits of the host. It should be noted that older fish not only consume different food items but an increased amount as well. Other helminths such as Phyllodistomum lacustri and Posthodiplostomum minimum appeared to increase in larger fish but not as significantly. The last named species infects its host through the skin and presumably does not discriminate either to size or species of host. Therefore the increases observed are probably due only to an accumulation of metacercariae in older fish. Hoffman (1967) had observed that these metacercariae may persist in fish for four years under laboratory conditions.

The incidence and severity of infections with Rhabdochona spp. were negatively correlated with size in the channel catfish. This was thought to be due to a lessening of the dependence on mayfly larvae (the intermediate host) in the diet of larger catfish. Large fish, such as carp, which do not change their insectivorous food habits, did not display a similiar decrease in susceptibility to this helminth.

Gorbunova (1936; in Dogiel, et al., 1961: 8) classified parasites of Esox lucius and Rutilis rutilus as being (1) independent of the age of the host, (2) as increasing with the age of the host, and (3) as decreasing with the age of the host. The majority of the parasites of that study fell into the second group.

Adopting this classification for the parasites of white crappie and channel catfish from Lake Carl Blackwell, the occurrence of Camallanus oxycephalus and Rhabdochona spp. in white crappie and Spinitectus spp. in both fishes appear to be independent of the host's age. Corallobothrium spp. and Contracaecum spiculigerum in the channel catfish and Posthodiplostomum minimum in the white crappie increased with the age of the host. Rhabdochona decaturensis in the catfish exhibited the characteristics of the last case. Its success was inversely correlated with aging in channel catfish. Other species of helminths reported in the present survey were generally not numerous enough to classify. However, in most cases (Table XIX), the data show a constant increase in both prevalence and intensity of the total helminthocenoses of selected fishes with increasing size of these fishes.

TABLE XIX

EFFECTS OF INCREASING AGE ON THE HELMINTHOCENOSES OF SELECTED FISHES FROM LAKE CARL BLACKWELL

Host	Age	Percent Infected	No. of Fish	Average Number of Parasite Genera	Average Intensity of Infection-All Parasites
Channel catfish	I and II	66.7	3	1.00	4.7
	III and IV	98.4	59	2.41	11.6
	V and VI	91.2	34	2.59	8.8
	Over VI	98.1	53	3.19	21.9
Flathead catfish	III and Under	87.5	8	1.88	11.6
	IV	100.0	10	2.90	20.0
	V	100.0	13	2.62	30.7
	VI and Over	100.0	5	4.00	42.2
White crappie	I and II	93.0	43	1.63	12.5
	III	98.7	70	1.62	15.5
	IV and V	98.1	51	2.02	14.6
	VI and Over	100.0	12	2.64	38.6
Largemouth bass	0 and I	100.0	7	2.29	6.6
	II	100.0	8	2.75	8.0
	III and IV	100.0	10	2.40	11.3
	V and VI	100.0	6	2.67	15.3
Longear sunfish	I and II	60.0	5	0.80	2.0
	III	80.0	15	1.60	8.4
	IV	83.3	6	1.17	8.7
Bluegill	I	90.9	11	1.64	71.9
	II	100.0	18	1.78	95.3
	III and IV	100.0	8	2.38	300.8

Influence of the Sex of the Hosts

Except for Posthodiplostomum minimum in sunfishes, the occurrence of parasitism did not differ significantly between the sexes of the hosts. Higher incidences and intensities of P. minimum were found in male centrarchids, especially the largemouth bass.

Consideration of differential growth or dietary factors between the sexes seems of little importance with P. minimum since the route of infection is through the skin. Possibly the different gonadatropic hormones have a dichotomous effect on the establishment of P. minimum in male and female sunfishes. Also, differences in spawning behavior between the sexes may account for an increase in strigeid metacercariae in mature males. These males are first to arrive to the inshore spawning areas in the spring, and since they alone guard the nests after egg deposition, they are consequently the last to leave. If, as is supposed in Lake Carl Blackwell, snails are restricted to the narrow perimeter of the lake, then males would be exposed to more cercariae by virtue of their close proximity to the intermediate host.

Effect of Seasonal Changes

The changes in season produce many effects on the host-parasite relationship of fishes from temperate zones. The rates of feeding and metabolism, gonadal maturation, and other aspects of the physiology of both host and parasite, because they are poikilothermic, might be expected to drastically influence the success of helminth parasitism in fishes. The immunological response of fishes is temperature dependent (Krantz, et al., 1964) and probably determines the success of some helminths. Both specific and non-specific anthelminthic immunity occurs in many vertebrates (E. D. Besch, personal communication).

Many aspects of seasonal changes on the helminthocenoses of fishes have been described in the previous chapter (Bogitsh, 1958; Chubb, 1963; Connor, 1953; Holl, 1932; and others). The present study indicated that changes in season result in many demonstrable changes in the composition of the helminthocenoses of fishes.

Dacnitoides robusta is abundant in channel catfish only during the summer. Significant age differences in Rhabdochona spp. were most evident in the winter months, and so interaction between age and season probably existed. The highest incidence and intensity of infection with P. minimum in white crappie was in the late spring and summer months and conversely Camallanus oxycephalus was not found in the May (1968) and June (1967) channel catfish samples.

Highly significant seasonal variations were observed in the prevalence of Corallobothrium spp. from the channel catfish. The highest infection rate was observed in the winter collections of catfish (Figures 5 and 6). Biacetabulum sp. from the river carpsucker, and Atractolytocestus huronensis from the carp occurred with greater frequency during the winter than during other seasons.

Seasonal variation in incidence and severity of helminth parasitism in fishes, especially those utilizing fish as definitive hosts, was probably influenced by the annual life cycle of the parasite. Observations made in this study and those by Essex (1928), Dogiel, et al., (1961: 76), and others support this view. Annual life cycles may arise from changes in the temperature of the environment. Cross (1934) and others have shown that the annual maturation of sex cells of helminths

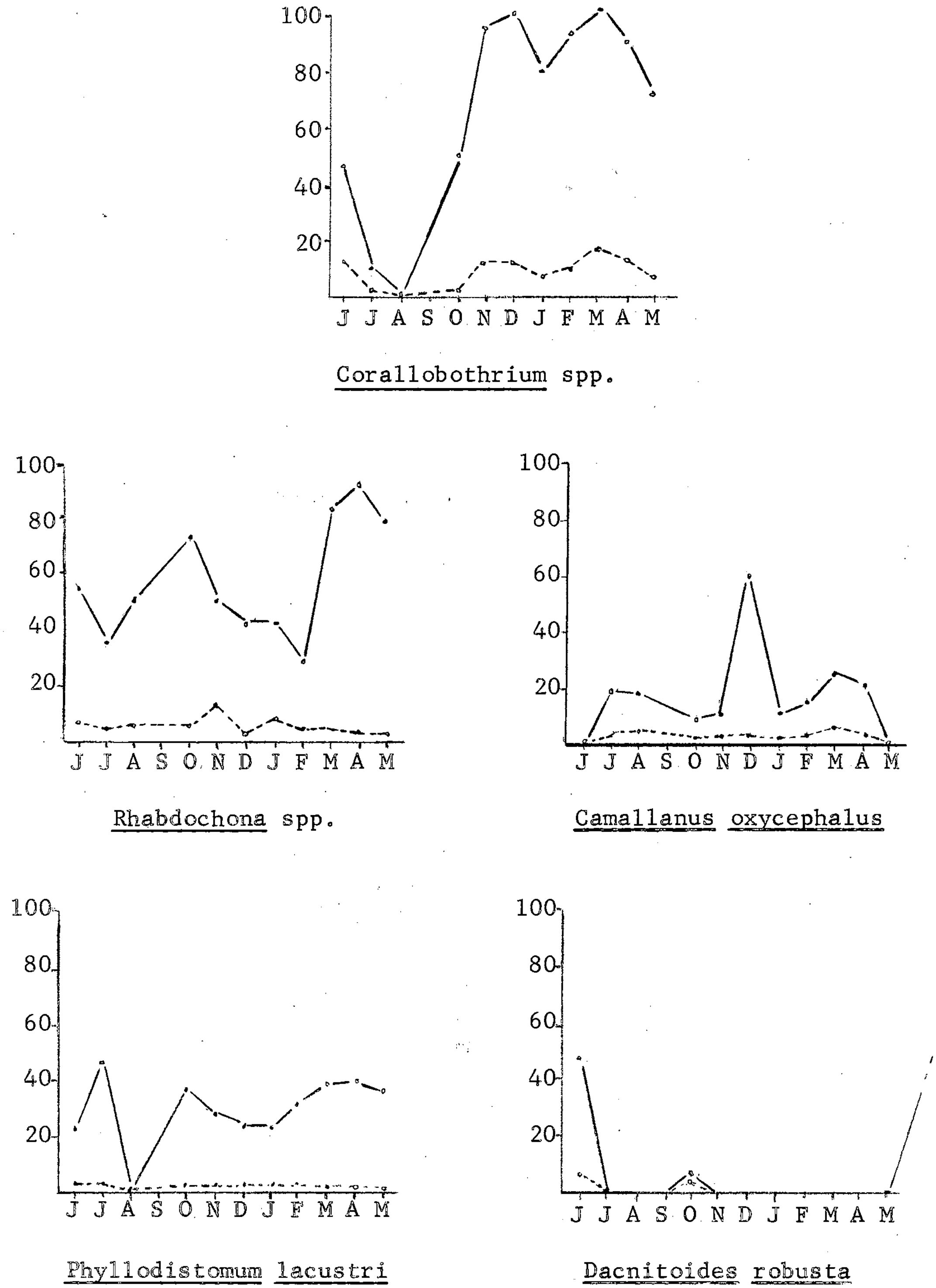

Figure 5. Monthly Variation in the Prevalence (solid line) and Average Intensity (broken line) of Five Selected Helminths in Channel Catfish (June, 1967 through May, 1968; no collections during September). Ordinate Scale Indicates Percent Prevalence and Numbers of Parasites.

is temperature dependent. Somatic maturity, as shown by strobilization in tapeworms, would also seem to be temperature dependent.

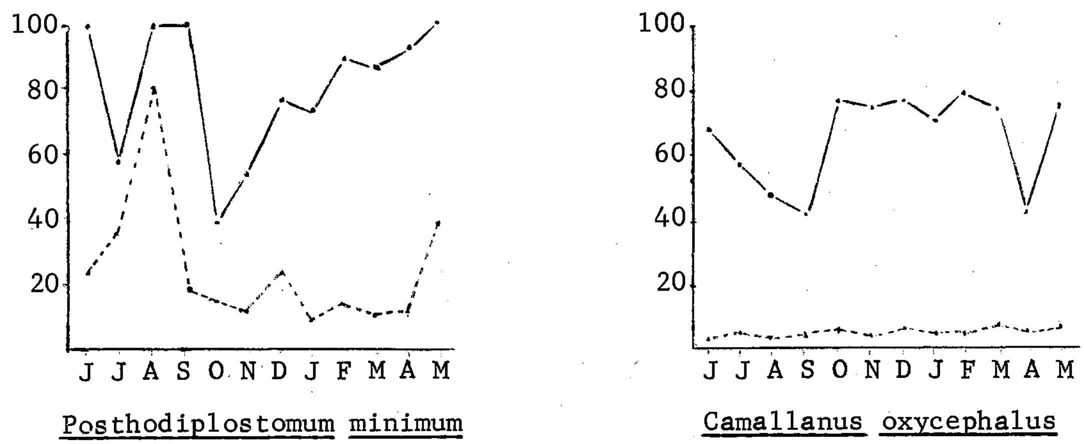

Figure 6. Monthly Variation in the Prevalence (solid line) and Average Intensity (broken line) of Two Selected Helminths in White Crappie (June, 1967 through May, 1968). Ordinate Scale Indicates Percent Prevalence and Numbers of Parasites.

Influences of the Food Habits of Fishes

Changing food habits of the host has been cited to explain observable differences in its helminth fauna (Table XX). The classification of the fishes according to food habits was quite arbitrary, nevertheless certain similarities in the helminthocenoses within each group were observed, particularily with respect to the average numbers of different helminth genera found in a host species. Planktophagous and benthophagous fishes generally have fewer kinds and numbers of helminth parasites than predatory fishes. Predators are often infected by feeding on small food fish which act as intermediate hosts. The omnivorous feeding habits of the channel catfish resulted in a greater variety of helminths than any other host. It should be remembered that all species of fish transcend a period of planktophagous (microcrustacea) habits, albeit very short for some, such as the basses and flathead catfish.

TABLE XX

INFLUENCE OF THE GENERAL FOOD HABITS OF FISHES ON THEIR HELMINTHOCENOSES

Feeding Habits and Host	No. of Genera Collected[1]	Ave. No. Genera/ Infected Fish	Prevalence[2] (%)	Average Intensity/ Infected Fish[2]
PLANKTOPHAGOUS HABITS				
Gizzard shad	1	1.00	8.6	3.7
BENTHOPHAGOUS HABITS (MACROINVERTEBRATES)				
River carpsucker	7	1.40	39.4	2.8
Carp	5	1.82	91.6	41.8
Freshwater drum	5	1.38	80.0	18.9
PISCIVOROUS HABITS				
Largemouth bass	7	2.51	100.0	25.7
Flathead catfish	7	2.80	97.3	25.8
CARNIVOROUS HABITS (GENERAL VERTEBRATES AND INVERTEBRATES)				
White bass	5	1.33	69.2	4.6
White crappie	9	1.82	97.2	16.2
Bluegill	5	1.92	97.4	136.2[3]
Longear sunfish	6	1.75	80.8	9.0
OMNIVOROUS HABITS				
Channel catfish	13	2.80	96.0	15.1

[1]Does not include subcutaneous metacercariae which did not infect *per os*.

[2]All species of helminths.

[3]99.2% consist of the single species *Posthodiplostomum minimum* (ave. 135.4).

The variables of season, water depth, and feeding behavior, sex and size of the host are all functions of the same environment with respect to the parasite, and doubtless these variables interact significantly with one another. For example, food habits of fishes have been shown to be a major influence in determining the occurrence and distribution of their helminth parasites. But food habits of fishes are directly related to season, water depth, size and probably sex, at least during the spawning season. Interaction is difficult to detect by non-parametric statistical tests and nearly impossible to interpret. Therefore, in most cases where interaction was thought to exist, it was largely ignored, and the variables were treated independently.

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APPENDIX A

A LIST OF MACROPARASITES OF FRESHWATER FISHES OF THE SOUTHCENTRAL UNITED STATES[1]

PARASITE	HOST AND INVESTIGATOR
DIGENEA	
Pisciamphistoma reynoldsi	*Micropterus salmoides*, *Pomoxis annularis* (Allison and McGraw, 1967); *Lepomis cyanellus*, *L. megalotis* (McGraw and Allison, 1967).
Pisciamphistoma stunkardi	*Ictaluras natalis* (Harms, 1959); *Micropterus salmoides*, *Chaenobryttus gulosus*, *Lepomis macrochirus*, *Pomoxis nigromaculatus*, *P. annularis* (Houghton, 1963); *L. cyanellus* (McDaniel, 1963).
Paramphistomum stunkardi	*Huro* (*Micropterus*) *salmoides* (Sparks, 1951).
Nematobothrium texomensis	*Ictiobus bubalus* (McIntosh and Self, 1955); *I. bubalus*, *I. cyprinella* (Self and Campbell, 1956); *I. bubalus*, *I. cyprinellus*, *I. niger* (Self, Peters and Davis, 1963).
Rhipidocotyle papillosum	*Micropterus salmoides*, *M. punctulatus*, *M. dolomieui* (Becker, Heard and Holmes, 1966).
Rhipidocotyle lepisostei	*Lepisosteus spatula*, *Lepisos. osseus* (Hopkins, 1967).
Bucephalus elegans	*Lepomis macrochirus*, *L. cyanellus* (McDaniel, 1963).
Caecincola parvulus	*Huro* (*Micropterus*) *salmoides* (Sparks, 1951); *Micropterus salmoides* (Allison and McGraw, 1967); *Lepomis cyanellus* (McGraw and Allison, 1967).

[1]Arkansas, eastern Colorado, Kansas, Oklahoma and Texas.

APPENDIX A (Continued)

DIGENEA (Continued)

Phyllodistomum carolini	*Ictaluras melas* (Harms, 1959, 1960).
Phyllodistomum caudatum	*Ameiuras* (*Ictaluras*) *melas* (Steelman, 1938); *A.* *Ictaluras*) *melas* (Beilfuss, 1954); *Ictaluras melas*, *I. natalis* (Harms, 1959, 1960).
Phyllodistomum lacustri	*Ictaluras punctatus* (Harms, 1959, 1960).
Phyllodistomum lohrenzi	*Apomotis* (*Lepomis*) *cyanellus* (listed as *Catoptroides lohrenzi*, Loewen, 1935); *Huro* (*Micropterus*) *salmoides* (Sparks, 1951); *Lepomis cyanellus* (Beilfuss, 1954); *L. cyanellus*, *L. megalotis*, *L. humilis* (McDaniel and Bailey, 1966).
Xystretrum papillosum (Probably *Phyllodistomum* sp.)	*Ictalurus punctatus* (Caruthers, 1935).
Leuceruthrus micropteri	*Micropterus dolomieui*, *M. punctulatus* (Holmes, 1964); *M. salmoides*, *M. punctulatus*, *M. dolomieui* (Becker, Heard and Holmes, 1966).
Alloglossidium corti	*Ictaluras melas*, *I. natalis* (Harms, 1959, 1960); *I. punctatus*, *I. natalis* (Houghton, 1963).
Distomum sp. (Probably *Alloglossidium* sp.)	*Ameiuras* (*Ictaluras*) *nebulosus* (Caruthers, 1935).
Crepidostomum cornutum	*Lepomis macrochirus*, *Chaenobryttus gulosus* (Houghton, 1963); *Micropterus dolomieui*, *M. punctulatus* (Becker, Heard and Holmes, 1966).
Crepidostomum cooperi	*Lepomis cyanellus*, *L. megalotis*, *Pomoxis annularis* (McDaniel and Bailey, 1966); *L. cyanellus*, *L. megalotis*, *L. macrochirus*, *Micropterus salmoides* (Allison and McGraw, 1967); *L. cyanellus*, *L. megalotis* (McGraw and Allison, 1967).

APPENDIX A (Continued)

DIGENEA (Continued)

Crepidostomum ictaluri	*Ictaluras punctatus*, *I. melas* (Harms, 1959).
Crepidostomum illinoiense	*Hiodon alosoides* (Self, 1954).
Crepidostomum sp.	*Ictaluras punctatus*, *I. natalis* (Houghton, 1963).
Homalometron armatum	*Lepomis megalotis* (Allison and McGraw, 1967); *L. megalotis* (McGraw and Allison, 1967).
Paramacroderoides echmus	*Lepisosteus osseus* (Casto and McDaniel, 1967).
Macroderoides spiniferus	*Lepisosteus productus* (Casto and McDaniel, 1967).
Lissorchis gullaris	*Ictiobus bubalus*, *I. cyprinella*, *I. niger* (Self and Campbell, 1956).
Plagioporus sp.	*Ictaluras melas* (Harms, 1959).
Maculifer chandleri	"Catfishes" (Harwood, 1935).
Uvulifer amblopiltes	*Lepomis cyanellus*, *L. humilis*, *L. microlophus* (McDaniel and Bailey, 1966).
Clinostomum marginatum	*Huro* (*Micropterus*) *salmoides* (Sparks, 1951); *Ictaluras punctatus*, *I. melas* (Harms, 1959); *Micropterus salmoides*, *Chaenobryttus gulosus* (Houghton, 1963); *I. melas*, *Lepomis cyanellus*, *L. macrochirus*, *L. humilis*, *Pomoxis annularis*, *M. salmoides*, *Notemigonus chrysoleucas*, *Pimephales promelas* (Klass, 1963); *M. salmoides*, *M. dolomieui*, *M. punctulatus* (Holmes, 1964); *M. salmoides*, *M. dolomieui*, *M. punctulatus* (Becker, Heard and Holmes, 1966); *P. annularis* (Lawrence and Murphy, 1967).
Clinostomum sp.	*Lepisosteus spatula*, *L. osseus* (Casto and McDaniel, 1967).
Cercaria bessiae	*Eupomotis* (*Lepomis gibbosus*, *Apomotis* (*Lepomis*) *cyanellus* (Krull, 1932).

DIGENEA (Continued)

Cercaria flexicorpa	*Apomotis* (*Lepomis*) *cyanellus*, *Helioperca* (*Lepomis*) *macrochirus* (Hobgood, 1938); *Lepomis megalotis*, *L. cyanellus*, *L. humilis* (McDaniel, 1963).
Neascus sp.	*Roccus chrysops*, *Micropterus salmoides*, *M. dolomieui*, *M. punctulatus* (Holmes, 1964).
Posthodiplostomum minimum	*Micropterus salmoides*, *Chaenobryttus gulosus*, *Lepomis macrochirus*, *Pomoxis nigromaculatus*, *P. annularis*, *Ictaluras punctatus* (Wilson, 1957); *M. salmoides* (Houghton, 1963); *L. macrochirus*, *L. megalotis*, *L. cyanellus*, *L. humilis* (McDaniel, 1963); *M. salmoides*, *M. punctulatus*, *M. dolomieui* (Holmes, 1964); *M. salmoides*, *M. punctulatus*, *M. dolomieui*, *L. cyanellus*, *L. megalotis*, *L. macrochirus* (Holmes and Mullen, 1965); *M. salmoides*, *M. dolomieui*, *M. punctulatus* (Becker, Heard and Holmes, 1966); *L. cyanellus*, *L. megalotis*, *L. humilis*, *L. macrochirus*, *L. microlophus* (McDaniel and Bailey, 1966); *L. cyanellus*, *L. megalotis*, *L. macrochirus*, *M. salmoides* (Allison and McGraw, 1967); *C. gulosus*, *L. macrochirus*, *M. salmoides* (Lawrence and Murphy, 1967); *L. megalotis*, *L. macrochirus*, *M. salmoides* (McGraw and Allison, 1967); *L. macrochirus*, *L. microlophus*, *L. megalotis*, *L. cyanellus*, *C. gulosus*, *M. salmoides*, *P. annularis*, *I. punctatus*, *Gambusia affinis* (Meade and Bedinger, 1967).

CESTODARIA

Caryophyllaeus sp.	*Cyprinus carpio* (Wilson, 1957); this is *Khawia iowensis* according to Mackiewicz, 1965, in Hoffman, 1967).
Spartoides wardi	Catostomidae (Mackiewicz, 1964).
Biacetabulum meridianum	*Carpiodes carpio* (Self and Timmons, 1955).
Biacetabulum infrequens	*Catastomus commersoni* (Cook, 1952).

CESTODARIA (Continued)

Biacetabulum spp.	Catostomidae (Mackiewicz, 1964).
Glaridacris confusus	Carpiodes carpio (Self and Timmons, 1955); Ictiobus bubalus, I. niger (Self and Campbell, 1956); Catostomidae (Mackiewicz, 1964).
Capingens singularis	Ictiobus bubalus (Self and Campbell, 1956); Catostomidae (Mackiewicz, 1964).
Pseudolytocestus differtus	Ictiobus bubalus (Self and Campbell, 1956).
Monobothrium ingens	Ictiobus bubalus (Self and Campbell, 1956); Catostomidae (Mackiewicz, 1964).
Khawia iowensis	Cyprinus carpio (Mackiewicz, 1964).
Atractolytocestus huronensis	Cyprinus carpio (Mackiewicz, 1964).

EUCESTODA

Proteocephalus ambloplitis	Ictaluras punctatus (Caruthers, 1935); Huro (Micropterus) salmoides (Sparks, 1951); I. punctatus, M. salmoides, Pomoxis annularis, P. nigromaculatus (Wilson, 1957); I. punctatus, I. melas, I. natalis (Harms, 1959); Lepomis macrochirus, L. megalotis (McDaniel, 1963); M. salmoides, M. punctulatus, I. melas, Chaenobryttus gulosus, L. macrochirus (Houghton, 1963); Roccus chrysops, M. salmoides, M. punctulatus, M. dolomieui (Holmes, 1964); M. salmoides, M. dolomieui, M. punctulatus, L. megalotis, L. cyanellus, L. macrochirus (Holmes and Mullan, 1965); M. salmoides, M. dolomieui, M. punctulatus (Becker, Heard and Holmes, 1966); L. cyanellus (McDaniel and Bailey, 1966); L. cyanellus, L. megalotis, L. macrochirus, M. salmoides, P. annularis (Allison and McGraw, 1967); L. macrochirus, M. salmoides (Lawrence and Murphy, 1967); L. macrochirus, L. megalotis, M. salmoides, P. annularis (McGraw and Allison, 1967).

APPENDIX A (Continued)

EUCESTODA (Continued)

Proteocephalus pe[illegible]us	Ictaluras punctatus (Caruthers, 1935).
Proteocephalus sp.	Lepibema (Roccus) Chrysops (Bynum, 1951); Ictaluras punctatus, I. melas (Harms, 1959).
Corallobothrium fimbriatum	Ictaluras lacustris (punctatus), Pylodictus olivaris (Sneed, 1950); I. punctatus, I. melas (Harms, 1959); I. punctatus, I. melas (Houghton, 1963); I. punctatus (Lawrence and Murphy, 1967).
Corallobothrium giganteum	Ictaluras punctatus (Wilson, 1957); I. punctatus, I. melas, I. natalis (Harms, 1959); I. natalis (Houghton, 1963); I. punctatus (Lawrence and Murphy, 1967).
Corallobothrium procerum	Ictaluras furcatus (Sneed, 1950).
Corallobothrium thompsoni	Ictaluras lacustris (punctatus) (Sneed, 1950).
Corallobothrium sp.	Ictaluras punctatus (Wilson, 1957); I. punctatus, I. melas (Harms, 1959).
Bothriocephalus claviceps	Lepomis macrochirus, L. megalotis, L. cyanellus (McDaniel, 1963); L. cyanellus (McDaniel and Bailey, 1966).
Bothriocephalus texomensis	Hiodon alosoides (Self, 1954).
Bothriocephalus sp.	Lepibema (Roccus) chrysops (Bynum, 1951); Lepomis cyanellus, L. megalotis (McDaniel and Bailey, 1966).
Ligula intestinalis	Catastomus commersoni, Perca flavescens (Cook, 1952).
Haplobothrium globuliforme	Hiodon tergisus (Caruthers, 1935).
Marsipometra sp.	Pylodictus olivaris (Minckley and Deacon, 1959).

APPENDIX A (Continued)

NEMATODA

Contracaecum spiculigerum	Pomoxis nigromaculatus, Micropterus salmoides, Ameiurus (Ictaluras) melas (Cook, 1952); Ictaluras punctatus, M. salmoides (Wilson, 1957); M. salmoides, P. nigromaculatus (Houghton, 1963); L. macrochirus (McDaniel, 1963); M. punctulatus, M. salmoides (Holmes, 1964); M. punctulatus (Holmes and Mullen, 1965); Lepomis cyanellus, L. megalotis, L. macrochirus, M. salmoides, P. annularis (Allison and McGraw, 1967); Lepisosteus spatula, Lepisos. productus, Lepisos. osseus (Casto and McDaniel, 1967); L. cyanellus, L. megalotis, L. macrochirus (McGraw and Allison, 1967).
Contracaecum brachyurum	Lepomis cyanellus (McDaniel and Bailey, 1966).
Contracaecum sp.	Ictaluras natalis (Harms, 1959); Huro (Micropterus) salmoides (Sparks, 1951); Micropterus salmoides, M. punctulatus (Becker, Heard and Holmes, 1966); Dorosoma petenense (Hopkins, 1966); Lepisosteus productus, L. osseus (Casto and McDaniel, 1967).
Camallanus oxycephalus	Lepibema (Roccus) chrysops (Bynum, 1951); Perca flavescens, Pomoxis nigromaculatus (Cook, 1952); Carpiodes carpio (Self and Timmons, 1955); Micropterus salmoides, P. nigromaculatus, Aplodinotus grunniens (Wilson, 1957); Ictaluras punctatus (Harms, 1959); M. punctulatus, M. salmoides, Chaenobryttus gulosus, Lepomis macrochirus, P. nigromaculatus, P. annularis (Houghton, 1963); L. cyanellus (McDaniel, 1963); M. punctulatus, M. salmoides (Holmes, 1964); M. salmoides, M. punctulatus, M. dolomieui, L. cyanellus, L. macrochirus, L. megalotis (Holmes and Mullen, 1965); M. salmoides, M. punctulatus (Becker, Heard and Holmes, 1966); L. cyanellus (McDaniel and Bailey, 1966); M. salmoides, P. annularis (Allison and McGraw, 1967); M. salmoides, P. annularis (Lawrence and Murphy, 1967); L. cyanellus, M. salmoides, P. annularis (McGraw and Allison, 1967).
Camallanus ancylodirus	Lepibema (Roccus) chrysops (Bynum, 1951); Ictiobus bubalus, I. cyprinella (Self and Campbell, 1956); Cyprinus carpio (Roberts, 1957).

APPENDIX A (Continued)

NEMATODA (Continued)

Camallanus trispinosus	Lepomis megalotis, L. cyanellus (McDaniel, 1963).
Camallanus sp.	Huro (Micropterus) salmoides (Sparks, 1951); Dorosoma petenense (Hopkins, 1966).
Rhabdochona cascadilla	Lepibema (Roccus) chrysops (Bynum, 1951).
Spinitectus carolini	Micropterus salmoides, Chaenobryttus gulosus, Lepomis macrochirus, Pomoxis nigromaculatus, P. annularis (Houghton, 1963); L. macrochirus, L. humilis, L. megalotis, L. cyanellus (McDaniel, 1963); M. salmoides, M. punctulatus, M. dolomieui (Holmes, 1964); M. salmoides, M. dolomieui, M. punctulatus, L. megalotis, L. cyanellus, L. macrochirus (Holmes and Mullen, 1965); M. salmoides, M. dolomieui, M. punctulatus (Becker, Heard and Holmes, 1966); L. cyanellus, L. megalotis, L. microlophus (McDaniel and Bailey, 1966); L. cyanellus, L. megalotis, L. macrochirus, P. annularis (Allison and McGraw, 1967); L. macrochirus, C. gulosus (Lawrence and Murphy, 1967); L. cyanellus, L. macrochirus (McGraw and Allison, 1967).
Spinitectus gracilis	Ictaluras punctatus, I. melas, I. natalis (Harms, 1959); Micropterus punctulatus (Becker, Heard and Holmes, 1966).
Spinitectus sp.	Lepibema (Roccus) chrysops (Bynum, 1951); Micropterus salmoides, Lepomis macrochirus, Pomoxis nigromacultatus, P. annularis (Houghton, 1963).
Dichelyne robusta	Ictaluras punctatus (Harms, 1959); I. punctatus (Lawrence and Murphy, 1967).
Dichelyne lepisosteus	Lepisosteus spatula, L. productus (Casto and McDaniel, 1967).
Philometra nodulosa	Micropterus salmoides (Lawrence and Murphy, 1967).
Philometra cylindracea	Catastomus commersoni (Cook, 1952).

APPENDIX A (Continued)

NEMATODA (Continued)

Eustrongylides sp.	Lepomis cyanellus (McDaniel and Bailey, 1966); Lepisosteus spatula, Lepisos. osseus (Casto and McDaniel, 1967).

ACANTHOCEPHALA

Neoechinorhynchus cylindratus	Huro (Micropterus) salmoides (Sparks, 1951); Micropterus salmoides (Wilson, 1957); Ictalurus natalis, M. punctulatus, M. salmoides, Lepomis macrochirus (Houghton, 1963); L. cyanellus, L. humilis (McDaniel, 1963); M. dolomieui, M. salmoides, M. punctulatus (Holmes, 1964); M. salmoides, M. punctulatus, M. dolomieui, L. cyanellus, L. megalotis, L. macrochirus, (Holmes and Mullen, 1965); M. salmoides, M. dolomieui, M. punctulatus (Becker, Heard and Holmes, 1966); L. cyanellus, L. megalotis (McDaniel and Bailey, 1966); M. salmoides, Pomoxis annularis (Allison and McGraw, 1967); L. macrochirus, M. salmoides, P. annularis (Lawrence and Murphy, 1967); L. cyanellus (McGraw and Allison, 1967).
Neoechinorhynchus prolixus	Carpiodes carpio (Van Cleave and Timmons, 1952); C. carpio (Self and Timmons, 1955).
Neoechinorhynchus sp.	Ictalurus natalis (Harms, 1959); Lepomis cyanellus, L. megalotis, L. microlophus (McDaniel and Bailey, 1966).
Gracilisentis gracilisentis	Dorosoma cepedianum, D. petenense, D. cep. X D. pet. (hybrid) (Hopkins, 1966).
Tanaorhamphus longirostris	Lepibema (Roccus) chrysops (Bynum, 1951); Dorosoma cepedianum, D. petenense, D. cep. X D. pet. (hybrid) (Hopkins, 1966).
Leptorhynchoides thecatus	Micropterus salmoides (Houghton, 1963); M. salmoides (Becker, Heard and Holmes, 1966).
Pomphorhynchus bulbocolli	Ictaluris natalis (Harms, 1959).

APPENDIX A (Continued)

OTHERS

Monogenea

Helioperca macrochira (Lepomis macrochirus), Ictaluras punctatus, Ameiuras (Ictularas) melas, Apomotis (Lepomis) cyanellus, Pomoxis annularis, P. sparoides (nigromaculatus), Micropterus dolomieui, Aplites (Micropterus) salmoides, Allotis (Lepomis) humilis (Seamster, 1938); Lepibema (Roccus) chrysops (Bynum, 1951); Huro (Micropterus) salmoides (Sparks, 1951); Catostomus catostomus (Cook, 1952); Cyprinus carpio (Roberts, 1957); I. punctatus, I. melas, I. natalis (Harms, 1959); M. salmoides, Chaenobryttus gulosus, P. annularis (Houghton, 1963); Lepomis macrochirus, L. megalotis, L. cyanellus (McDaniel, 1963); Roccus chrysops, M. punctulatus (Holmes, 1964); M. salmoides, M. punctulatus, M. dolomieui (Becker, Heard and Holmes, 1966); Dorosoma cepedianum (Hopkins, 1966); L. cyanellus, L. megalotis, L. humilis, L. microlophus, P. annularis (McDaniel and Bailey, 1966); L. cyanellus, L. megalotis (Allison, 1967); L. cyanellus, L. macrochirus, L. megalotis, M. salmoides, P. annularis (Allison and McGraw, 1967); I. punctatus, L. macrochirus, M. salmoides, P. annularis (Lawrence and Murphy, 1967); L. cyanellus, L. megalotis, L. macrochirus, M. salmoides, P. annularis (McGraw and Allison, 1967); Ameiuras natalis, Catostomus commersoni, Chaenobryttus coranarius, L. cyanellus, M. salmoides, P. annularis, Carassius auratus, Cyprinus carpio, Notemigonus crysoleucas, Gambusia affinis (Nowlin, Price and Schlueter, 1967).

Hirudinea

Ameiurus (Ictaluras) nebulosus (Caruthers, 1935); A. (Ictalurus) melas (Cook, 1952); Ictaluras punctatus, I. melas (Harms, 1959); Aplodinotus grunniens (Branson, 1961); Micropterus dolomieui, M. punctulatus, M. salmoides (Holmes, 1964); Lepomis cyanellus (Holmes and Mullen, 1965); M. salmoides, M. dolomieui, M. punctulatus (Becker, Heard and Holmes, 1966); I. punctatus (Lawrence and Murphy, 1967).

Glochidia

Lepomis cyanellus (McDaniel and Bailey, 1966).

OTHERS (Continued)

Crustacea

Pimephales promelas, *Cyprinus carpio*, *Pomoxis nigromaculatus* (Cook, 1952); *C. carpio* (Roberts, 1957); *Ictaluras punctatus*, *I. melas*, *I. natalis* (Harms, 1959); *Notropis venustus*, *N. lutrensis*, *N. volucellus*, *Pimephales vigilax*, *Gambusia affinis*, *Micropterus salmoides*, *Lepomis punctatus*, *L. macrochirus*, *L. megalotis*, *Elassoma zonatum*, *Hadropterus scierus*, *Percina caprodes*, *Etheostoma lepidum* (Delco, 1962); *L. macrochirus*, *L. cyanellus*, *L. megalotis* (McDaniel, 1963); *M. dolomieui*, *M. punctulatus*, *M. salmoides* (Holmes, 1964); *M. salmoides*, *M. punctulatus*, *M. dolomieui* (Becker, Heard and Holmes, 1966); *Dorosoma petenense* (Hopkins, 1966); *L. cyanellus*, *L. macrochirus* (McDaniel and Bailey, 1966); *I. punctatus*, *Chaenobryttus gulosus*, *L. macrochirus*, *M. salmoides*, *P. annularis* (Lawrence and Murphy, 1967).

VITA

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