A SURVEY OF THE OCCURRENCE, DISTRIBUTION AND INCIDENCE OF INFECTION OF HELMINTH PARASITES OF MARINE AND ESTUARINE MOLLUSCA FROM GALVESTON, TEXAS

A Dissertation

by

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ABSTRACT

A Survey of the Occurrence, Distribution and Incidence of Infection of Helminth Parasites of Marine and Estuarine Mollusca from Galveston, Texas. (May 1974)

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The results of a 3-year study of the helminth parasite fauna of the marine Mollusca of the Galveston Bay, Texas area are presented, including data on morphology, behavior, ecology, systematics and life cycles of the parasites, and their effects upon their molluscan hosts. Three species of Turbellaria, 34 species of digenetic Trematoda, eight species of Cestoda and one species of Nematoda were found among the 12,131 individual molluscs examined. Most of the parasites are identifiable with previously-described species, but five species of larval digenetic trematodes appear to be significantly different from known forms and may represent new species. These include a tail-less fellodistomatid cercaria, a trichocercous fellodistomatid cercaria, a renicolid xiphidiocercaria, a cercariaeum

which encysts in its own redia, and a setose cystophorous appendiculate cercaria of the family Hemiuridae. The three turbellarians appear to utilize no other host in their life cycle. Of the 34 trematode species, 18 resemble species whose adult forms are parasites of warm-blooded aquatic vertebrates and 16 appear to be related to species whose adult forms are parasites of marine fishes. The eight cestode larvae are all forms whose adult stages occur in the gut of elasmobranch fishes, and the single nematode larva probably utilizes marine teleost fishes as hosts for the adult stage.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to Dr. Sewell H. Hopkins who served as senior co-chairman of this committee and whose guidance and encouragement made the study possible, and to my other co-chairman, Dr. Sammy M. Ray, who permitted me to utilize research facilities at the Marine Laboratory at Galveston where most of the work was performed. I am grateful also to the other past and present members of my committee including Dr. L. Berner, Dr. M. Sweet, Dr. K. Horvath, Dr. A. K. Sparks and Dr. D. V. Aldrich, from whom much valuable advice was obtained.

Appreciation is also expressed to the many persons who collected or helped collect some of the mollusc hosts utilized in this study, especially Dr. Roger Anderson, Mr. Steve Coker, Mr. John Ogle, Mr. Tom Bullington, Mr. Robert Oja, Mr. Philip Turk, Mr. L. Freeberg and Mrs. Selma Snider. I also wish to thank Mrs. Margie Watson for invaluable advice in manuscript preparation and for typing, and my wife, Aline, for her moral support throughout the study.

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I. INTRODUCTION

Human alteration of the coastal areas of Texas is proceeding rapidly. Knowledge of the faunal ecology of the area must keep pace in order to permit formulation of intelligent policies to minimize permanent detrimental effects to the environment. All species of animals with the exception of man exist near their limits of tolerance to or requirement of one or more environmental parameters. When such limits are exceeded, there is a reduction in numbers of individuals of the species, balancing it in relation to other species in the community. Environmental parameters may include temperature, salinity, pH, O_2, inorganic and organic nutrients, food organisms, predator population levels, parasite populations, and the presence of man-caused pollutants and habitat destruction. Helminth parasites are often important factors regulating the population cycles and abundance of their hosts by handicapping, lowering fertility and fecundity, and in some cases, totally sterilizing (Cheng, 1964). Many helminth parasites utilize as many as four different species of host animals. They are passed from host to host when one host

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feeds directly upon another (Cheng, 1964). Helminth parasites may lower a host's resistance to environmental stresses (Cheng, 1964) both natural and man-caused. Knowledge of parasite presence and abundance may thus be of importance in considering the environmental impact of proposed engineering projects, or the location of potential sources of chemical and thermal pollution.

Studies on helminth parasites of marine and estuarine animals could lead to the discovery of other important biological information. Previous studies have yielded information on phylogenetic relationships among hosts (Bychowsky, 1933); biological tags revealing information concerning migration and reproductive behavior (Hopkins, 1947); information on hybridization of host populations (Hargis, 1957); and much additional information by many investigators on the ecology of marine and estuarine animals. In addition to the possibilities cited above, a study of the helminth parasites of the Mollusca of the Galveston area will provide a taxonomic foundation for experimental studies on the ecology and physiology of the parasites and their hosts.

II. LITERATURE REVIEW

Only a small percentage of the marine molluscan species of the Texas Coast have been examined for helminth parasites. Harry (1968) lists 178 species of marine Mollusca from the Galveston area, and a review of the literature has revealed reports of helminth parasites from only 28 of these species. Most of these reports are from Florida or the New England area. The range of many Texas species extends north to Cape Hatteras, and some dwell as far north as Cape Cod. Most of the reports are from the larger and more abundant mollusc species, many of which are of commercial importance.

The following is a list (from Harry, 1968) of the species of marine molluscs, known to occur in the Galveston area, from which helminth parasites have been previously reported. The list contains the name of the parasite, systematic position (if known), and locality. In the cases where many localities have been recorded, only those closest to the area of present concern are reported. Reports of entirely experimental infections have not been included. The letters in parentheses following the host name refer to the relative availability of the species for live collection in the study area as observed by the present investigator: A = abundant; C =

common; U = uncommon; R = rare; S = seasonal. Identification of mollusc species was based on Abbott (1954, 1968), Andrews (1971), and the unpublished checklist of Harry (1968). Nomenclature of mollusc species is that of Andrews (1971).

List of Helminth Parasites Previously Reported From the Species of Mollusca Inhabiting the Galveston Area, Arranged in Taxonomic Order of Mollusc Host

Class Amphineura

No helminth parasites have been reported from the species occurring in the Galveston area.

Class Gastropoda

Diodora cayensis (Lamarck) (U)

Cercaria caribbea XX Cable, 1956 (Trematoda: Opecoelidae), by Cable (1963), Jamaica

Cercaria caribbea LXXIV Cable, 1963 (Trematoda: Hemiuridae), Jamaica

Littorina irrorata (Say) (A)

Cercaria opaca Holliman, 1961 (Trematoda: Plagiorchoidea), Florida

Cercaria sp. "A" Epstein, 1972 (Trematoda: Microphallidae), Galveston, Texas

Cercaria sp. "B" Epstein, 1972 (Trematoda: Plagiorchioidea), Galveston, Texas

Cercaria sp. "C" Epstein, 1972 (Trematoda: Philophthalmidae), Galveston, Texas

Cercaria sp. "D" Epstein, 1972 (Trematoda: Philophthalmidae), Galveston, Texas

Lyrodes parvula Guilding (U)

Carenophallus basodactylophyllus Bridgman, 1969 (Trematoda: Microphallidae), Louisiana

Carenophallus choanophallus Bridgman, 1969 (Trematoda: Microphallidae), Louisiana

Modulus modulus (Linné) (U)

Cercaria "O" Hutton, 1952 (Trematoda), Florida

Bittium varium (Pfeiffer) (U)

Cercaria caribbea XIII Cable, 1956 (Trematoda: Opisthorchiidae), Puerto Rico

Cercaria caribbea XIV Cable, 1956 (Trematoda: Opisthorchiidae), Puerto Rico

Cercaria sp. Hutton, 1964 (Trematoda: Microphallidae), Florida

Cerithidea pliculosa (Menke) (A)

Cercaria sp. "E" Epstein, 1972 (Trematoda: Heterophyidae), Galveston, Texas

Cercaria sp. "F" Epstein, 1972 (Trematoda: Schistosomatidae), Galveston, Texas

Cercaria sp. "G" Epstein, 1972 (Trematoda: Renicolidae), Galveston, Texas

Cercaria sp. "H" Epstein, 1972 (Trematoda: Renicolidae), Galveston, Texas

Cercaria sp. "I" Epstein, 1972 (Trematoda: Echinostomidae), Galveston, Texas

Crepidula plana Say (A)

Cercaria sp. "M" Epstein, 1972 (Trematoda: Megaperidae), Galveston, Texas

Thais haemastoma (Linné) (A)

Hoploplana inquilina (Wheeler, 1894) (Turbellaria: Hoploplanidae), by Schechter (1943), Louisiana

Parorchis acanthus Nicoll, 1906 (Trematoda: Echinostomidae), by Schechter (1943), Louisiana

Anachis avara (Say) (C)

Cercaria sp. "L" Epstein, 1972 (Trematoda: Lepocreadiidae), Texas

Anachis obesa (C. B. Adams) (C)

Cercaria caribbea LXV Cable, 1963 (Trematoda: Lepocreadiidae), Jamaica

Cercaria caribbea LXXII Cable, 1963 (Trematoda: Acanthocolpidae "?"), Jamaica

Cercaria contorta Holliman, 1961 (Trematoda: Allocreadiidae), Florida

Cercaria portosacculus Holliman, 1961 (Trematoda: Hemiuroidea), Florida

Mitrella lunata (Say) (C)

Zoogonoides laevis (Linton, 1940) (Trematoda: Zoogonidae), by Stunkard (1943), Massachusetts

Anisoporus manteri Hunninen and Cable, 1941 (Trematoda: Allocreadiidae), Florida

Cercaria contorta Holliman, 1961 (Trematoda: Allocreadiidae), Florida

Nassarius vibex (Say) (A)

Cercaria caribbea LXVI Cable, 1963 (Trematoda: Lepocreadiidae), Jamaica

Cercaria "G" Hutton, 1952 (Trematoda: Echinostomidae), Florida

Himasthla quissetensis (Miller and Northrup, 1926) (Trematoda: Echinostomidae), by Holliman (1961), Florida

Cercaria sp. "J" Epstein, 1972 (Trematoda: Echinostomidae), Texas

Cercaria "H" Hutton, 1952 (Trematoda: Schistosomatidae), Florida

Cercaria sp. Hutton, 1964 (Trematoda: Microphallidae), Florida

Pleuroploca gigantea (Kiener) (U)

Lophotaspis vallei Stossich, 1899 (Trematoda: Aspidogastridae) by Wharton (1939), Florida

Melampus bidentatus Say (C)

Cercaria sp. "N" Epstein, 1972 (Trematoda: family unknown), Galveston, Texas

Class Scaphopoda

No helminth parasites have been reported from Galveston species. Trematode pre-cercarial stages have been found in other species (Arvy, 1949).

Class Bivalvia

Modiolus demissus (Dillwyn) (C)

Paravortex gemellipara (Linton, 1910) (Turbellaria: Paravorticidae), Massachusetts

Brachidontes recurvus (Rafinesque) (A)

Cercaria brachidontis Hopkins, 1954 (Trematoda: Fellodistomatidae), Louisiana

Ostrea equestris Say (C)

Cercaria sp. Hopkins, 1951 (Trematoda: Bucephalidae), Texas

Crassostrea virginica (Gmelin) (A)

Bucephalus cuculus McCrady, 1873 (Trematoda: Bucephalidae), South Carolina and Gulf Coast

Bucephalus sp. Cheng and Burton, 1965 (Trematoda: Bucephalidae), Rhode Island

Acanthoparyphium spinulosum Johnston, 1917 (Trematoda: Echinostomatidae) by Little *et al*. (1966), Texas

Tylocephalum sp. Sparks, 1963 (Cestoda: Lecanicephalidae), Hawaii

"unidentified nematode" Burton, 1961, Maryland

Aequipecten irradians (Lamarck) (U)

Cercaria sp. Linton, 1915 (Trematoda), Massachusetts)

Porrocaecum pectinis Cobb, 1930 (Nematoda: Heterocheilidae), North Carolina

Aequipecten gibbus (Dall) (U)

"larval cestode" Hutton, 1964 (Cestoda), Florida

Metacercaria sp. Hutton, 1964 (Trematoda), Florida

Porrocaecum pectinis Cobb, 1930 (Nematoda: Heterocheilidae), Florida

Laevicardium mortoni (Conrad) (C)

Cercaria laevicardium Martin, 1945 (Trematoda: Fellodistomatidae), Massachusetts

Petricola pholadiformis (Lamarck) (C)

Cercaria sp. Freeman and Llewellyn, 1958 (Trematoda), Europe

Mercenaria campechiensis (Gmelin) (C)

Himasthla muehlensi Vogel, 1933 (Trematoda: Echinostomidae), New York

Malacobdella grossa (O. F. Müller, 1776) (Nemertea: Malacobdellidae) by Verrill (1892), Connecticut

Donax variabilis Say (SA)

Bucephalus loeschi Hopkins, 1958 (Trematoda: Bucephalidae), Texas

Parvatrema donacis Hopkins, 1958 (Trematoda: Fellodistomatidae), Texas

Cercaria choanura Hopkins, 1958 (Trematoda: Monorchiidae), Texas

Cercaria asymmetrica Holliman, 1961 (Trematoda: Aporocotylidae), Florida

Distomum cornifrons Leidy, 1878 (Trematoda), New Jersey

Lobatostoma sp. Hopkins, 1958 (Trematoda: Aspidogastridae), Texas

Semele proficua (Pulteney) (U)

Cercaria fimbriata Holliman, 1961 (Trematoda: Fellodistomatidae), Florida

Cumingia tellinoides (Conrad) (U)

Monorcheides cumingiae Martin, 1938 (Trematoda: Monorchiidae), Massachusetts

Tagelus plebeius (Solander) (C)

Cercaria "A" Wardle, 1970 (Trematoda: Fellodistomatidae), Texas

Cercaria "B" Wardle, 1970 (Trematoda: Fellodistomatidae), Texas

Scolex sp. Wardle, 1970 (Cestoda: Oncobothriidae), Texas

Tagelus divisus (Spengler) (U)

Cercaria sp. Fraser, 1967 (Trematoda: Bucephalidae), Florida

Cercaria sp. Fraser, 1967 (Trematoda: Aporocotylidae), Florida

Mulinia lateralis (Say) (C)

Cercaria imbecilla Holliman, 1961 (Trematoda: Fellodistomatidae), Florida

Cercaria granosa Holliman, 1961 (Trematoda: Fellodistomatidae), Florida

Cercaria apalachiensis Holliman, 1961 (Trematoda: Bucephalidae), Florida

Spisula solidissima (Say) (C)

Cercaria sp. Yancey and Welch, 1968 (Trematoda), New Jersey

Raeta plicatella (Lamarck) (U)

Scolex sp. Harry, 1969 (Cestoda), Texas

Class Cephalopoda

No helminth parasites have been reported from the species occurring in the Galveston area.

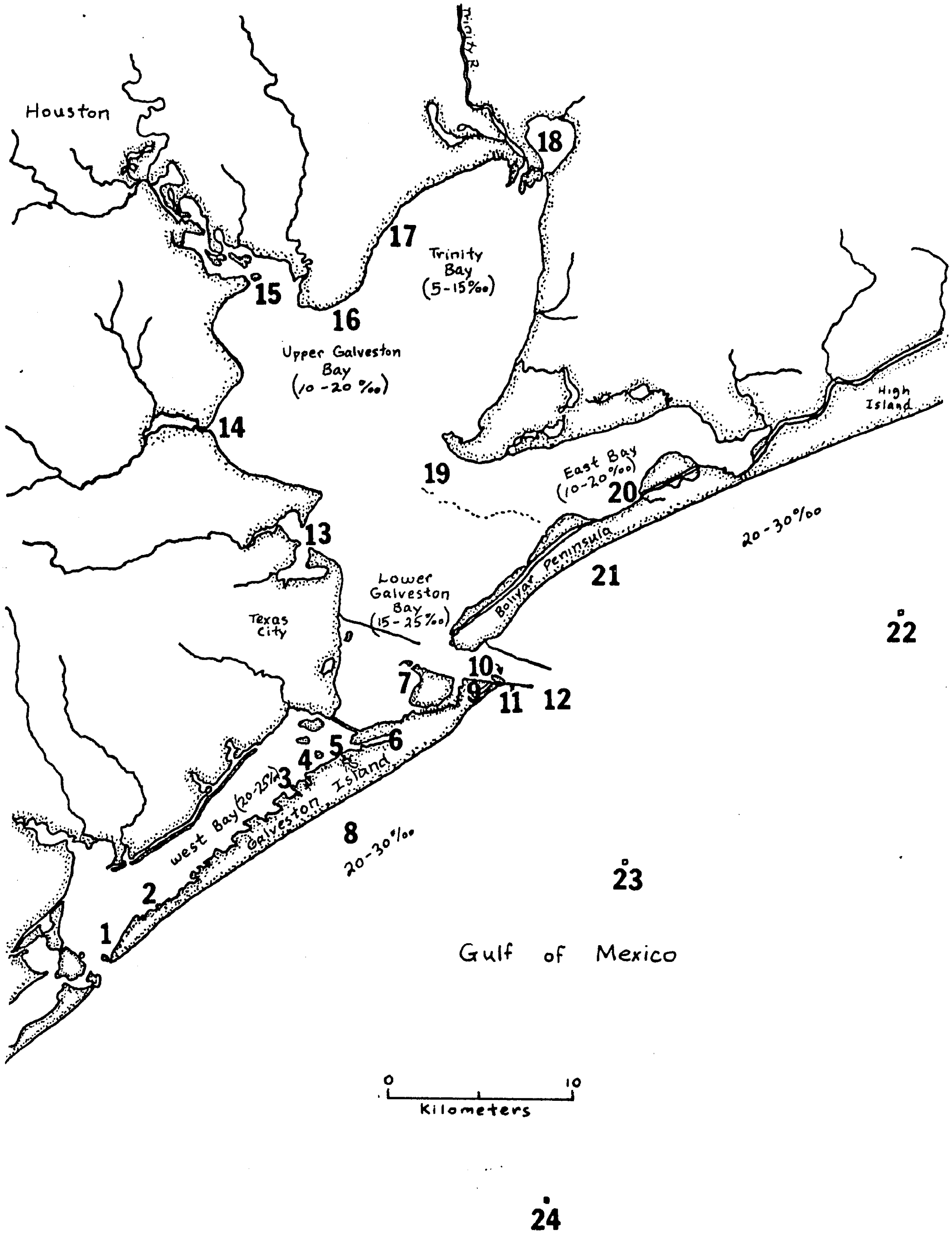
From the remaining species of Galveston Mollusca, no helminth parasites are recorded. Ten of these molluscs are abundant, 27 are common and 3 are seasonally common. The other 110 species in Harry's (1968) list are uncommon or rare.

III. MATERIALS AND METHODS

Molluscs were collected from the Galveston Bay area, Texas, extending from San Luis Pass northeast to High Island, inland to the Trinity River Delta at the northern end of Galveston Bay, and from offshore up to 40 km from the coast (Fig. 1). Collections were made year-around from January 1970 to December 1973. Live molluscs were collected by hand after being stranded on beaches, or were dug and sieved from the mud of coastal marshes, picked from emergent vegetation, scraped from submarine grasses by push net, dredged with oyster dredges and beam trawls from sandy bottoms and oyster reefs, or were collected by skin divers from jetties and offshore oil well drilling platforms.

Cephalopod molluscs were killed and kept on ice from the time of collection. Molluscs other than cephalopods were isolated individually in the laboratory in small quantities of filtered 25‰ seawater at room temperature, just sufficient to totally immerse the mollusc, permit limited mobility, and adequate oxygenation for a 24-hour period. The water and bowl bottom were examined periodically for the presence of emerged trematode cercariae, turbellarians,

Figure 1. Map of the Galveston Bay area, Texas, showing numbered stations from which live molluscs were collected during the present study. Mean annual salinity ranges indicated in parts of dissolved salts per thousand parts of water. 1. San Luis Pass; 2. Terramar Beach; 3. Eleven-mile Road; 4. Sportsman's Road; 5. Sydnor Bayou; 6. Offat's Bayou; 7. Pelican Island; 8. Galveston Beach; 9. East Lagoon; 10. East End Flats; 11. South Jetty; 12. End of South Jetty; 13. Moses Lake; 14. Clear Lake; 15. Morgan's Point; 16. Beasley's Reef; 17. McCollum Park; 18. Lake Anahuac; 19. Hanna's Reef; 20. Yates' Bayou; 21. Bolivar Beach; 22. High Island Platform; 23. Twelve Mile Platform; 24. Twenty-five Mile Platform.


Houston
Trinity R.
18
17
Trinity Bay (5-15‰)
15
16
Upper Galveston Bay (10-20‰)
14
19
East Bay (10-20‰)
20
High Island
13
Lower Galveston Bay (15-25‰)
Texas City
Bolivar Peninsula
21
20-30‰
22
10
7
9
11
12
6
5
4
3
West Bay (20-25‰)
Galveston Island
8
20-30‰
2
1
23
Gulf of Mexico
0
10
Kilometers
24

plerocercoids and larval nematodes. The water was changed at 24 hours and the isolation was terminated after 48 hours. Emerged parasites were transferred to a watch glass by pipette and subjected to side lighting for observations of swimming and crawling behavior and phototaxes. Live specimens were then transferred to two separate drops of seawater on two glass slides, one containing 0.5% neutral red and the other not containing a vital dye. A plexiglass cover slip was placed over each drop and the bulk of the description of each parasite were thus obtained by observation of living specimens. Fine structures such as flame cells and their ducts were best observed by placing small slivers of paper towel beside the cover slips to gradually withdraw the seawater, flattening the parasite and permitting greater resolution of detail.

Infected molluscs were often retained for experimental infection attempts with suspected intermediate hosts. All such molluscs were eventually sacrificed and the non-emerging stages were examined alive as described above. The location of the parasite within the host and any pathological effects were noted. Samples of emerged and intermolluscan stages of Platyhelminthes were killed and fixed in hot formalin-acetic acid and preserved in 70% alcohol for measurement and preparation of permanent slides. Nematodes were killed, fixed, and preserved in hot glycerin-alcohol, and later mounted in glycerin jelly for further measurement and study. Permanent slides of platyhelminth parasites were made by dehydration in a graded isopropyl alcohol series, staining with Semichon's carmine (Cable, 1958), destaining with 1% HCl, clearing in xylene and mounting in Permount on glass slides with cover slips. Final drawings of parasites are based primarily on notes and sketches taken during live observation in seawater and with the aid of vital dye. Additional information was obtained from photomicrographs of both living specimens and prepared slides, and from preserved specimens in 70% alcohol or glycerin jelly. All measurements are in millimeters and were taken from living specimens under light cover slip pressure in apparently normal positions. Degrees of body extension and contraction were also noted. Unless otherwise stated, measurements represent averages and ranges of those taken from 10 individual specimens.

A. Collection Sites

A total of 12,131 individual molluscs were collected from 24 collection sites from January 1970 to December 1973 in the Galveston Bay area (Fig. 1). The collection sites encompass a broad range of habitats varying in mean annual salinity, substrate type, depth, turbidity, proximity to pollution sources, and extent of physical modification and habitation. Stations 1 through 4 are located on the West Bay or north shore of Galveston Island, on intertidal mud flats adjacent to dense growths of Spartina grass. The westernmost stations (1 and 2) are generally higher in salinity and lower in turbidity, and submarine grasses (Ruppia, Thalassia) are present in some areas. The more easterly stations (3-5) are lower in salinity and higher in turbidity; oyster reefs are present in some areas but submarine grasses are rare. Stations 6 and 7, 9 and 10 are located in relatively "developed" areas near the City of Galveston, amid numerous sewage-pollution sources and sites of industrial waste discharge. Salinities are medium to high and turbidities are high. Stations 8 and 21 are sandy beachfront areas directly exposed to the waves, currents, and tides of the Gulf of Mexico. Most molluscs were collected directly from the intertidal zone or picked alive from the beach following winter storms. Stations 11 and 12 are adjacent to a man-made stone jetty projecting beyond the surf zone, containing a mollusc fauna confined to hard substrata which are rare along the coast of the Gulf of Mexico. Stations 13, 14 and 19 are middle bay stations of intermediate salinity and high turbidity. Stations 15-17 are upper bay stations with low salinity. Station 15 is located adjacent to the Houston ship channel, which conducts vast amounts of biological and chemical wastes from the nearby city of Houston. Station 18 is a brackish water lake at the extremity of the bay virtually isolated from the Bay proper. Station 19 is at the end of a submerged oyster reef near the geographical center of the bay in an area of medium salinity. Station 20, in a *Spartina* marsh in East Bay in medium to high salinity waters, is some 20 km to the northeast of the other marsh stations. Stations 22-24 are offshore gas and oil-drilling platforms belonging to various oil companies; these platforms or drilling rigs rest on the bottom in 10 to 20 meters of water and provide a firm substrate for the attachment of sessile marine life including clams and snails.

IV. RESULTS

In the 12,131 individual molluscs examined for helminth parasites, a total of 2,721 infections (22.4%) were found as follows: 28 infested by three types of turbellarians (0.2% of all molluscs examined), 1,279 by trematodes (10.5%), 984 by Cestoda (8.0%), and 430 by Nematoda (3.5%). The species found within each group are presented below accompanied by brief synopses of the main characteristics of the higher taxa to which they belong. The presentation for each species of helminth parasite includes a consideration of its morphology, behavior (if noted), identity, life cycle and ecology.

V. TURBELLARIA

Most turbellarians are free-living carnivores and scavengers; however, the orders Rhabdocoela, Temnocephala and Polycladida contain numerous species that are commensalistic, and the former two orders also contain definitely parasitic forms. The Temnocephala are restricted to freshwater environments, but the Rhabdocoela and Polycladida both contain species that live in marine molluscs.

A. Order Rhabdocoela

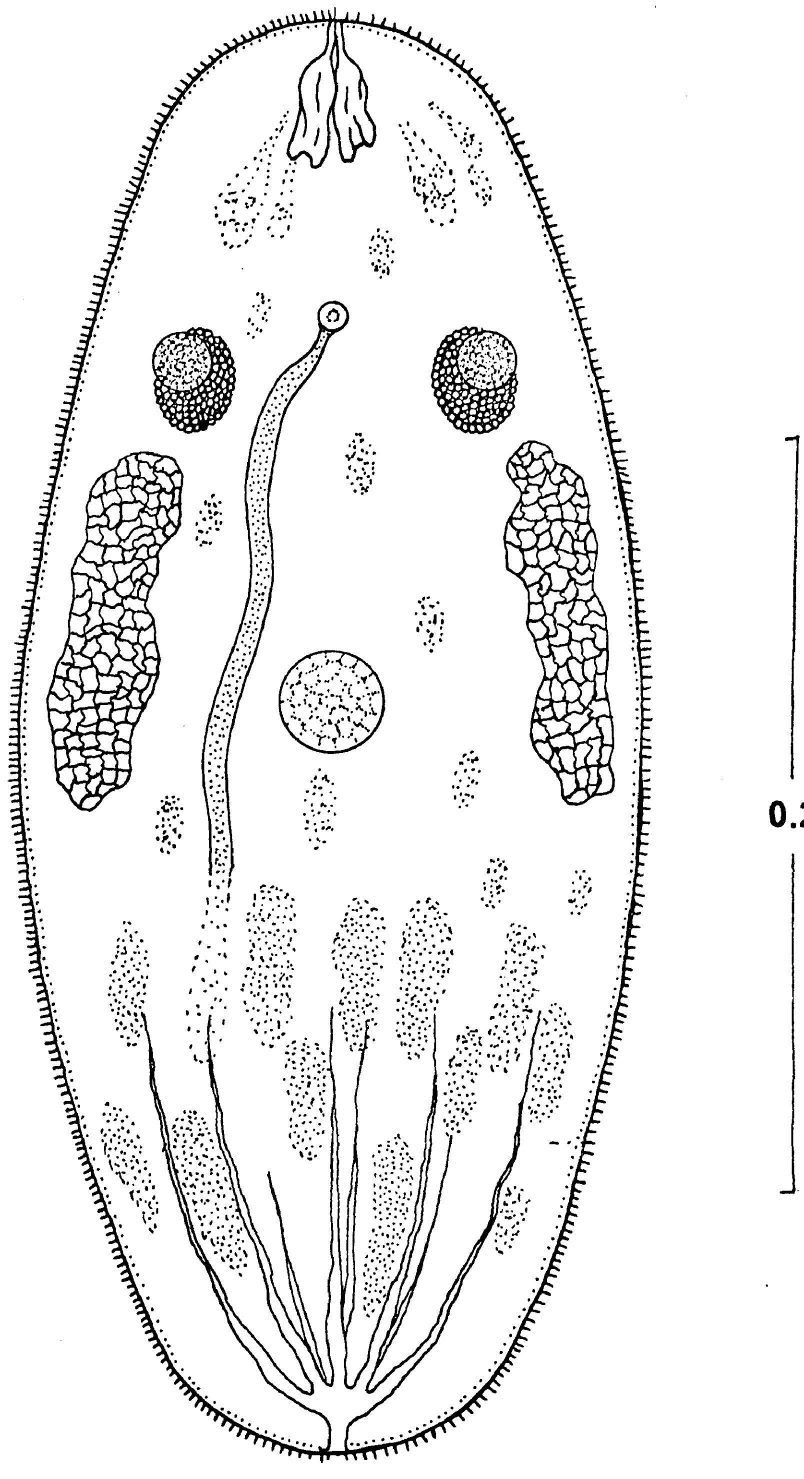
Rhabdocoels are minute turbellarians with a terminal or ventral mouth, a pharynx, and a straight unbranched gut extending posteriorly. Most species are free-living, but some are commensal or parasitic in various invertebrates, including marine molluscs.

"Rhabdocoele" sp. I

(Figure 2)

Diagnosis: Body oval, 0.38 to 0.44 long, 0.16 to 0.18 wide, mouth on ventral surface in anterior fourth of body, pharynx 0.01 in diameter, gut rhabdocoele, extending posteriorly to right of body midline. A pair of saccular glands present in anterior portion of

Figure 2. "Rhabdocoele" sp. I from Echinochama cornuta, ventra
view of entire animal.



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body staining orange in neutral red, no nuclei seen. Ducts opening anteriorly on frontal margin. Three or four pairs of indistinct nucleated glands, not staining in neutral red stain, also present in anterior end of body, their ducts appearing to extend anteriorly also. Paired lateral ocelli present just posterior to pharynx, oval, dark brown, 0.03 long by 0.02 wide, each bearing a circular lens lying dorsal and slightly anterio-lateral to ocellus, 0.013 in diameter. Shell gland median, circular, 0.025 in diameter, located just anterior to mid-level of body. Uteri paired, lateral to shell gland and posterior to ocelli, elongate, 0.09 to 0.12 in length by 0.18 to 0.25 in width. Excretory pore located on posterior margin of body, bladder radiating into 6 to 10 rays extending anteriorly in posterior third of body. Numerous oval granular bodies 0.02 to 0.04 in length, staining light yellow in neutral red stain, located throughout body but concentrated in posterior third, their long axes corresponding to longitudinal axis of body of worm. Body cuticla uniformly ciliated.

Host: *Echinochama cornuta* (Conrad), spiny jewel box

Locality: Offshore drilling platform (25-mile platform) 40 km southwest of Galveston, Texas.

Incidence: 2 of 3 clams (66.6%)

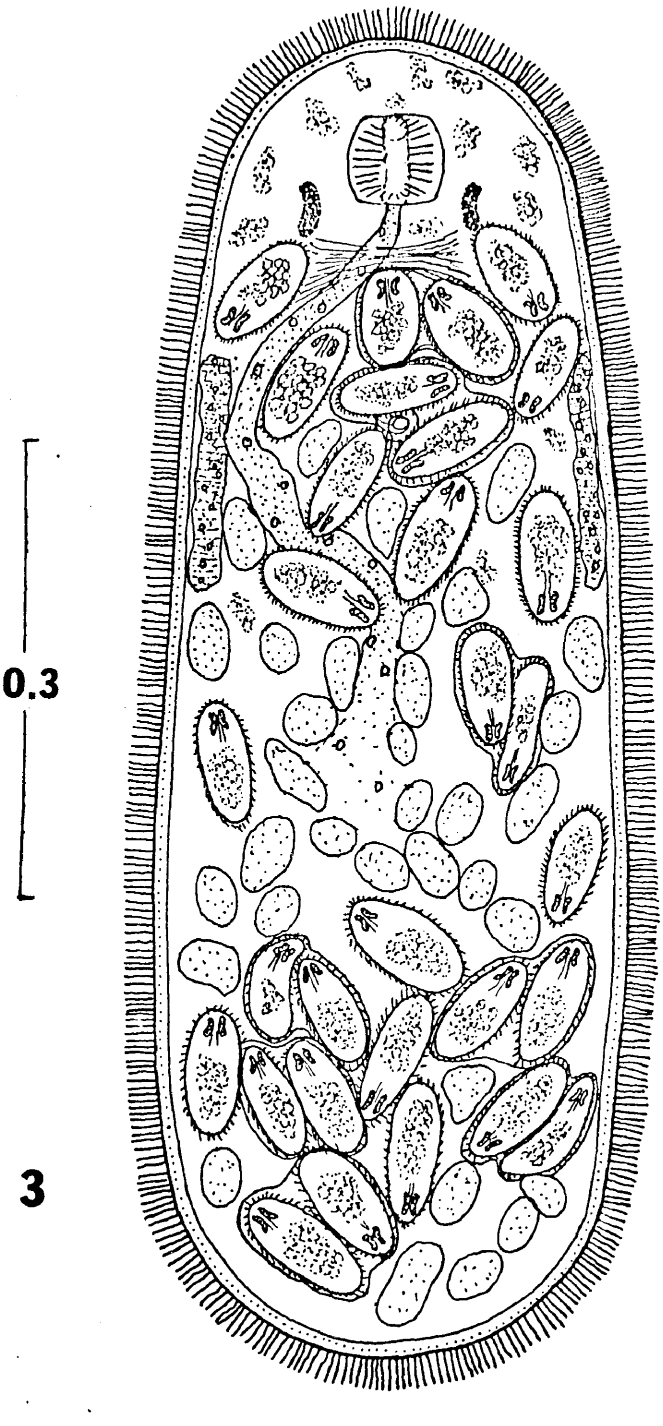
Ecology: The host clams were attached to steel supports but their exact depth was not recorded. The collection of clams was made in July 1972. The worms are very active and crawl on the mantle tissue and gills of the host within its mantle cavity. Only one specimen was found in each of two clams, and no pathogenic effects were noted, indicating that this worm is either a commensal or an accidental intruder.

"Rhabdocoele" sp. II

(Figure 3)

Diagnosis: Body ovoid, narrower anteriorly, up to 1.20 long by 0.32 wide. Mouth ventral and subterminal on body midline, pharynx doliiform, 0.07 long by 0.06 wide, immediately dorsal and posterior to mouth. Intestine rhabdocoele, extending past middle of body length. Paired lateral ocelli consisting of reniform clusters of dark brown spherical bodies present at level of posterior margin of pharynx. Ocelli 0.04 long by 0.02 wide. Ovaries paired, lateral, elongated, 0.26 long by 0.03 wide, in anterior half of body posterior to ocelli. Median genital pore on ventral surface of body between ovaries. Nerve commissure crossing intestine laterally between level of ocelli and anterior margin of ovaries. Epidermis relatively

Figure 3. "Rhabdocoele" sp. 2 from Modiolus demissus, ventral view of mature adult animal containing encapsulated larvae.



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thick and uniformly ciliated. Body of gravid specimens 0.60 to 1.20 in length, each containing up to 30 fully-formed young often in pairs surrounded by a thin flexible encapsulating membrane. Fully-formed juveniles measuring up to 0.10 to 0.04 while still in parent body.

Host: Modiolus demissus (Dillwyn), Atlantic ribbed mussel, "marsh mussel".

Locality: Offat's Bayou: 15 of 70 mussels (21.4%)

Overall Incidence: 15 of 151 mussels (10.0%)

Host: Brachidontes recurvus (Rafinesque), hooked mussel

Locality: Sportsman's Road, 1 of 8 mussels (12.5%)

Overall Incidence: 1 of 305 mussels (0.3%)

Host: Congeria leucopheata (Conrad), Conrad's false mussel, platform mussel

Locality: Sportsman's Road, 1 of 4 mussels (25.0%)

Overall Incidence: 1 of 264 mussels (0.4%)

Identity: This species is Paravortex gemellipara (Linton, 1910) (Turbellaria: Paravorticidae) from its type host M. demissus, and from two new additional hosts, B. recurvus and C. leucopheata. The occurrence of Paravortex gemellipara in Galveston extends the known range of this turbellarian from the northeast U.S. Coast to the Gulf of Mexico and to Texas.

Ecology: All known species of Paravortex are associated with marine bivalved molluscs. The European species, P. scrobiculariae (Von Graff, 1882) and P. cardii Hallez, 1909 were found in the digestive tracts of their hosts (tellins and cockles, respectively) and the single American species, P. gemellipara (Linton, 1910) was found in the mantle cavity of Modiolus demissus, the "ribbed mussel" in New England. These turbellarians of the Genus Paravortex are unique in that they are viviparous, giving birth to living young as fully-formed miniature replicas of the parents. The European species are regarded as parasites (Atkins, 1934) and the American species as commensals (Linton, 1910; Ball, 1916). Patterson (1912) reports the possibility that P. gemellipara is a parasite in the kidney of its host and is found in the mantle cavity due to mechanical rupture of the kidney during the process of opening the mussel. Patterson (1912) also notes sudden disappearances of populations of P. gemellipara which he attributes to the reproductive cycle of the parasite. P. gemellipara was found in the mantle cavity of all three hosts in the present study, and it is possible that the kidneys have been accidentally ruptured in opening the shell. Since I read Patterson's (1912) paper, however, no additional M. demissus containing P. gemellipara have been available to settle the question concerning the site of their occurrence, since the mussel beds have not yet recovered from decimation by storms.

Prior to 1971, P. gemellipara was fairly abundant (about 20% incidence) in Modiolus demissus from Offat's Bayou. At that time an extensive and dense bed of Modiolus demissus inhabited the Spartina flats of the intertidal zone. In 1971, frequent storms and rising water physically eroded the Spartina flats, washing the mussels out of their substrate and destroying the beds. Since that time no Paravortex have been found in the few surviving mussels, indicating that a dense mussel population may be necessary for their proliferation. Sparse mussel beds exist elsewhere in the area but no Paravortex were found in them. Brachidontes and Congeria may serve as reservoir hosts, but infection intensity and infection incidence by P. gemellipara was low in each species, indicating that these might be occasional or accidental hosts.

B. Order Polycladida

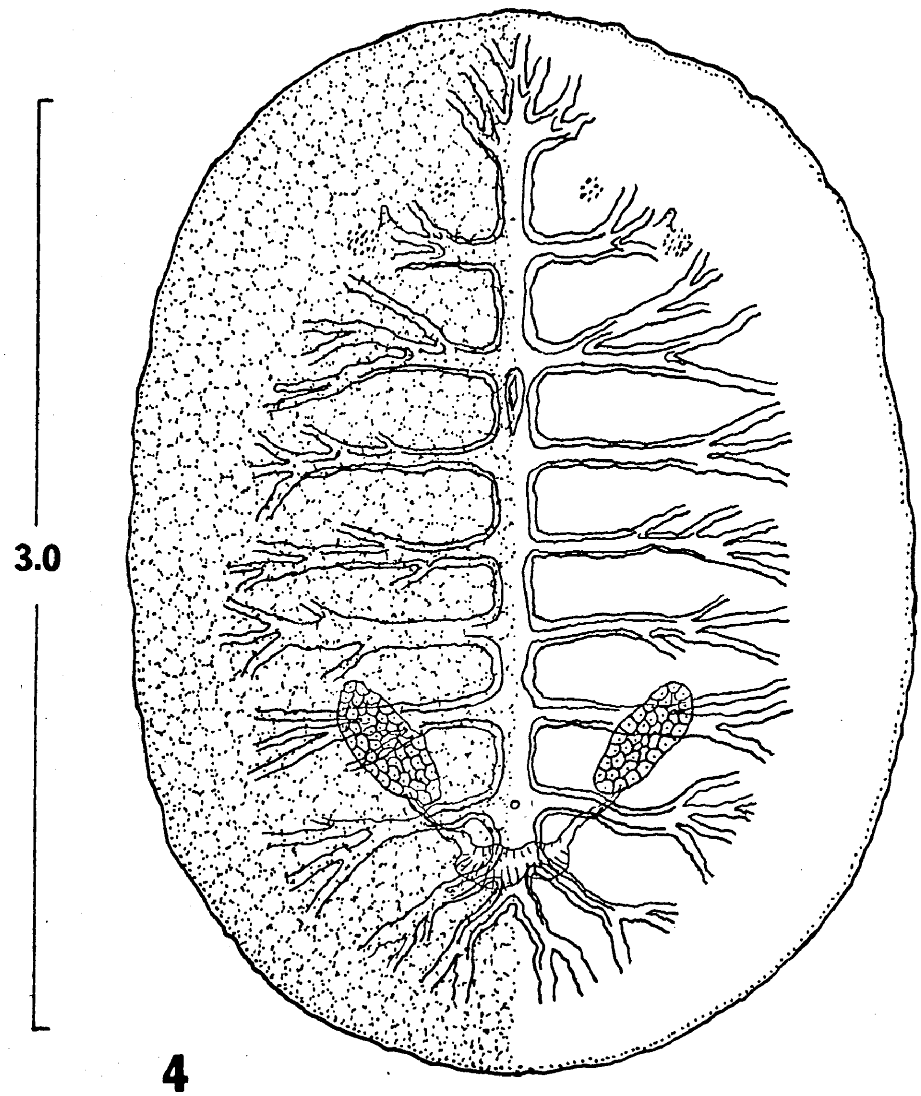
Polyclad turbellarians possess a ventral mouth and pharynx and a greatly ramified dendritic gut. They are the largest of the turbellarians, some species reaching several centimeters in body length. The body may be oval or elongate and may be camouflaged or brightly colored. All species are carnivorous, feeding on benthic invertebrates and carrion. Some predacious forms border on being parasites by feeding on prey larger than themselves, such as bivalved molluscs. Members of the Genus Stylochus are important in the regulation of populations of commercial oysters in some areas.

"Polyclad" sp. I

(Figure 4)

Diagnosis: Body oval, 3.60 long by 2.85 wide, mouth ventral and located in anterior two-fifths of body. Pharynx elongate, 0.15 long, gut with numerous primary, secondary and tertiary branches radiating throughout body. Reticulated pigmentation of light brown granules covering tan body in its entirety. Four clusters of eyespots present in anterior fourth of body as shown in Figure 3, each consisting of 10 to 20 dark brown ocelli. Paired tentacles present on anterio-medial margin of lateral eyespots, 0.05 in height. Female gonopore located on body midline in posterior fourth of body, shell gland 0.25 wide located posterior to female opening, with paired ducts extending anterio-laterad to paired uteri located in posterior third of body, 0.50 long by 0.28 wide. Male genitalia not observed.

Figure 4. "Polyclad" sp. 1 from _Thais haemastoma_. Ventral view of entire animal.



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Host: Thais haemastoma (Linné), oyster drill, Florida rock shell

Locality: Offat's Bayou, 1 of 5 snails (20%); East Lagoon, 8 of 50 snails (16%)

Overall Incidence: 9 of 107 snails (16%)

Identity: Wheeler (1894) described Hoploplana inquilina from the carnivorous snail Busycon canaliculatum from Massachusetts. Pearse (1938) described as a new species H. thaisiana from Thais haemastoma in western Florida. Hyman (1940) considered Pearse's H. thaisiana to be at best a subspecies of H. inquilina, and listed it as H. inquilina thaisiana, differing from H. inquilina inquilina only in being somewhat smaller and occurring in a different host from a different geographical area. The specimens from T. haemastoma from Galveston differ from Pearse's description only in being somewhat larger (3.6 instead of 1 to 3 mm in length) and are therefore referrable to Hoploplana inquilina (Wheeler, 1894).

Ecology: This polyclad was found in the mantle cavity of the snail host where its reticulated color pattern camouflages it against the reticulated mantle tissue of the snail. The worm is slow moving and not fixed to the tissues of the snail. Its relationship to the host snail is probably one of commensalism. No damage to the gills or mantle tissue of the host was observed. The polyclad flatworms are carnivorous and *H. inquilina* could benefit from the association by sharing in kills made by *Thais*, as well as enjoying the protection afforded by the shell and operculum in times of crisis.

VI. TREMATODA

Trematodes or "flukes" are all parasitic but have retained a functional gut. Sucking and attachment organs are usually well developed, and life cycles are variable in complexity. The class is divided into three orders. The Monogenea are mostly ectoparasites of aquatic vertebrates, and have a simple direct life cycle; none are known to parasitize marine molluscs. The Aspidogastrea may have a one or two host life cycle, and commonly parasitize freshwater and marine Mollusca as well as cold-blooded vertebrates. The flukes of the Order Digenea require at least two hosts to complete their often complex life cycle, and the first host after sexual reproduction is always a mollusc with the exception of a single family (Aporocotylidae) known to utilize tubiculous marine annelids as the first host. Adult Digenea are endoparasites of vertebrates.

Most adult digenetic trematodes are monoecious but cross fertilization commonly occurs, with sperms from the testes of one individual fertilizing eggs in the uterus of another after copulation. Reproduction occurs in the intestine or other (usually tubular) organs of the final vertebrate host. Fertilized eggs pass out with the excretory products of the vertebrate host, and the egg hatches producing a ciliated swimming larva called a "miracidium", containing numerous undifferentiated germ balls within, which bear a sibling relationship to each other, having arisen through the process of polyembryony. The miracidium seeks out a suitable molluscan host and penetrates the host's integument, sloughs off its coat of cilia and develops into a sporocyst in a specific organ, usually the gonadal area. Germ balls within each sporocyst may develop into new sporocysts or into rediae, which are germinal sacs possessing a pharynx and an unbranched blind intestine.

Sporocysts and rediae are referred to as "intramolluscan" or "precercarial" stages, and their function is to profliferate and produce enormous numbers of free swimming tailed larvae called cercariae. In some families, including most of those whose larvae develop in bivalved molluscs, the redial stage is omitted and cercariae develop from germ balls contained in the sporocysts. In other families, cercariae develop only from germ balls contained in rediae. Mature germinal sacs often each contain hundreds of cercariae, and heavily infected molluscs may each contain thousands of germinal sacs, resulting in enormous numbers of cercariae emerging from an individual mollusc. The cercarial body resembles that of an adult except for the small size, the lack of genitalia, and the possession of cystogenous glands in most species. Cercarial tails are quite varied in relative size and form, and the cercarial stages of some Digenea lack tails entirely. Cercariae usually emerge from the molluscan host, swim for a short period, and then penetrate and encyst in the body of an intermediate host, which may be an invertebrate or a vertebrate such as a fish. In the blood fluke families, the cercariae penetrate directly into the final host, and in some other species the cercariae come to rest and encyst on external surfaces. The stage in the intermediate host is called a "metacercaria". Metacercariae are usually encysted but are occasionally free in the body of the host. They have lost the cercarial tail and the genitalia are usually visible although often incompletely formed. Some species are "progenetic" and their metacercariae have functional gonads. The adult stage is reached when the metacercariae are ingested by the final (vertebrate) host. The cyst wall is dissolved by the acids and enzymes of the host, and the metacercaria is liberated and finds its way to the organ which it characteristically parasitizes, depending on the species. Most Digenea live in the alimentary tract; some live in the bile duct, kidneys, urinary bladder, lungs, or eyes; some dwell in the vessels of the circulatory system. Some species are parasitic in humans and many others can cause irritation and discomfort in attempting to parasitize humans. Most species are quite host specific with regard to the primary and final hosts, but much less so with regard to the intermediate host.

A. Family Cyathocotylidae

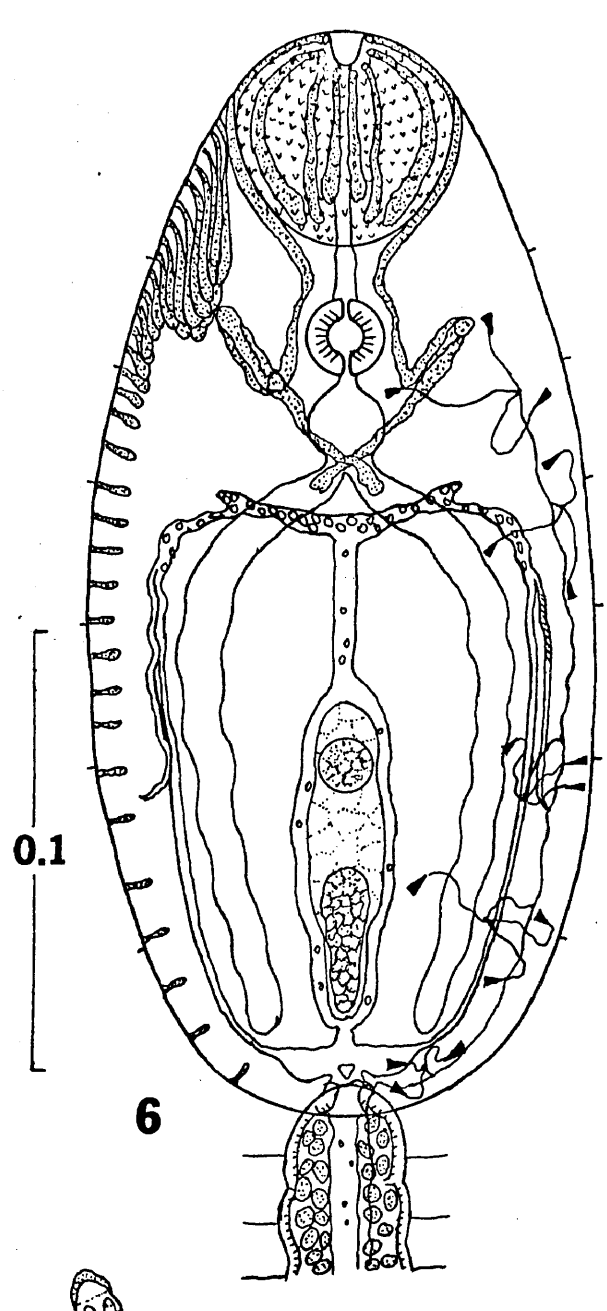
Cyathocotylid larvae develop in marine and freshwater gastropod molluscs. The cercariae are longicercous non-ocellate pharyngeate monostomes possessing a very distinctive excretory system. From a thin-walled excretory vesicle, four separate tubules extend anteriorly, two being median and two lateral. The two median tubules eventually fuse to form a single tubule connected anteriorly with the lateral tubules by a cross commissure (Cable, 1956). Marine cyathocotylid larvae occur in prosobranch snails of the Superfamily Cerithiacea (Cerithiidae, Potamididae). Metacercariae encyst in small fishes, and adults occur in all classes of vertebrates.

Cercaria sp. I

(Figures 5, 6, 7)

Diagnosis: Body 0.22 to 0.25 long and 0.10 to 0.12 wide at mid-body. Tail stem 0.25 to 0.28 long, furcae 0.18 to 0.20 in length. Oral sucker 0.05 by 0.04 and covered by small spines. Pharynx 0.016 by 0.012, prepharynx 0.010 long. Gut expanding slightly posterior to pharynx and narrowing again at crural fork.

Figures 5-7. Larval stages of *Cercaria* sp. I from *Cerithidea pliculosa*. 5. Ventral view of cercaria. 6. Ventral view of body of cercaria. Flame cells and excretory tubules omitted from right side, cystogenous glands omitted from left side. 7. Sporocyst.



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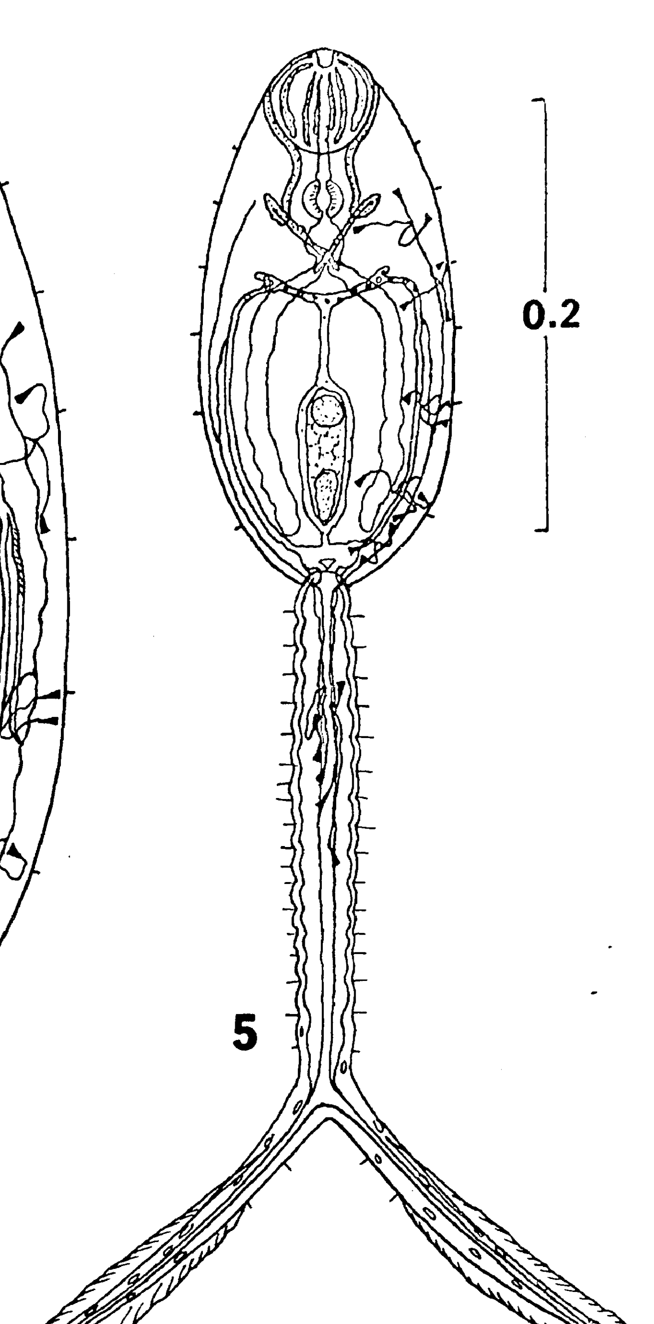

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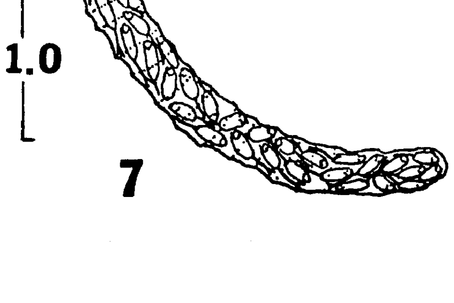

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Intestinal crura staining red with neutral red, extending posteriad almost to anterior margin of excretory bladder. Four pairs of narrow penetration glands present, staining pink in neutral red, ducts extending anteriad, dorsal to oral sucker and ending in pores surrounding mouth. Three median pairs short and not extending beyond margin of oral sucker. Lateral pair extending posteriad beyond oral sucker, recurving twice at level of pharynx, and crossing each other at point of bifurcation of intestine. Numerous cystogenous glands present on sides of body, being larger and more numerous between oral sucker and pharynx. Two primordia present on body midline anterior to excretory bladder. Anterior one round and possibly representing ventral sucker.

Flame cell formula $2[(3+3+3) + (3+3+3)] = 36$. Six flame cells extending into base of tail, namely the posterior cluster of three cells from each lateral half of excretory system. Excretory duct extending posteriad from bladder inside tail stem, bifurcating with caudal furcae, and each branch opening through pore located medially to furcal tips. Excretory bladder with island of Cort. Lumen of main excretory tubules ciliated from point receiving anterior and posterior collecting tubules, to point of junction with lateral tubules peculiar to cyathocotylid cercariae. Body cuticula aspinose, but bearing minute setae that become more numerous on tail stem and furcae. Tail stem often weakly constricted at regular intervals throughout entire length, forming 15 to 17 pseudosegments. Caudal furcae bearing dorsal and ventral fins attached to distal two-thirds of furcae and confluent around furcal tips.

The cercariae swim tail first in short rapid bursts to the surface of the sea water, then remain motionless and sink head first again to the bottom of the container. No concentration of cercariae in the lighted half of the dish was observed.

Sporocysts (Fig. 7) large (2.70 to 3.98 long, by 0.35 wide) and pale white in color. Anterior tip pointed and bearing minute bristles. Birth pore subterminal. Anterior two-thirds of sporocyst bearing 12 to 16 annelid-like constrictions caused by presence of girdles of opaque fibrous material at points of constriction. Sporocysts very active; each containing 30 to 60 cercariae in various stages of development. Sporocysts occurring in rectum of host, which is much swollen by sporocysts where it passes gill of snail. Single infection containing up to 135 sporocysts.

Host: *Cerithidea pliculosa* (Menke), horn snail

Locality: Sportsman's Road

Incidence: 8 of 1,164 snails (0.07%)

Identity: This species most nearly resembles *Cercaria ogatai* Ito, 1956 from *Cerithidea cingulata* in Japan, in which three pairs of cephalic glands extend posterior to the ventral sucker, but C. ogatai differs from Cercaria sp. I in that these glands do not cross. Cercaria sp. I could possibly be the cercaria of Mesostephanus appendiculatoides (Price, 1934) Lutz, 1935 which it resembles in all details except for the cephalic glands which are not shown in the figure of that cercaria. In Florida, Hutton and Sogandares-Bernal (1960) have found that the cercaria of M. appendiculatoides leaves the snail host Cerithium muscarum and penetrates juvenile mullet (Mugil spp.), encysting in the body musculature. Adult specimens were obtained by these workers by feeding infested mullet flesh experimentally to a suckling opossum (Didelphis marsupialis), a heron (Nycticorax nycticorax), a gull (Larus delawarensis), and a raccoon (Procyon lotor). The natural definitive host in Florida is the brown pelican (Pelecanus occidentalis), which, according to Hall et al. (1959) is also "an abundant resident" of Galveston Island. Populations of this bird in the Galveston area have declined greatly since 1959, possibly due to the effects of pesticide pollution and habitat destruction. Hutton (1964) lists three additional undescribed adult cyathocotylids from the eastern Gulf of Mexico, one from the double crested cormorant (Phalacrocorax auritus), one from the frigate bird (Fregata magnificens) and one from the black-crowned night heron (Nycticorax nycticorax).

According to Hall et al. (1959) all three of these birds also occur in the Galveston area. F. magnificens is an "uncommon summer visitant", P. auritus a "common winter resident", and N. nycticorax a "common resident".

Ecology: This cercaria was found in the summer and fall. Mullet (Mugil cephalus and M. curema) are very common year around in Galveston, are abundant in the habitat of the snail host Cerithidea pliculosa, and are likely to be the second intermediate host here as in Florida. F. magnificens may possibly be the definitive host since its arrival in Galveston may precede the season of peak infection in Cerithidea pliculosa.

B. Family Schistosomatidae

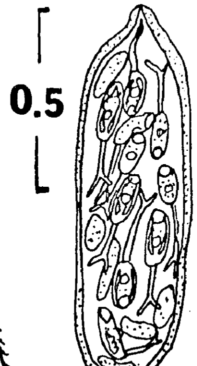
Adult schistosomes are dioecious parasites of the blood vascular system of their vertebrate final host. Cercariae are furcocercous, ophthalmate and apharyngeate and are produced in sporocysts in various marine and freshwater gastropods. There is no second intermediate host. The cercariae penetrate directly into the integument of the vertebrate final host to complete the cycle. Final hosts include birds and mammals (including man), but not cold blooded vertebrates. The cercariae of some bird schistosomes often accidentally penetrate the skin of humans who bathe or wade in infested waters, causing an immune response resulting in a form of dermatitis, occurring in both fresh waters ("swimmer's itch") and salt waters ("sea bather's eruption", "swimmer's itch", and "clam digger's itch").

Cercaria sp. II

(Figures 8, 9, 10)

Diagnosis: Body 0.22 to 0.25 long, 0.08 to 0.10 wide, tail stem 0.18 to 0.25 long, 0.04 wide, furcae 0.13 long, body and tail covered with cuticular spines, those on anterior part of body and on tail more developed than those on posterior part of body. Oral sucker a penetration organ, pyriform, 0.09 by 0.05 with three granular glands, one median and two lateral. Mouth ventral and subterminal, esophagus narrow, ceca short, terminating anterior to ventral sucker and staining red with neutral red stain. Ventral sucker 0.035 by 0.032. Penetration gland ducts open in a "V" arrangement at anterior end of penetration organ, extending posteriad in two lateral bundles of six ducts each. Nuclei of anterior three pairs of glands not extending posterior to middle of ventral sucker. Glands finely granulated. Nuclei of posterior three pairs lying posterior to ventral sucker and these three pairs of glands coarsely granulated. Eyespots circular, 0.008 in diameter, consisting of small dark brown granules, located

Figures 8-10. Larval stages of *Cercaria* sp. II from *Cerithidea pliculosa*. 8. Ventral view of cercaria. 9. Ventral view of body of cercaria. Flame cells and excretory tubules omitted fro[m] right side. 10. Sporocyst.



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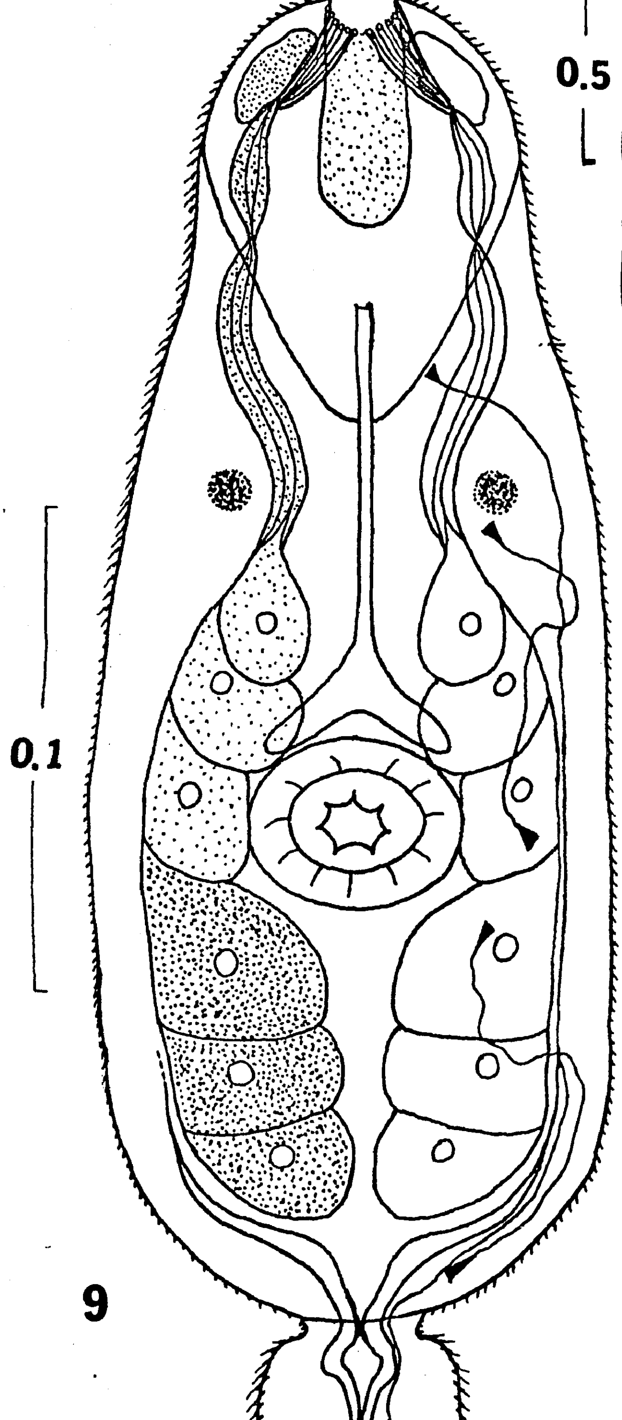

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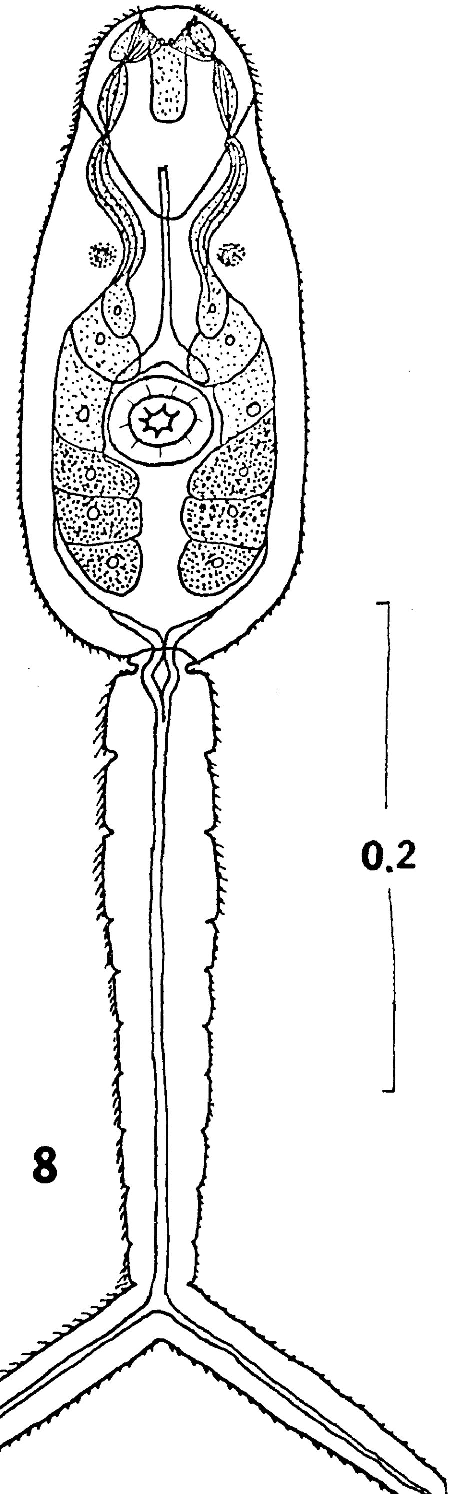

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midway between center of ventral sucker and anterior margin of penetration organ. Caudal excretory duct opening anteriorly in upper part of tail stem but right and left halves touching again before final separation at junction of body and tail. Flame cell formula 2[(1+1+1) + (1+1+1)] = 12, with posterior flame cell of each half of excretory system located in anterior part of tail stem.

Sporocysts (Fig. 10) located in digestive gland and gonad area of host, 0.50 to 1.00 long, 0.25 to 0.30 wide, cream colored, containing 8 to 15 tailed larvae emerging singly and tail first from terminal birth pore. Free cercariae swimming tail-first by rapid vibrations of tail stem, and coming to rest on surface of water with tail bent anteriad beside body.

Host: *Cerithidea pliculosa* Menke, horn snail

Locality: Sportsman's Road

Incidence: 25 of 1,164 snails (2.1%)

Identity: This species is identical to the cercaria of *Austrobilharzia variglandis* (Miller and Northrup, 1926) from *Nassarius obsoletus* in Massachusetts. Holliman (1961) described a closely related cercaria, *Austrobilharzia penneri*, from *Cerithidea scalariformis* in Florida, which he distinguishes from the cercaria of *A. variglandis* in details of body and tail spination, the position of the tail when at rest on the surface film, and "possibly in the form of the main excretory bladder ducts and bladder". The natural final hosts of *Austrobilharzia variglandis* are *Aythya affinis*, the lesser scaup duck, in Maryland (Price, 1929) and *Mergus serrator*, the red-breasted merganser, in New England (Penner, 1953). Hall *et al.* (1959) list the lesser scaup duck and red-breasted merganser as common winter migrants to Galveston Island. Experimental hosts include canaries, pigeons, gulls (*Larus* spp.) and ducklings (Stunkard and Hinchliffe, 1952).

Ecology: Chu and Cutress (1954) have found that the snail host of *A. variglandis* in Hawaii is *Littorina pintado* and that snails which are experimentally infected with miracidia will produce cercariae 4 months later, retaining the infection for a period of 1 year or more. It would therefore be difficult to correlate the seasonal incidence levels in the snail host with the seasonal migrations of suspected final hosts into the study area. The seasonal incidence of *Cercaria* sp. II in *Cerithidea pliculosa* from the Galveston area is: summer 2.1%, fall 6.3%, winter 2.0% and spring 4.3%. These figures do not indicate significant seasonal differences in incidence.

The cercariae of *Austrobilharzia variglandis* and *A. penneri* and other marine schistosomes are known to produce "sea bather's eruption" in man (Hutton, 1952; Stunkard and Hinchliffe, 1952; Holliman, 1961). Since Cerithidea pliculosa, the snail host in Galveston, is restricted to the salt marshes, it should pose no threat to bathers on Galveston beaches. In regions where clams are dug for food in habitats similar to the Sportsman's Road site, such schistosomatid cercariae frequently cause "clam digger's itch".

C. Family Aporocotylidae

Adult Aporocotylidae are parasites of the blood vascular system of cold blooded vertebrates, both fishes and reptiles. The larvae of marine species develop in sporocysts in bivalved molluscs and in both sporocysts (Linton, 1915) and rediae (Martin, 1952) in polychaete annelids. The cercariae are apharyngeate, longicercous brevifurcous with a penetration organ on the anterior end of the body where four or five pairs of penetration glands open through long ducts. A median dorsal fin is often present on the body of the cercaria. Fins may also be present on the caudal furcae.

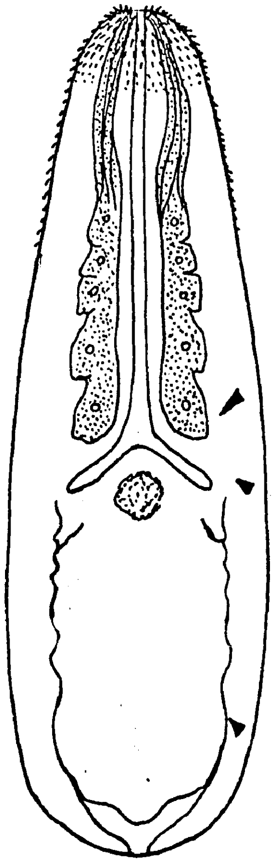
Cercaria sp. III

(Figures 11, 12, 13)

Diagnosis: Body of cercaria 0.25 long and 0.03 wide. Undulating fin present, inserted on dorsal surface of body above anteriormost penetration gland, and terminating posteriorly midway between intestinal crura and excretory bladder. Five pairs of penetration glands staining light pink with neutral red, situated lateral to esophagus, their ducts extending forward and opening medially into slightly subterminal suckerless oral cavity. Esophagus 0.14 long and straight, extending just into posterior half of body then branching into two relatively short intestinal crura, each 0.02 long, staining pink with neutral red. Excretory bladder "V"-shaped and 0.04 in height. Collecting tubules extending anterior to fork of intestine then branching into two finer collecting tubules. Three pairs of flame cells occurring in positions shown in Figure 12. Integument on anterior half of body minutely spinose, spines coarser on penetration organ. Posterior half of body and tail aspinose. Tail stem 0.35 long and bearing two symmetrical furcae 0.05 in length, each with lateral fins arising at base of furcae and confluent around furcal tips. Median excretory tubule extending from opening of excretory bladder and branching with caudal furcae, opening at each furcal tip.

Sporocysts (Fig. 13) pale white, 0.23 long and 0.11 wide, containing up to seven identifiable cercariae and two to four additional germ balls. Sporocysts appearing as pale white mass in gonad of

Figures 11-13. Larval stages of _Cercaria_ sp. III from _Mercenaria campechiensis_. 11. Lateral view of body of cercaria, with caudal furcae rotated 90° around axis of tail stem to present dorso-ventral view. 12. Ventral view of body of cercaria. Flame cells omitted from right side. 13. Sporocyst.



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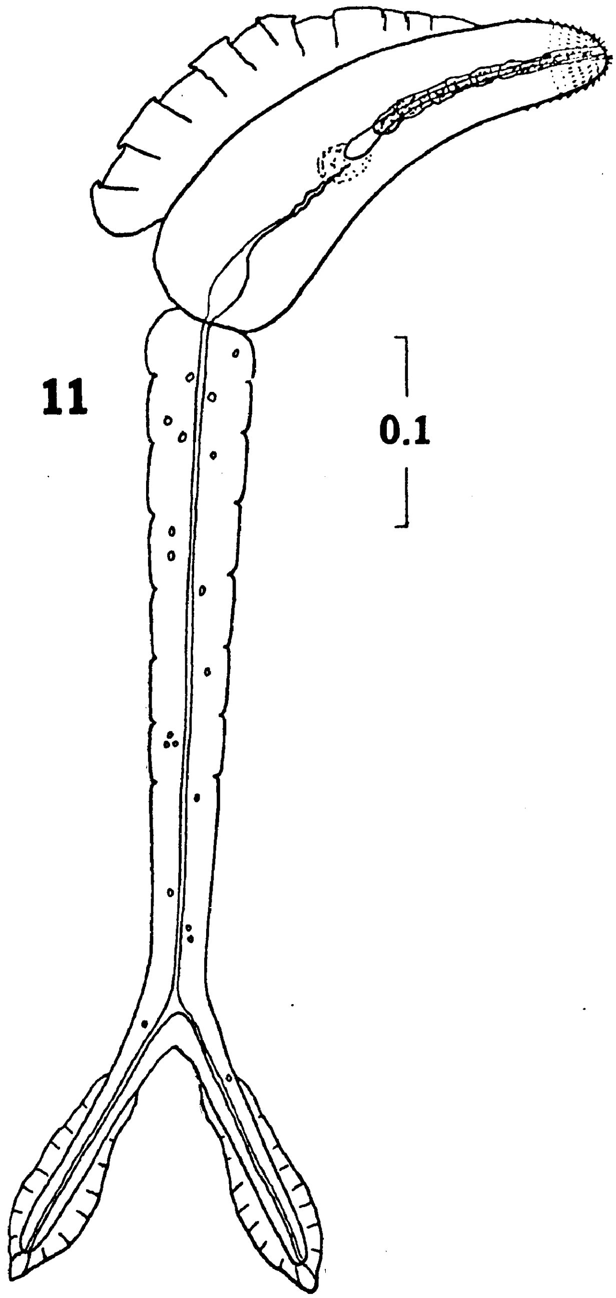

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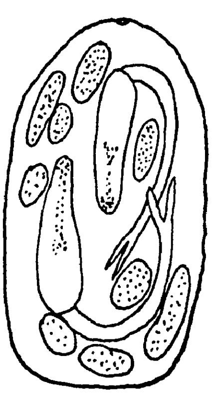


0.3

13

host clam. No identifiable gametes seen, indicating parasitic castration of host.

Host: Mercenaria campechiensis (Gmelin), southern quahog

Localities: San Luis Pass, 3 of 5 clams (60.0%); Terramar Beach, 5 of 23 clams (21.7%)

Overall Incidence: 8 of 116 clams (6.9%)

Identity: Cercaria sp. III most nearly resembles Cercaria loossi Stunkard, 1929 in the possession of five pairs of penetration glands, three pairs of flame cells, V-shaped excretory bladder, and symmetrical caudal furcae with lateral fins confluent around the furcal tips. Four species of adult aporocotylids have been reported from marine fishes in the Gulf of Mexico. Two of these were reported from host species which Parker (1965) lists as being present in Galveston Bay. Cardicola laruei Short, 1953 parasitizes the heart of Cynoscion nebulosus and C. arenarius. Both of these fishes are found throughout the year in all parts of the Galveston Bay system. Selachohemecus olsoni Short, 1954 inhabits the heart of Scoliodon terrae-novae, a small shark which according to Parker (1965) is a rare visitor to West Bay. Due to the geographical and seasonal correlation of the occurrence of Scoliodon terrae-novae and the aporocotylid infections of Mercenaria, this shark could possibly be the definitive host.

Ecology: This cercaria was found only during summer months and in the high salinity (25-30‰) areas of West Bay on the relatively natural area along the western north shore of Galveston Island. The same host clam was also found living in the sand beyond the surf zone along Galveston Beach, and in the medium salinity (20-25‰) area of the eastern portion of West Bay, but clams from those habitats were not found to be infected.

D. Family Fellodistomatidae

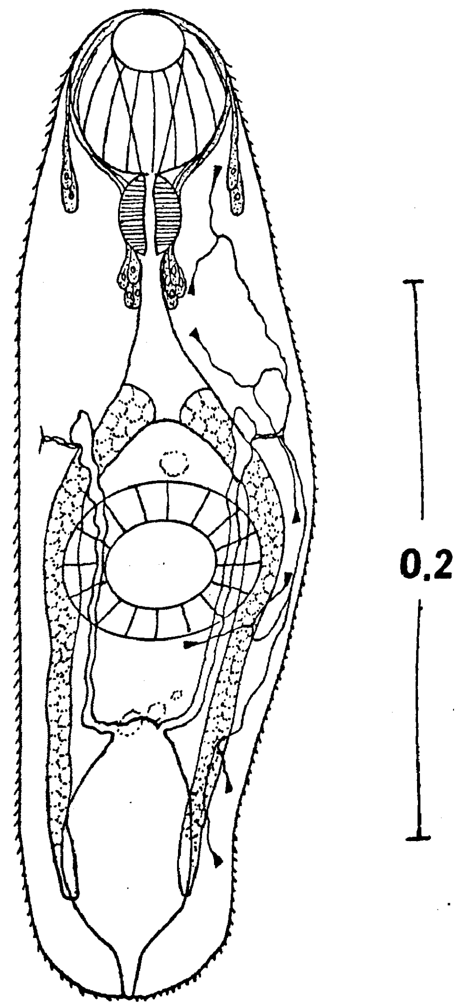
Larval fellodistomatids are distomes, without eyespots or stylet, which develop in sporocysts in marine bivalve molluscs. The excretory bladder is thin-walled, V, U or Y-shaped, with long arms reaching in some cases to the posterior margin of the oral sucker. The tail may be present or lacking; when present it is either trichocercous or trichofurcocercous. Metacercarial stages have been found only in invertebrates, and the adults occur in the intestine of marine and freshwater fishes. The family Gymnophallidae (which has been treated as a subfamily of the Fellodistomatidae by Cable, 1956) will be treated separately, following the example of James (1964) who advocates separate familial status.

Cercaria sp. IV

(Figures 14, 15, 16, 17)

Diagnosis: Cercariaeum, elongate to oval, 0.33 to 0.40 long, 0.15 wide, oral sucker 0.075, mouth ventral and subterminal. Ventral sucker 0.10 and located near body midpoint. Prepharynx absent, pharynx 0.045 by 0.038. Intestine bifurcating anterior to ventral sucker into furcae extending posteriad almost to end of body. Intestinal crura staining pink with neutral red stain. Two pairs of cephalic glands located on each side of esophagus just posterior to pharynx, with ducts extending anteriad, dorsal to oral sucker. One additional pair of cephalic glands located distally, anterior and lateral to pharynx with ducts extending dorsad over oral sucker. Cephalic glands staining yellow with neutral red stain. Anlage of gonotyl 0.02 in diameter, located on ventral midline just anterior to ventral sucker. Genital anlagen located near anterior margin of excretory bladder and posterior to ventral sucker. Excretory bladder oval, 0.08 long, arms extending from anterior lateral margin of bladder to level of bifurcation of intestine, and slightly expanding at this point. Main excretory collecting tubules joining arms just posterior and lateral to terminal swellings of arms. Flame cell formula $2[(2+2) + (2+2)] = 16$. Some cercariae showing small (0.01)

Figures 14-16. Larval stages of *Cercaria* sp. IV from *Brachidon recurvus*. 14. Lateral view of body of cercaria. Flame cells anc excretory tubules omitted. 15. Ventral view of body of cercaria 16. Sporocyst.



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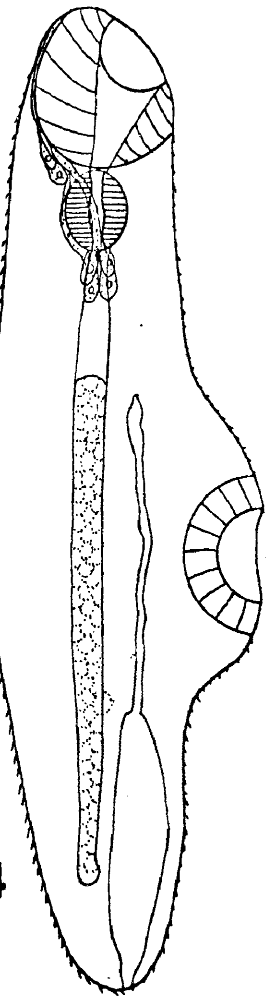

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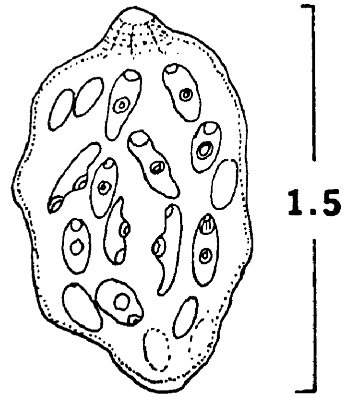

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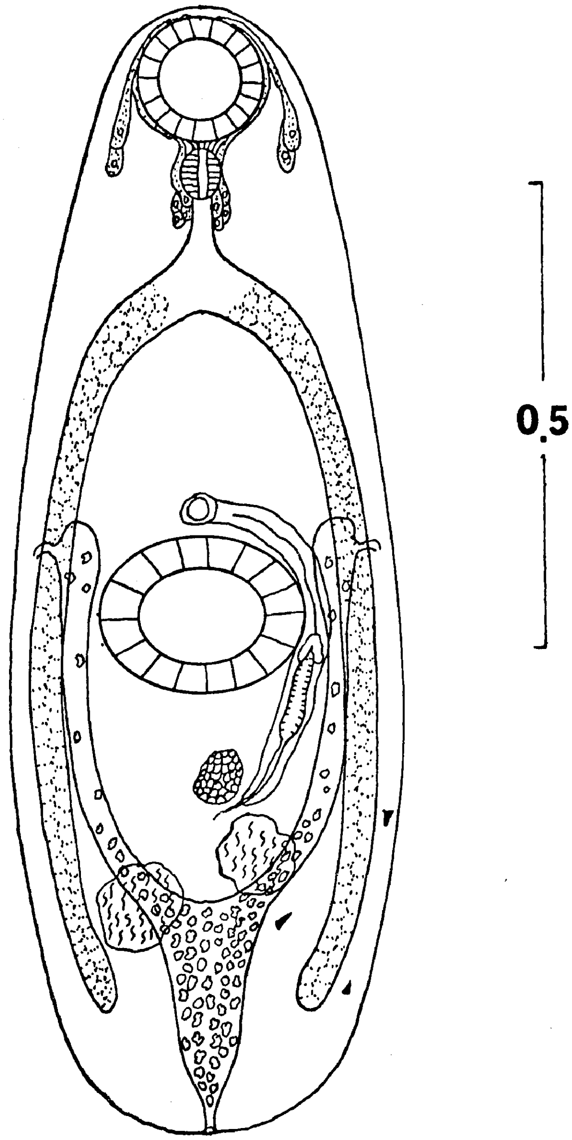
Figure 17. Metacercarial stage of *Cercaria* sp. IV from *Brachidontes recurvus*, ventral view. Flame cells omitted from right side.



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bulbous structure externally, posterior to excretory pore, possibly representing vestigial tail. Body cuticula minutely spinose.

Cercaria not swimming, but lying on bottom of container and flexing body slowly dorsally and ventrally and also laterally, making little or no directional progress. No taxes occurring.

Sporocysts (Fig. 16) occupying gonadal area of host, imparting orange hue to gonadal tissues normally appearing bright yellow in uninfected mussels. Orange-pigmented sporocysts several hundred in number, measuring up to 0.50 in length and 0.20 in width, containing up to 45 discernible cercariae in various stages of development. Sporocysts weakly motile, maggot-like.

Host: Brachidontes recurvus (Rafinesque), hooked mussel

Locality: Hanna's Reef, 1 of 17 mussels (5.8%)

Overall Incidence: 1 of 295 mussels (0.33%)

Metacercaria

(Figure 17)

Metacercariae morphologically similar to the above cercaria were found in the same host at the same locality, and also in one additional host at another locality.

Diagnosis: Body 1.00 to 1.53 in length, 0.037 to 0.056 wide. Oral sucker 0.13 in diameter, pharynx 0.06 long by 0.03 wide.

Ventral sucker laterally oval to round, protrusile, 0.19 to 0.23 in diameter. Metacercaria almost progenetic, with paired lateral oblique testes located at anterior margin of excretory bladder, measuring 0.082 in diameter. Cirrus sac present, originating near anterior border of left testis and extending around left side of ventral sucker to its anterior margin, then emptying into a circular gonotyl measuring 0.03 in diameter. Ovary median, entire, oval, located anterior to testes, measuring 0.06 in diameter. Entire flame cell formula not resolved due to opaque cuticula and tissues. Excretory bladder large and Y-shaped, stem measuring 0.25 and arms measuring 0.35 and extending to level of gonotyl. No eggs occurring in metacercaria.

Host: *Brachidontes recurvus* (Rafinesque), hooked mussel

Locality: Hanna's Reef, 5 of 17 mussels (29%)

Overall Incidence: 5 of 295 mussels (0.17%)

Host: *Congeria leucopheata* (Conrad), platform mussel

Locality: Six Mile Road, 2 of 10 mussels (20%)

Overall Incidence: 2 of 264 mussels (0.8%)

Identity: This species is *Cercaria brachidontis* Hopkins, 1954, described from *Brachidontes recurvus* in Louisiana. Stunkard and Uzmann (1959) have worked out a life cycle for a very similar if not identical species, *Proctoeces maculatus* Looss, 1901 (= *Cercaria* milfordensis Uzmann, 1953) from Mytilus edulis in Long Island Sound. The cercariae develop into a progenetic metacercaria which they assigned to the genus Proctoeces. Loos-Frank (1969) has reported a similar life cycle for two other species of Proctoeces, and on the basis of similarity in morphology of the metacercaria, Cercaria brachidontis should also be assigned to this genus. The final hosts of Proctoeces spp. are marine fishes belonging to the families Sparidae, Labridae, Blenniidae, Serranidae, Acanthuridae, Ostrachiidae, Coridae, and Embiotocidae (Dollfus, 1964), most of which are shallow water reef-dwellers. This report represents two original host records for the metacercarial stages, and a range extension for the species from Louisiana to Texas.

Ecology: This cercaria and its metacercarial stage were found in areas of medium salinity where oyster reef bottoms were present for the attachment of the host mussels. Of the fish families containing known hosts of species of Proctoeces listed by Dollfus (1964), two appear worthy of special consideration as possible final hosts of Cercaria sp. IV. The family Sparidae is represented in Galveston by the "pinfish", Lagodon rhomboides, and the "sheepshead" Archosargus probatocephalus, which are common in waters of medium to high salinity (Parker, 1965) and are known to feed around oyster reefs. The family Blenniidae is represented at Galveston by

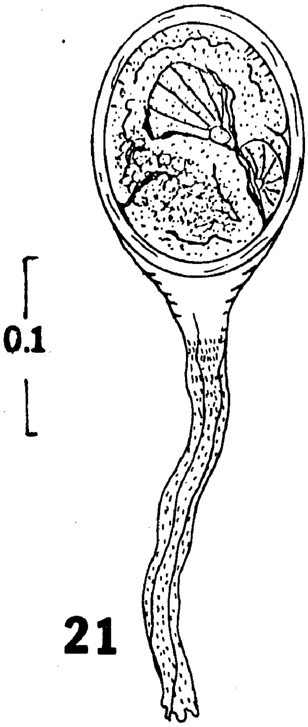
Hypleurocheilus geminatus, Chasmodes bosquianus and Hypsoblennius ionthas. The latter two are common near oyster reefs and jetties (Hopkins, personal communication; Parker, 1965).

Cercaria sp. V

(Figures 18, 19, 20, 21)

Diagnosis: Cercariaeum, body elongate, tailless, 0.20 to 0.24 long, 0.04 wide anterior to ventral sucker. Oral sucker 0.03 by 0.024. Ventral sucker circular, 0.02 in diameter. Mouth slightly ventral and subterminal. Prepharynx short, pharynx 0.012 in length. Intestine bifurcating anterior to ventral sucker and crura not extending past its posterior margin. Contents of gut staining light pink with neutral red stain. Cystogenous glands present on sides of body between level of pharynx and bifurcation of gut. Excretory bladder I-shaped. Anterior portion of bladder and its associated tubules not seen due to unusually thick and opaque cuticula of cercaria. Entire flame cell formula not determined but two pairs of flame cells located lateral to pharynx; two additional pairs located lateral to caudal excretory duct. Gonotyl 0.007 in diameter located in ventral midline of body midway between posterior margin of pharynx and anterior margin of ventral sucker. Cirrus pouch 0.02

Figures 18-21. Larval stages of *Cercaria* sp. V from *Tagelus plebeius*. 18. Lateral view of entire cercaria. Cystogenous glands, excretory tubules and flame cells omitted. 19. Ventral view of entire cercaria. 20. Sporocyst. 21. Lateral view of metacercarial cyst.



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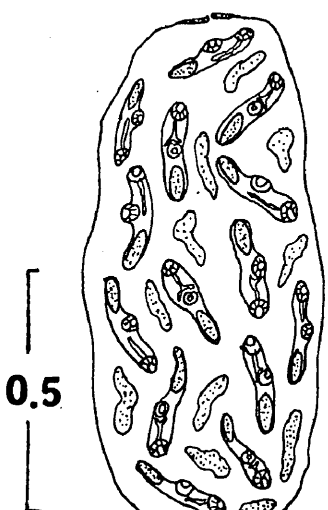

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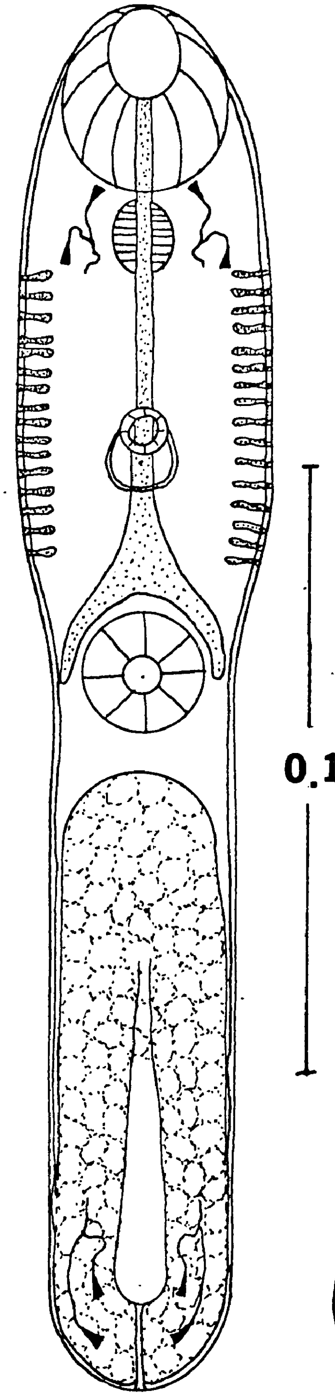

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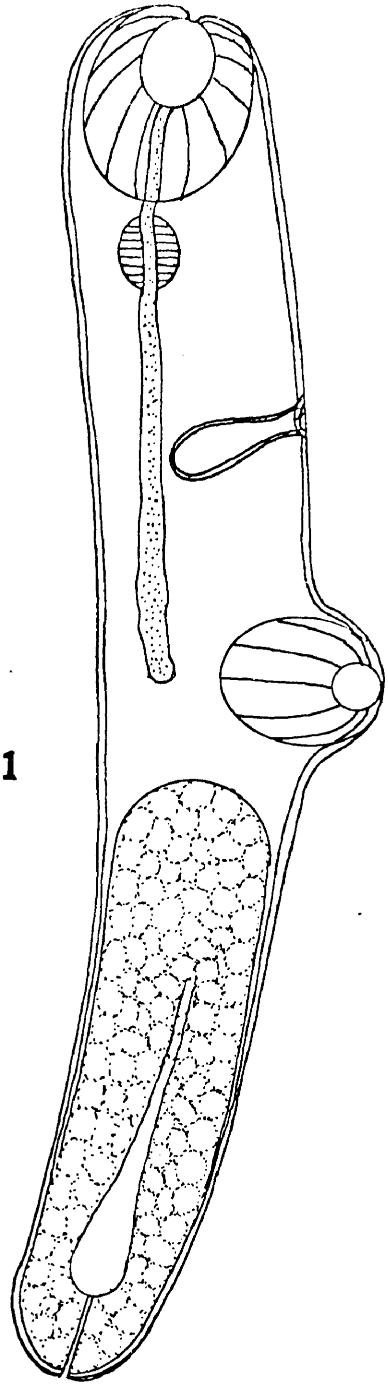

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deep extending dorsal and posterior from gonotyl. Posterior portion of body occupied by well defined cavity containing densely-packed parenchyma cells surrounding excretory bladder and its caudal duct. Body cuticula thick (0.002), opaque, giving exterior surface a wrinkled appearance. Cuticula bearing minute spines over entire surface.

Cercariae not swimming but merely lying on bottom of container, flexing body from I-shape to U-shape every 3 to 5 seconds; movement possibly serving to attract bottom-feeding second intermediate hosts. No phototaxis observed.

Sporocysts (Fig. 20) 1.00 to 1.50 in length by 0.50 in width, white, transparent; each sporocyst containing 12 to 20 cercariae. Sporocysts located in gonadal area of host clam and no host gametes identifiable, indicating that parasitic castration may have occurred.

Host: *Tagelus plebeius* (Solander), stout razor clam

Locality: Sydnor Bayou, 1 of 271 clams (0.37%); East End Flats, 3 of 1414 clams (0.23%)

Overall Incidence: 4 of 1721 clams (0.23%)

Metacercaria

Cercaria encysting in gonad and digestive gland of same host clam. Cysts (Fig. 21) thick-walled, 0.14 to 0.18 in outside diameter, by 0.12 in width. Each cyst bearing ribbon-like filament attached at one end of cyst wall and extending from cyst approximately five times length of cyst. Filament bearing numerous rows of minute spines. Metacercarial body within cyst bent in U-shape and definite movement occurring within. Details of the cercarial body within the cyst are difficult to resolve in vivo, but material fixed in formalin-acetic acid and stained with Semichon's carmine shows the contents of the cyst after clearing in xylene. Attempts to dissect the cercaria from the cyst resulted in the complete disintegration of the body upon rupturing the cyst. Treatment with artificial digestive fluids (Hunter and Chait, 1952) also gave negative results.

Identity: The thin-walled excretory bladder of the cercaria, its lack of a tail and eyespot, its slender body form, short intestine, and protrusile ventral sucker, and its occurrence in a bivalved mollusc, indicate an affinity to the Family Fellodistomatidae. However, since details of the anterior part of the excretory bladder are missing, only a provisional taxonomic placement can here be made. The species is unique in the possession of a large parenchyma-filled cavity occupying the posterior end of the body of the cercaria, and in the possession of the "tailed" metacercarial cyst, and does not closely resemble any previously-described cercaria.

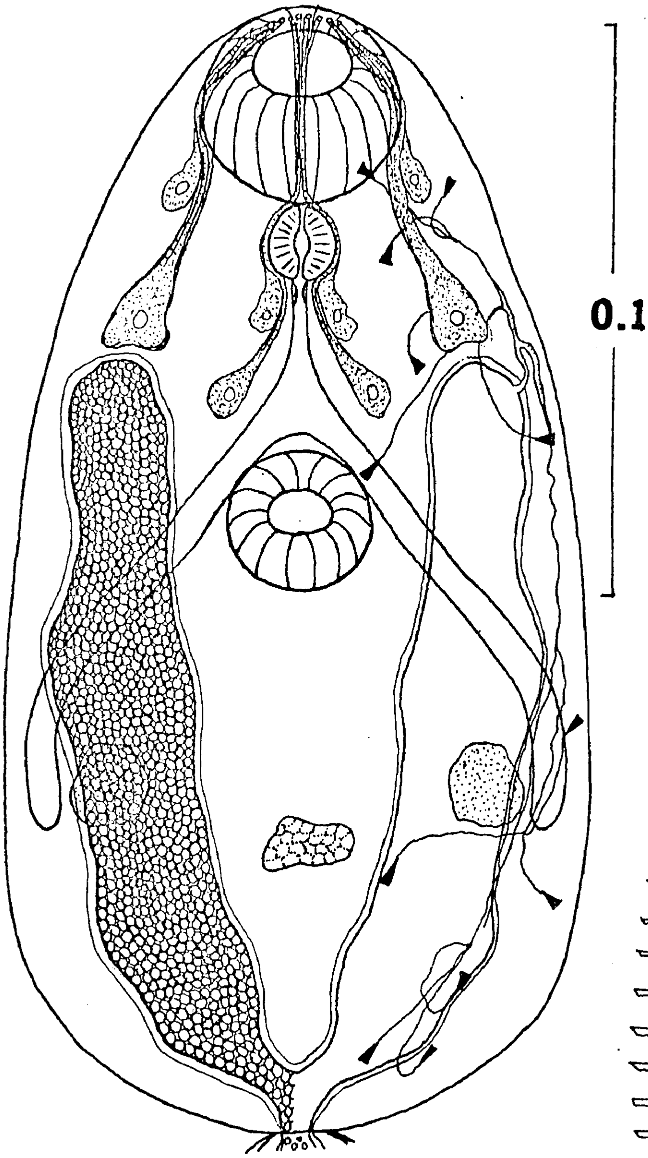
Ecology: This cercaria was found in clams of intertidal mud flats surrounded by *Spartina* grass with only limited access to the open bay. The cercaria was found in the summer months only, but cysts were found in the digestive gland tissue of *Tagelus plebeius* year around. Since the same clam apparently serves as both the primary and second intermediate host, the final host is probably a fish which is capable of feeding directly on *Tagelus plebeius* by digging or sucking the clams out of their burrows. Fishes present in the area which might be capable of so doing are the black drum, *Pogonias cromis*, and the Atlantic stingray, *Dasyatis sabina*. Both fish are listed by Parker (1965) as being abundant in shallow water. The stingray is more common in spring and summer whereas the drum is present year around.

Cercaria sp. VI

(Figures 22, 23, 24)

Diagnosis: Trichocercous cercaria, body pyriform to oval, 0.15 to 0.21 long, by 0.12 wide posterior to ventral sucker. Tail 0.25 to 0.34 long by 0.038 wide, bearing 27 to 28 pairs of lateral finlets, each composed of six rays arranged in a line dorso-ventrally and connecting to each other by a membrane or web. Longest rays 0.09 in length. Oral sucker circular to oval, 0.036 in diameter. Mouth

Figures 22-24. Larval stages of *Cercaria* sp. VI from *Tagelus plebeius.* 22. Ventral view of entire cercaria, caudal finlets omitted from left side of tail. 23. Ventral view of body of cercaria. Concretions of excretory bladder omitted from left side of body, and flame cells and tubules omitted from right side. 24. Sporocyst.



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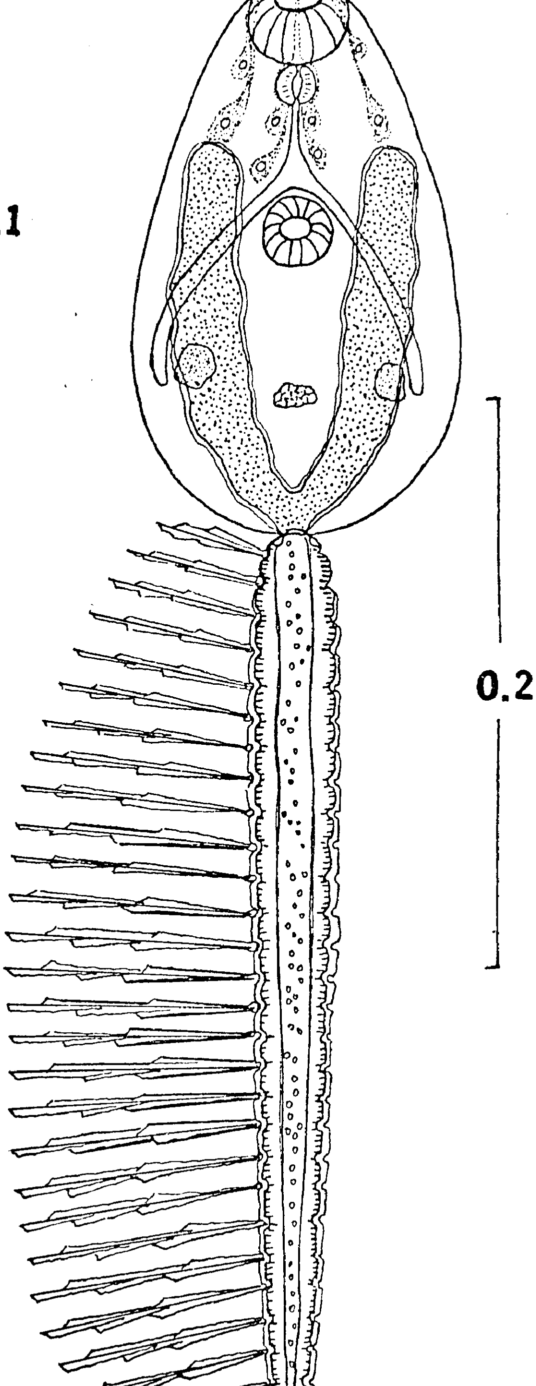

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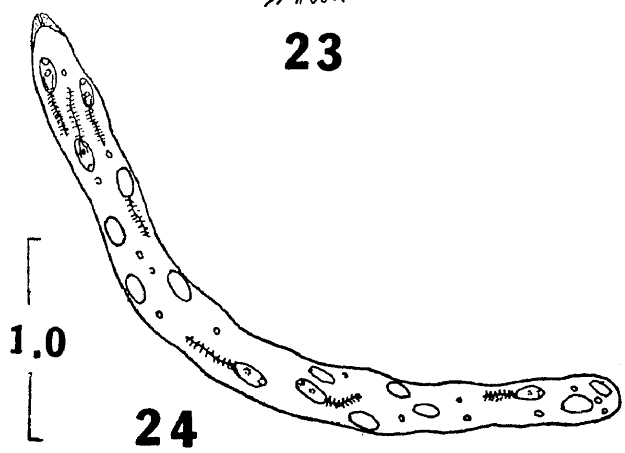

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ventral and subterminal. Ventral sucker 0.028 in diameter, slightly anterior to body midpoint. Prepharynx absent, pharynx 0.022 to 0.224 in length. Constriction of esophagus present just posterior to pharynx. Intestine bifurcating anterior to ventral sucker and crura extending just into posterior third of body. Gut contents staining red with neutral red stain. Four pairs of penetration glands present, not staining with neutral red. One pair lateral and anterior to pharynx, another pair lateral and posterior to pharynx, and two pairs medial, posterior to pharynx and adjacent to esophagus. Ducts of four medial glands uniting into a common bundle anterior to pharynx, extending dorsad over oral sucker, and opening above mouth. Ducts of each lateral pair of penetration glands extending dorso-laterad over pharynx and opening laterally to pores of medial penetration glands over mouth. Excretory bladder V-shaped, with arms extending anteriad past point of bifurcation of intestine. Bladder containing densely packed concretions and appearing bounded by double membrane, layers of which become widely separated in some specimens. Caudal excretory duct extending through entire length of tail and opening posteriorly at tail tip. Concretions present throughout entire length. Main excretory tubules enter bladder on its anterior lateral margin, their lumina appearing ciliated, with ciliary beat resembling flickering of cilia of flame cells. Flame cell formula

2[(3+3) + (3+3)] = 24. Anlagen of paired testes occurring laterally, midway between ventral sucker and posterior end of body. Outline of testes roughly circular, 0.018 in diameter. Ovary primordium medial, laterally oval, 0.019 by 0.012 and located posterior to testes in most specimens but appearing medial to, and also slightly anterior to testes in some specimens. Body cuticula aspinose.

Cercaria swimming tail first by lateral undulations of tail stem. Cercariae swimming to surface, then remaining motionless with tail twisted, or dropping slowly down with occasional resumption of swimming. No phototaxes observed.

Sporocysts (Fig. 24) long and thin, up to 3.45 in length by 0.25 in width, pale orange-yellow, and each containing from 15 to 25 larvae. Sporocysts occurring in region of gonad and digestive gland of host clam and causing parasitic castration. No identifiable gametes seen in infected clams. Cercariae emerging body-first from terminal birth pore. Sporocysts creeping actively when isolated on bottom of glass container.

Host: *Tagelus plebeius* (Solander), stout razor clam

Locality: Sydnor Bayou, 3 of 271 clams (1.1%); East End Flats, 18 of 1414 clams (1.2%)

Overall Incidence: 18 of 1721 (1.05%)

Infection Experiments: Grass shrimp (Palaemonetes pugio) and unidentified gammarid amphipods were exposed to the cercariae for 2 days and dissected on various occasions up to 2 weeks after exposure with negative results.

Identity: This cercaria is very similar to the cercaria of Bacciger bacciger described by Palombi (1934) from venerid, donacid and pholadid clams in Italy; to Cercaria laevicardium Martin, 1945 (=Cercaria laevicardii Cable, 1954) from Laevicardium mortoni in Massachusetts; and to Cercaria caribbea XXXIX Cable, 1956 in Puerto Rico. The final hosts of Bacciger bacciger are fishes of the Family Atherinidae. Minor differences in the number and arrangement of the penetration glands and in structure of caudal finlets prevent the inclusion of Cercaria sp. VI in any previously described species, pending life cycle studies.

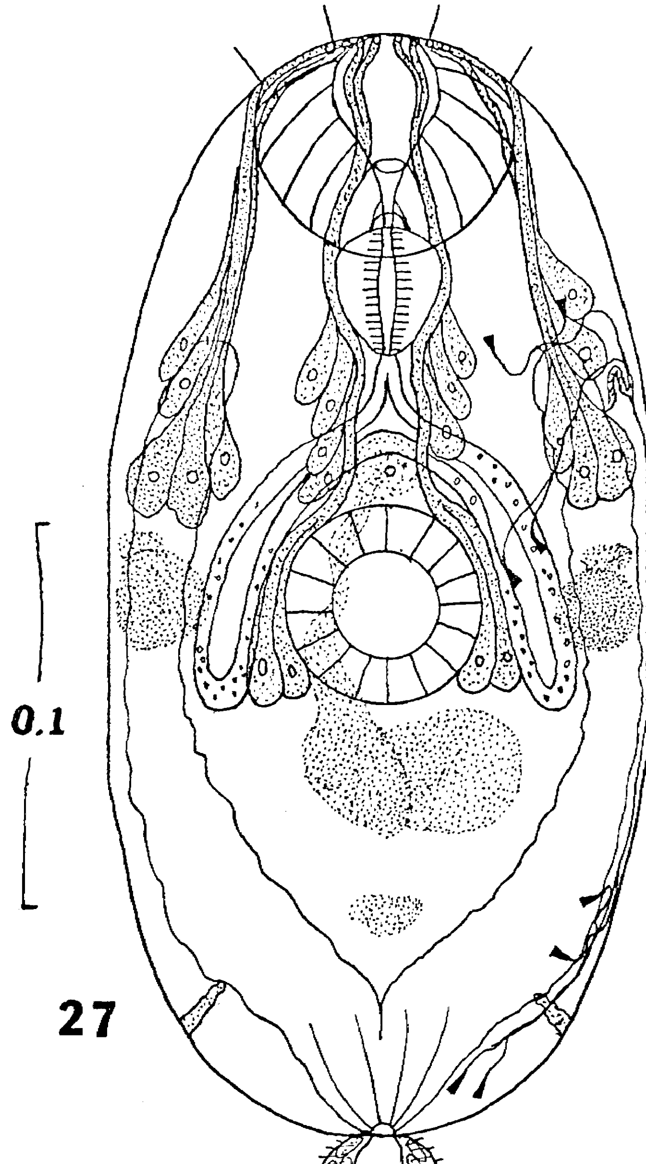
Ecology: These cercariae were found from November through May in clams collected from shallow water intertidal mud flats. Infected clams measured from 32 to 56 mm, and were large enough to have attained sexual maturity (Wardle, 1970). Palombi (1934) found that the cercariae escape the host clam and penetrate and encyst in the mud-dwelling corophiid amphipod Erichthonius difformis, which, when eaten by Atherina spp., develop into adults in the alimentary tract. Two atherinid fishes are common in the areas where infected clams were taken in Galveston: Menidia beryllina, the tidewater silverside, and Membras martinica, the rough-scaled silverside. Corophiid amphipods of the genera Corophium and Erichthonius are also common in lower Galveston Bay, hence a life cycle similar to that found for Bacciger bacciger in Italy by Palombi (1934) is quite possible in Galveston Bay.

Cercaria sp. VII

(Figures 25, 26, 27, 28)

Diagnosis: Trichocercous cercaria, body 0.26 to 0.30 long by 0.14 at level of ventral sucker. Tail 0.40 to 0.45 long, 0.045 wide, bearing 21 pairs of lateral finlets each up to 0.12 in length and composed of six setae connected by a fine web (Fig. 25). Setae arranged in dorso-ventral plane, their complexity not evident from dorsal or ventral view unless tail under great cover slip pressure. Oral sucker oval, 0.06 wide and 0.053 long, mouth subterminal and ventral. Ventral sucker slightly anterior, circular, 0.054 in diameter. Prepharynx absent, pharynx 0.036 long, crura of gut relatively short, extending just past posterior margin of ventral sucker. Walls of intestine thick and staining red with neutral red stain. Five pairs of penetration glands occurring laterally between level of pharynx and ventral sucker, four pairs occurring medially between pharynx and

Figures 25-28. Larval stages of _Cercaria_ sp. VII from _Rangia cuneata_. 25. Ventral view of entire cercaria with caudal finlets omitted from left side. 26. Anterior view of tenth caudal finlet from right side of tail stem. 27. Ventral view of body of cercaria. Flame cells and excretory tubules omitted from right side. 28. Sporocyst.



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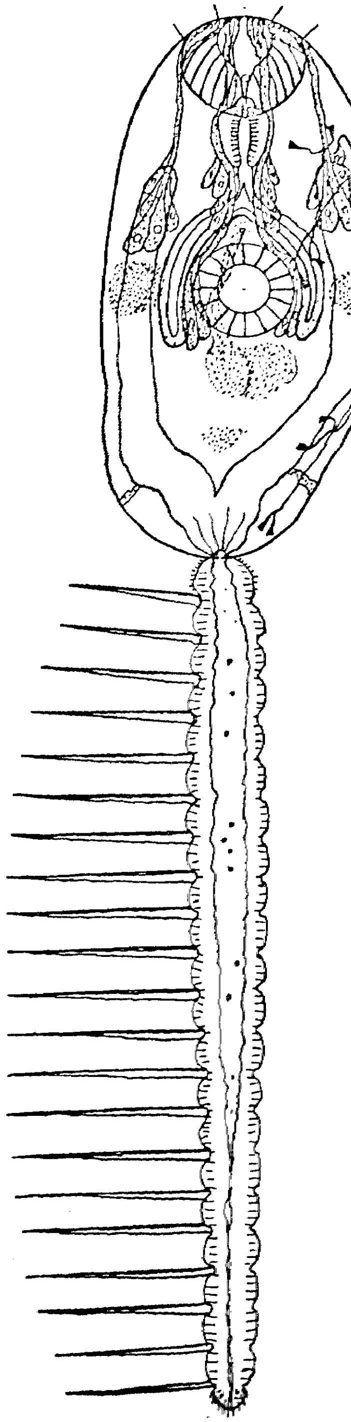

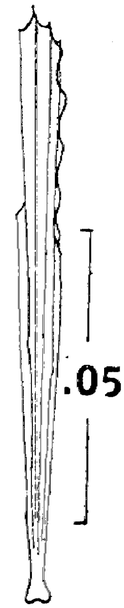

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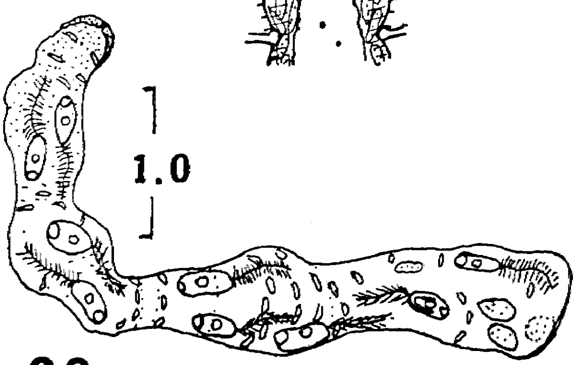

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bearing coarser spines between finlets (Fig. 23), and coarser spines on posterior tip.

Swimming strong, cercaria proceeding tail first by lateral undulations of tail stem to surface of water, then sinking slowly to bottom. No phototaxis observed.

Sporocysts located in gonad and digestive gland of host clam and orange in color due to presence of orange colored globules embedded in cuticula of sporocyst. Infected clams showing orange hue of visceral area, distinguishing them from non-infected clams appearing creamy white due to presence of gonad material. Thousands of sporocysts occurring in most infections, each sporocyst containing up to 12 fully-formed cercariae and additional germ balls. Sporocysts 8.0 long and 0.7 wide, widest point located near posterior tip. Individual sporocysts moving actively by creeping action of anterior portion. Birth pore terminal, cercariae emerging body-first from sporocyst.

Host: *Rangia cuneata* (Gray), common rangia

Localities: Lake Anahuac, 186 of 428 clams (43.4%); McCollum Park, 24 of 279 clams (8.6%)

Overall Incidence: 210 of 701 clams (29.9%)

Identity: This species is unique among the trichocercous fellodistomatid cercariae in its flame cell formula, having flame cells grouped in "twos" instead of "threes"; its lack of concretions in the excretory bladder (possibly attributable to its low salinity environment); its relatively low number of caudal finlets (21 compared to 26 to 28 for most described species); and its possession of posteriolateral cystogenous glands.

Ecology: This cercaria was found all year around, and persisted for 2 months and more in clams held in the laboratory in aquaria. Attempts to infect grass shrimp (*Palaemonetes pugio*) and gammarid amphipods with this species yielded negative results. The final host is probably a fish which can adapt to both the fresh waters of Lake Anahuac (Fig. 1, Sta. 18) and to the higher salinities (5 to 10‰, Pullen *et al.*, 1971) at McCollum Park (Fig. 1, Sta. 17). Of the fishes of Trinity Bay listed by Pullen (1960), about 15 seem to be common in this salinity regime, and could possibly be the final host. The second intermediate host is probably a small crustacean which can withstand very low salinity waters.

E. Family Gymnophallidae

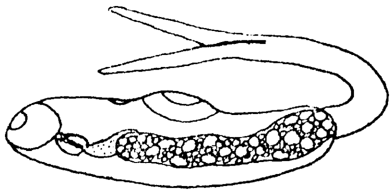
The larvae of the Gymnophallidae develop in sporocysts in the gonad and digestive gland of marine bivalved molluscs, excepting one in a gastropod reported by James (1964). The cercariae (of the "dichotoma" type) are minute, short-tailed furcocercous distomes with large Y-shaped excretory bladders which are usually densely packed with concretions. The metacercariae do not encyst but come to lie between the shell and the mantle of their molluscan second intermediate host (but one metacercaria was reported in a brachiopod by Paine, 1962). The adults are parasites of aquatic birds and are usually located in the gut, gall bladder or bursa fabricii. The Gymnophallidae were originally regarded as a subfamily of the Microphallidae, whose larvae are xiphidiocercariae developing in gastropods. Later Cable (1953) transferred the Gymnophallinae to the family Fellodistomatidae whose members have trichocercous or trichofurcocercous larvae with large Y or V-shaped excretory bladders, which develop in the gonad and digestive gland of marine bivalves. James (1964) advocated separate familial status for the Gymnophallidae on the basis of: differences in the excretory system, lack of a cirrus sac in the Gymnophallidae and its presence in the Fellodistomatidae, differences in relative length of the intestinal crura, and differences in the arrangement of the reproductive system. He recognized however the close affinity proposed by Cable (1953) and favored the inclusion of the Family Gymnophallidae in the superfamily Fellodistomatoidea.

Cercaria sp. VIII

(Figures 29, 30, 31)

Diagnosis: Furcocercous cercaria, body 0.094 to 0.098 long, by 0.048 wide. Oral sucker 0.028 long by 0.031 wide, mouth terminal. Ventral sucker round, 0.024 to 0.027 in diameter. Prepharynx absent, pharynx 0.011 long by 0.010 wide. Esophagus widening abruptly midway between pharynx and bifurcation of intestine. Crura of intestine short and thick-walled, not extending to middle of ventral sucker. Contents of intestine staining red with neutral red stain. Two pairs of cephalic glands medial, adjacent to esophagus; ducts extending anteriad along lateral contour of pharynx, passing over oral sucker and terminating in four pores above mouth. Glands staining orange in neutral red stain. Four additional pairs of pores on ventral margin of mouth. Connecting ducts and glands indistinct. Excretory bladder large, Y-shaped, with stem 0.019 long. Thick arms extending anteriad to point of bifurcation of intestine. Bladder and its arms densely packed with spherical concretions of varying diameter up to 0.002. Flame cell formula $2 [(2) + (2)] = 8$. Caudal excretory duct bifurcating with caudal furcae, each branch ending in a pore at tip

Figures 29-31. Larval stages of *Cercaria* sp. VIII from *Macoma constricta*. 29. Ventral view of entire cercaria. Excretory tubules and flame cells omitted from right side. 30. Lateral view of cercaria in swimming position. 31. Sporocyst.



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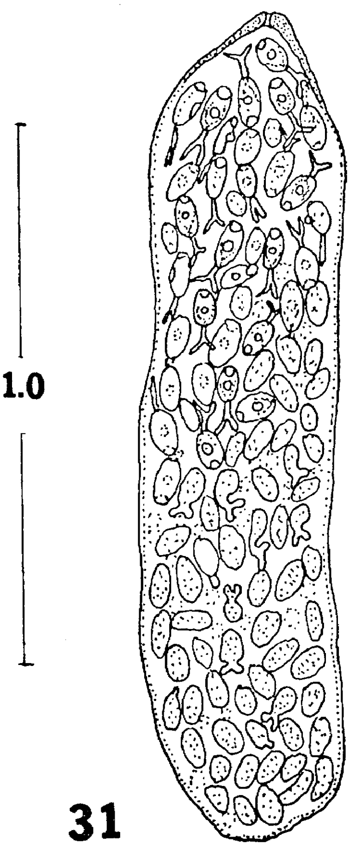

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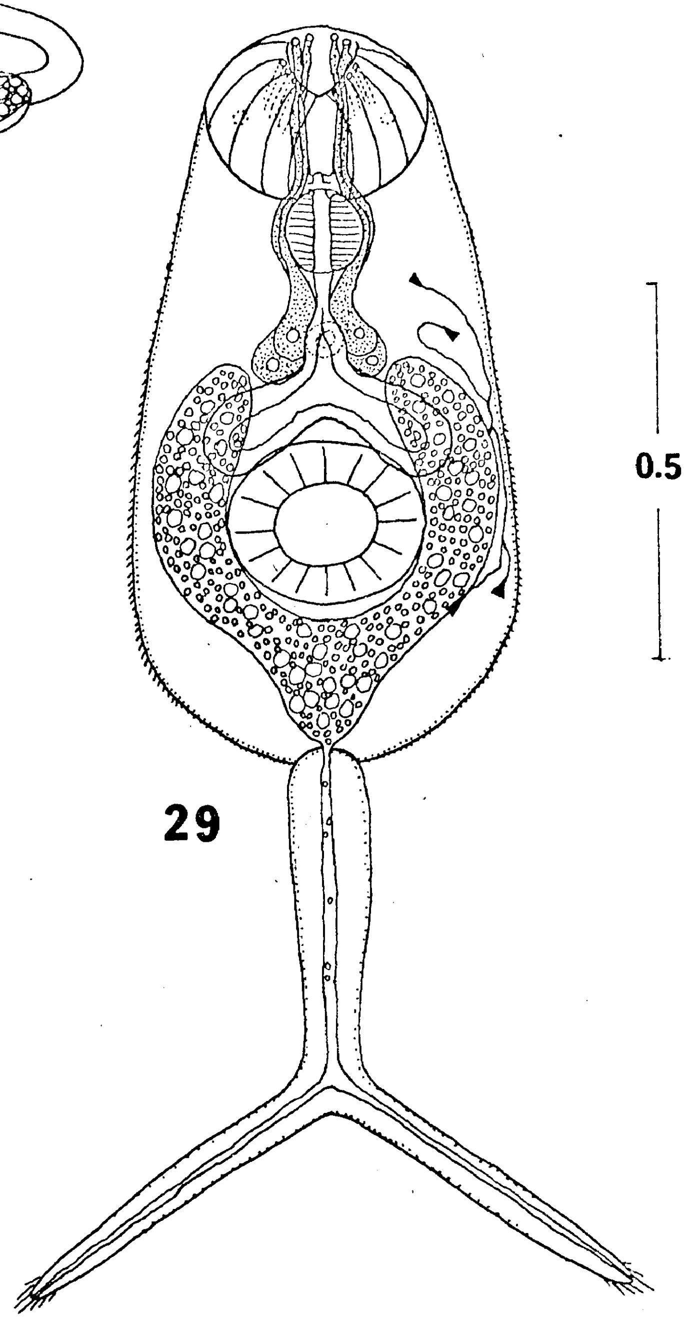

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of each furca. Apparent gonotyl on body mid-ventral surface, ventral to esophagus, 0.004 in diameter. No gonadal anlagen present. Body cuticula minutely spinose at level of ventral sucker and strongly spinose on tips of caudal furcae; aspinose elsewhere. Tail stem 0.045 to 0.050 long, 0.01 in maximum width.

This cercaria swims intermittently with the ventral surface of the body up and the tail curved forward so that the tail fork lies over the ventral sucker (Fig. 30). The tail stem beats laterally in strong swift strokes, driving the body forward. No phototaxes were observed.

Sporocysts (Fig. 31) located in gonad of host clam imparting orange hue to normally white gonadal area. Mature host gametes also observed in infected clam. Sporocysts up to 1.5 long by 0.7 wide. Birthpore terminal, each sporocyst containing up to 50 cercariae in various stages of development. Body of sporocyst mostly orange pink in color, but area immediately posterior to birthpore translucent white.

Host: *Macoma constricta* Bruguiere, constricted macoma

Locality: Sydnor Bayou: 1 of 20 clams (5.0%)

Overall Incidence: 1 of 20 clams (5.0%)

Other Stages: Some cercariae of this type are known to become metacercariae between the mantle and shell of the host clam (Cable, 1953; Hopkins, 1958) but no metacercariae were found in any of the M. constricta examined.

Identity: This cercaria most nearly resembles Cercaria fragosa Holliman, 1961; they have identical flame cell formulae, similar penetration glands, and a similarly large number of cercariae per sporocyst. Cercaria fragosa differs from Cercaria sp. VIII, however, in being slightly larger in size, lacking large setae on furcal tips, and having a crenulated inside margin of the ventral sucker. Ching (1965) described Lacunovermis conspicuus which parasitizes the clam Macoma inconspicua on the U.S. Pacific Coast. Cercariae encyst in their own sporocysts, and the cycle is completed when the clams are eaten by the greater scaup duck, Aythya marila, where the adults mature and reproduce. Hall et al. (1959) list A. marila as an uncommon winter resident in Galveston, and its relative Aythya affinis, the lesser scaup duck, as a common winter resident. It is possible, therefore, due to the apparent habitat and host correlation, that Cercaria sp. VIII is a species of Lacunovermis, found at a stage prior to encystment in sporocysts. The cercaria differs from that of L. inconspicuua in the flame cell formula (which also differs between the cercaria and metacercaria of L. inconspicuua) which in Cercaria sp. VIII is 2[(1+1) + (1+1)] = 8 versus 2[(2+2) + (2+2)] = 16 for L. inconspicuua.

Ecology: This parasite was found only once, in September 1972 in a 39 mm clam, which was dug from an intertidal mud flat, living about 15-20 cm below the substrate surface. The habitat is one of varying salinity (8-25‰) and is frequently exposed for several hours during low tide. Numerous birds were seen in the area but no systematic bird survey was made.

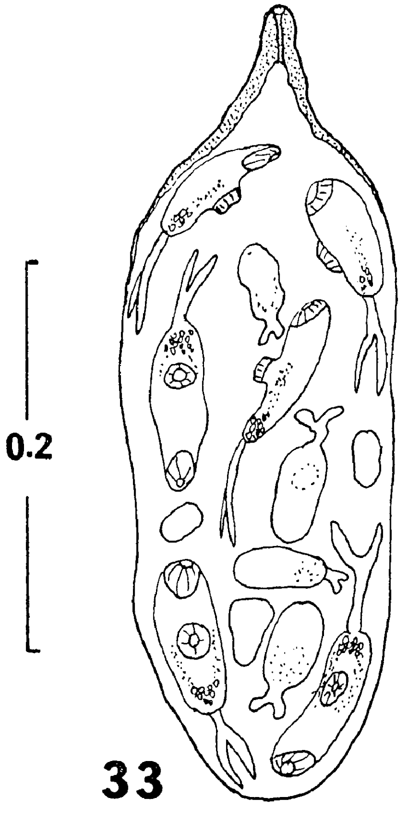
Cercaria sp. IX

(Figures 32, 33, 34)

Diagnosis: Furcocercous distome cercaria, body 0.110 to 0.096 long by 0.054 wide, tail stem 0.048 long by 0.001 wide, furcae 0.050 long. Oral sucker 0.033 long by 0.029 wide, ventral sucker oval 0.025 long by 0.028 wide. Mouth ventral and subterminal. Prepharynx absent, pharynx 0.014 long by 0.012 wide, crura of intestine short and thick, not extending to middle of ventral sucker. Crura staining red with neutral red. Two pairs of cephalic glands medial, adjacent to intestine and posterior to pharynx, ducts extending anteriorly dorsal to oral sucker and opening in four pores above mouth; glands staining light yellow in neutral red stain. Excretory bladder Y-shaped, large, arms extending to level of cephalic glands, divided

Figures 32-33. _Cercaria_ sp. IX from _Donax_ _variabilis_.

32. Ventral view of entire cercaria. Excretory tubules and flame cells omitted from right side. 33. Sporocyst.



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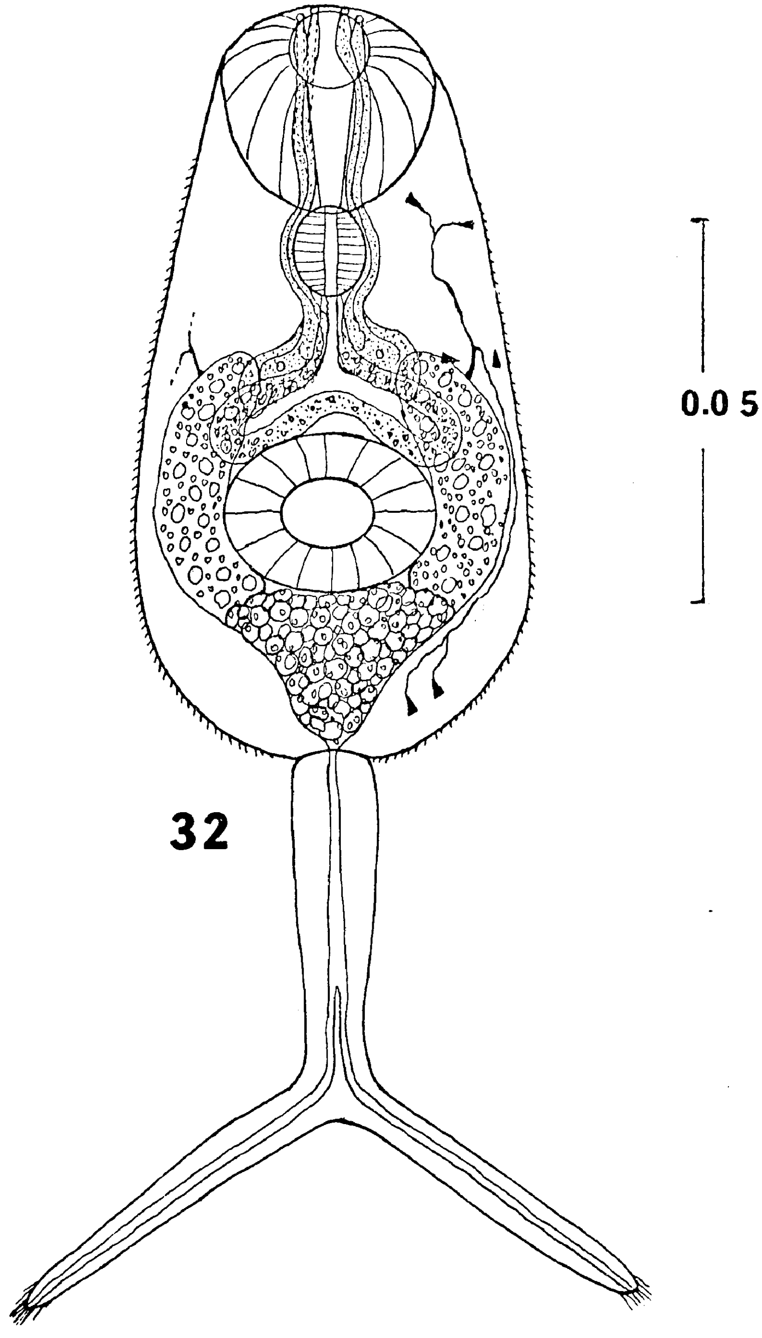

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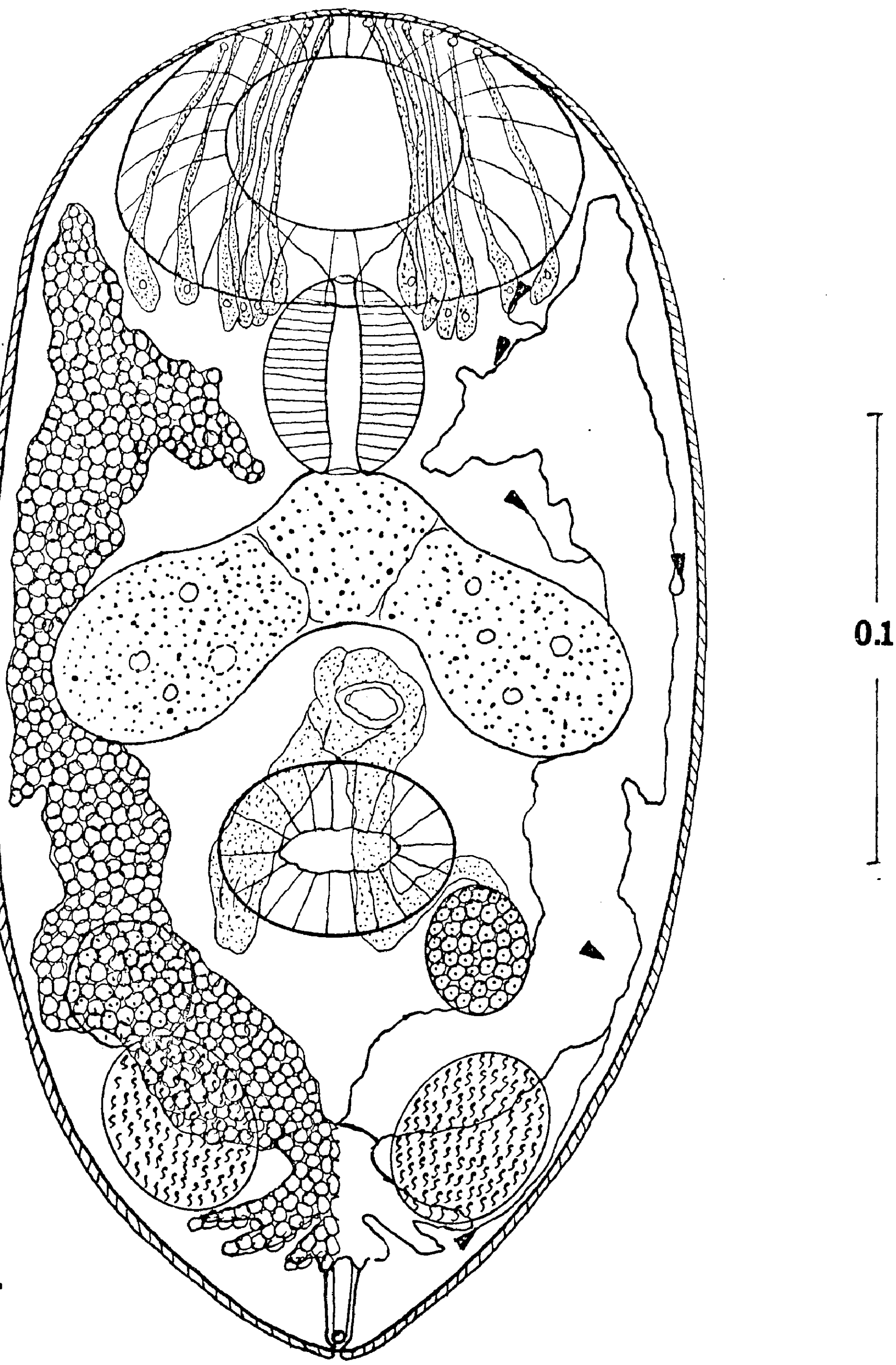
Figure 34. Metacercarial stage of Cercaria sp. IX from Donax variabilis, ventral view. Concretions in excretory bladder omitted from left side, excretory tubules and flame cells omitted from right side.



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from stem of bladder by definite line of demarcation at level of posterior margin of ventral sucker. Caudal excretory duct bifurcating anterior to point of bifurcation of tail stem and emptying through pores located on furcal tips. Flame cell formula appearing to be 2[(2+2) + (2)] = 12, but connections of tubules of middle pair of flame cells not seen. No genital anlagen seen. Body cuticula minutely spinose, aspinose anteriorly and on tail. Furcal tips bearing coarse setae.

The behavior of this cercaria is identical to that of *Cercaria* sp. VIII described above. Sporocysts (Fig. 33) in gonad and digestive gland of host clam. Individual sporocysts up to 0.040 in length by 0.13 wide, with terminal birthpore, each containing up to 10 tailed larvae. Color translucent white.

Host: *Donax variabilis* Say, coquina clam

Locality: West Beach, 6 of 239 clams (2.5%)

Overall Incidence: 6 of 584 clams (1.02%)

Metacercaria

(Figure 34)

A stage which is believed to be the metacercaria of this species was found unencysted in the same host clam.

Diagnosis: Length 0.26 to 0.33, by 0.15 wide, oral sucker 0.07 long by 0.10 wide, ventral sucker posterior to body midpoint, 0.04

long by 0.05 wide. Mouth ventral and subterminal. Prepharynx absent, pharynx 0.045 long by 0.034 wide; crura short and thick, not reaching anterior margin of ventral sucker, contents staining red with neutral red stain. About 12 pairs of cephalic glands located lateral to pharynx in semicircle along posterior margin of oral sucker, with ducts extending dorsad and opening in pores over mouth; glands staining light pink with neutral red stain. Excretory bladder voluminous, U-shaped, densely packed with spherical bodies, arms of bladder differentiated from stem by a marked lateral constriction and line of demarcation. Anterior tips of arms greatly expanded at level of pharynx and oral sucker. Stem of bladder bearing two or three pairs of lateral diverticula posterior to insertion of arms. Flame cell formula apparently identical to that of cercaria, $2[(2+2)+(2)] = 12$, but some tubules obscured by dense excretory bladder contents. Excretory pore terminal, on posterior end of body, communicating with bladder via a short straight tubule 0.02 in length. Testes paired and lateral, in posterior end of body at level of insertion of arms of excretory bladder. Margin entire, obliquely oval, 0.041 by 0.032. Ovary in left side of body, on posterior lateral margin of ventral sucker, entire, oval, 0.026 long by 0.022 wide. Uterus extending from anterior portion of ovary mediad to ventral sucker, then anteriad to genital pore on ventral surface of body anterior to ventral sucker.

Cirrus sac arising near posterior right margin of ventral sucker and extending directly to genital pore. Cirrus sac 0.056 long, genital pore laterally oval, 0.024 by 0.012. Body minutely spinose.

The metacercariae are located between the mantle tissue and shell of the host; they have no true cyst, but instead are surrounded by a mass of gelatinous mucoid secretion. Older metacercariae may become calcified by the host mantle tissue reaction to this foreign body. Spherical calcareous cysts of varying diameter were found attached to the outer surface of the host mantle near the umbo.

Host: *Donax variabilis* Say, coquina clam

Locality: Galveston Beach, 377 of 568 clams (66.3%)

Overall Incidence: 377 of 584 clams (62.7%) (16 clams from Bolivar Beach were negative)

Identity: This species is *Parvatrema donacis* Hopkins, 1958, found again in its type host and slightly north of its type locality which is Mustang Island, Texas. Two slight additional features are noted here, namely the possession of a small tuft of setae on each of the furcal tips of the cercaria, and the possession of two to three lateral diverticula of the excretory bladder posterior to the testes in the metacercaria.

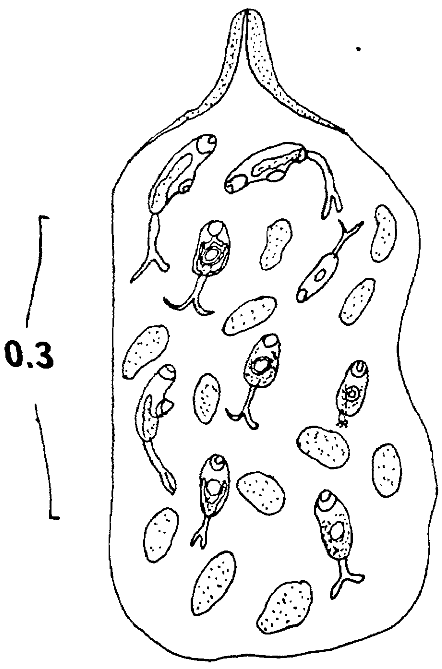
Ecology: The cercaria was found only during the summer months but the metacercariae were present year around in over half of the clams examined. The seasonality of infection suggests that the final host is a migratory bird, infecting Donax in the winter or spring. The infections are apparently lost by the clams in the fall. Cable (1953) stated that in Puerto Rico, the final host of Parvatrema boringueñae is "probably a duck". P. boringueñae closely resembles the present species. The habitat of Donax variabilis in Galveston, the wash zone of the beaches, is frequented by many species of aquatic birds, but ducks are not common here.

Cercaria sp. X

(Figures 35, 36, 37)

Diagnosis: Furcocercous cercaria, body 0.096 to 0.098 long by 0.049 wide. Oral sucker 0.028 long by 0.023 wide, mouth ventral and subterminal. Ventral sucker circular to oval, 0.020 by 0.027 in diameter. Prepharynx absent, pharynx 0.011 long by 0.009 wide. Esophagus widening gradually to point of bifurcation of intestine. Crura short and thick, not extending to midpoint of ventral sucker. Contents of gut staining red with neutral red stain. Two pairs of cephalic glands medial, adjacent to esophagus, their ducts extending anteriad and laterad to pharynx and terminating in four pores located dorsally to mouth. Excretory bladder large, Y-shaped, with arms extending anteriad to point of bifurcation of intestine. Bladder

Figures 35-36. Larval stages of *Cercaria* sp. X from *Tagelus plebeius*. 35. Ventral view of entire cercaria. Concretions in excretory bladder omitted from left side, excretory tubules and flame cells omitted from right side. 36. Sporocyst.



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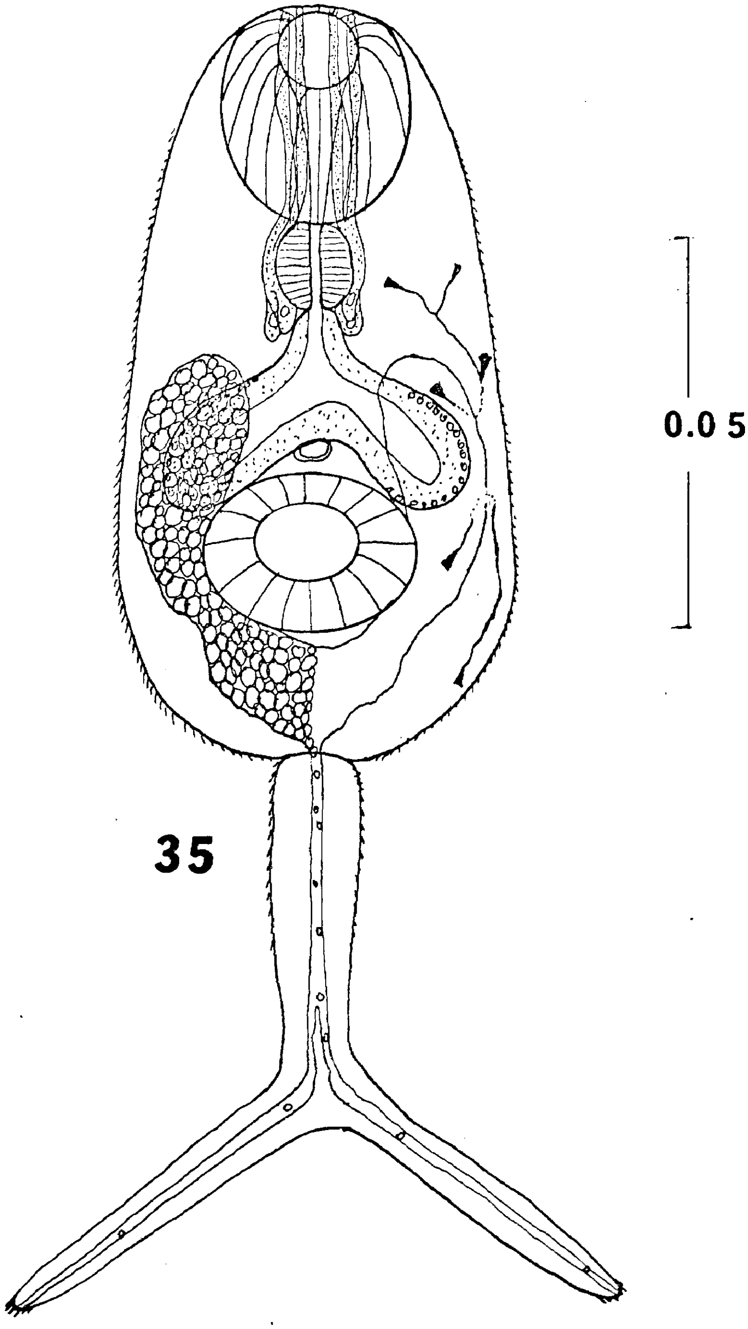

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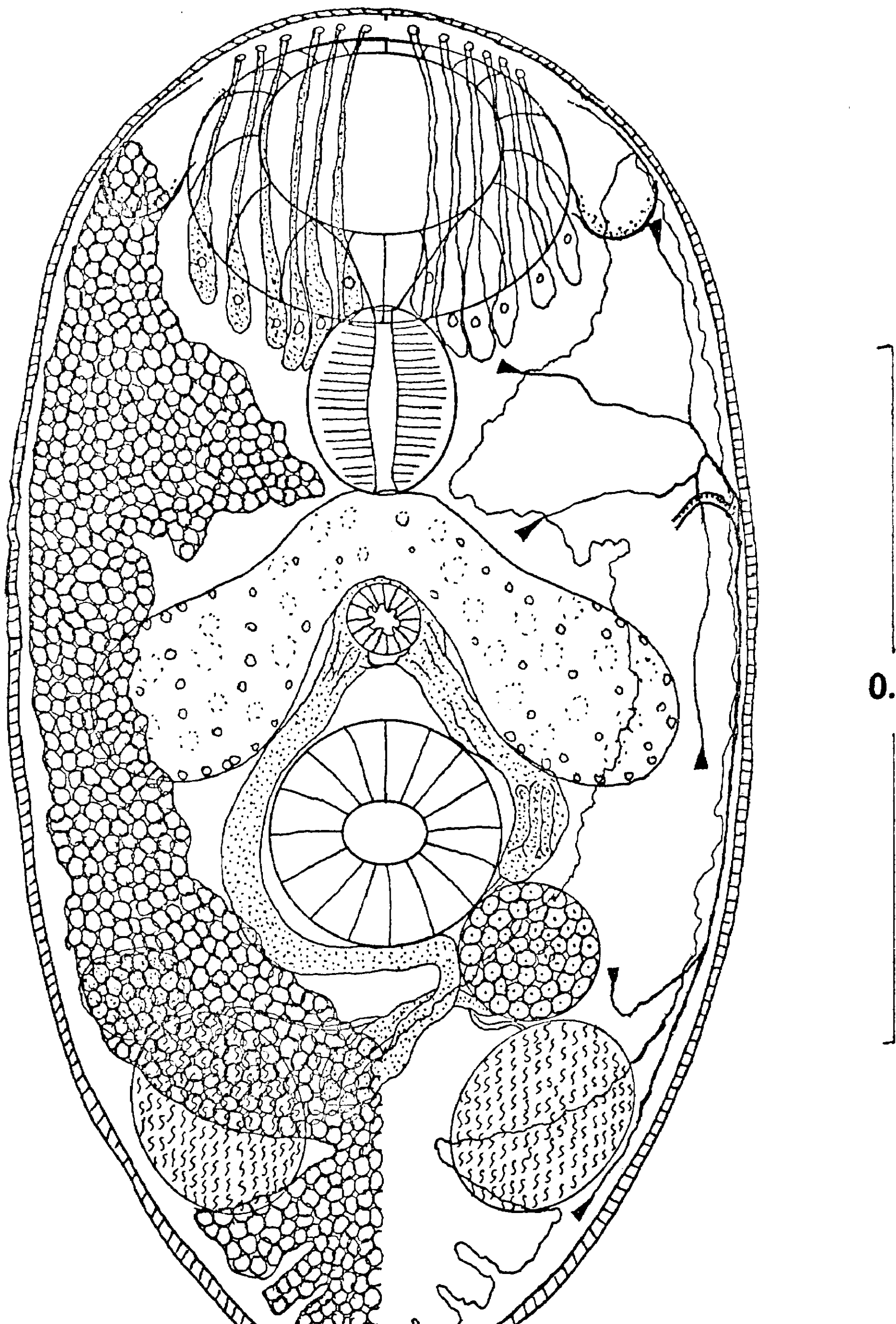
Figure 37. Metacercarial stage of *Cercaria* sp. X from *Tagelus plebeius*. Ventral view with inclusions of excretory bladder omitted from left side and excretory tubules and flame cells omitted from right side.



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filled with concretions. Flame cell formula 2[(2+2) + (2)] = 12, but some connections of tubules obscured by excretory concretions. Caudal excretory duct bifurcating somewhat anterior to point of bifurcation of caudal furcae, and ending in pores at furcal tips. Genital pore 0.004 in diameter, anterior to ventral sucker. The body cuticula minutely spinose. Tail stem 0.042 long and 0.015 wide; furcae 0.043 long, bearing coarse setae on their tips.

The behavior of the cercaria is identical to that of *Cercaria* sp. VIII described above.

Sporocysts (Fig. 36) located in gonad and digestive area of host and translucent white in color. Sporocysts up to 0.60 long by 0.38 wide and containing up to 15 cercariae. Hundreds of sporocysts occurring in single infection.

Host: *Tagelus plebeius* (Solander), stout razor clam

Localities: Sydnor Bayou, 1 of 271 clams (0.37%); East End Flats, 8 of 1414 clams (0.56%)

Overall Incidence: 9 of 1721 clams (0.53%)

Metacercaria

(Figure 37)

Unencysted metacercariae of the *Parvatrema* type similar to those described by Cable (1953), Hopkins (1958) and Stunkard and Uzmann

(1958) were found in the same host, Tagelus plebeius, located between the mantle and shell, and are probably the next stage in the development of Cercaria sp. X.

Diagnosis: Body 0.16 to 0.22 long by 0.09 to 0.14 wide, oral sucker 0.04 long by 0.06 wide, ventral sucker 0.031 in diameter and located just posterior to body midline. Mouth ventral and subterminal, prepharynx absent, pharynx 0.030 long by 0.025 wide, intestine short and thick, crura not reaching middle of ventral sucker. Six pairs of cephalic glands anterior and lateral to pharynx, arranged in semicircle along posterior margin of oral sucker, with ducts extending dorsad to oral sucker and emptying through pores over mouth. Excretory vesicle U-shaped, very large, arms extending anteriad and laterad to oral sucker; posterior portion of bladder bearing three to four diverticula, constricted abruptly at junction of arms; short, straight duct 0.016 long leading to pore on posterior tip of body. Anterior terminal portion of arms greatly thickened at level of pharynx. Entire bladder filled with spherical bodies which may be haplosporidian spores similar to those reported by Menke (1968) from gymnophallid metacercariae in coquina clams, Donax variabilis, from Galveston, Texas. Flame cell formula of metacercaria from Tagelus is 2[(2+2) + (2)] = 12, as in Cercaria sp. IX. Lumen of common excretory tubule (receiving anterior and posterior tubules) apparently ciliated. (Excretory system best studied in specimens with bladders of reduced content.) Testes, paired lateral oval bodies midway between posterior margin of ventral sucker and excretory pore, 0.036 long by 0.028 wide. Ovary, spherical, 0.023 in diameter, anterior and slightly medial to left testis and bordering on posterior lateral margin of ventral sucker. Circular genital pore, 0.012 in diameter, anterior to ventral sucker, receiving uterus and cirrus sac; latter 0.041 long, extending posteriad past middle of ventral sucker. Some specimens showing circular mass, anterior to right testis and up to 0.032 in diameter, possibly representing primordium of vitellaria. Cuticula minutely spinose, produced into two conspicuous ambulatory processes lateral to oral sucker on ventral surface.

Host: *Tagelus plebeius* (Solander), stout razor clam

Localities: Sydnor Bayou, 94 of 271 clams (39.9%); East End Flats, 622 of 1414 clams (43.9%); Sportsman's Road, 12 of 15 clams (80.0%)

Overall Incidence: 728 of 1721 clams (42.3%)

Identity: The overall morphology and the flame cell formula of this cercaria and metacercaria indicate a close affinity to *Parvatrema donacis* Hopkins, 1958 from *Donax variabilis* (= *Cercaria* sp. IX above). The species from *Tagelus* differs slightly by its possession of three to four distinct paired lateral diverticula of the excretory bladder posterior to the testes. It is doubtful, however, if this difference merits specific distinction.

Ecology: Pre-cercarial infections were found in the spring and summer months at two localities. The East End Flats, which are extensive intertidal mud flats, serve as a bird sanctuary and are inhabited by a dense population of gulls and other aquatic birds. Sydnor Bayou and Sportsman's Road, the second and third localities, are similar habitats but with no large gull populations and more remote communication to the open bay waters. The seasonality of infections indicates that the final host may be a migratory bird. Cable (1953) speculated that the final host of the closely related *Parvatrema borinqueñae* is "probably a duck". Ducks were seen in all three localities, but no systematic survey of the bird fauna was made. Hall *et al*. (1959) lists 19 species of ducks which are winter inhabitants of Galveston Island. Allen (1942) reported that the shoveler duck *Spatula clypeata* feeds on *Tagelus plebeius*, and since Hall *et al*. (1959) list the shoveler duck as a common winter resident on Galveston Island, it could possibly be the final host of *Cercaria* sp. X.

F. Family Bucephalidae

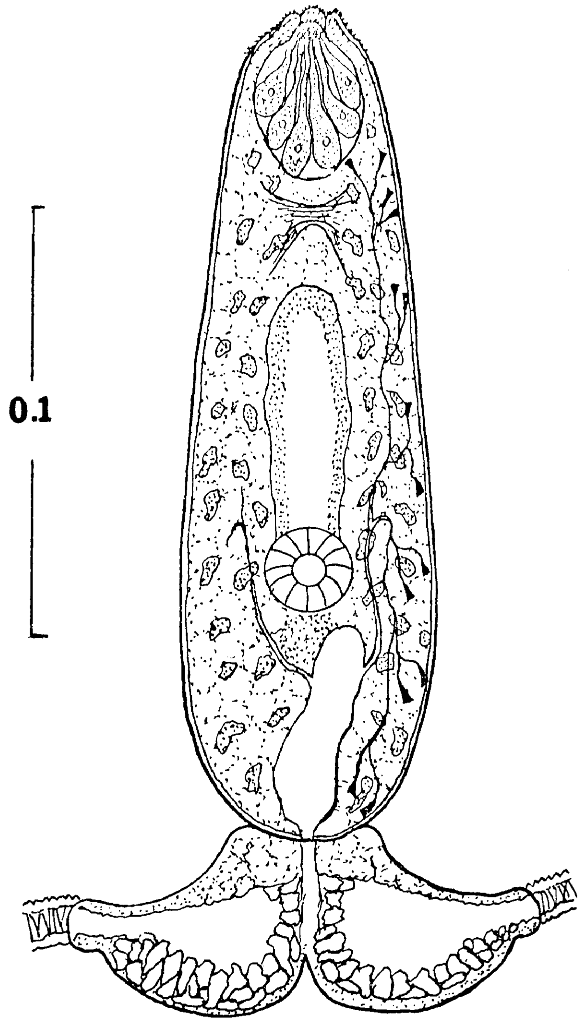
Adult bucephalids are gasterostomatous intestinal parasites of marine and freshwater teleost fishes. Larvae develop in branched sporocysts in bivalved molluscs, producing peculiar "ox head" cercariae. The cercariae leave the molluscan host and attach to small fishes by means of their extremely flexible and extensible caudal furcae. The metacercariae become imbedded in the body of the fish until this fish is eaten by the final host which is a piscivorous fish. Cercariae of different species are difficult to differentiate, and have in common the following characteristics (Cable, 1956): body with an anterior organ having no connection with the digestive system, the mouth opening on the ventral surface of the body, and leading into a pharynx followed by a rhabdocoele intestine. The tail is essentially furcocercous; the stem is a broad basal piece bearing laterally a pair of furcae which are capable of extreme elongation and contraction.

Cercaria sp. XI

(Figures 38, 39, 40)

Diagnosis: Bucephalid ("ox head") cercaria, body 0.09 to 0.15 long by 0.06 wide. Oral sucker absent, replaced by a cephalic

Figures 38-40. Larval stages of *Cercaria* sp. XI from *Anadara brasiliana*. 38. Ventral view of body and tail base of cercarial stage, details of excretory system omitted from right side. 39. Ventral view of cercaria with right caudal furca omitted. 40. Portion of sporocyst from gonadal area.



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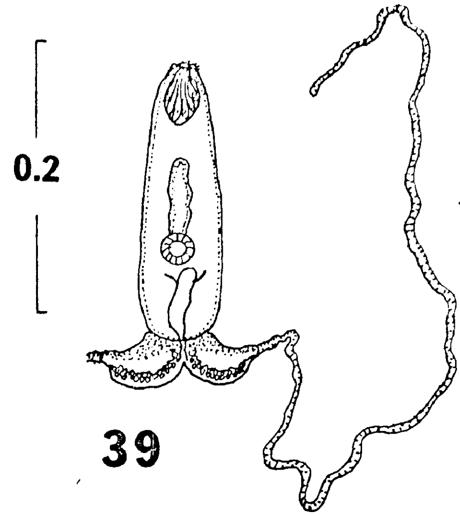

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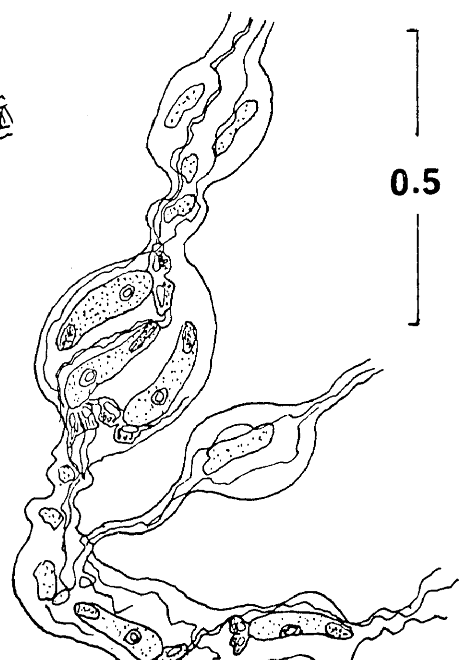

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organ 0.035 long by 0.025 wide, containing about 12 elongated glands opening anteriorly through ducts arranged in a circle. Anterior end of body with four distinct lobes bearing relatively coarse spines. Pharynx 0.018 by 0.022, opening medially on ventral surface in posterior portion of body. Intestine rhabdocoele, 0.05 to 0.07 in length, extending anteriad from pharynx, contents staining red with neutral red stain. Excretory bladder I -shaped, 0.045 to 0.052 long, its anterior portion slightly displaced from medial by presence of pharynx and genital primordium. Flame cell formula 2[(2+2+2+2) + (2+2+2)] = 28, anterior and posterior collecting tubules joining anterior to pharynx and entering into anterior third of excretory bladder. Genital promordium present posterior to pharynx, indistinct, staining red with neutral red. Nerve commissure present posterior to cephalic organ. Cuticle minutely spinose. Basal portion of tail 0.04 in length and 0.10 across, strongly indented posteriorly. Caudal furcae of greatly varying length, extremely protrusile, 0.012 to 0.015 in thickness. Sporocysts (Fig. 40) long and branching in bucephalid fashion, located in gonad of host causing parasitic castration. Sporocysts bearing numerous orange pigment spots in cuticula, imparting bright orange color to gonadal area of infected clams. Cercariae not swimming but crawling on bottom.

Host: *Anadara brasiliana* (Lamarck), incongruous ark

Locality: Galveston Beach, living in shallow water just beyond surf zone

Incidence: 172 of 358 clams (48.0%)

Identity: The distinct medial indentation of the posterior margin of the tail base, and the surf-zone habitat of this cercaria indicate a possible affinity or identity with the cercaria described by Hopkins (1958) as *Bucephalus loeschi* from *Donax variabilis* at Mustang Island, Texas. The lateral cephalic glands and primordial cirrus sac of *B. loeschi*, however, were not seen in *Cercaria* sp. XI.

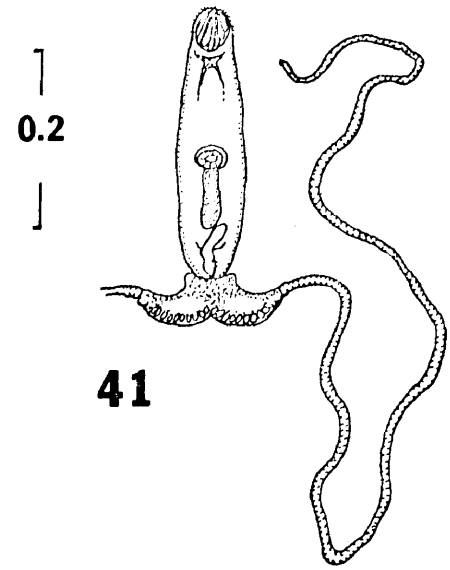
Ecology: This cercaria was found year around in clams living in the shallow sand substrate off Galveston beach. The adult is probably one of the many predacious fishes found in the area. The cercariae probably encyst in one of the many species of small forage fishes which school along the front beach.

Cercaria sp. XII

(Figures 41 to 45)

Diagnosis: Bucephalid ("ox head") cercaria, body 0.30 to 0.35 long, 0.05 to 0.07 wide. Cephalic organ pyriform, 0.05 long by 0.04 wide, containing about 12 elongated glands opening anteriorly through ducts arranged in a circle. Anterior end of body with four

Figures 41-43. Larval stages of *Cercaria* sp. XII from *Brachidontes recurvus*. 41. Ventral view of cercaria. Right caudal furca omitted. 42. Ventral view of body and tail base of cercaria. Details of excretory system omitted from right side. 43. Portion of sporocyst from gonadal area.



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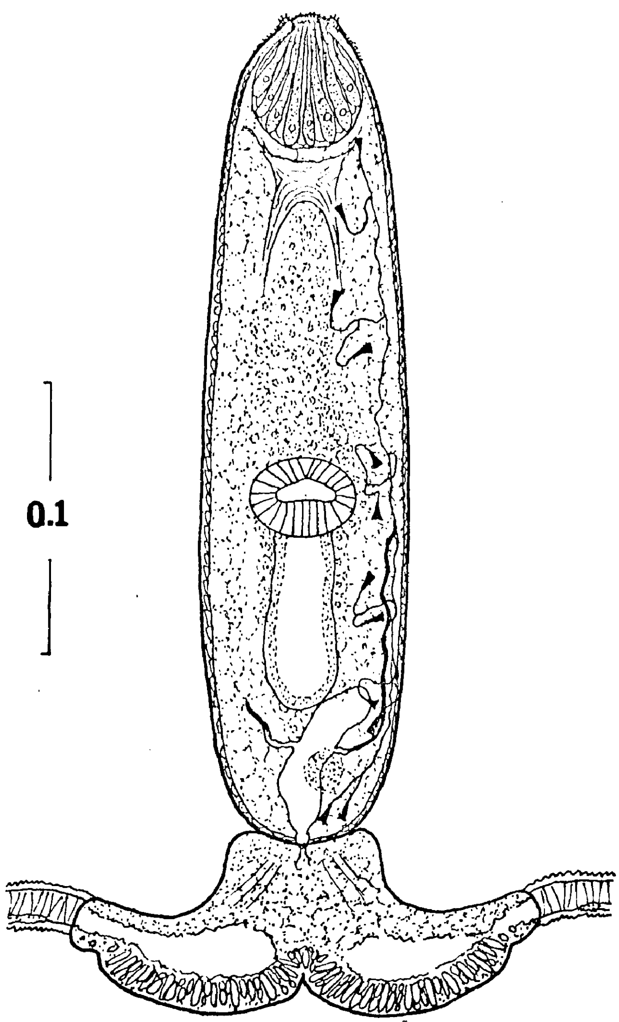

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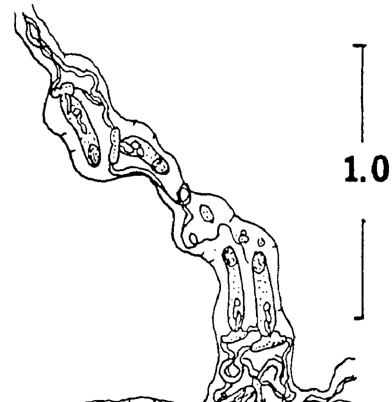

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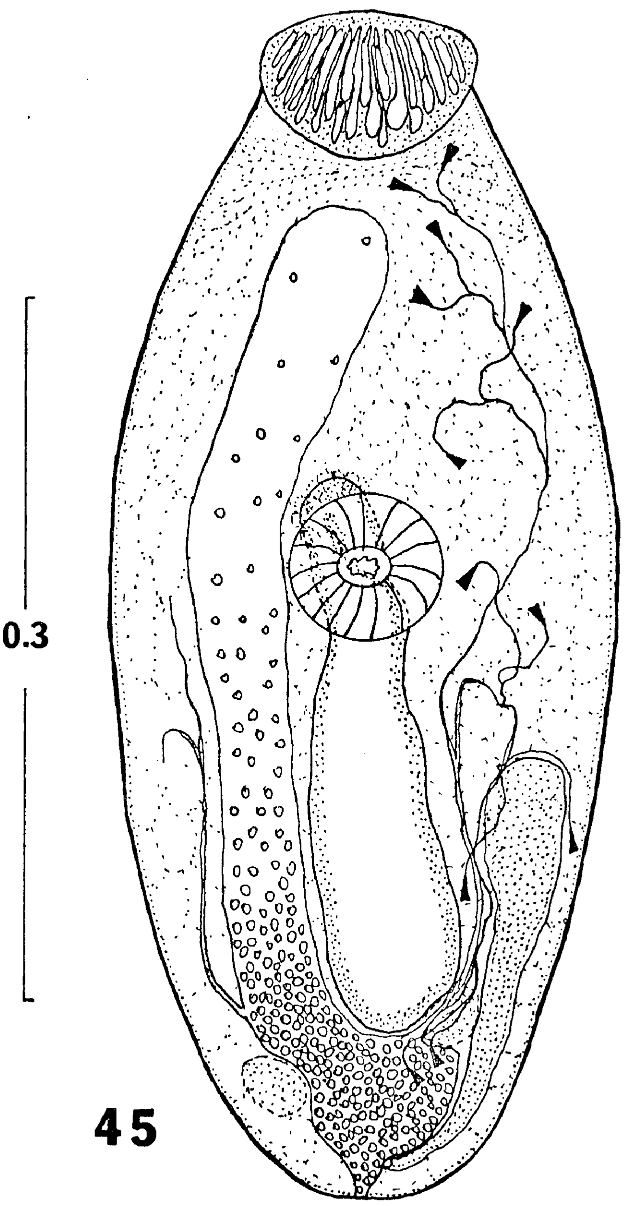
Figures 44-45. Metacercarial stage of _Cercaria_ sp. XII from _Brachidontes recurvus_. 44. Two encysted metacercarie from body musculature of _Fundulus similis_. 45. Ventral view of excysted metacercaria. Details of excretory system omitted from right side of body.



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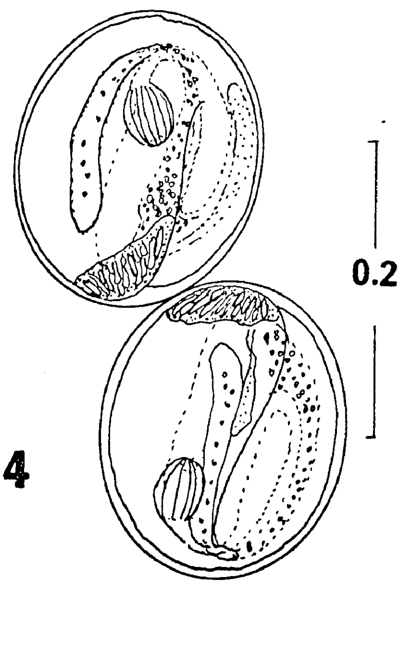

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distinct lobes bearing coarse spines. Pharynx 0.04 wide by 0.03 long, located on posterior half of body. Intestine rhabdocoele, 0.065 long by 0.025 wide, extending posteriorly from pharynx. Contents of intestine staining red with neutral red stain. Excretory bladder I-shaped, 0.06 in height, its anterior extremity deflected to left of medial by presence of intestine. Flame cell formula 2[(2+2+2) + (2+2+2)] = 24. Anterior and posterior collecting tubules joining posterior to pharynx, and common tubule entering laterally into middle of excretory bladder. Indistinct genital primordium present near midpoint of excretory bladder staining pink with neutral red stain. Nerve commissure present posterior to cephalic organ. Cuticula minutely spinose. Basal portion of tail 0.16 wide by 0.07 in height, indented posteriorly. Caudal furcae of greatly varying length, extremely protrusile, 0.015 to 0.020 in thickness. Sporocysts (Fig. 43) located in gonad of host clam causing parasitic castration. Walls of sporocysts bearing orange-yellow pigment spots imparting gross pale yellow hue to gonadal area of infected mussels. Sporocysts long and branching masses typical of Bucephalidae. Cercariae not swimming but crawling on bottom.

Host: Brachidontes recurvus (Rafinesque), hooked mussel

Localities: Morgan's Point, 3 of 256 mussels (1.2%); Offat's Bayou, 1 of 43 mussels (2.3%)

Overall Incidence: 4 of 305 mussels (1.3%)

Metacercaria

(Figures 44, 45)

The metacercarial stage of this species was obtained experimentally by exposing fishes to infected mussels in aquaria. Fishes from the same stock which were not exposed to infected mussels were also dissected and found to be negative for bucephalid metacercariae.

Diagnosis: Cysts (Fig. 44) oval, thin-walled, 0.20 long by 0.18 wide, body bent double inside. Cyst wall clear and contents visible within. Body of mechanically-excysted specimens (Fig. 45) elongated, 0.35 to 0.50 in length by 0.16 to 0.24 in width. Anterior organ roughly triangular 0.07 long by 0.09 wide. Pharynx ventral (often displaced laterally in specimens under cover slip pressure) circular, 0.06 in diameter. Intestine rhabdocoele, 0.17 in length, extending posteriad from pharynx. Excretory bladder large, extending almost to anterior organ and passing on right side of intestine and pharynx. Base of bladder filled with concretions which become less dense anteriorly. Flame cell formula $2[(2+2+2) + (2+2+2)] = 24$. Three genital primordia present staining pink with neutral red stain. Primordium of cirrus sac located on left side of intestine, 0.19 in length, terminating posteriorly in genital pore near base of excretory bladder. Two other indistinct primorida oval, 0.025 in length, located posterior to tip of intestine. Body cuticula minutely spinose.

The metacercariae were encysted in the muscle tissue of the host fishes just below the integument. Metacercariae were especially numerous around the bases of the dorsal, ventral and caudal fins of the host.

Experimental Hosts: *Fundulus similis* (Baird and Girard), long-nosed killifish; *Fundulus grandis* (Baird and Girard), gulf killifish

Identity: The structure of the cephalic organ of the metacercaria indicates that this is a species of *Rhipidocotyle*. Chandler (1935) described the metacercaria of *R. transversale* in the silversides, *Menidia beryllina* in Galveston Bay. It differs from the present metacercaria in that it has only 16 instead of 24 flame cells, and a much shorter excretory bladder. *R. lintoni* Hopkins, 1954 was described from the needlefish *Strongylura marina* in Louisiana; the adult however, has only 16 flame cells. Sparks (1957) stated that Bullock found metacercariae of *R. lintoni* in *Fundulus grandis*, *Cyprinodon variegatus* and *Mollinesia latipinna* at Clear Lake on Galveston Bay, but that species differs from *Metacercaria* sp. XII in having a much shorter excretory bladder. *R. lepisostei* Hopkins, 1954 whose metacercaria was found in mullet (*Mugil* spp.) in Louisiana, differs in having 48 flame cells but its excretory bladder is very similar to that of the metacercaria of *Cercaria* sp. XII. Armstrong (1969) found metacercariae of *R. lepisostei* in *Fundulus grandis* and *Cyprinodon variegatus* from Clear Lake and East Lagoon in Galveston Bay. The adult form of *R. lepisostei* was described by Hopkins (1954) from the intestine of the alligator gar, *Lepisosteus spatula* Lacépède in Louisiana, and was found subsequently in gars from fresh water near Dayton, Texas (Hopkins, 1967).

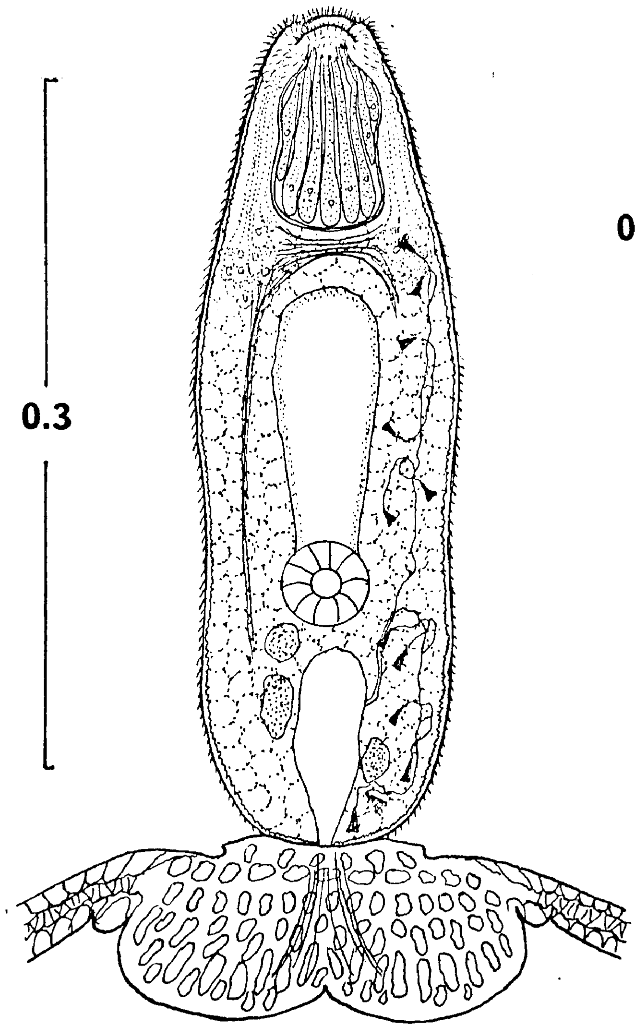
Ecology: This cercaria was found in November and December at Morgan's Point, a low salinity upper bay station, and in September at Offat's Bayou, a medium salinity lower bay station, indicating that the final host must be somewhat euryhaline and widely distributed in the bay. Infected mussels were living on oyster reefs, attached to the shells of living oysters. Oysters from these reefs were also examined for bucephalids but none were found, indicating that the bucephalid in *Brachidontes* is probably distinct from *Bucephalus cuculus* McCrady, the oyster parasite.

Cercaria sp. XIII

(Figures 46, 47, 48)

Diagnosis: Bucephalid ("ox-head") cercaria, body 0.28 to 0.35 long, by 0.06 to 0.08 wide, widest point in anterior half of body.

Figures 46-48. Larval stages of *Cercaria* sp. XIII from *Rangia cuneata*. 46. Ventral view of cercaria, right caudal furca omitted. 47. Ventral view of body and tail base of cercaria. Details of excretory system omitted from right side, posterior extension of nerve trunk omitted from left side. 48. Portion of sporocyst from gonadal area.



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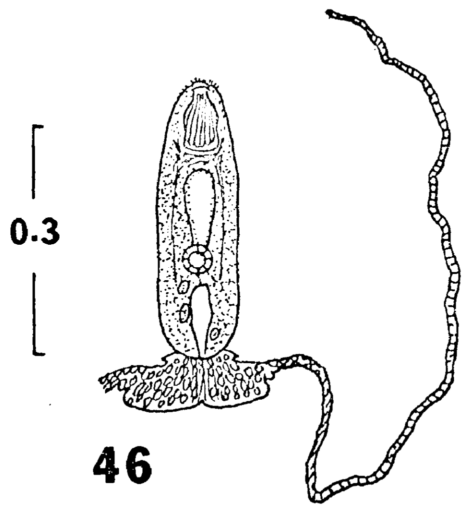

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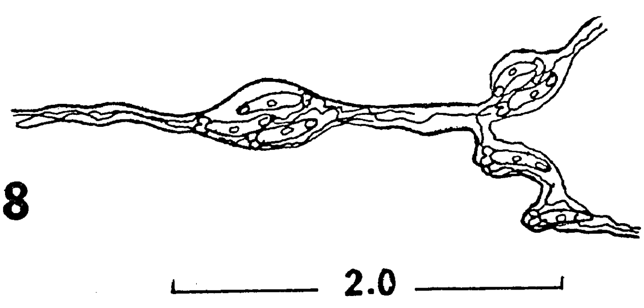

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Cephalic organ 0.06 long by 0.03 wide, containing numerous indistinct glands opening anteriorly through ducts. Anterior end of body divided into four distinct lobes bearing relatively coarse spines. Pharynx in posterior two-fifths of body, 0.034 in diameter. Intestine rhabdocoele extending anteriad from pharynx, 0.10 to 0.14 in length, contents staining red in neutral red stain. Paired clusters of numerous indistinct cephalic glands present on either side of cephalic organ and extending to level of anterior extent of intestine. Glands staining very light pink in neutral red stain. Excretory bladder I-shaped, 0.08 in height. Flame cell formula $2[(2+2+2) + (2+2+2)] = 24$. Three genital primordia present, each 0.18 to 0.15 in diameter, located lateral and anterior to excretory bladder in the positions shown in Figure 47. Primordia staining pink in neutral red stain. Nerve commissure present posterior to cephalic organ with trunks extending posteriad to level of excretory bladder. Body cuticula minutely spinose, but moderately spinose on anterior third of body. Basal portion of tail 0.17 wide by 0.08 in height, weakly indented posteriorly. Caudal furcae varying greatly in length, extremely protrusile, 0.017 to 0.022 in thickness. Sporocysts (Fig. 48) long and branching, of varying thickness, walls containing orange pigment and imparting gross light orange color to gonadal area of infected clams. Cercariae not swimming but crawling on substrate.

Host: Rangia cuneata Gray, common rangia

Localities: Lake Anahuac, 50 of 428 clams (11.6%); McCollum Park, 10 of 279 clams (3.6%)

Overall Incidence: 60 of 701 clams (8.5%)

Identity: This cercaria very closely resembles the cercaria of Bucephalus cuculus McCrady, 1874 from the oyster Crassostrea virginica as figured by Hopkins (1954). These cercariae both possess the same flame cell formula, cephalic glands lateral to the cephalic organ, and a weak or lacking indentation of the posterior margin of the tail stem.

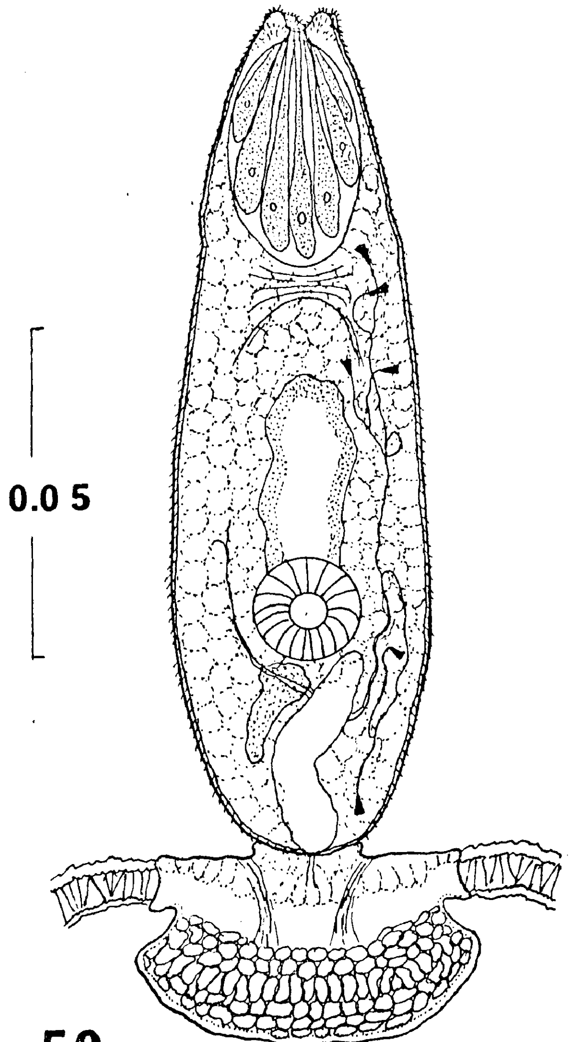
Ecology: Lake Anahuac is a brackish water enclosure adjacent to the Trinity River delta. Alligator gars, Lepisosteus spatula are abundant here and are known to harbor Rhipidocotyle lepisostei Hopkins, 1954. These gars also venture into the open bay which could account for the low incidence of infection found at McCollum Park. Hopkins (1954) found the metacercarial stage of R. lepisostei in the striped and white mullet (Mugil cephalus, M. curema) in Louisiana. Mugil cephalus is common in upper Galveston Bay and is tolerant of brackish water, whereas M. curema appears to be restricted to higher salinity waters (Parker, 1965). Infected clams were kept in aquaria during the summer of 1973 and attempts were made to infect minnows (Fundulus spp.), Mugil cephalus and

Gambusia affinis but no metacercariae were obtained, indicating that the activity of the cercariae might be seasonal, corresponding to the annual spring influx of young mullet into the upper bay.

Cercaria sp. XIV

(Figures 49, 50, 51)

Diagnosis: Bucephalid ("ox-head") cercaria, body 0.09 to 0.14 in length, 0.025 to 0.038 wide. Cephalic organ 0.030 to 0.036 long by 0.018 wide, containing about 12 glands with ducts opening on anterior end of body arranged in circle. Anterior end of body divided into four distinct lobes bearing coarse spination. Pharynx located in posterior two-fifths of body, round, 0.015 in diameter. Intestine rhabdocoele, extending anteriad, 0.025 to 0.030 in length. Contents of intestine staining red with neutral red stain. Excretory bladder I-shaped, 0.03 in height, anterior portion deflected to left of body midline by presence of pharynx. Flame cell formula 2[(2+2) + (2)] = 12. Genital promordium present on right side of excretory bladder posterior to pharynx, 0.018 by 0.010, staining light pink in neutral red stain. Nerve commissure present posterior to cephalic organ. Cuticula minutely spinose, spines coarser on anterior fifth of body. Basal portion of tail 0.045 wide by 0.028 long and not constricted on posterior margin. Caudal furcae long and protrusile, Figures 49-51. Larval stages of *Cercaria* sp. XIV from *Periploma inequale*. 49. Ventral view of cercaria, right caudal furca omitted. 50. Ventral view of body and tail base of cercaria. Details of excretory system omitted from right side. 51. Portion of sporocyst from gonadal area.



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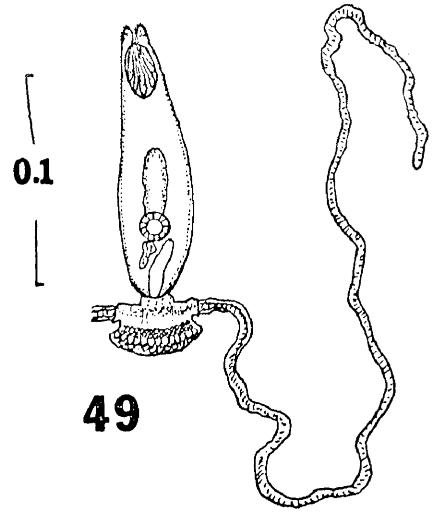

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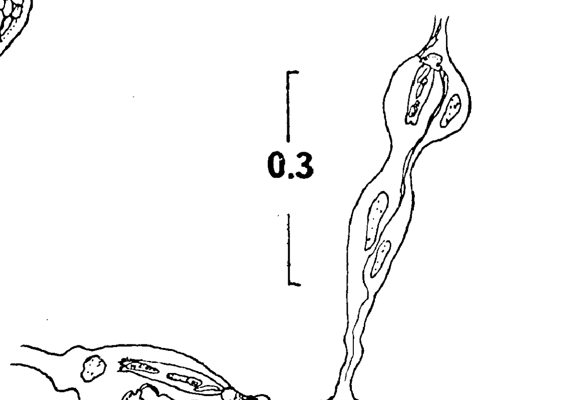

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0.008 to 0.010 in thickness. Sporocysts (Fig. 51) branching in bucephalid fashion, pale white in color, gonadal area of infected clams appearing pale white instead of cream white for normal clams. Cercariae not swimming but crawling on substrate.

Host: *Periploma inequale* (C. B. Adams), spoon clam

Locality: Galveston Beach

Incidence: 4 of 268 clams (1.5%)

Identity: This species is similar to *Cercaria apalachiensis* Holliman, 1961 from *Mulinia lateralis* in Florida. *C. apalachiensis*, like *Cercaria* sp. XIV, has 24 flame cells, about 12 glands in the penetration organ, and the sporocysts are white in color. *C. apalachiensis* however, has a cleft in the posterior margin of the tail base which was not seen in *Cercaria* sp. XIV. The habitats of the molluscan hosts also differ. Infected *M. lateralis* were found in a salt marsh environment by Holliman (1961) whereas infected *P. inequale* were taken from the surf zone along an exposed beach in the present study.

Ecology: This cercaria was found in late winter and early spring in clams which had been washed out of the substrate by stormy seas and deposited on the beach alive. The adult of this species of cercaria is probably a parasite of one of the numerous predacious fishes common to the Galveston beachfront. The final host is probably a fish closely associated with the bottom substrate; this would make possible a more efficient transfer of miracidia from fish to mollusc in these turbulent waters.

G. Family Echinostomidae

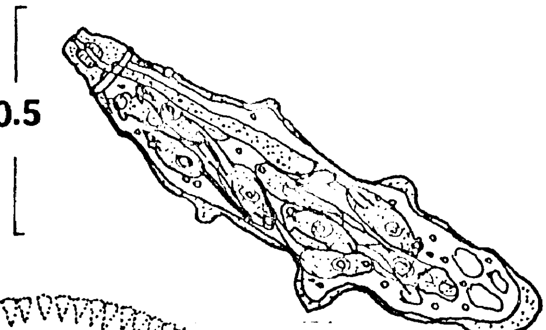
Echinostome cercariae develop in rediae in marine and freshwater gastropods. The rediae are distinctive in that they bear a cuticular "collar" posterior to the pharynx. Ambulatory processes in the form of cuticular projections are also present on the redia. The cercariae are characterized by the presence of a collar anterior to the pharynx bearing one or more rows of spines interrupted ventrally, and a thin-walled, relatively small excretory bladder with long arms which often extend anteriad to the level of the oral sucker, recurve and join the anterior and posterior collecting tubules in the midbody region. The cercarial tail is unbranched and devoid of setae and may be simple or greatly expanded. Medial fins are sometimes present on tails of certain species. Cercariae are weak swimmers and eventually adhere to an exterior surface, lose their tails and form dome-shaped cysts. Encystment often occurs on other animals, for instance on the mantle tissue of bivalve molluscs, on the exoskeleton of crustaceans, or on the fins and scales of fishes. Encystment may also occur on vegetation or on non-living substrates. Final hosts include mainly warm blooded vertebrates. This is a large family containing over 20 genera.

<u>Cercaria</u> sp. XV

(Figures 52 to 60)

<u>Diagnosis</u>: Echinostome cercaria, body pyriform, 0.30 to 0.52 long by 0.20 to 0.25 wide posterior to ventral sucker. Oral sucker circular, 0.06 in diameter, mouth ventral and subterminal. Prepharynx short, 0.015 in length, pharynx 0.35 long by 0.030 wide. Esophagus long and narrow, 0.11 long by 0.012 wide. Intestine bifurcating near anterior margin of ventral sucker with crura extending almost to posterior margin of body. Ventral sucker slightly posterior with its anterior margin at mid-level of body, circular, 0.06 in diameter. Cephalic glands present, six pairs arranged in two clusters, each situated lateral and posterior to pharynx and staining light pink in neutral red stain. Ducts of cephalic glands extending anteriad and opening in a semicircle on anterior margin of oral sucker. Excretory bladder V-shaped, arms extending to level of oral sucker, recurving, and extending posteriad to level of excretory bladder base. Common collecting tubules ciliated. Bladder and arms filled with dense concretions. Excretory ducts extending posteriad 0.021 into base of tail, bifurcating, and terminating in paired

Figures 52-55. Larval stages of _Cercaria_ sp. XV from _Cerithidea pliculosa_. 52. Entire cercaria, ventral view, details of excretory system and cystogenous glands omitted. 53. Ventral view of body of cercaria, details of excretory system omitted from right side, cystogenous glands and concretions of excretory bladder omitted from left side. 54. Arrangement of collar spines of cercaria. 55. Redia from gonadal area.



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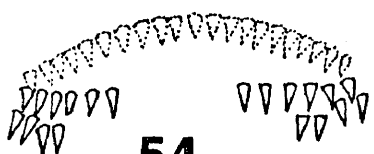

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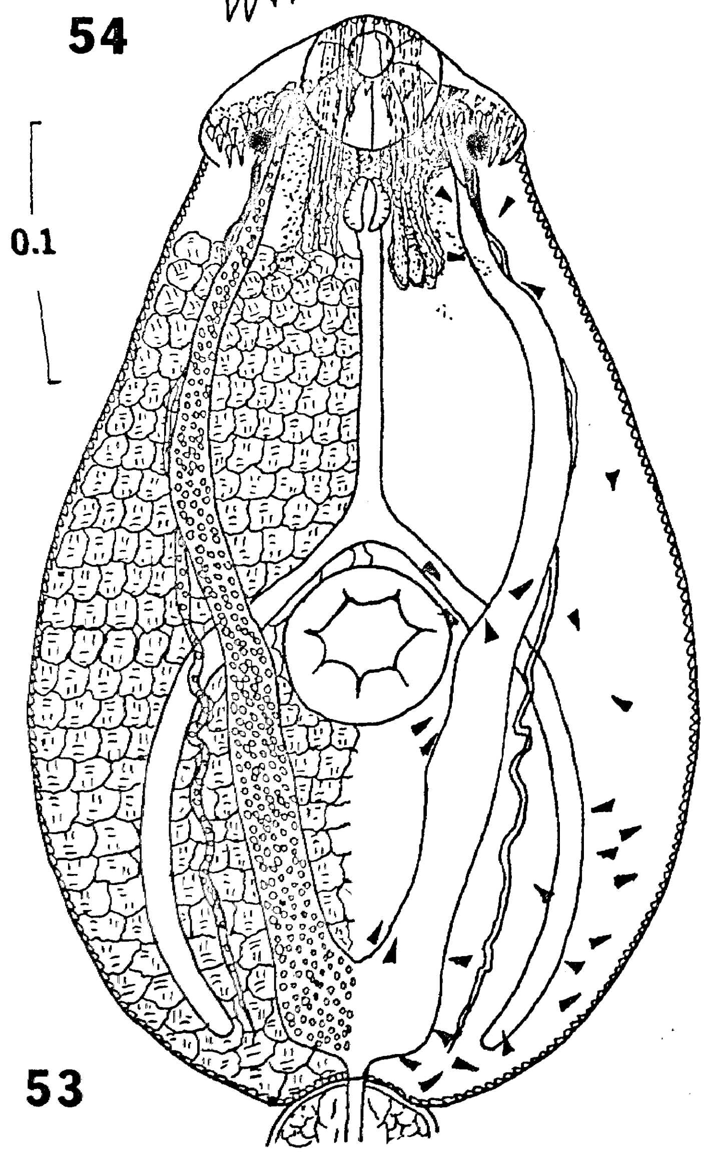

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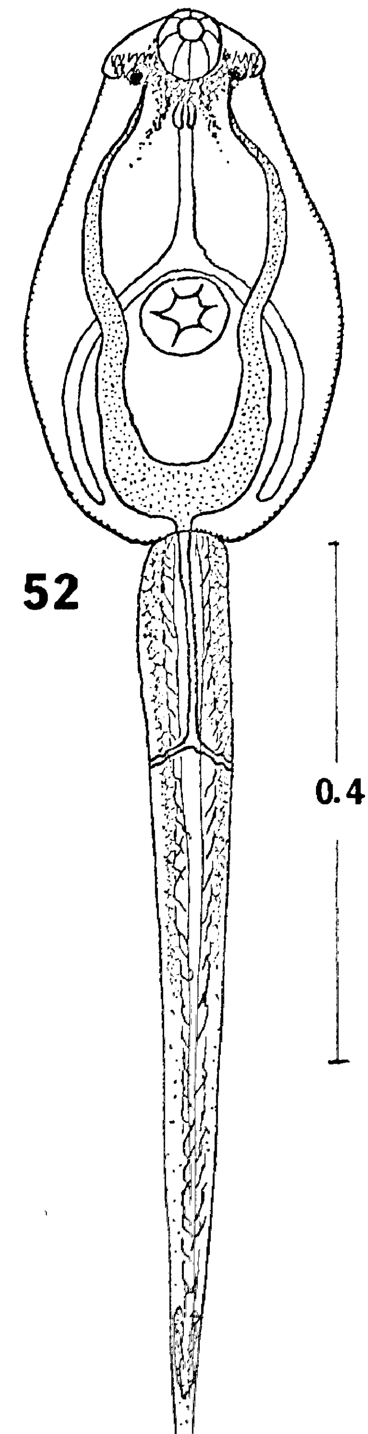

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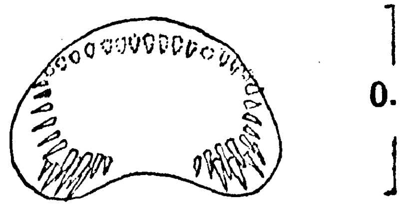
Figures 56-60. Larval stages of _Cercaria_ sp. XV from _Cerithidea pliculosa_. 56. Side view of metacercarial cyst from abdomen of _Palaemonetes pugio_. 57. Front view of metacercarial cyst. 58. Lateral view of cercaria in swimming position. 59. Ventral view of collar area of excysted metacercaria. 60. Ventral view of entire excysted metacercaria.



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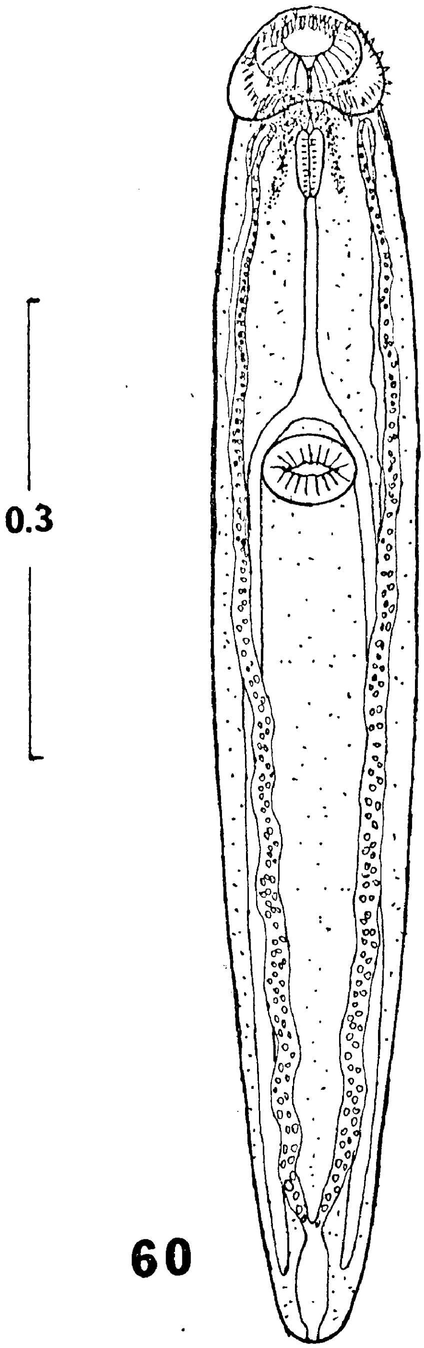

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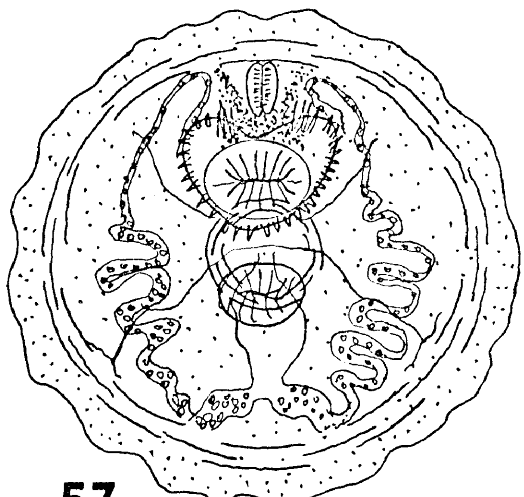

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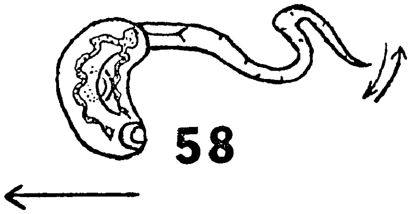


58

lateral pores. Flame cell formula not discernible due to presence of densely packed cystogenous glands. Thirty-two pairs of flame cells occurring in positions shown in Figure 52. No genital primordia seen. Cuticular "collar" present on sides of body at level of posterior margin of ventral sucker. Collar bearing a single row of 31 to 33 spines interrupted ventrally (Fig. 55). Eight additional spines present posterior to first row on ventral surface of collar only and widely interrupted ventrally, for a total of 39 to 41 spines. Paired lateral eyespots present on ventral margin of collar, roughly circular, 0.015 in diameter, dark brown in color. Lesser concentrations of dark brown pigment granules present between eyespots and along posterior margin of oral sucker, extending to anterior margin of pharynx, branching laterally, and extending in decreasing numerical concentration to level of middle of esophagus. Relatively light and uniform concentration of brown pigment spots present over entire body cuticula imparting a light brown color to cercarial body when viewed under low power magnification (30 to 100 x). Entire body posterior to pharynx filled with densely-packed rod-bearing cystogenous glands staining light pink in neutral red stain. Tail 0.75 to 1.00 in length, by 0.07 in width near base, and narrow at posterior end.

Cercaria positively phototactic, swimming in peculiar position (Fig. 58), with body rounded up into concave disc and proceeding with dorsal surface forward. Posterior third of tail thin and whip-like, producing violent lateral vibrations of body while swimming. Cercariae developing in rediae located in gonadal region of host, causing parasitic castration. Length of rediae 1.30 to 1.50, width 0.40 to 0.53. Pharynx 0.10 to 0.13 in length, gut rhabdocoele, 0.5 to 0.7 in length, extending posterior of redial midpoint. Contents of intestine naturally orange red in color, imparting gross orange-speckled appearance to infected gonadal region of host. Two pairs of appendages present on redia as shown in Figure 55. Cuticular collar present posterior to pharynx, 0.05 wide. Birth pore located on body cuticle on midpoint of line from mouth to midway between anterior pair of appendages. Rediae containing up to 10 cercariae in various stages of development.

Host: Cerithidea pliculosa (Menke), horn snail

Localities: Sportsman's Road, 11 of 1075 (1.1%); Yates Bayou, 3 of 89 (3.3%)

Overall Incidence: 14 of 1164 (1.2%)

Metacercaria

(Figures 56 to 60)

The metacercarial stage of this species was found encysted on the exterior of the exoskeleton of grass shrimp which were collected from the same habitat where infected snails were found. The cysts were located on the ventral surface of the abdomen of the shrimp. Uninfected grass shrimp obtained from a marsh area containing no Cerithidea were found to be negative for the presence of cysts. These shrimp were isolated in aquaria for a period of 2 weeks with Cerithidea parasitized by Cercaria sp. XV and were subsequently found to bear the same metacercaria seen on naturally infected shrimp.

Diagnosis: Cyst a circular to oval disc, 0.20 to 0.23 in diameter and 0.05 in height, slightly expanded at point of contact with substratum, bearing circular concavity 0.01 deep in center of exterior face (Figs. 56, 57). Cyst wall pale brown in color due to presence of brown pigment granules. Cyst wall of two layers, outer layer attaching to substratum and inner layer lining body of metacercaria. Inner layer containing metacercarial body easily removed by dissection. Removal of body from inner cyst difficult as most metacercariae disintegrate under pressures sufficient to rupture cyst. No excystment occurring in artificial digestive medium of Hunter and Chait

(1952). Occasional pressure-excysted specimens revealing significant morphological details. Body 0.60 to 0.78 long, 0.10 to 0.13 wide, oral sucker oval, 0.076 wide by 0.048 long, mouth ventral and subterminal, prepharynx 0.02 long, pharynx 0.045 long by 0.02 wide, esophagus 0.13 to 0.15 long, bifurcating just anterior to ventral sucker into crura extending almost to posterior end of body. Ventral sucker in anterior two-fifths of body, oval, 0.065 wide by 0.040 long. Excretory bladder 0.07 in height, free of concretions. Arms of bladder filled with concretions, extending anteriad to pharynx, recurving and extending back to level of excretory bladder. Eyespots absent, dark brown pigment granules concentrated between posterior margin of oral sucker and anterior margin of pharynx, and dispersed evenly over other body tissues resulting in light tan-colored appearance of entire body. Cuticular collar present ventral and lateral to oral sucker, bearing 42 spines arranged in two vertical rows interrupted ventrally. Spines comprising anterior row 34 in number, and 8 spines comprising posterior row in two groups of four spines each located on ventral surface of collar.

Host: *Palaemonetes pugio* Holthius

Locality: Sportsman's Road

Incidence: 10 of 10 (100%)

Identity: This species closely resembles Cercaria (Echinostome) I Maxon and Pequegnat, 1949 from Cerithidea californica, in California, and Cercaria fuscata Holliman, 1961 from Cerithidea scalariformis in Florida. C. (Echinostome) I has 35 collar spines in two vertical rows and 40 pairs of flame cells. C. fuscata has 49 collar spines in three vertical rows, and its flame cells were not described. C. sp. XV has 39 to 41 collar spines in two vertical rows and 33 pairs of flame cells. That these differences are real and are of specific value is doubtful due to the difficulty of locating and counting flame cells through the dense cystogenous glands and also due to the fact that the number of spines has been found to differ between the cercaria and metacercaria of C. sp. XV, being 39 to 41 and 42, respectively. Adams and Martin (1960) reported (in a brief abstract) that an echinostome from Cerithidea californica in California developed experimentally into an adult of the genus Himasthla. Maxon and Pequegnat (1949), reported three "echinostomes" from C. californica. One was a philophthalmid, another a species of Acanthoparyphium, and the third a "large pigmented echinostome" similar to Cercaria sp. XV. The latter must have been the cercaria used by Adams and Martin (1960) in obtaining Himasthla type adults. It is therefore likely that Cercaria sp. XV from C. pliculosa is also a species of Himasthla, but not H. quissetensis whose cercaria has been recorded from Galveston in Nassarius vibex by Epstein (1972), and is distinctly different from Cercaria sp. XV.

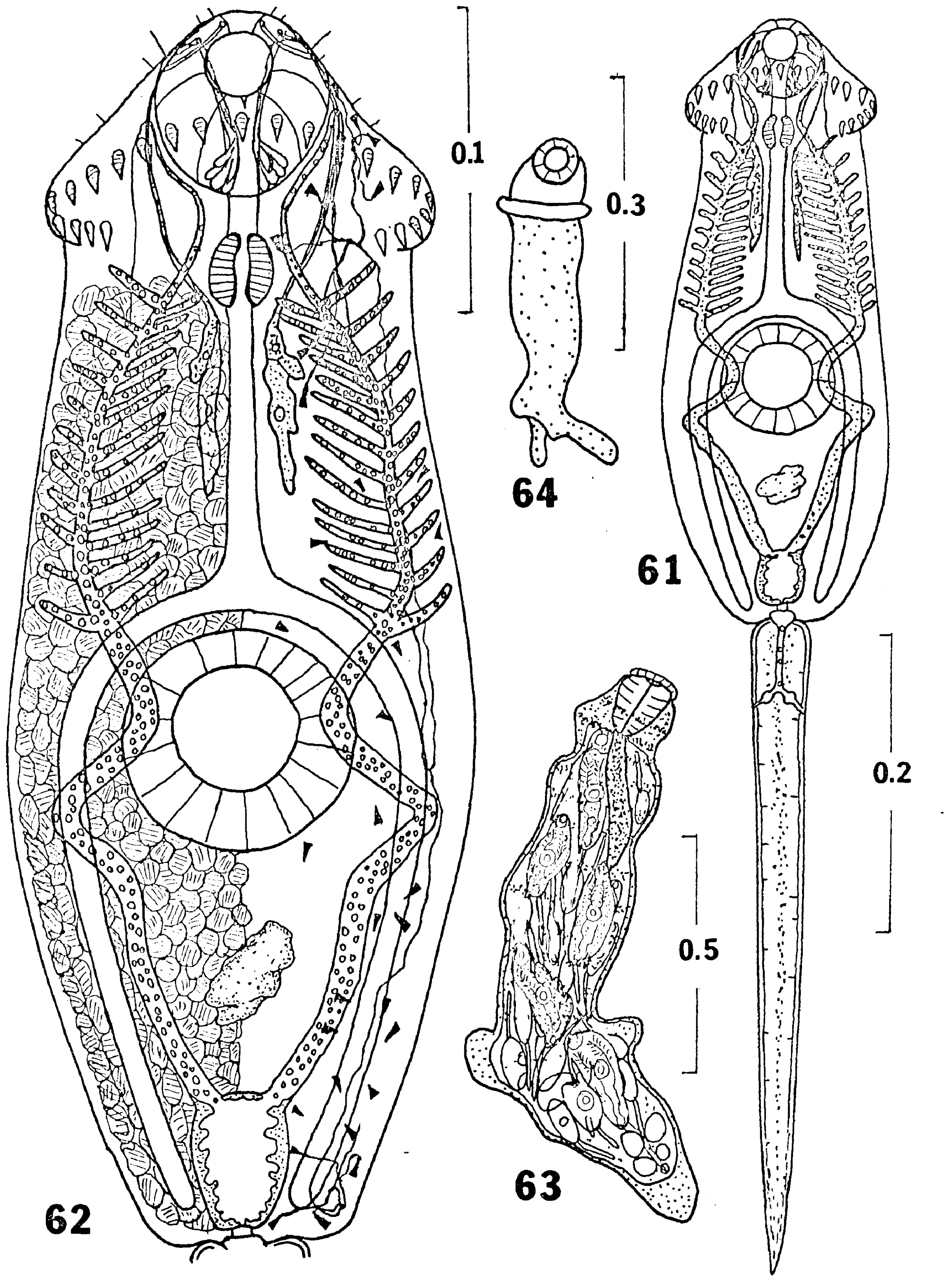
Ecology: This cercaria was found in overall low incidence (1.2%) with a peak intensity in October of 4.3% (7 of 161 snails), indicating that the final host may be a migratory bird which is more prevalent in the marsh during the summer months.

Cercaria sp. XVI

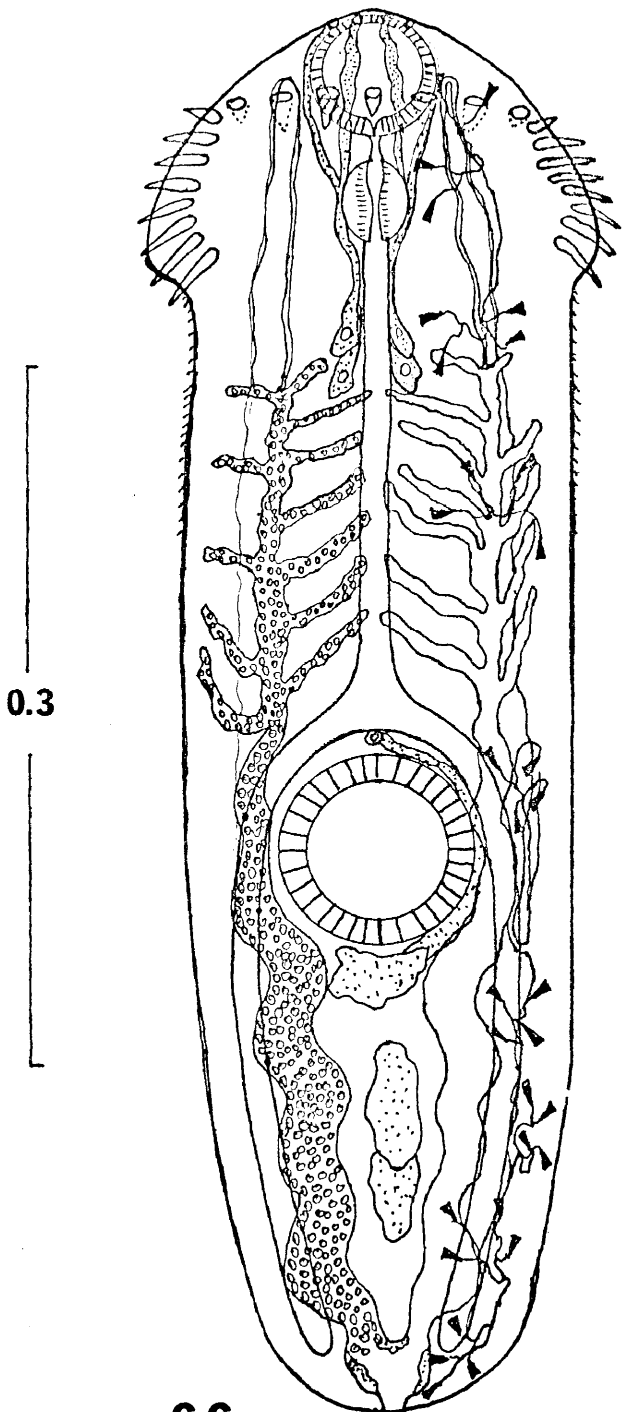
(Figures 61 to 66)

Diagnosis: Simple-tailed echinostome cercaria, body 0.38 to 0.40 in length, 0.12 to 0.14 wide, oral sucker circular, 0.048 in diameter, mouth ventral and subterminal, prepharynx short, 0.012 long, pharynx 0.025 long by 0.018 wide. Esophagus 0.09 long, bifurcating into intestinal crura just anterior to ventral sucker. Ventral sucker circular, 0.075 in diameter, located in posterior half of body. Crura extending posteriad almost to end of body, contents staining pink with neutral red stain. About six pairs of cephalic glands at level of oral sucker with ducts extending anteriorly. Two larger pairs of cephalic glands posterior to pharynx with ducts extending anteriad, lateral to pharynx, and emptying by four pores anterior and dorsal to mouth. Glands not staining in neutral red

Figures 61-64. Larval stages of *Cercaria* sp. XVI from *Cerithidea pliculosa*. 61. Ventral view of cercaria. Details of excretory system and cystogenous glands omitted. 62. Ventral view of body of cercaria. Flame cells omitted from right side, cystogenous glands omitted from left side. 63. Mature redia from gonadal area. 64. Early redia from gonadal area.


0.1
0.3
64
61
0.2
0.5
63
62

Figures 65-66. Metacercarial stage of *Cercaria* sp. XVI. 65. Metacercarial cyst from *Crassostrea virginica*. 66. Excysted metacercaria, ventral view, details of excretory system omitted from right side, concretions in excretory bladder omitted from left side.



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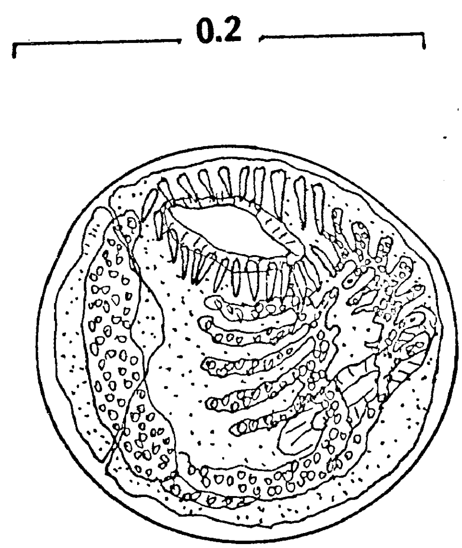

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stain. Cuticular collar present anterior to pharynx, bearing a single row of 23 spines interrupted ventrally. Excretory bladder oval, with thick and indented wall, 0.04 long by 0.03 wide, arms long and extending anteriad to level of oral sucker, recurving, and extending posteriad to level of ventral sucker. Anterior and posterior tubules joining main tubule at this point. Anterior portion of arms of bladder with bipinnate lateral diverticula between levels of oral and ventral suckers. Arms of bladder filled with dense concretion granules. Flame cell formula $2[4(2+2) + 4(2+2)] = 64$. Excretory duct extending into tail, bifurcating and opening in two lateral pores, 0.05 from tail base. Genital primordium located midway between ventral sucker and excretory bladder, 0.035 long by 0.020 wide, staining light pink in neutral red stain. Body cuticle minutely spinose, three pairs of setae present on anterior lateral portion of body anterior to collar. Body posterior to pharynx densely packed with rod-bearing cystogenous glands. Tail straight and unadorned, 0.35 to 0.45 in length, 0.02 to 0.03 wide at base and tapering to a fine tip. Cercariae swimming vigorously but erratically with little directional progress. No phototaxes observed. Cercariae failing to encyst on glass dish after 24 hour isolation in seawater. Rediae (Fig. 65) located in gonadal area of host, 0.9 to 1.2 mm long by 0.02 wide, pharynx 0.05 long by 0.025 wide, intestine rhabdocoele not reaching to midpoint of redial body. Single pair of ambulatory processes located on posterior third of redia. Redia bearing 10 to 12 distinct orange colored cuticular bands and thus appearing annulated. Orange bands imparting a gross orange-yellow hue to gonadal area of infected snails. Rediae bearing 30 to 60 cercariae each, in varying stages of development. Young rediae (Fig. 64) 0.35 in length, containing no cercariae, bearing two relatively long ambulatory processes on posterior end of body and an apparent collar posterior to pharynx which is apparently lost during development.

Host: *Cerithidea pliculosa* (Menke), horn snail

Localities: Sportsman's Road, 5 of 1075 snails (0.6%); Yates Bayou, 2 of 89 snails (2.2%)

Overall Incidence: 7 of 1164 snails (0.6%)

Metacercaria

(Figures 65, 66)

What is believed to be the metacercarial stage of this species was found naturally encysted in the mantle tissue of oysters collected from the same marsh areas where infected *Cerithidea pliculosa* were collected. Experiments were performed in the laboratory by exposing uninfected oysters to cercariae from crushed snails for several days without success. Apparently one or more critical factors such as cercarial maturity, seasonal timing or water quality was out of tolerance and inhibited encystment. Cercariae also failed to penetrate excised oyster gill and mantle tissue during a 48 hour exposure.

Diagnosis: Cyst spherical, thick walled and transparent, 0.20 in diameter, embedded in mantle tissue of oyster. Bipinnate anterior diverticula of excretory bladder evident through cyst wall. Total of 23 collar spines also discernible through cyst wall. Cyst walls dissolving in artificial digestive medium of Hunter and Chait (1952). Mechanical excystment possible after much trial and error. Mechanically excysted metacercaria 0.45 to 0.62 long by 0.15 wide. Mouth ventral and subterminal, oral sucker circular, 0.053 in diameter, prepharynx 0.01, pharynx 0.036 long by 0.025 wide, its axis often tilted up to 45° from vertical. Esophagus straight, 0.20 long, bifurcating anterior to ventral sucker into two intestinal crura which extend posteriad almost to end of body. Ventral sucker circular, 0.075 in diameter, located in posterior half of body. Two pairs of cephalic glands present posterior to pharynx and lateral to esophagus, with ducts extending anteriad lateral to pharynx and terminating in four pores anterior and dorsal to mouth. Excretory bladder oval to circular, thick-walled, 0.03 long by 0.035 wide, emptying into an an excretory pore located on posterior tip of body. Arms of bladder large, extending anteriad to level of oral sucker, recurving and extending back to level of ventral sucker and giving off anterior and posterior collecting tubules. Arms of bladder giving off numerous medial and lateral diverticula between level of ventral sucker and pharynx. Arms of bladder and diverticula filled with densely packed concretions. Flame cell formula same as that of cercaria, 2[4(2+2) + 4(2+2)] = 64. Primordia of testes in tandem arrangement, located midway between ventral sucker and excretory bladder, each primordium 0.05 long by 0.02 wide. Primordium of ovary an irregular mass 0.04 wide by 0.025 long located on posterior margin of ventral sucker. Primordium of cirrus sac arising lateral to left side of ovary, extending around left side of ventral sucker and terminating in a median genital pore anterior to ventral sucker. All genital primordia staining light pink in neutral red stain. Anterior portion of body from level of pharynx expanded laterally to form a "collar" 0.175 wide and bearing a single row of 23 spines interrupted ventrally.

Host: *Crassostrea virginica* (Gmelin), American oyster

Locality: Sportsman's Road Marsh, 9 of 28 oysters (32.1%)

Overall Incidence: 9 of 190 oysters (4.7%). Oysters from stations 5, 15 and 20 were not found to be infected.

Identity: This species is identical to *Acanthoparyphium spinulosum* Johnston, 1917 described from the duodenum of the golden plover, <u>Charadrius dominicus</u> in Australia. The species has been subsequently reported from birds in Japan by Yamaguti (1934), and by Russell (in Martin and Adams, 1961) from plovers and avocets in California. Bearup (1956) worked out the life cycle of this species in Australia and found that it develops in rediae in the marsh-dwelling potamidid gastropods <u>Pyrazus australis</u> Quoy and Gaimard and <u>Salinator fragilis</u> (Lamarck). The metacercariae encyst on the mantle tissue of <u>Salinator fragilis</u>; these were fed experimentally to young gulls, <u>Larus novaehollandiae</u>, and adults were recovered from the intestine. Martin and Adams (1961) have worked out the life cycle of the same species in California and found that the cercariae develop in rediae in <u>Cerithidea californica</u> Haldeman, encysting in the buccal nass of the host snail as well as in other molluscs, and mature experimentally in baby chicks.

Little <u>et al</u>. (1966) found the metacercaria of <u>A</u>. <u>spinulosum</u> encysted in the mantle tissue of the oyster <u>Crassostrea virginica</u> at Port Isabel, Texas. The metacercariae were fed to baby chicks and mature adult <u>A</u>. <u>spinulosum</u> were recovered. Cable (1956) described <u>Cercaria Caribbea</u> II from Puerto Rico with 23 collar spines which does not differ significantly from the cercaria of <u>A</u>. <u>spinulosum</u>. The redia infected <u>Cerithidea costata</u> and metacercariae were found in "small lamellibranchs".

Ecology: This cercaria was found only during the cooler months of the year and was absent in June through September, indicating that the final host in Galveston may be a migratory bird. Oysters carrying the metacercaria were found only in marsh areas in close association with large populations of *Cerithidea pliculosa*. Oysters from other parts of the bay where *C. pliculosa* was absent or rare were not found to harbor this metacercaria.

H. Family Philophthalmidae

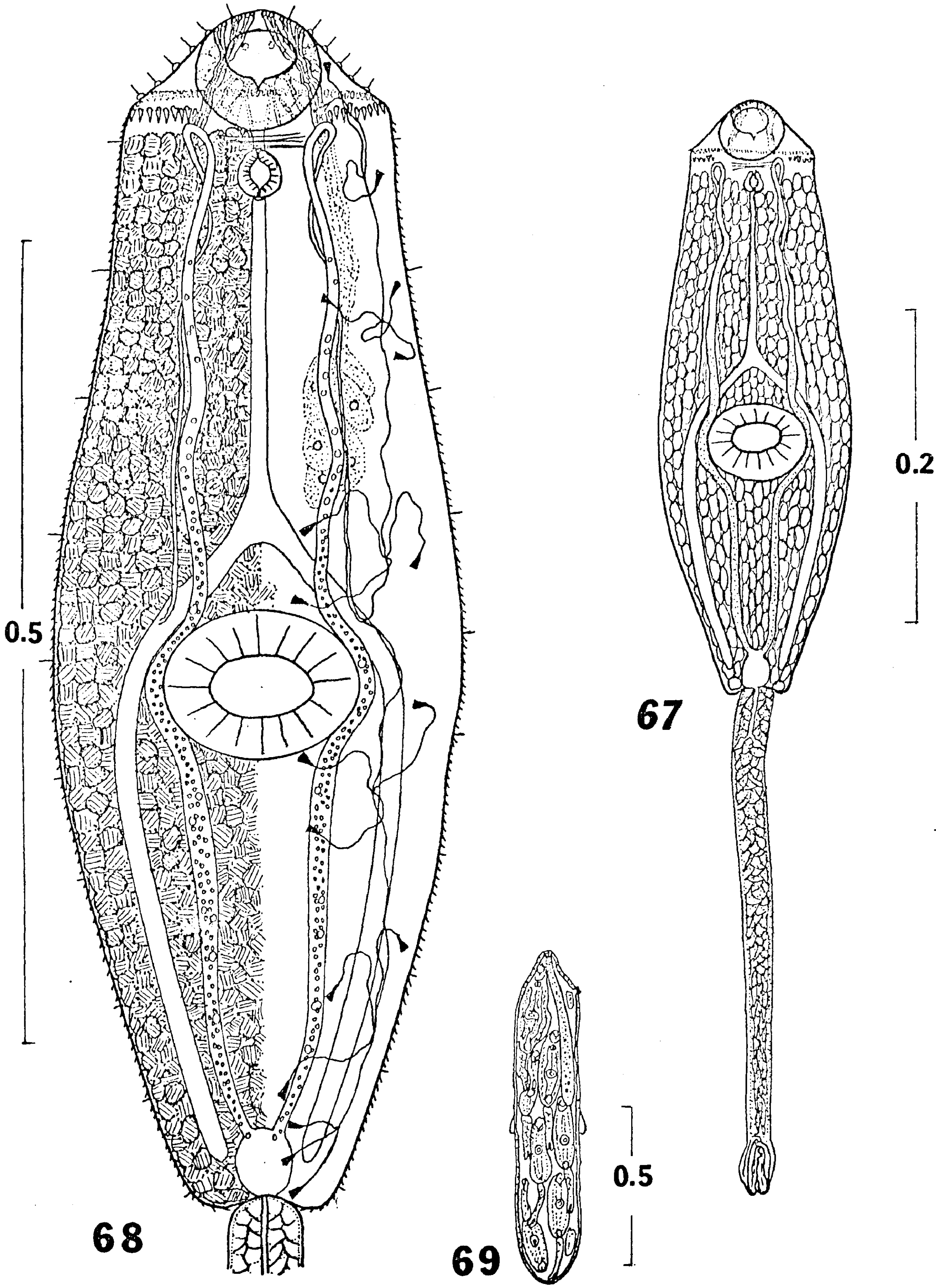
Philophthalmid cercariae develop in rediae in the gonad of marine and freshwater gastropods. They are echinostome-like in appearance, some possessing a collar of spines interrupted ventrally, but differ from echinostome cercariae in possessing a glandular invaginated tail tip. Cercariae are "outside encysters", not penetrating a second intermediate host, but encysting on its shell, exocuticle or integument, or on vegetation or mineral substrates. Final hosts are warm blooded vertebrates which become infected by ingesting the encysted metacercariae. Some species of *Philophthalmus* are known to infect the eyes of mammals and birds, including humans (Alicata and Ching, 1960), but most species of *Philophthalmus* are intestinal parasites of birds.

Cercaria sp. XVII

(Figures 67 to 69)

Diagnosis: Megalurous cercaria, body 0.65 to 0.82 long, 0.11 to 0.13 wide, oral sucker circular, 0.09 to 0.12 in diameter, mouth ventral and subterminal, prepharynx 0.01, pharynx 0.025 by 0.020, esophagus 0.20, bifurcating immediately anterior to ventral sucker and extending almost to posterior tip of body. Contents staining red with neutral red stain. Ventral sucker oval, 0.14 by 0.10. Six pairs of penetration glands present lateral to esophagus, not staining in neutral red stain, their ducts extending anteriad, dorsal to oral sucker, and opening in six pairs of pores on anterior end of body. Excretory bladder oval, 0.05 long by 0.035 wide, arms long, extending to posterior margin of oral sucker, recurving and returning to level of anterior margin of ventral sucker and receiving anterior and posterior excretory tubules at this point. Arms of bladder containing concretions to level of pharynx but not anterior. Flame cell formula $2[(3+3+3) + (3+3+3)] = 36$. Excretory duct extending into tail a distance of 0.06, bifurcating and terminating in paired lateral pores on sides of tail. No genital primordia seen. Body cuticula moderately spinose, six pairs of coarse setae on anterior lateral margin of body lateral to oral sucker, and nine pairs of setae located on sides of

Figures 67-69. Larval stages of *Cercaria* sp. XVII from *Thais haemastoma*. 67. Ventral view of entire cercaria, details of excretory system omitted. 68. Ventral view of body of cercaria. Details of excretory system omitted from right side, cystogenous glands omitted from left side. 69. Redia from gonadal area of host.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0.5
69

body from level of pharynx to posterior end of body. Collar present at level of posterior margin of ventral sucker, bearing single row of 64 to 66 spines interrupted ventrally. Body filled with rod-bearing cystogenous glands from posterior margin of oral sucker to posterior end of body, staining light red in neutral red stain. Tail 0.28 to 0.37 long, 0.05 wide, bearing an invaginated glandular sucker on its posterior tip 0.06 in length, by 0.03 in width.

Cercaria swimming weakly by dorso-ventral undulation of tail and body, interrupted by frequent pauses and slow sinking. Encysts readily on any firm substrate shortly after emergence from host.

Cercariae developing in rediae (Fig. 69) inhabiting gonadal area of host, causing parasitic castration. Redia 1.00 to 1.40 in length by 0.30 wide, each containing up to 12 cercariae in various stages of development. Birth pore anterior and lateral. Pharynx 0.08 long, gut rhabdocoele, orange in color, extending posteriad to midpoint of redia. No apparent collar present on mature rediae.

Host: *Thais haemastoma* (Linné), oyster drill

Localities: Offat's Bayou, 1 of 6 snails (16.6%); East End Flats, 16 of 27 snails (59.2%); East Lagoon, 4 of 50 snails (8.0%); Pelican Island, 1 of 5 snails (20.0%)

Overall Incidence: 22 of 107 snails (20.5%)

Host: Cerithidea pliculosa (Menke), horn snail

Localities: Yates Bayou, 12 of 89 snails (13.5%); Sportsman's Road, 95 of 1075 snails (8.8%)

Overall Incidence: 107 of 1164 snails (9.1%)

Host: Littorina irrorata (Say), marsh periwinkle

Localities: Sportsman's Road, 5 of 452 snails (1.1%); East Lagoon, 5 of 550 snails (0.9%); East End Flats, 6 of 238 snails (2.6%)

Overall Incidence: 16 of 1777 snails (0.90%)

Identity: This species is Parorchis acanthus Nicoll, 1906, the cosmopolitan parasite of seagulls (Larus spp.) and other shore birds which develops in several marine snails belonging to the families Thaisidae, Muricidae, Littorinidae and Potamididae. Agreement as to body size, collar spines, flame cell formula and cephalic gland number and arrangement serve to affirm this identity.

Ecology: This parasite was found in relatively constant incidence throughout the year. Intensities of infection were highest in intertidal areas where host snails could be bathed in high concentrations of miracidia trapped in tidepools at low tide. Cooley (1958, 1962) found this parasite in Thais haemastoma in Galveston. He examined 1277 snails and found only 45 infections (3.52%) and noted a correlation between drill infection rates and the presence of resident seagull populations, noting that more snails are infected near seagull feeding grounds. Cooley succeeded in infecting the least tern, Sterna albifrons, by force-feeding suspensions of 200+ encysted metacercariae from Thais haemastoma. He recovered adult P. acanthus upon autopsy of the bird. He also succeeded in infecting Thais by isolating individual snails for 24 hours in 100 ml of seawater containing miracidia from adult worms to complete the cycle. Epstein (1972) found 3 of 69 T. haemastoma (4.9%) in Galveston to be infected with P. acanthus, but no infections were found in the 188 Cerithidea pliculosa or the 947 Littorina irrorata which he examined. Menzel and Hopkins (1954) observed that many old T. haemastoma from Louisiana carried heavy infections of P. acanthus larvae which destroyed the gonads and caused complete sterility. This effect was also noted in the present study for infected snails in Galveston, where larger (older) specimens of each host species are found to be infected much more frequently than smaller specimens, and castration appears to be total.

Cercaria sp. XVIII

(Figures 70 to 73)

Diagnosis: Megalurous cercaria, body 0.52 to 0.78 long by 0.20 to 0.25 wide, mouth ventral and subterminal, oral sucker oval, 0.10 long by 0.07 wide, prepharynx 0.01, pharynx 0.036 by 0.025, esophagus 0.2 long, bifurcating just anterior to ventral sucker. Intestinal crura extending almost to posterior end of body. Ventral sucker circular, 0.12 in diameter, in posterior half of body. Excretory bladder oval, 0.07 long by 0.05 wide, excretory duct extending into tail, bifurcating and terminating in paired lateral pores on sides of tail 0.08 from body-tail junction. Arms of bladder long, without concretions, extending to level of oral sucker, recurving and returning to level of ventral sucker and joining anterior and posterior collecting tubules. Flame cell formula 2[(3+3+3) + (3+3+3)] = 36. Numerous paired lateral cephalic glands present between level of pharynx and ventral sucker, their ducts extending anteriad and terminating in six pairs of pores anterior and dorsal to mouth. Glands and ducts not staining with neutral red stain. Single genital primordium located on anterior margin of ventral sucker, laterally oval, 0.04 wide by 0.02 long, staining light pink with neutral red stain. Nerve commissure present anterior to pharynx. Entire body from level of posterior

Figures 70-73. Larval stages of *Cercaria* sp. XVIII from *Littorina irrorata.* 70. Ventral view of entire cercaria. 71. Ventral view of body of cercaria, details of excretory system omitted from right side, cystogenous glands omitted from left side. 72. Scheme of arrangement of collar spines, ventral view. 73. Redia from gonadal area of host.

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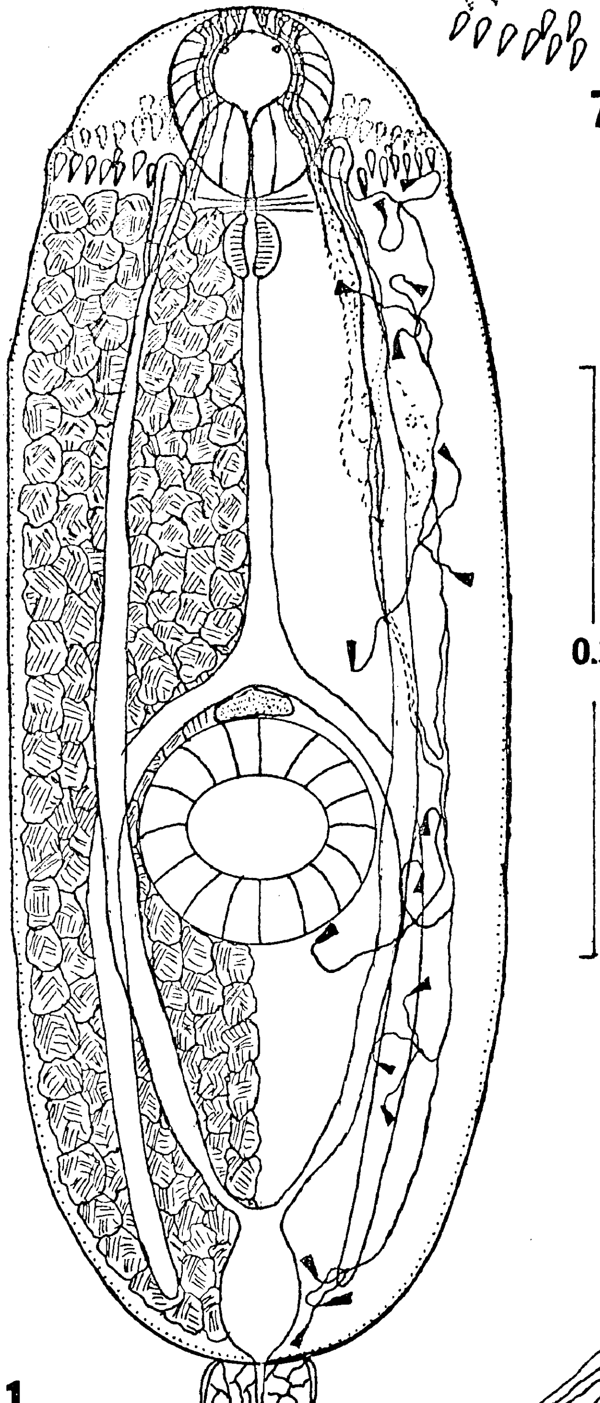

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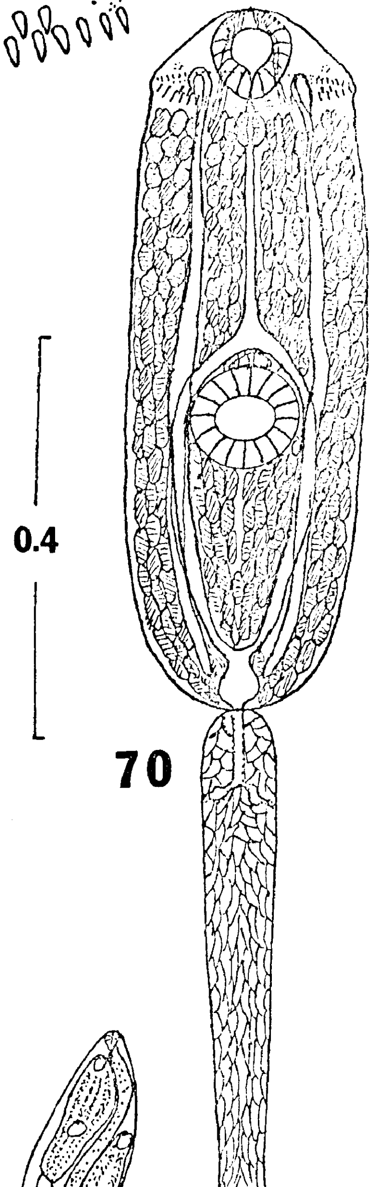

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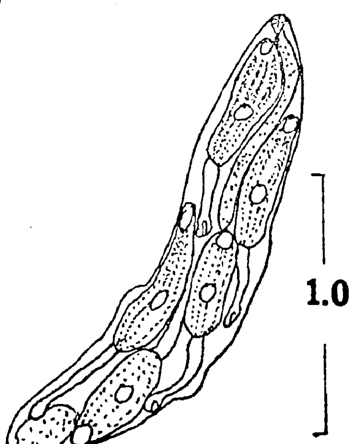

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margin of oral sucker to posterior end of body filled with rod-bearing cystogenous glands staining pink in neutral red stain. Body cuticula moderately spinose. Tail 0.40 to 0.65 in length, by 0.05 to 0.08 in width, bearing an invaginated glandular tip 0.07 to 0.15 in length. Cells inside tail staining light pink in neutral red stain. Sides of anterior portion of body adjacent to oral sucker produced laterad to form a "collar" bearing an alternating row of 34 spines interrupted both dorsally and ventrally as shown in Figure 72. Cercaria swimming weakly by dorsoventral flexure of body and tail, with frequent rest pauses. Cercariae finally attaching to firm surfaces by caudal gland and encysting externally.

Cercariae developing in redia (Fig. 73) in gonad and digestive gland of host, 0.18 to 0.23 long by 0.05 wide, containing up to 15 cercariae in various stages of development. Gut of redia orange in color, extending posterior to middle of length of redia. Birthpore on anterior lateral margin of redia. Body of redia pale white and translucent.

<u>Host</u>: <u>Littorina irrorata</u> (Say), marsh periwinkle

<u>Localities:</u> Sportsman's Road, 2 of 452 snails (0.46%); East Lagoon, 7 of 550 snails (1.2%); East End Flats, 1 of 238 snails (0.49%); San Luis Pass, 1 of 124 snails (0.8%)

Overall Incidence: 11 of 1777 snails (0.62%)

Identity: This is *Cercaria* sp. "C" Epstein, 1972 reported from *Littorina irrorata* in Galveston. Differences noted in the present report include 34 collar spines instead of 31, up to 15 larvae present per redia instead of six, and six pairs of cephalic gland ducts instead of the four reported by Epstein. The arrangement of spines in this cercaria is unique and unlike that of any other known megalurous cercaria.

Ecology: No seasonal patterns were noted in the occurrence of infections, which were of uniformly low incidence. Epstein (1972) reported this cercaria from 9 of 497 snails at Sportsman's Road (1.8%), which is higher than the 0.62% incidence found in the present study. The host snails are parasitically castrated by heavy infections and are usually larger in size than the average of the population. The final host of this species is probably a marsh-dwelling bird.

I. Family Renicolidae

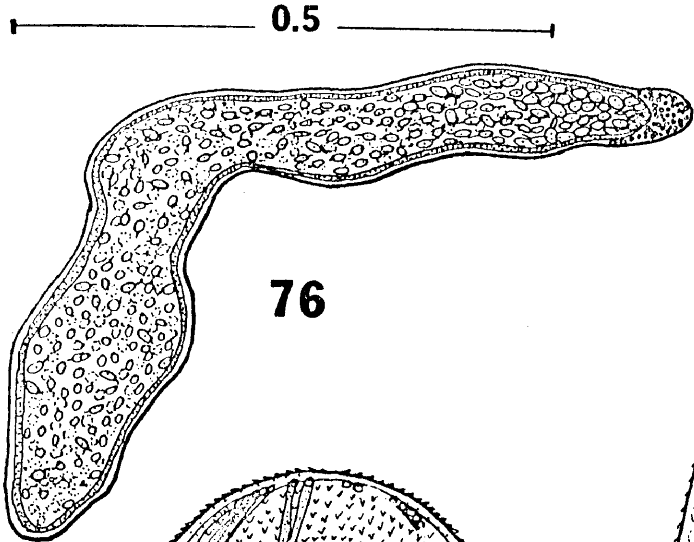
Adult renicolid trematodes are parasites of the kidney of birds. The adult excretory system is characteristic, the bladder being Y-shaped with numerous lateral diverticula. The larvae are produced in sporocysts in marine and freshwater gastropod molluscs. The cercaria also has the Y-shaped excretory bladder, may have a stylet, and has well developed penetration glands. The tail may be simple, adorned with fins, or magnacercous. Cercariae encyst in small fishes (Fundulus etc.) or in other molluscs, and become adult when the fishes or molluscs are eaten by the proper species of bird (Anas, Spatula, Larus, Sterna, etc.).

Cercaria sp. XIX

(Figures 74 to 76)

Diagnosis: Simple-tailed cercaria, body 0.08 to 0.12 in length by 0.06 in width, mouth ventral and subterminal, oral sucker oval, 0.03 wide by 0.024 long, ventral sucker in center of body, circular, 0.025 in diameter, slightly smaller than oral sucker. Prepharynx absent, pharynx 0.004 long by 0.003 wide, esophagus 0.018, crura short, 0.016, extending only to level of anterior margin of ventral sucker. Contents of gut staining red with neutral red stain. Seven pairs of cephalic glands present, two small pairs medial, located anterior to ventral sucker, their ducts extending forward near esophagus and dorsal to oral sucker. Six pairs of larger glands located posterior and lateral to ventral sucker, their ducts extending anteriad in a group, separating into a medial group of two ducts and a lateral group of four ducts at level of ventral sucker and reuniting dorsal to

Figures 74-76. Larval stages of *Cercaria* sp. XIX from *Cerithidea pliculosa*. 74. Ventral view of entire cercaria. 75. Ventral view of body of cercaria. Details of excretory system omitted from right side, glands and ducts omitted from left side. 76. Sporocyst from rectum of host snail.



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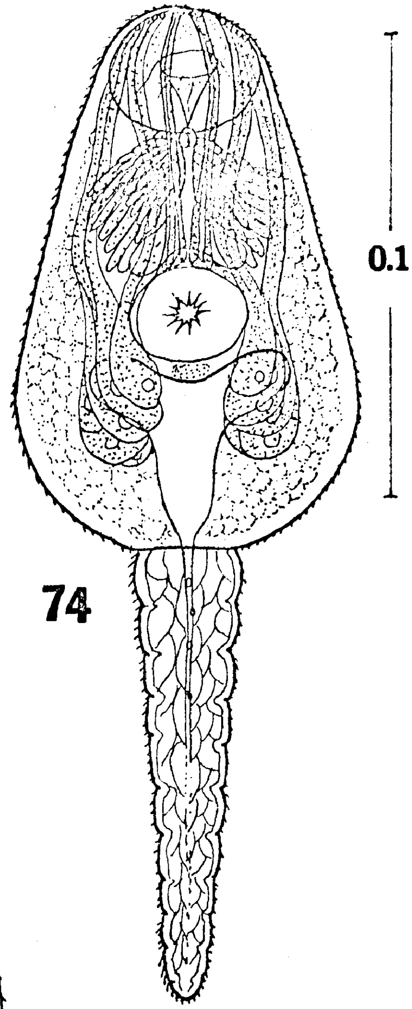

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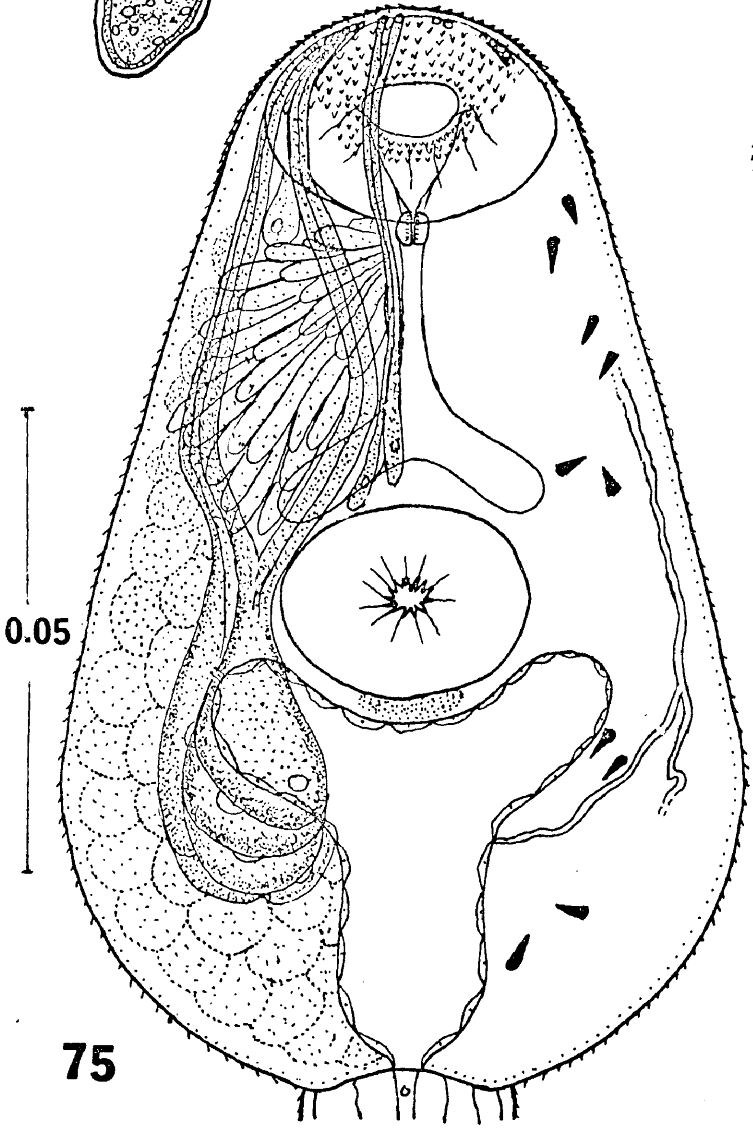

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oral sucker. All eight pairs of glands terminating in a semicircular arrangement of 14 pores dorsal and anterior to mouth. Numerous additional glands present in forebody, their ducts (if any) not seen. Entire body from posterior margin of oral sucker to posterior end of body filled with densely-packed granular cystogenous glands. All glands staining light pink in neutral red stain. Excretory bladder large, Y-shaped, excretory duct extending into tail stem. Arms of bladder extending anteriad to level of ventral sucker. Common collecting tubule entering bladder on anterior-lateral margin of stem. Anterior and posterior collecting tubules uniting posterior to ventral sucker. Flame cell formula not determined due to presence of densely-packed cystogenous glands, but at least 10 pairs of flame cells present. Genital primordium present posterior to ventral sucker. Body cuticula moderately spinose, spination especially pronounced anteriorly. A row of 38 to 44 stout spines encircling mouth. Tail 0.09 to 0.15 long, pseudo-segmented when contracted.

Cercariae swimming weakly, moving forward by lateral flexure of tail. No phototaxes observed. Development of cercariae occurring in elongated yellow sporocysts (Fig. 76). Each sporocyst 0.7 to 0.9 in length by 0.2 wide, bearing 2 to 4 bands of yellow pigment. Thick-walled sporocysts containing 50 to 100 larvae each.

Sporocysts infecting rectum of host in dorsal wall of mantle cavity. Heavy infections containing hundreds of sporocysts appearing to occlude rectal lumen.

Host: Cerithidea pliculosa (Menke), horn snail

Locality: Sportsman's Road, 28 of 1075 snails (2.8%)

Overall Incidence: 28 of 1164 snails (2.4%)

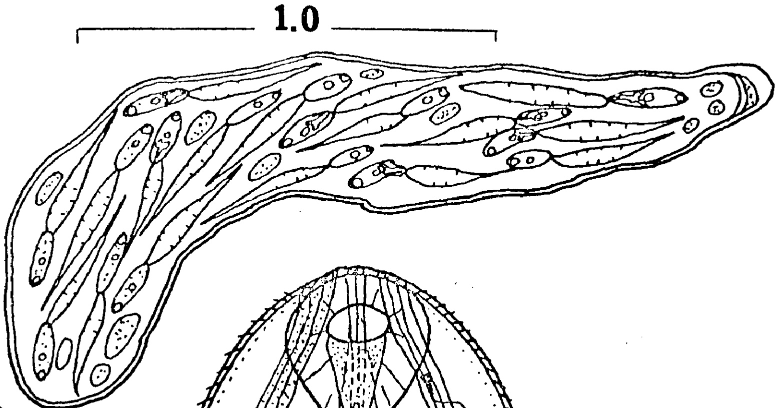
Identity: This species closely resembles Renicola cerithidicola Martin, 1971 from Cerithidea californica in California, but differs in possessing an additional small pair of cephalic glands anterior to the ventral sucker and in the possession of numerous elongated (cystogenous?) glands between the suckers. Holliman (1961) described Cercaria nubeculata from Cerithidea scalariformis in Florida which is also very similar to R. cerithidicola and Cercaria XIX, but the flame cell formula and cephalic gland condition was not worked out for that species. It is quite possible that all three forms are conspecific.

Ecology: Martin (1971) states that R. cerithidicola inhabits the mantle wall and viscera of the host snail, and Holliman (1961) states that C. ingentis inhabits the pericardium of its snail host. The sporocysts of Cercaria XIX were found only in the lumen of the rectum of Cerithidea pliculosa which is greatly distended as it passes through the wall of the right dorsal part of the mantle cavity of the snail, and is bright orange yellow in color due to the pigmentation of the sporocysts. Infections in C. pliculosa were low and fairly constant throughout the year. Martin (1971) worked out the life cycle of R. cerithidicola in California and found that the cercariae encyst in the gills of Fundulus parvipinnis and adults were recovered after experimental feeding of cysts to young gulls, Larus californicus. It is possible that a similar cycle exists in Galveston involving either Fundulus grandis or F. similis as intermediate hosts and Larus argentatus or L. atricilla as final hosts. These have all been seen frequently in the vicinity of the Sportsman's Road collecting station.

Cercaria sp. XX

(Figures 77 to 79)

Diagnosis: Magnacercous cercaria. Body 0.23 to 0.25 long, 0.09 wide, tail up to 0.02 wide near base and tapering to fine flexible tip extending three to four times length of body. Oral sucker pyriform, 0.06 long by 0.04 wide, mouth ventral and subterminal. Ventral sucker slightly anterior to midlevel of body, protrusile, circular, 0.06 in diameter. Prepharynx absent, pharynx 0.012 to 0.014, by 0.010. Esophagus inconspicuous, intestinal crura short, Figures 77-79. Larval stages of *Cercaria* sp. XX from *Cerithidea pliculosa*. 77. Ventral view of entire cercaria. 78. Ventral view of body of cercaria. Details of excretory system omitted from right side, cystogenous glands and granulation of cephalic glands omitted from left side. 79. Sporocyst from rectum of snail.



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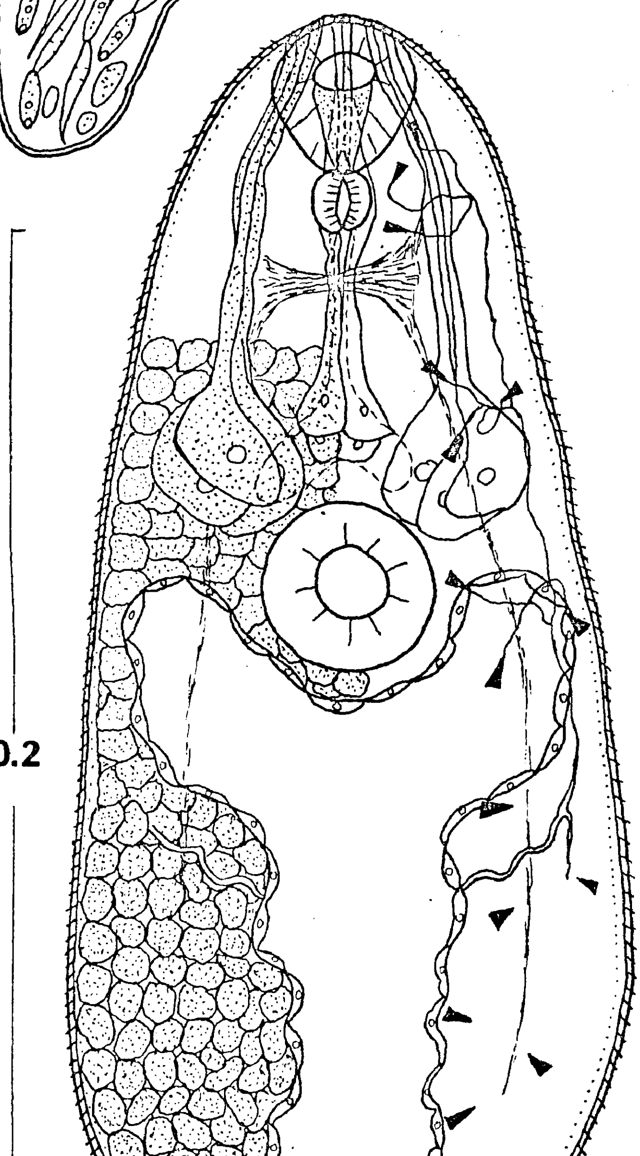

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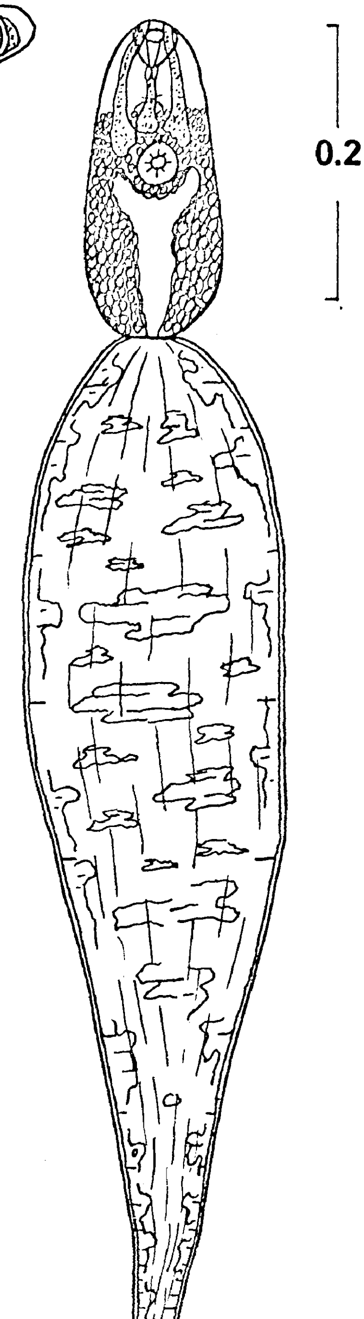

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not reaching anterior margin of ventral sucker, contents staining red in neutral red stain. Nerve commissure present posterior to pharynx, trunks extending posteriad to posterior fifth of body. Five pairs of cephalic glands present, two pairs median, adjacent to esophagus and anterior to ventral sucker, their ducts combining and extending anteriad as one pair dorsal to oral sucker. Three pairs of cephalic glands lateral and anterior to ventral sucker, their ducts extending anteriad in a common bundle lateral to pharynx and dorsal to oral sucker. All ducts terminating in pores on anterior margin of oral sucker in 3-2-3 arrangement. Genital primordia not seen. Flame cell formula probably 2[(3+3+3) + (3+3+3)] = 36, but only tubules of anterior triplets of flame cells discernible. Excretory bladder large, Y-shaped, arms extending to mid-level of ventral sucker. Stem of bladder receiving common collecting tubules on anterior lateral margin. Body cuticula moderately spinose.

Cercariae developing in elongated sporocysts (Fig. 79) 1.8 to 2.3 in length with narrow anterior ends, bright orange-yellow in color, each containing up to 15 developing larvae. Birthpore terminal on anterior end. Sporocysts developing in rectum of host in dorsal wall of right side of mantle cavity.

Cercariae swimming "upside down" and wriggling posterior tip of tail to maintain constant position in water column. Body bent in "C" shape below tail.

Host: *Cerithidea pliculosa* (Menke), horn snail

Locality: Sportsman's Road, 33 of 1075 snails (3.0%)

Overall Incidence: 33 of 1164 snails (2.56%)

Identity: This cercaria does not differ significantly from *Renicola buchanani* (Martin and Gregory, 1951) Martin, 1971 from *Cerithidea californica* in California. Holliman (1961) described *Cercaria ingentis* from *Cerithidea scalariformis* in Florida, which does not appear to differ significantly from *R. buchanani*, and all three designations probably belong to the same species.

Ecology: This cercaria apparently gains access to its second intermediate host by using the motion of its large conspicuous tail to attract the attention of small fishes. The cercaria, when swallowed by the fish, probably bores through the walls of the alimentary tract. Martin (1971) experimentally fed encysted renicolid metacercariae from the liver of *Fundulus parvipinnis* to a gull (*Larus californicus*), and found adult renicolids in the bird's kidney. He suspected that the cysts from the liver of *Fundulus parvipinnis* were those of *R. buchanani* but this was not proven. It is likely that a similar cycle exists for *Cercaria* sp. XX in Galveston, the cercaria being ingested by *Fundulus grandis* or *F. similis*, penetrating its intestine and encysting in its liver, and maturing in the kidney of a piscivorous bird which feeds upon *Fundulus*.

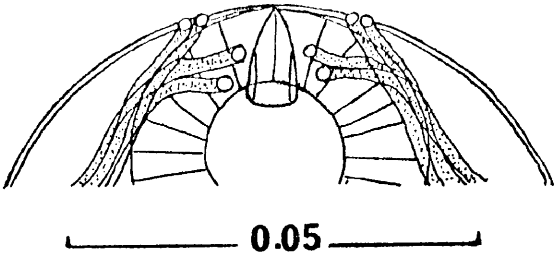
No location of the pre-cercarial stages within the host snail was reported by Martin and Gregory (1951) or by Martin (1971) for *R. buchanani*. Holliman (1961) reported that *Cercaria ingentis* occurs in the "branchial region" of the host snail. The sporocysts of *Cercaria* sp. XX develop in the lumen of the rectum of the host snail which is greatly swollen and distended in the dorsal wall of the mantle cavity, possibly occluding the rectal lumen.

Cercaria sp. XXI

(Figures 80 to 83)

Diagnosis: Simple-tailed distome xiphidiocercaria, body 0.18 to 0.22 long by 0.07 to 0.11 wide. Mouth ventral and subterminal. Xiphidium present, fusiform, truncated posteriorly, 0.012 long, located medially, dorsal to anterior portion of oral sucker. Oral sucker circular, 0.038 in diameter, ventral sucker circular, slightly anterior to body mid-point, 0.039 in diameter, almost equal to oral sucker. Prepharynx 0.008, pharynx 0.012 long by 0.009 wide, esophagus 0.024 long, bifurcating just anterior to ventral sucker

Figures 80-83. Larval stages of Cercaria sp. XXI from Cerithidea pliculosa. 80. Ventral view of entire cercaria. Details of excretory system omitted from right side, cystogenous glands omitted from left side. 81. Ventral view of anterior part of oral sucker showing ducts and pores of cephalic glands, and xiphidium.
82. Lateral view of entire cercaria in swimming position.
83. Sporocyst from gonadal area of host.



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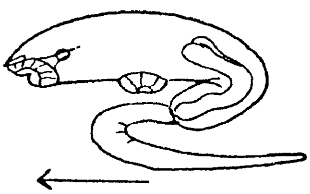

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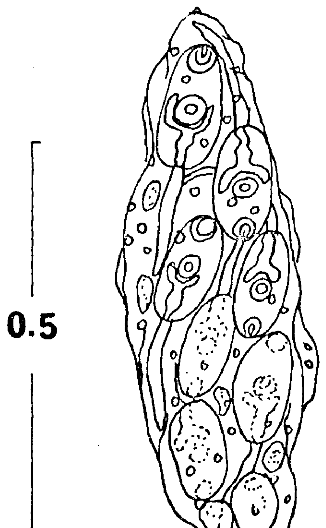

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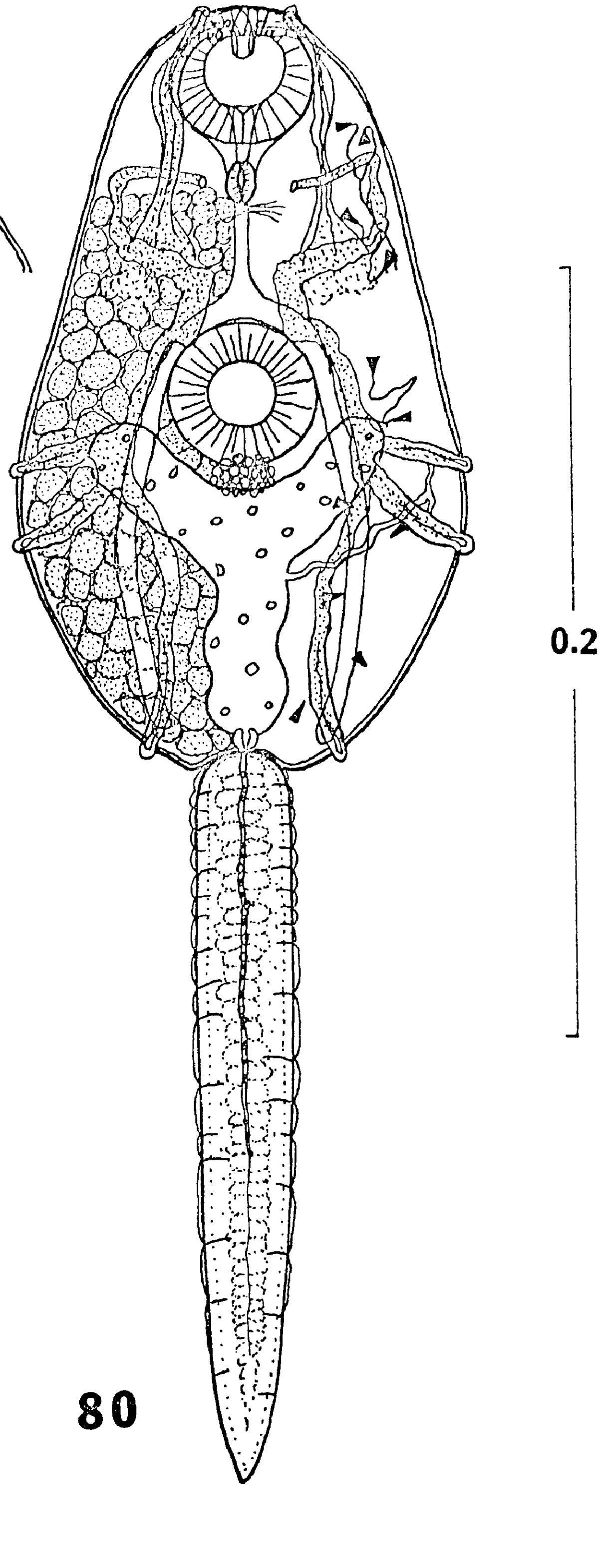

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into crura extending almost to posterior margin of body. Several indistinct pairs of cephalic glands located laterally between level of pharynx and ventral sucker, with ducts extending anteriad in paired common bundles of four ducts each, lateral to oral sucker, terminating in four pairs of pores on anterior margin of oral sucker, two pairs dorsal and two pairs adjacent to stylet (Fig. 81). Entire body below level of pharynx to posterior end of body filled with densely-packed granular cystogenous glands. In addition, a paired granular gland-like system of ducts present, originating in paired ventral pores lateral to pharynx, extending laterad to anterio-lateral sides of body, bending ventrad to level of cephalic glands, thence curving mediad to a point lateral to bifurcation of gut, then turning ventrad to anterio-lateral margin of ventral sucker, extending ventrad lateral to ventral sucker to a point lateral to ventral margin of ventral sucker. From this point, ducts branching into three apparently doubled or looped diverticula, one extending laterad and slightly posterior and just barely piercing cuticle and then recurving and returning to point of ramification. A second branch extending posterio-laterad, piercing cuticle laterally at a point midway between ventral sucker and posterior margin of body, immediately recurving and returning to point of ramification. A third branch then extending ventrad, piercing cuticle at a point just dorsal and lateral to body-tail junction, recurving, and returning to point of ramification. Excretory bladder large, Y-shaped, excretory pore surrounded by sphincter 0.005 long. Excretory duct extending through axis of tail. Arms of bladder extending almost to level of middle of ventral sucker. Bladder containing sparse evenly-distributed concretion bodies. Common collecting tubule entering stem of bladder on anterior lateral margin. Anterior and posterior tubules joining common tubule at point posterior to posterior margin of ventral sucker. Flame cell formula not fully resolved. Eleven pairs of flame cells seen in position shown in Figure 80. Genital primordium present posterior to ventral sucker, staining pink in neutral red stain. Nerve commissure crossing esophagus at posterior margin of pharynx. Body cuticula aspinose. Tail 0.15 to 0.30 in length by 0.025 wide. Cercaria swimming by reflexing posterior portion of body ventral and forward, extending tail forward, then recurving it ventrally then posteriorly, and vibrating tail laterally to drive body of cercaria forward (Fig. 82).

Sporocysts (Fig. 83) inhabiting gonad and digestive gland of host, 0.50 to 0.70 in length, by 0.23 in width, pale white in color, each containing up to 17 larvae in various stages of development. Birthpore terminal and anterior. Many hundreds of sporocysts occurring in each host snail.

Host: Cerithidea pliculosa (Menke), horn snail

Localities: Sportsman's Road, 176 of 1075 (19.1%); Yates Bayou, 3 of 89 snails (4.5%)

Overall Incidence: 179 of 1164 snails (14.5%)

Identity: The unusual system of glands and ducts which protrude through the body cuticle sets this cercaria apart from all known marine distome xiphidiocercariae. Its closest relative appears to be Cercaria caribbea XXXIII Cable, 1956 described from Cerithidea costata and Batillaria minima in Puerto Rico, and found again by Cable (1963) in Cerithium variabile from Curaçao. C. caribbea XXXIII has a pair of gland ducts which open ventrally on the posterior margin of the ventral sucker, but the extent of the ducts and glands were not traced posteriad among the dense cystogenous glands. The figure of Cercaria parvicaudata Stunkard and Shaw, 1931, from Littorina littorea shows two posterior lateral ducts and pores which may represent part of the duct-gland system seen in Cercaria sp. XXII. C. parvicaudata differs in having 18 pairs of flame cells instead of 11. These cercariae are morphologically and ecologically similar to those of the Genus Renicola whose life cycle has been worked out experimentally by Stunkard (1964). Renicola thaidis develops in sporocysts in Thais lapillus from Massachusetts.

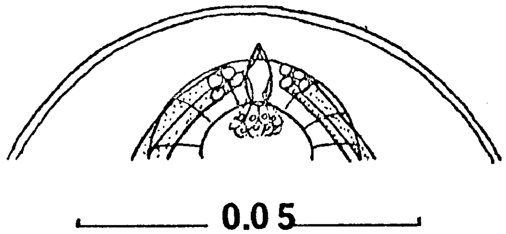
Cercariae emerge and encyst in the mantle tissues of Mytilus edulis and Aequipecten irradians. These cysts were fed experimentally to young gulls (Larus argentatus) and adult renicolid worms were recovered from the kidney of the bird.

Ecology: Infections of Cerithidea pliculosa with Cercaria sp. XXI were more prevalent in the summer months (25% in July). Cysts resembling the metacercarial cysts of R. thaidis Stunkard 1969 were found in the mantle tissues of Modiolus demissus and Brachidontes recurvus from Sportsman's Road, but attempts to infect these mussels in the laboratory with Cercaria sp. XXI were unsuccessful. Since a similar type of cercaria was found in Littorina irrorata from the same area, the origin of the metacercariae in the mussels could be from either snail or possibly from a yet undiscovered third source. The final host of this cercaria is probably one of the aquatic birds common in the marsh during the spring and summer.

Cercaria sp. XXII

(Figures 84 to 87)

Diagnosis: Simple-tailed distome xiphidiocercaria, body 0.14 to 0.22 long by 0.09 to 0.12 wide, tail 0.24 to 0.28 long by 0.025 wide. Oral sucker circular, 0.03 in diameter, ventral sucker circular, 0.03 in diameter, same as oral sucker. Stylet (Fig. 85) fusiform, Figures 84-86. Larval stages of *Cercaria* sp. XXII from *Littorina irrorata*. 84. Ventral view of entire cercaria. Details of excretory system omitted from right side, cystogenous glands omitted from left side. 85. Ventral view of anterior portion of oral sucker showing arrangement of ducts and pores of penetration glands and xiphidium. 86. Sporocyst from gonadal area of host.



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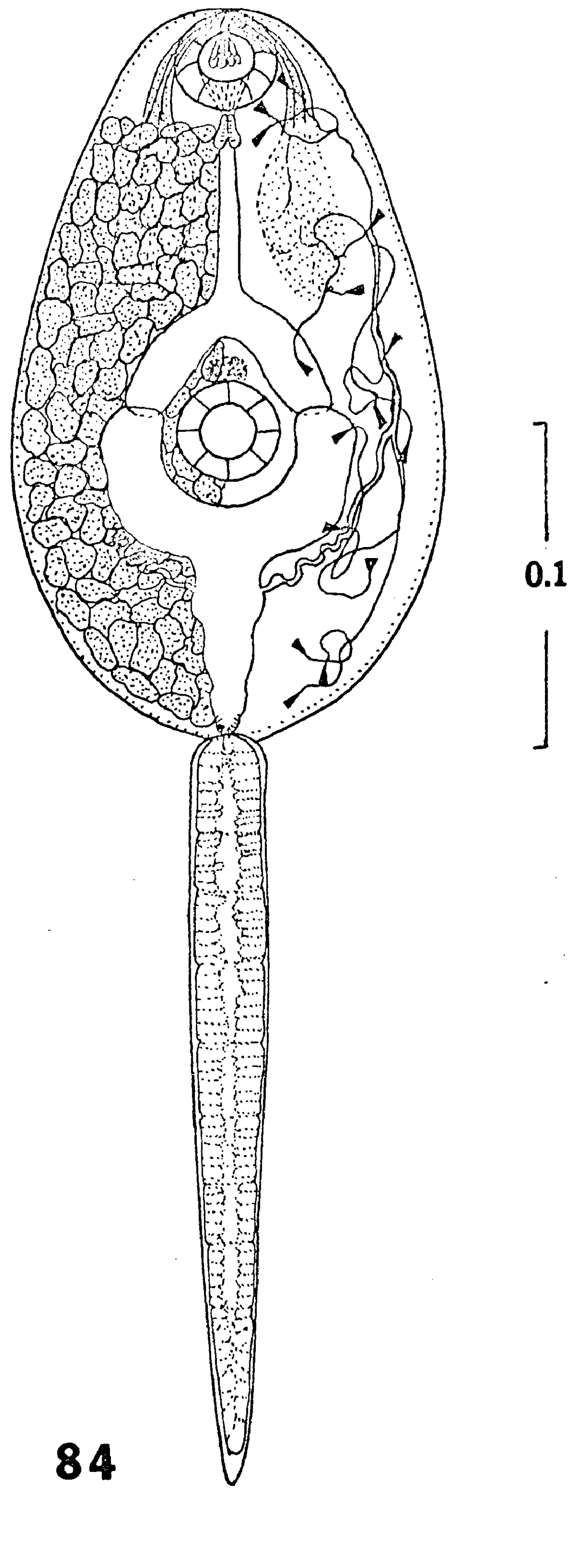

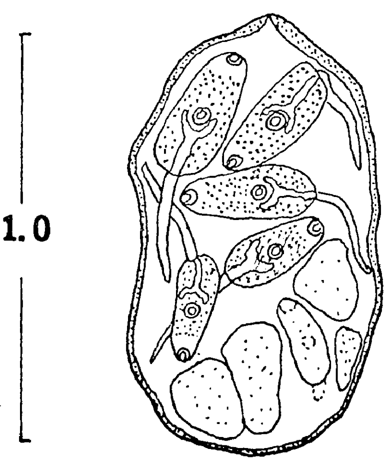

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0.01 in length, bearing about eight small indistinct glandular cells in a cluster at its base. Prepharynx absent, pharynx pyriform, 0.012 in length by 0.008 wide. Esophagus straight, 0.04 long, bifurcating anterior to ventral sucker into two relatively short and thick intestinal crura not extending to level of middle of ventral sucker. Contents of esophagus and intestinal crura staining red with neutral red stain. Approximately eight pairs of cephalic glands present in paired clusters lateral to esophagus, with ducts united into paired clusters of four ducts each, extending anteriad, dorsal to oral sucker and terminating in paired clusters of four pores lateral to base of stylet on anterior margin of oral sucker (Fig. 85). Cephalic glands and ducts staining light pink in neutral red stain. Entire body posterior to pharynx filled with densely packed granular cystogenous glands, staining dark reddish brown in neutral red stain. Excretory bladder large, Y-shaped, arms extending just past middle of ventral sucker. Flame cell formula 2[(3+3+3) + (3+3)] = 30. Common collecting tubule sinuous, entering bladder on anterior lateral margin of stem. No concretions present in bladder. Genital primordium indistinct, on anterior margin of ventral sucker, staining light pink in neutral red stain. Nerve commissure not seen, possibly obscured by dense cystogenous glands. Body cuticula aspinose. Cercaria swimming in same manner as Cercaria sp. XXI above. No phototaxes observed. Sporocysts (Fig. 86) occurring in gonad and digestive gland of host snail, pale white in color, 0.08 to 0.12 in length, each containing up to 28 (usually less than 10) identifiable larvae in various stages of development. Birthpore terminal and anterior.

Host: Littorina irrorata (Say), marsh periwinkle

Localities: Sportsman's Road, 5 of 452 snails (1.1%); East Lagoon, 1 of 550 snails (0.2%)

Overall Incidence: 6 of 1777 snails (0.3%)

Metacercaria

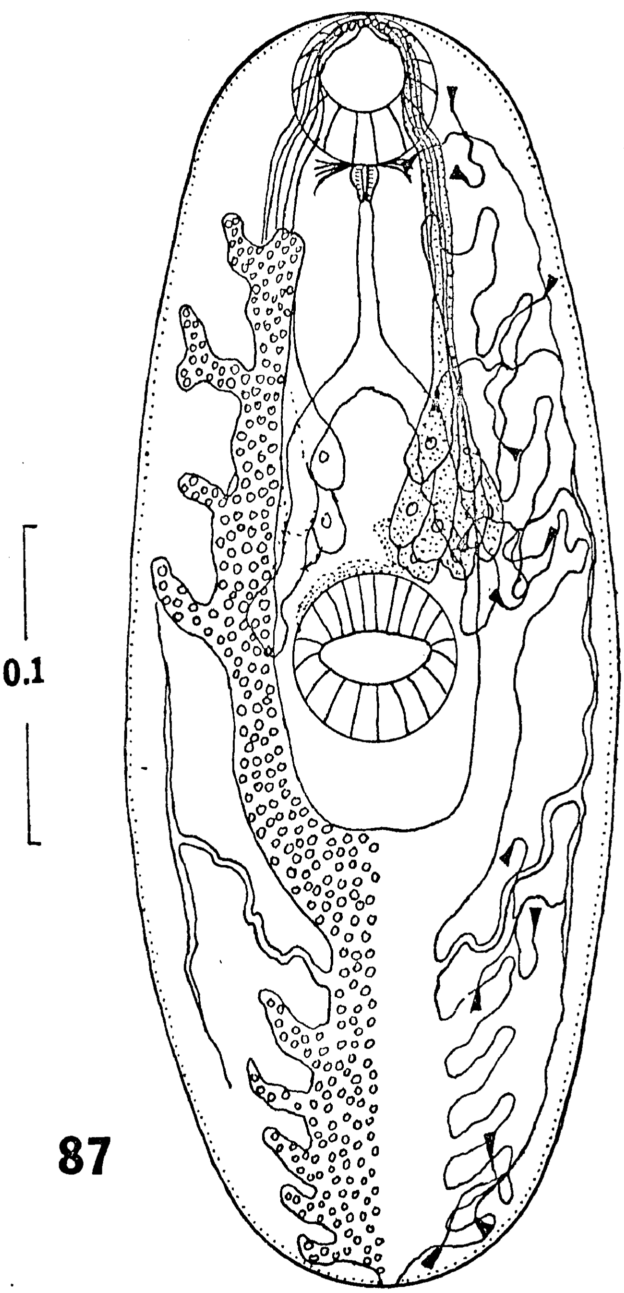
(Figures 87, 88)

What is believed to be the metacercarial stage of this cercaria was found naturally encysted in the mantle of the same host species, and was also found encysted unattached in glass bowls of seawater containing only Cercaria sp. XXII and host snail fecal matter.

Diagnosis: Cyst (Fig. 88) spherical, 0.35 to 0.40 in diameter, opaque cyst wall 0.10 thick, inner cyst containing metacercaria spherical, transparent, 0.20 in diameter, larval suckers and outline of anterior concretion-bearing diverticula of excretory bladder discernible through cyst wall. Excystment occurring 24 hours after

Figures 87-88. Metacercarial stage of *Cercaria* sp. XXII.

87. Excysted metacercaria, ventral view, details of excretory system omitted from right side, concretions in excretory bladder omitted from left side. 88. Encysted metacercaria.



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heating viable cysts in the artificial digestive medium of Hunter and Chait (1952) for 1 hour at 40°C. Excysted metacercaria (Fig. 87) elongate, 0.20 to 0.40 in length by 0.08 to 0.15 wide. Oral sucker circular 0.045 in diameter, ventral sucker oval 0.050 wide by 0.040 long. Prepharynx absent, pharynx 0.18 long, esophagus short, 0.05, bifurcating halfway to ventral sucker, crura extending almost to middle of ventral sucker. Contents of esophagus and intestinal crura staining red with neutral red stain. About eight pairs of cephalic glands located in paired clusters anterior and lateral to ventral sucker, their ducts combining into paired bundles of four each, extending anteriad, dorsal to oral sucker and ending in eight pores located on anterior margin of oral sucker. Glands and ducts staining light pink in neutral red stain. Excretory bladder large, Y-shaped, arms extending anteriad almost to level of pharynx. Stem of bladder bearing four to five pairs of lateral diverticula. Anterior portion of stem receiving common collecting tubules. Arms of bladder bearing four lateral diverticula each, some bearing secondary diverticula. Entire bladder and all diverticula filled with concretions. Flame cell formula $2[(3+3+3) + (3+3)] = 30$, same as that of cercaria. Excretory pore posterior and terminal. Cuticula aspinose. Indistinct genital primordium anterior to ventral sucker, staining light pink in neutral red stain. Nerve commissure present anterior to pharynx on posterior margin of ventral sucker.

Host: Littorina irrorata (Say), marsh periwinkle

Localities: Sportsman's Road, 6 of 25 snails (24.0%); East Lagoon, 1 of 25 snails (4%)

Combined Incidence (at only two stations where cysts were found): 7 of 50 snails (14.0%

Identity: This species resembles Cercaria parvicaudata Stunkard and Shaw, 1931 from Littorina littorea from Massachusetts in general body plan and host type, but differs in lacking one posterior triplet of flame cells on each side of the body. Other similar cercariae include Cercaria opaca Holliman, 1961 from the same host snail in Florida which was described as having one less triplet of flame cells on each side of body and more numerous penetration glands. The metacercarial cyst, however, is very similar and the two cercariae may be identical. Another similar cercaria is Cercaria caribbea XXXII from Cerithidea costata which differs only in the possession of a muscle band or sphincter around the excretory duct pore, but the number of cephalic glands and flame cell formula were not worked out for that cercaria.

Ecology: All infected snails were found in December and March but since only five infections were found, the seasonal pattern could only be guessed. Holliman (1961) found that his *Cercaria opaca* encysted in the gonad of the host snail. Metacercariae of *Cercaria* sp. XXII were found in the gonad of *L. irrorata*, but infections were much more common in the wall of the rectum and in the mantle. It is possible that this cercaria also encysts in the mantle of the ribbed mussel, *Modiolus demissus*, but attempts at experimental infection were unsuccessful. The natural cysts in *M. demissus* are rapidly calcified and diagnostic features of the causative agent could not be determined. The final host of this cercaria is probably a bird which feeds directly upon *L. irrorata*.

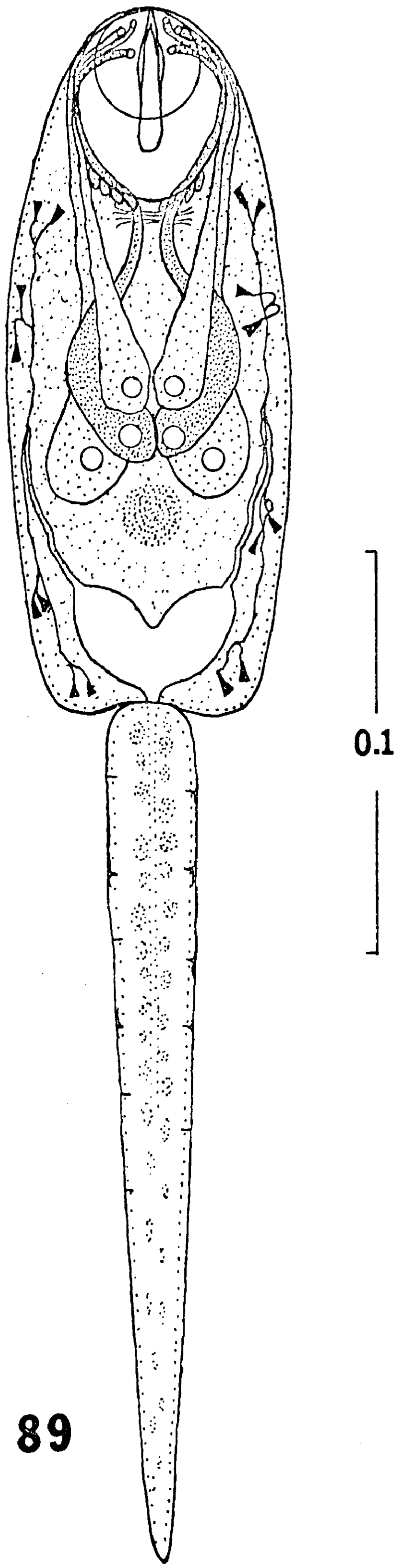
J. Family Microphallidae

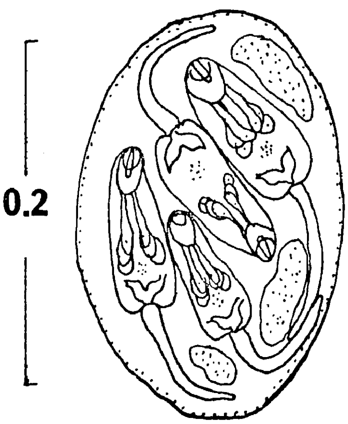
Adult microphallids are small pyriform distome intestinal parasites of all classes of vertebrates. Monostome xiphidiocercariae with prominent penetration glands are produced in sporocysts in marine and freshwater snails. Cercariae penetrate and encyst in the body musculature of crustaceans, which are then ingested by the final host. The encysted metacercaria (now distome) is freed by the digestive fluids of the final host and attaches to the walls of the intestine. Microphallid metacercariae are known to infect commercial shrimps and crabs and one species has been experimentally established in man.

Cercaria sp. XXIII

(Figures 89, 90)

Diagnosis: Simple-tailed monostome xiphidiocercaria, body fusiform, truncated posteriorly, 0.16 to 0.20 long by 0.07 wide. Tail 0.18 to 0.22, slightly longer than body, 0.02 wide at base. Oral sucker oval, 0.05 long by 0.04 wide. Stylet (Fig. 89) 0.03 long located dorsal to anterior margin of oral sucker. Ventral sucker wanting, represented by a weak circular primordium 0.018 in diameter, located in posterior third of body. Pharynx and gut absent. Three pairs of large cephalic glands located in center of body, their ducts extending dorsad and anteriorly, in paired lateral bundles of three ducts each, separating into a single medial and a double lateral bundle posterior to oral sucker, reuniting at mid-level of oral sucker into two lateral paired bundles of three ducts each, and then separating just before terminating in a triangular arrangement of pores on each side of stylet. Posterior-most and anterior-most penetration glands finely granulated, their ducts remaining united laterally to mid-level of oral sucker. Middle pair of penetration glands coarsely granulated, its duct separating from that of others, bending mediad posterior to oral sucker, then reuniting at level of oral sucker. Excretory bladder bilobed, 0.030 long by 0.045 wide, Figures 89-90. Larval stages of Cercaria sp. XXIII from Cerithidea pliculosa. 89. Ventral view of entire cercaria. 90. Sporocyst from gonadal area of host.





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common collecting tubules entering bladder on anterio-lateral margin. Flame cell formula 2[(2+2) + (2+2)] = 16, anterior and posterior collecting tubules joining common tubule at level of nucleus of middle penetration gland. Nerve commissure present below posterior margin of oral sucker. About eight small indistinct glands located along posterior margin of oral sucker, 0.005 in diameter. Body cuticula aspinose.

Sporocysts (Fig. 90) occurring in gonad and digestive gland of host snail, thin-walled, transparent white and sac-like, 0.22 to 0.31 long, 0.18 to 0.23 wide, containing up to five larvae in various stages of development.

Cercariae swimming by flexing body in a "C" shape ventrally and undulating tail laterad. A slightly increased concentration of cercariae noted on lighted side of observation bowl.

Host: *Cerithidea pliculosa* (Menke), horn snail

Locality: Sportsman's Road, 21 of 1075 snails (1.85%)

Overall Incidence: 21 of 1164 snails (1.80%)

Identity: This cercaria is identical to *Cercaria lanceolata* Holliman, 1961, from *Cerithidea scalariformis* in Florida, the only differences being the slightly smaller size of *C. lanceolata* and the small inconspicuous glands on the posterior margin of the oral sucker of C. sp. XXIII which were not shown on the figure of C. lanceolata by Holliman. These apparent differences are considered to be insignificant for specific separation. C. lanceolata and C. sp. XXIII differ from all other known microphallid larvae in the possession of only three pairs of penetration glands instead of the usual number of four.

Ecology: The occurrence of this cercaria showed no seasonal pattern, being at a fairly constant low incidence. Epstein (1972) in a survey of 188 C. pliculosa from Sportsman's Road in Galveston did not encounter this cercaria. Infections are generally light, with few sporocysts; they often occur in conjunction with heavier infections of heterophyids, opisthorchiids, renicolids or schistosomatids and could easily be overlooked. The possibility exists that Cerithidea pliculosa and C. scalariformis are not the proper natural hosts for this parasite which could account for the sparse proliferation of sporocysts in the host snail.

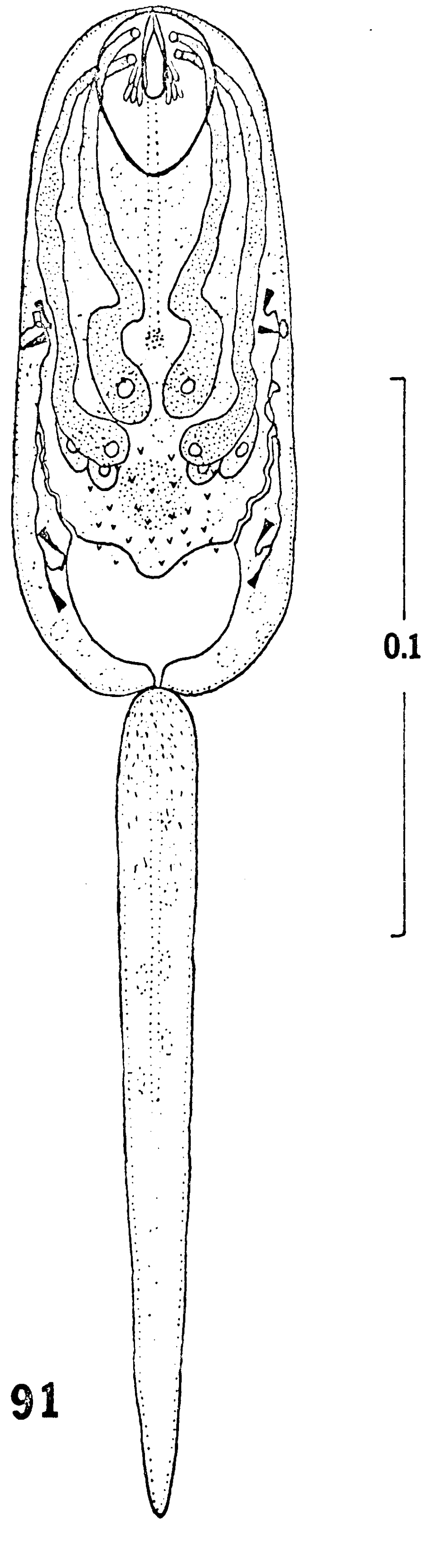
Sarkissian (1957) described Maritrema uca, from Cerithidea californica in California, which has four pairs of penetration glands and only eight flame cells (increasing to 16 in the metacercarial stage), but otherwise resembles C. lanceolata and C. sp. XXIII, especially in host and habitat. Sarkissian found the metacercaria encysted in the fiddler crab Uca crenulata; it resembled Maritrema glandulosa Coil, 1955, from the little blue heron, Florida caerulea in Mexico. A similar metacercaria has been found encysted in Uca minax at Sportsman's Road, Galveston, but attempts at experimental infection of this species with Cercaria sp. XXIII were unsuccessful. It cannot be concluded that these cysts must originate with Cercaria sp. XXIII because one other species of microphallid cercaria was found in the area from two other snail hosts.

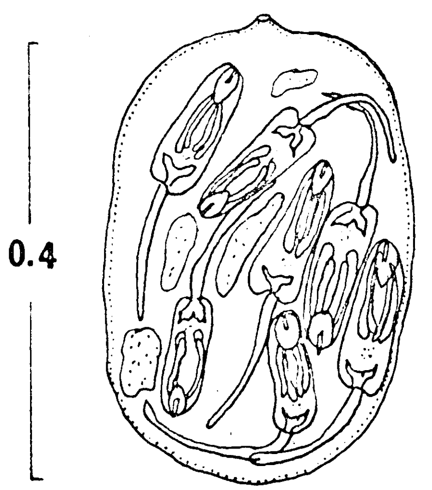
Cercaria sp. XXIV

(Figures 91, 92)

Diagnosis: Simple-tailed monostome xiphidiocercaria, body (Fig. 91) 0.90 to 1.30 long by 0.40 to 0.60 wide. Tail 0.15 to 0.20 in length by 0.015 wide. Oral sucker pyriform, 0.03 long by 0.02 wide, ventral sucker wanting, represented by circular primordium staining red-brown in neutral red stain, 0.15 in diameter in posterior third of body. Stylet present on anterior margin of oral sucker, 0.015 long. Pharynx absent, gut indistinct, esophagus straight and narrow, bifurcating at body mid-level into short crura not extending to anterior margin of primordium of ventral sucker. Four pairs of penetration glands present in center of body. Two large pairs situated anteriorly, staining red in neutral red stain, coarsely

Figures 91-92. Larval stages of *Cercaria* sp. XXIV from *Littorina irrorata*. 91. Ventral view of entire cercaria. 92. Sporocyst from gonadal area of host snail.





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granulated, their ducts extending anteriad dorsal to oral sucker and terminating in two pairs of pores located lateral to stylet on anterior margin of oral sucker. Two additional pairs of finely granulated penetration glands staining pink in neutral red stain, located posterior to coarsely granulated penetration glands, their ducts not seen, apparently fusing with ducts of posterior-most coarsely granulated penetration gland. Excretory bladder bilobed, 0.025 long by 0.030 wide, arms extending to posterior margin of primordium of ventral sucker. Common collecting tubules entering arms of bladder on their anterio-lateral margins. Flame cell formula $2[(1+1) + (1+1)] = 8$. A small circular primordial gonotyl (?) 0.003 in diameter located on ventral surface of body just anterior to bifurcation of intestine. Body cuticula aspinose excepting ventral surface at location of ventral sucker primordium. This area bearing numerous ventrad directed spines.

Sporocysts (Fig. 92) sac-like, transparent, white, 0.30 to 0.60 in length by 0.15 to 0.35 in width, bearing up to 10 larvae in various stages of development. Birthpore terminal on anterior end.

Cercariae swimming weakly tail-first by lateral undulations of tail stem as in Cercaria sp. XXIII. No phototaxes observed.

Host: Littorina irrorata Say, marsh periwinkle

Localities: Sportsman's Road, 1 of 452 snails (0.22%); East Lagoon, 1 of 550 snails (0.18%)

Overall Incidence: 2 of 1777 snails (0.11%)

Host: Crepidula plana Say, flat slipper limpet

Locality: Offat's Bayou, 3 of 40 snails (7.5%)

Overall Incidence: 3 of 284 snails (1.1%)

Identity: This cercaria most closely resembles that of *Microphallus similis* (Jagerskiold, 1900) Baer, 1943 as figured and described by Stunkard (1957). They differ somewhat in that *Cercaria* sp. XXIV has ventral posterior cuticular spines and a primordial ventral sucker which are lacking in the cercaria of *M. similis*. Both cercariae utilize snails of the genus *Littorina* as the molluscan host, but *Cercaria* sp. XXIV also infects *Crepidula plana*. *M. similis* cercariae encyst in crabs and the final host is a seagull (*Larus argentatus*).

Ecology: Since only two or three infections were found in each species of snail, no seasonal pattern of occurrence can be discerned. Epstein (1972) found this parasite in higher incidence in *L. irrorata* at Sportsman's Road, Galveston (5 of 497), being more than 1%, as compared to 0.22% in the present study, indicating the possibility of cyclic fluctuation in incidence from year to year, or possibly a decline in the frequency of bird visitation due to habitat alteration and human encroachment. Epstein did not find microphallid cercariae in the 98 Crepidula plana which he examined from Terramar Beach.

Encysted microphallid metacercariae were found in the fiddler crab Uca minax at Sportsman's Road, but since different microphallid cercariae were also found in Cerithidea from the same area, knowledge of their source must await infection experiments.

K. Family Lepocreadiidae

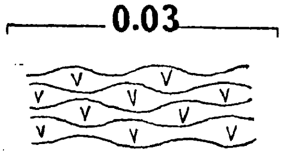
Adult lepocreadiids are intestinal parasites of many marine and a few freshwater fishes. Larvae are produced in elongate rediae in snails. Cercariae are occulate and trichocercous with an I -shaped excretory bladder, a well-developed pharynx and many flame cells. Cercariae are known to encyst in both plankton (coelenterate medusae, chaetognaths) and benthos (turbellarians, annelids, sea hares, bivalve molluscs) and adults are found in a wide taxonomic range of teleost fishes.

Cercaria sp. XXV

(Figures 93 to 96)

Diagnosis: Occulate trichocercous distome cercaria, body (Fig. 94) 0.14 to 0.23 in length by 0.10 to 0.13 wide. Tail (Fig. 93) 0.25 to 0.41 long by 0.015 wide, bearing 21 to 23 lateral pairs

Figures 93-96. Larval stages of *Cercaria* sp. XXV from *Cantharus cancellaria*. 93. Ventral view of entire cercaria, cystogenous glands and details of excretory system omitted. Caudal setae omitted from left side of tail. 94. Ventral view of body of cercaria. Details of excretory system omitted from right side, lateral cystogenous glands omitted from left side. 95. Cuticular spination. 96. Redia from gonadal area of host snail.



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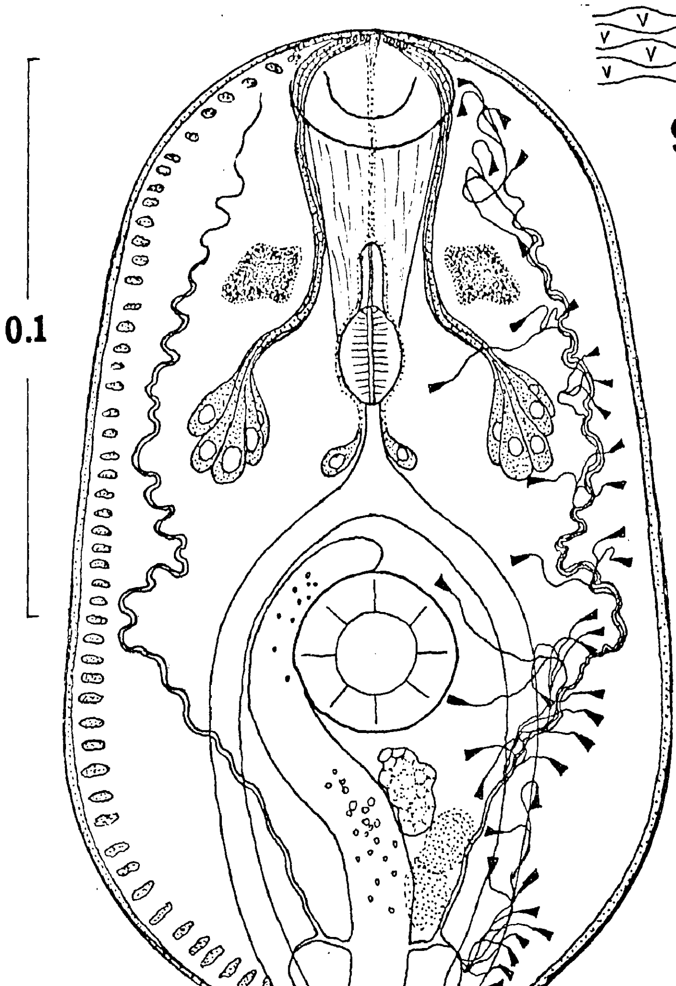

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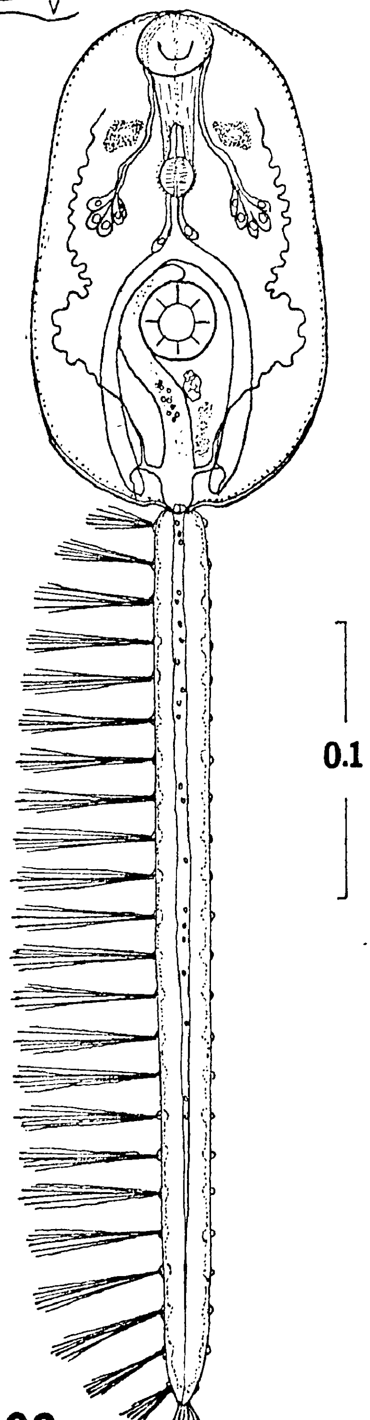

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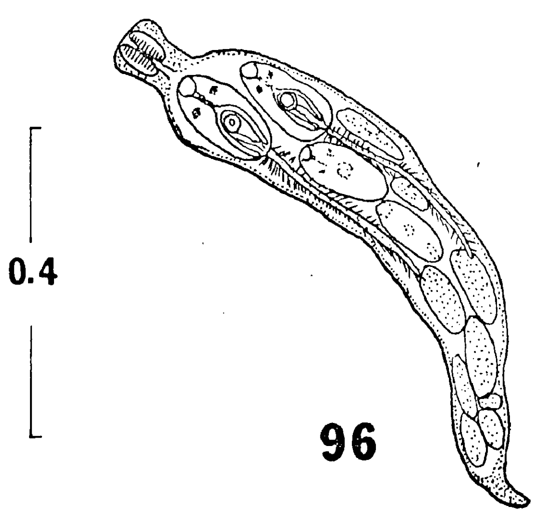

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of setal bundles and a single terminal bundle, each consisting of up to six setae, longest bundles 0.06 in length. Oral sucker oval, 0.03 wide by 0.02 long. Ventral sucker just posterior to body midpoint, circular, 0.028 in diameter. Prepharynx 0.02 long, pharynx 0.018 long by 0.011 wide and bearing an anterior extension 0.012 long by 0.004 wide. Esophagus short, 0.015, bifurcating anterior to ventral sucker, crura extending almost to posterior margin of body. Content of gut staining red in neutral red stain. About five pairs of cephalic glands situated in lateral clusters at level of esophagus, their ducts extending anteriad in a pair of common bundles dorsal to oral sucker and terminating in individual pores on anterior margin of oral sucker. An additional medial pair of cephalic glands lying adjacent to esophagus, their ducts extending separately anteriad close to pharynx, dorsal to oral sucker and terminating in two medial pores on anterior margin of oral sucker. Cephalic glands staining reddish-brown in neutral red stain. A pair of rhomboidal dark-brown eyespots present lateral to anterior extension of pharynx, 0.02 to 0.035 in maximum dimension. Eyespots composed of numerous dark brown spherical bodies concentrated around margins, leaving a lighter less dense area in center. Excretory bladder I-shaped, extending anteriad to level of bifurcation of intestine, clear, with very few concretion bodies. Excretory duct at body-tail junction bearing a muscular "sphincter". Common tubules very short, receiving anterior and posterior tubules 0.01 from junction with bladder. Anterior collecting tubule long and sinuous extending to level of eyespots. Posterior tubule very short, terminating 0.005 from junction with common tubule. Flame cell formula (Fig. 94) 2[(3+3+3+3+3+3+3+3+3+3) + (3+3+3+3)] = 84. Three genital primordia present posterior to ventral sucker, one anterior and composed of spherical cells, possibly ovarian, 0.012 long by 0.008 wide. Two posterior primordia finely granulated, possibly testicular, 0.010 long by 0.006 wide. Cystogenous glands 0.001 to 0.004 in maximum dimension present adjacent to body cuticle in single longitudinal lateral rows of 30 to 50 glands each, staining pink in neutral red stain. Body cuticula thick, transversely striated, moderately spinose (Fig. 95).

Cercaria swimming tail-first by lateral undulations of tail stem, positively phototactic.

Cercariae developing in rediae (Fig. 96) in gonad and digestive gland of snail host. Redia 0.40 to 0.65 in length by 0.15 to 0.20 in width, containing up to 37 larvae in various stages of development. Redial pharynx 0.05 long by 0.025 wide, redial gut not seen. Rediae bearing posterior cuticular projection used in creeping locomotion, 0.008 in length.

Host: Cantharus cancellarius (Conrad), cancellate cantharus

Localities: Tip of South Jetty, 1 of 13 snails (7.6%); High Island drilling platform, 1 of 1 snail (100%)

Overall Incidence: 2 of 14 snails (14.3%)

Identity: Cercaria sp. XXV resembles the cercaria of Lepocreadium setiferoides (Miller and Northrup, 1926) Martin, 1938 from Nassarius obsoletus from Massachusetts in general body form, but differs from that species in having 23 instead of 30 pairs of caudal setae, and 84 instead of 48 flame cells. Cercaria caribbea Cable, 1963 from Anachis obesa in Jamaica, is more similar but has 24 pairs of caudal setae and its flame cell formula has not been worked out. Epstein (1972) found a similar larva in Anachis avara at Terramar Beach, Galveston, having only 18 pairs of caudal setae and triangular eyespots, but its flame cell formula was not determined.

Ecology: The host snail of Cercaria sp. XXV prefers the deeper waters offshore and could not be obtained in sufficient numbers to gain a valid estimate of incidence or seasonal occurrence. Since many species of lepoceadiids are known to parasitize species of fishes which are common in the Galveston area, it is difficult to speculate on the specific identity of the adult. It is probably a member of the Genus Lepocreadium which possesses an I-shaped tubular excretory bladder as does Cercaria sp. XXV.

L. Family Megaperidae

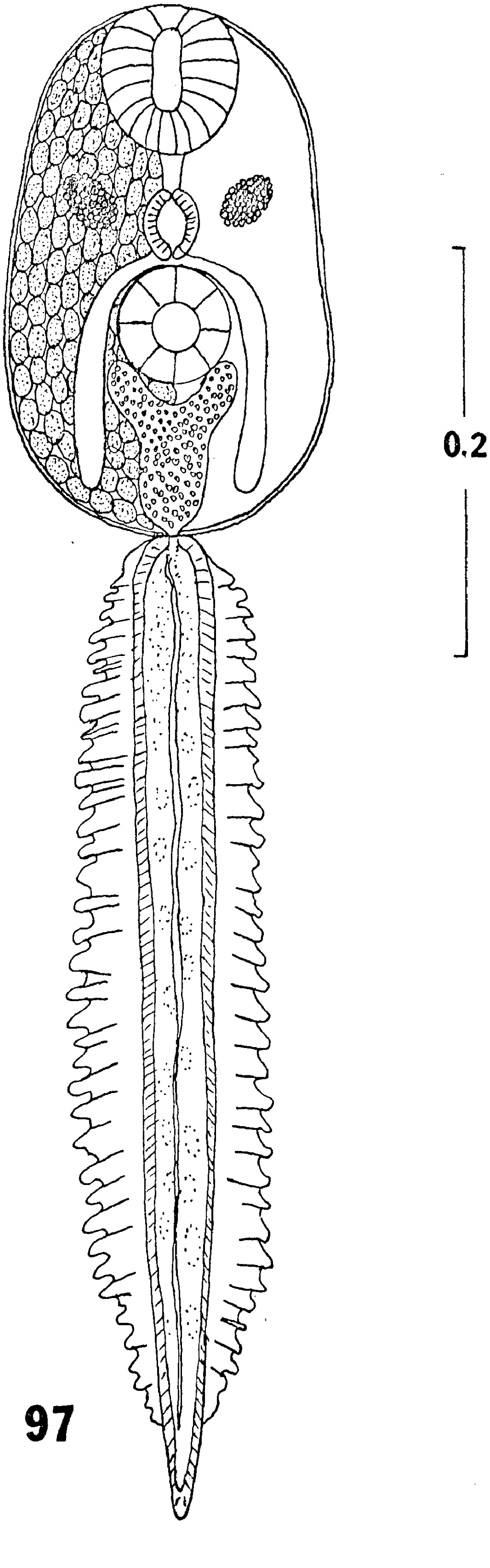
Adult megaperids are intestinal parasites of marine fishes. The family contains only two genera and five species which are known to parasitize only fishes of the genera Lactophrys and Monacanthus. Cable (1954) worked out the life cycle of Megapera gyrina (Linton, 1907) and found a bi-ocellate lophocercous cercaria developing from rediae in the gonad of Crepidula convexa in Puerto Rico. Cercariae leave the snail and encyst in the open. Cysts are ingested by the trunkfish, Lactophrys tricornis, and the parasite matures in the intestine of this fish.

Cercaria sp. XXVI

(Figures 97, 98)

Diagnosis: Bi-ocellate lophocercous distome cercaria (Fig. 97), body 0.23 to 0.27 long, by 0.15 to 0.18 wide, tail 0.50 to 0.65 in length by 0.04 wide. Paired lateral caudal fins present, arising near body-tail junction and extending posteriad, terminating 0.04 anterior to tip of tail. Length of lateral margin of fins greatly exceeding length of portion attached to tail stem; consequently, lateral margins with frilled or ruffled appearance. A median ventral fin also present, low and unruffled, arising near body tail junction and terminating

Figures 97-98. Larval stages of Cercaria sp. XXVI from Crepidula plana. 97. Ventral view of entire cercaria, cystogenous glands omitted from left side. 98. Redia from gonadal area of host snail.



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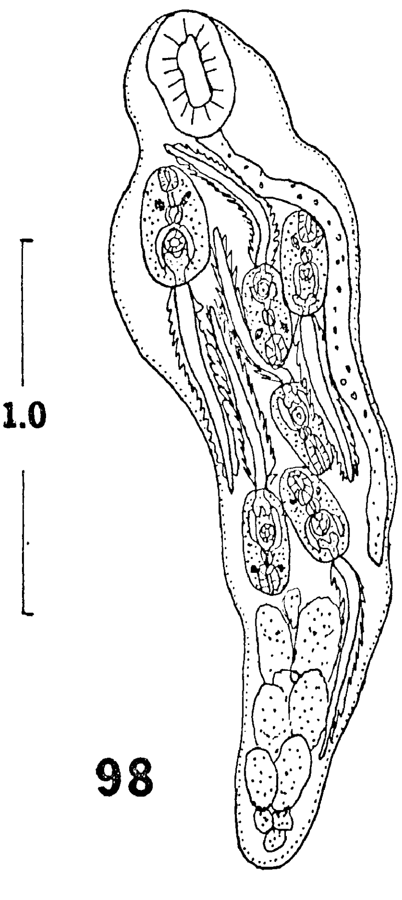

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0.04 from tail tip. Oral sucker 0.08 long by 0.07 wide, mouth ventral and subterminal, ventral sucker circular, 0.06 in diameter, located just posterior to body midline. Prepharynx 0.02, pharynx 0.03 long by 0.025 wide. Esophagus absent, gut bifurcating at posterior margin of pharynx and extending almost to posterior end of body. Paired lateral eyespots present, composed of dark brown spherical bodies. Eyespots transversely oval, 0.035 by 0.025, located at level of anterior margin of pharynx. Excretory bladder Y-shaped, arms extending almost to mid-level of ventral sucker. Bladder filled with concretion bodies. Details of excretory system not observed. Entire body filled with finely granulated cystogenous glands. Body cuticula aspinose.

Cercariae developing in gonad and digestive gland of host snail in elongated rediae (Fig. 98) 0.12 to 0.20 in length by 0.06 wide. Cuticula colorless. Pharynx 0.025 by 0.018, gut extending posteriorly just past redial mid-point, light brown in color. Up to 12 cercariae present in various stages of development. Swimming and behavior of cercariae not observed, single infected specimen of snail host moribund at time of collection and parasites inactive.

Host: *Crepidula plana* Say, flat slipper limpet

Locality: West Beach, 1 of 236 limpets (0.4%)

Overall Incidence: 1 of 284 limpets (0.3%)

Identity: This species can only be compared to the cercaria of Megapera gyrina (Linton, 1907) as described by Cable, 1954. M. gyrina has circular eyespots, 96 flame cells, and short rediae (1.0) with a short gut. Cercaria sp. XXVI has diagonally oval eyespots, the flame cell formula was not observed (host was moribund) and its rediae are 2.0 long with long guts. The final hosts of M. gyrina are known to be fishes of the Genus Lactophrys, none of which are listed among the ichthyofauna of the Galveston area (Parker, 1965). Megapera ovalis (Manter, 1933) was described from the filefish Monacanthus hispidus which is the only known megaperid host species occurring in the Galveston area. Parker (1965) lists this fish as being "common in high salinity waters" and it could possibly be the final host of Cercaria sp. XXVI.

Ecology: The single infection was found in a snail in the aperture of a Thais haemastoma shell inhabited by the hermit crab Clibanarius vittatus on the exposed Galveston beachfront in May, 1972. Epstein (1972) found a megaperid larva in the limpet Crepidula plana from Terramar Beach on West Bay in Galveston. The rediae of his form are similar to those of Cercaria sp. XXVI but the eyespots are circular as in M. gyrina. This difference alone however, is probably not of specific value, and these megaperids from C. plana in Galveston are probably identical.

M. Family Monorchiidae

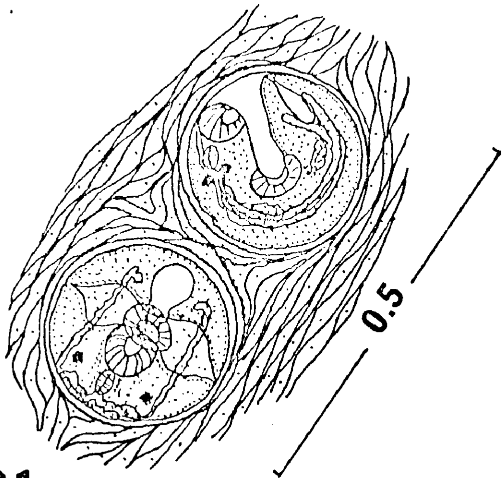
Adult monorchiids are small intestinal parasites of many marine and a few freshwater fishes. Nine of the 10 subfamilies listed by Yamaguti (1958) may be characterized as adult intestinal parasites of marine fishes, with a median genital pore. Cercariae may be tailless, microcercous or have simple straight tails. Some are bi-ocellate. The excretory bladder is thick-walled, the flame cell formula is $2[(2+2) + (2+2)] = 16$ and development is in sporocysts in marine bivalve molluscs. Encystment of cercariae usually occurs in the mantle or foot of a bivalved mollusc and metacercariae become mature in a wide variety of omnivorous teleost fishes. Members of the peculiar sub-family Asymphylodorinae, however, are non-ocellate intestinal parasites of freshwater fishes with a lateral genital pore, developing in rediae in gastropod molluscs and their microcercous cercariae encysting in other molluscs. Their metacercariae may contain 62 flame cells. The Asymphylodorinae, however, do closely resemble the other sub-families in characteristics such as form of excretory bladder, body shape and size, spination, suckers, digestive apparatus, and gland morphology.

Cercaria sp. XXVII

(Figures 99 to 102)

Diagnosis: Bi-ocellate distome microcercous cercaria. Body (Fig. 99) 0.25 to 0.29 long by 0.50 to 0.62 wide, tail 0.70 to 0.75 long, bearing a bell-shaped collar at body-tail junction 0.31 long by 0.30 wide. Musculature within tail striated both transversely and longitudinally, interior staining pink with neutral red stain. Mouth ventral and subterminal, oral sucker circular, 0.042 in diameter, ventral sucker posterior to body midpoint, circular, 0.036 in diameter. Prepharynx short, pharynx 0.020 long by 0.015 wide, esophagus 0.04, intestinal crura short, 0.025, and terminating well anterior to ventral sucker. Contents of intestine staining red in neutral red stain. About four pairs of penetration glands present anterior to ventral sucker, their ducts extending lateral to pharynx and either lateral or dorsal to oral sucker, and terminating in four pairs of pores on anterior margin of oral sucker in a 2-2-2-2 arrangement. Penetration glands and ducts staining pink in neutral red stain. Paired cuboidal eyespots present lateral to pharynx, consisting of dark brown spherical bodies. Nerve ganglion present anterior to esophagus with long trunks extending almost to posterior end of body. Excretory bladder oval, thick-walled, 0.06 long by 0.03 wide, collecting

Figures 99-101. Larval stages of *Cercaria* sp. XXVII from *Donax variabilis*. 99. Ventral view of entire cercaria, details of excretory system omitted from right side. 100. Sporocyst from gonadal area of host clam. 101. Two encysted metacercariae in foot of *Donax variabilis*.



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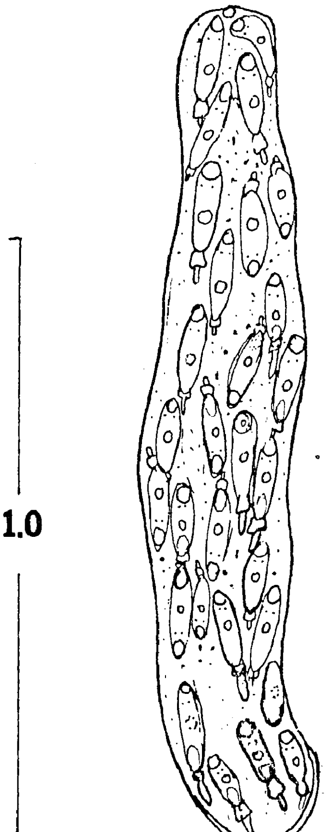

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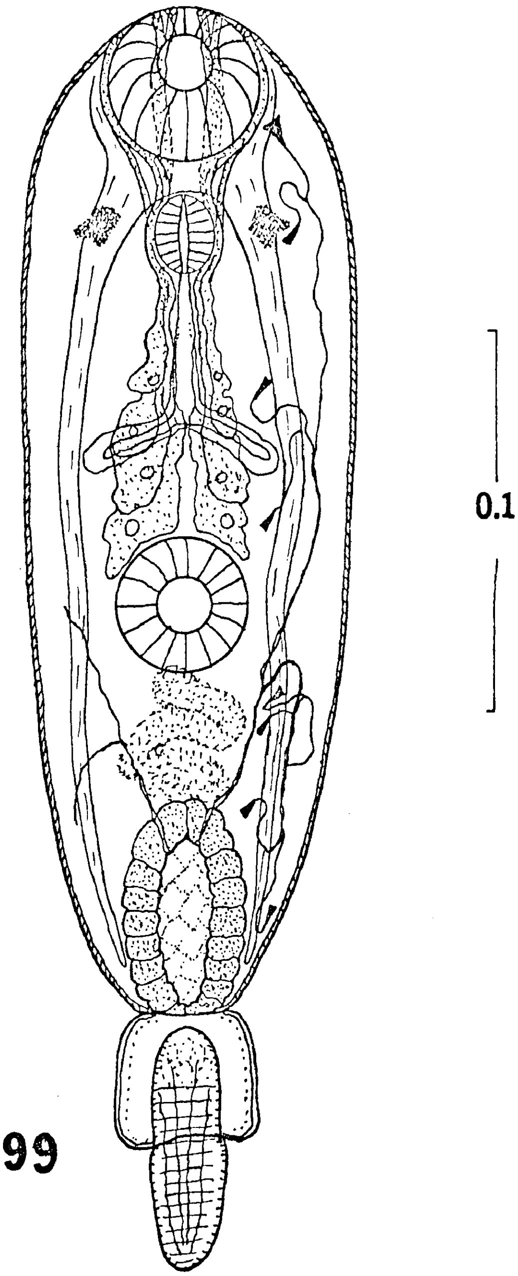

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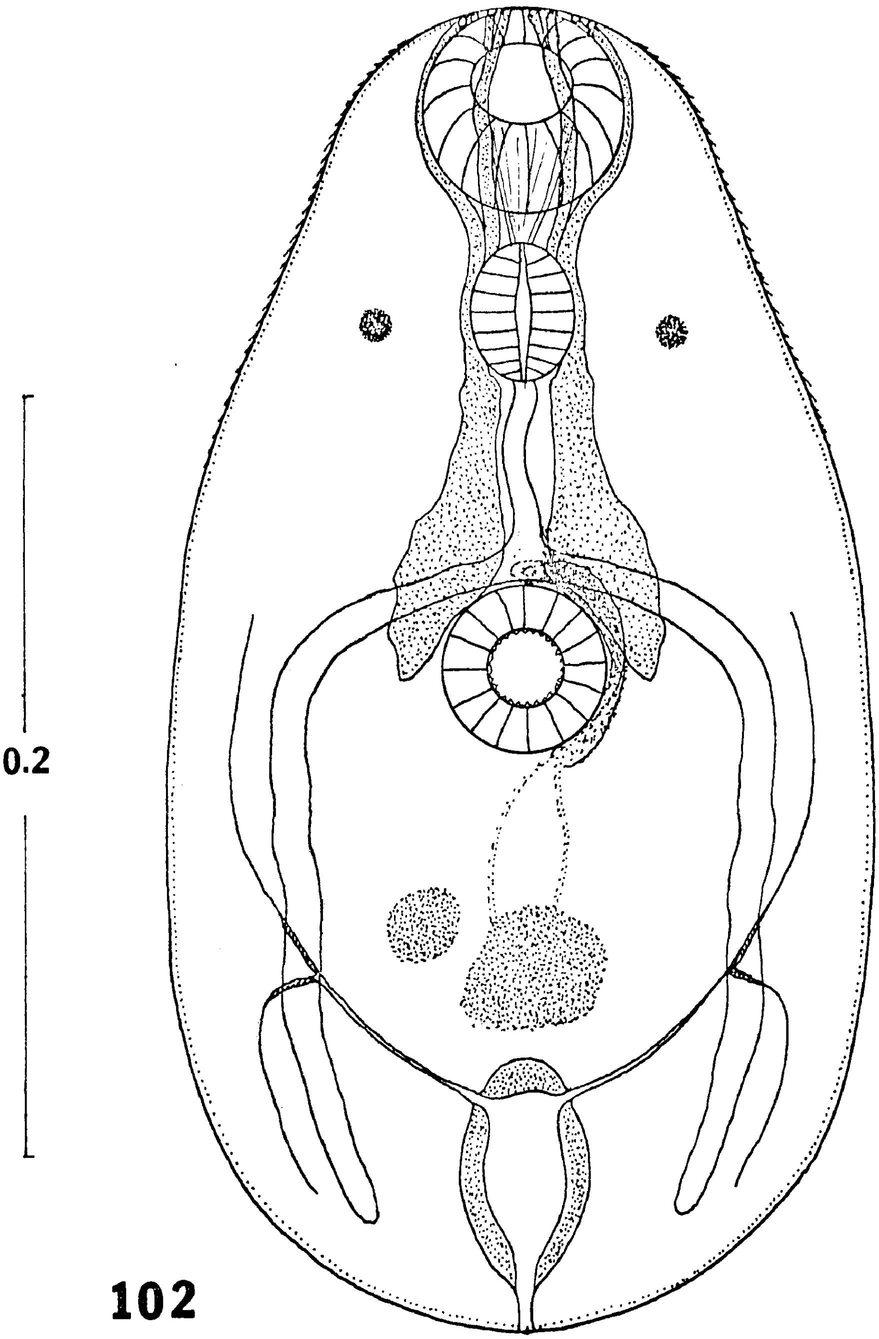
Figure 102. Excysted metacercarial stage of Cercaria sp. XXVII from foot of Donax variabilis. Dorsal view.



102

tubules entering bladder on anterior lateral margin. Anterior and posterior collecting tubules joining common tubule posterior to ventral sucker. Flame cell formula 2[(2+2) + (2+2)] = 16. Body cuticula relatively thick and moderately spinose. Spines in transverse rows. Cercaria not swimming but creeping on bottom of container. Cercariae developing in orange-colored elongated sporocysts (Fig. 100), 0.15 to 0.20 in length, by 0.25 to 0.30 wide, containing up to 25 cercariae in various stages of development. Birthpore terminal and anterior. Cercariae occurring in digestive gland and gonad of host causing parasitic castration.

Host: *Donax variabilis* Say, coquina clam

Locality: East Beach, 15 of 329 clams (4.5%); Bolivar Beach, 5 of 16 clams (30.1%)

Overall Incidence: 20 of 584 clams (3.4%)

Metacercaria

(Figures 101, 102)

What is believed to be the metacercarial stage of this species was found encysted in the foot and mantle tissue of the same host clam.

<u>Diagnosis</u>: Cyst (Fig. 101) spherical, wall thin and transparent, 0.19 to 0.24 in diameter. Mechanically excysted metacercaria (Fig. 102) 0.29 to 0.35 in length by 0.19 wide. Oral sucker circular 0.048 in diameter. Ventral sucker circular, 0.038, minute spines present on inner border. Prepharynx short, pharynx 0.04 long by 0.03 wide. Esophagus slightly sinuous, bifurcating at anterior margin of ventral sucker into crura extending almost to posterior end of body. Contents of gut staining red in neutral red stain. Paired clusters of cephalic glands present anterior and lateral to ventral sucker, their borders and nuclei indistinct, ducts extending anteriad in two paired bundles lateral to pharynx and both dorsal and lateral to oval sucker, terminating in four pairs of pores on anterior margin of oral sucker in a 2-2-2-2 arrangement. Glands and ducts staining pink in neutral red stain. Paired circular eyespots present lateral to esophagus, composed of spherical dark brown bodies, eyespots 0.008 in diameter. Two genital primordia located posterior to ventral sucker with paired ducts extending from medial primordial mass to near posterior margin of ventral sucker, then joining saccular primordium extending around right side of ventral sucker and terminating at a median ventral genital pore anterior to ventral sucker. Excretory bladder oval, 0.06 long by 0.03 wide, thick-walled; collecting tubules entering bladder

at anterior lateral margin. Anterior and posterior collecting tubules joining common tubule anterior to excretory bladder. Lumen of anterior and posterior tubules ciliated lateral to their point of junction. Excretory pore terminal and posterior. Cuticula thick and moderately spinose. Spination pronounced in anterior half of body.

Host: *Donax variabilis* Say, coquina clam

Localities: West Beach, 12 of 20 clams dissected (60%); East Beach, 36 of 50 clams dissected (72%); Bolivar Beach, 16 of 16 clams dissected (100%)

Overall Incidence: 64 of 86 clams (74.4%)

Identity: This species is *Cercaria choanura* Hopkins, 1954, found again in its type host and somewhat northeast of its type locality, Mustang Island, Texas. It is suspected that the adult is a species of monorchiid which was found to be present in 100% of 25 juvenile pompano (*Trachinotus carolinus*) autopsied from East Beach in the spring of 1972. All pompano measured from 20 to 80 mm in standard length and each contained from three to 40 monorchiids in various portions of the intestine. During the spring and summer, the juvenile pompano dwell with *Donax* in the wash zone of the beach, where they feed on various small invertebrates including moribund *D. variabilis*. Heat of the sun combined with low tides in late spring kills considerable numbers of stranded *D. variabilis*, which become available as food to juvenile pompano on the next incoming tide. A school of juvenile pompano in an aquarium suggest the behavior of piranhas while attacking and consuming moribund specimens of *D. variabilis*. Infection experiments could not be performed on pompano because no uninfected population could be found. Experiments performed by feeding infected *Donax* to *Lagodon rhomboides*, *Leiostomus xanthurus*, *Pogonias cromis* and *Fundulus similis* yielded negative results. The adult monorchiid in pompano closely resembles *Lasiotocus trachinoti* Overstreet and Brown, 1970 described from *T. carolinus* in Florida. The egg filaments of the Galveston specimens are somewhat shorter than those of the Florida specimens of Overstreet and Brown.

Ecology: Cercarial infections were all found from March to June, metacercarial cysts were present throughout the year. Cercarial infections were found in clams measuring from 14 to 19 mm in maximum shell dimension. Larger clams (20 to 28 mm) are also present, but were not found to be infected, indicating either that the infections are lost, or that the host is killed before it reaches 20 mm.

N. Family Zoogonidae

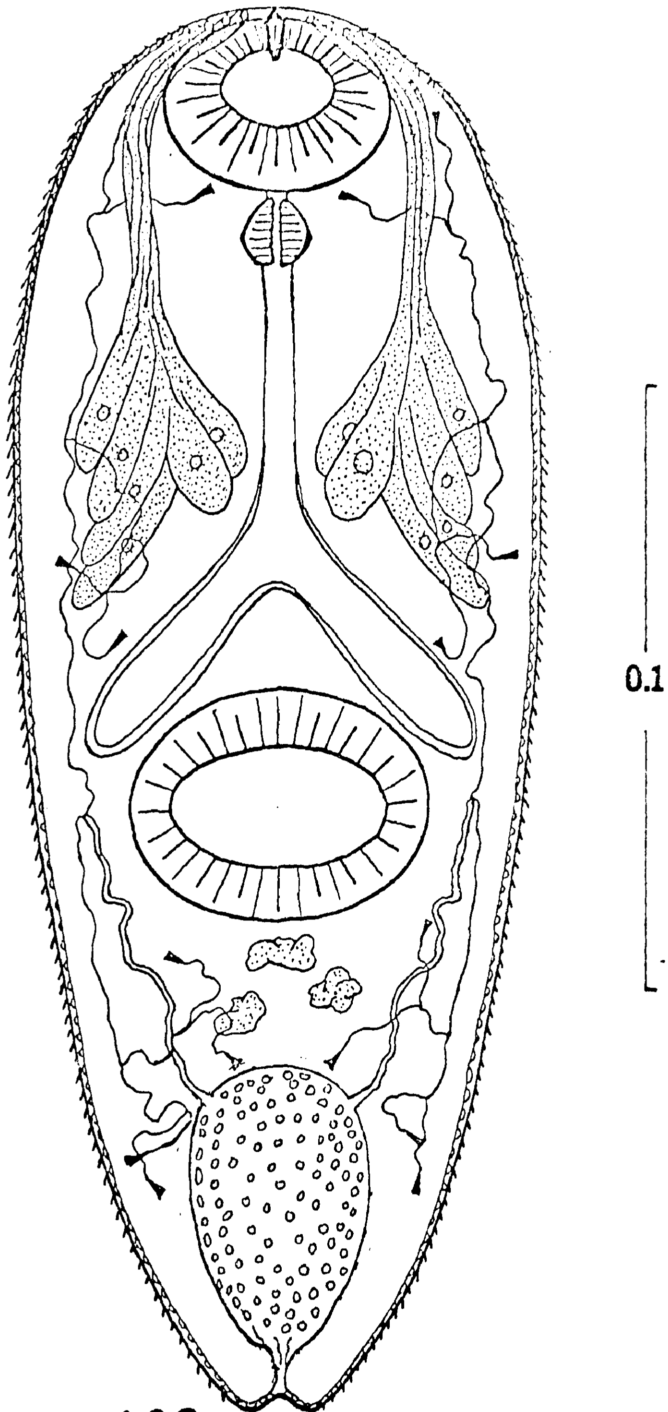
Adult zoogonids are parasites of marine and freshwater fishes and of reptiles. Most species inhabit the intestine of their host, but some infect the gall bladder and urinary bladder. Tailless xiphidiocercariae are produced in sporocysts in snails. Metacercariae crawl from the host and penetrate benthic invertebrates, especially polychaete annelids and echinoid echinoderms. Piscine final hosts belong to many different families of bottom feeding teleosts.

Cercaria sp. XXVIII

(Figures 103, 104)

Diagnosis: Distome cercariaeum (Fig. 103), stylet present, body 0.25 to 0.50, elongated, widest in anterior half, 0.04 to 0.06. Mouth ventral and subterminal, oral sucker oval, 0.030 to 0.040 wide by 0.025 to 0.035 long. Xiphidium present dorsal to oral sucker on anterior margin of body, 0.008 to 0.012 long. Prepharynx very short, absent in some specimens, pharynx 0.012 to 0.027 long. Esophagus straight, bifurcating well anterior to ventral sucker into short crura which extend almost to level of middle of ventral sucker, contents staining red in neutral red stain. Ventral sucker oval, 0.045

Figures 103-104. Larval stages of *Cercaria* sp. XXVIII from *Pleuroploca gigantea*. 103. Ventral view of entire cercariaeum. 104. Sporocyst from gonadal area of host snail.



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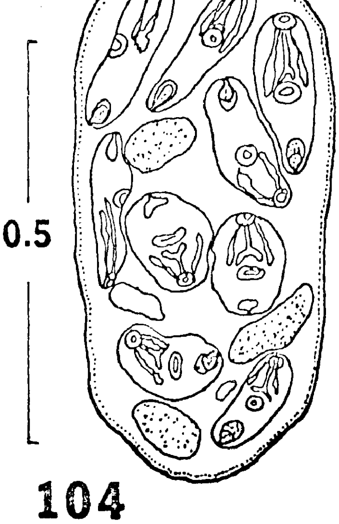

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to 0.060 wide by 0.035 to 0.050 long, located posterior to body mid-level. Six pairs of granular penetration glands present in paired clusters lateral to esophagus, their ducts extending forward in paired common bundles dorsal and lateral to oral sucker and terminating in a 3-3 arrangement at anterior margin of oral sucker. Glands and ducts staining light pink in neutral red stain. Three irregular genital primordia present posterior to ventral sucker staining light pink in neutral red stain. Excretory bladder oval, 0.05 to 0.08 long by 0.030 to 0.045 wide, containing loosely-packed evenly-distributed spherical concretions. Excretory pore posterior and terminal. Common collecting tubules entering bladder on anterior lateral margin. Anterior and posterior collecting tubules joining common tubule lateral to ventral sucker. Flame cell formula 2[(2+2) + (2+2)] = 16. Body cuticula thick and moderately spinose. Cercariae not swimming but creeping on substrate. Cercariae developing in sporocysts (Fig. 104) in gonad and digestive gland of host snails. Sporocysts transparent, thin-walled, containing up to 10 larvae in various stages of development. Sporocysts 0.65 to 0.75 long by 0.28 to 0.35 wide.

Host: *Busycon spiratum* (Lamarck), pear whelk

Locality: Galveston Beach, 1 of 22 snails (4.5%)

Overall Incidence: 1 of 22 snails (4.5%)

Host: Pleuroploca gigantea (Kiener), horse conch

Locality: Offshore platform 12 miles southeast of Galveston, Texas, 1 of 4 snails (25%)

Overall Incidence: Same

Identity: Cercaria sp. XXVIII most nearly resembles the cercaria of Zoogonoides viviparus (Olsson, 1868) Odhner, 1902, as described by Lebour (1916) from Buccinium undatum in Europe, in having six pairs of penetration glands, a short prepharynx and intestinal caeca, and development in a large carnivorous gastropod. Lebour (1916) did not describe the flame cell formula for this cercaria. Members of the Genus Zoogonoides have not been reported from fishes from the Gulf of Mexico. Due to the relatively high incidence of this parasite in the host snails, it is likely that the adult will be a zoogonid common to fishes which frequent the shallow coastal waters. Only three other zoogonid genera have a short prepharynx and short intestinal caeca and two of these have been reported from the Gulf of Mexico: Brachyenteron from flying fishes, and Diphterostomum in reef fishes. Diphterostomum americanum Manter, 1947, is the most probable final host species for this cercaria. D. americanum was described from a deep water fish but was subsequently found in Gobiosoma robustum, Lagodon rhomboides and Opsanus beta by

Sogandares-Bernal and Hutton (1959) from Western Florida. All of these host species are abundant in the Galveston area and probably harbor D. americanum.

Ecology: The single infected pear whelk (B. spiratum) was found stranded on Galveston Beach following a November storm. The infected horse conch (P. gigantea) was collected by Mr. S. Coker skin diving in about 8 m of water near an offshore gas platform in July 1972.

O. Family Heterophyidae

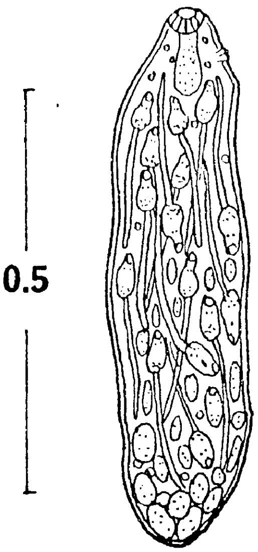
Adult heterophyids are intestinal parasites of both warm and cold-blooded vertebrates. They are small distomes covered with scale-like spines. A gonotyl or accessory sucker is always present. A ventral sucker may be lacking in some species. Heterophyid larvae develop in rediae in marine and freshwater snails. Cercariae have eyespots, may be pleurolophocercous, parapleurolophocercous, magnacercous or zygocercous and possess well-developed penetration glands. Cercariae encyst in small fishes and mature in piscivorous fishes, birds and mammals, including man.

<u>Cercaria</u> sp. XXIX

(Figures 105 to 108)

<u>Diagnosis</u>: Biocellate parapleurolophocercous cercaria (Fig. 105), body pyriform 0.11 to 0.14 long by 0.06 to 0.08 wide, tail 0.32 long, bearing paired lateral fins on its anterior portion and dorsal and ventral fins confluent around tail tip on posterior portion. Mouth ventral and subterminal, oral sucker circular, 0.022 in diameter, prepharynx long, pharynx 0.004 long by 0.003 wide. Intestine not seen, obscured by dense penetration glands. Paired cuboidal eye-spots present anterior and lateral to pharynx, consisting of dark brown sperical bodies. Nerve ganglion crossing esophagus anterior to pharynx. Seven pairs of penetration glands situated in posterior half of body with paired clusters of seven ducts each extending anteriad to posterior margin of oral sucker, each cluster separating into a lateral bundle of three and a medial bundle of four ducts, both pairs of bundles extending dorsad over oral sucker and terminating in pores on anterior margin of oral sucker in 3-4-4-3 arrangement, centers of lateral pores forming triangles and those of medial pores forming squares. Ventral sucker undeveloped, represented by a primordium posterior to penetration glands. Primordium staining red in neutral red stain. Excretory bladder transversely oval to weakly Y-shaped,

Figures 105-108. Larval stages of *Cercaria* sp. XXIX from *Cerithidea pliculosa*. 105. Ventral view of entire cercaria, details of excretory system omitted. 106. Same, left lateral view. 107. Ventral view of body of cercaria, details of excretory system omitted from right side, cystogenous glands omitted from left side. 108. Redia from gonadal area of host snail.



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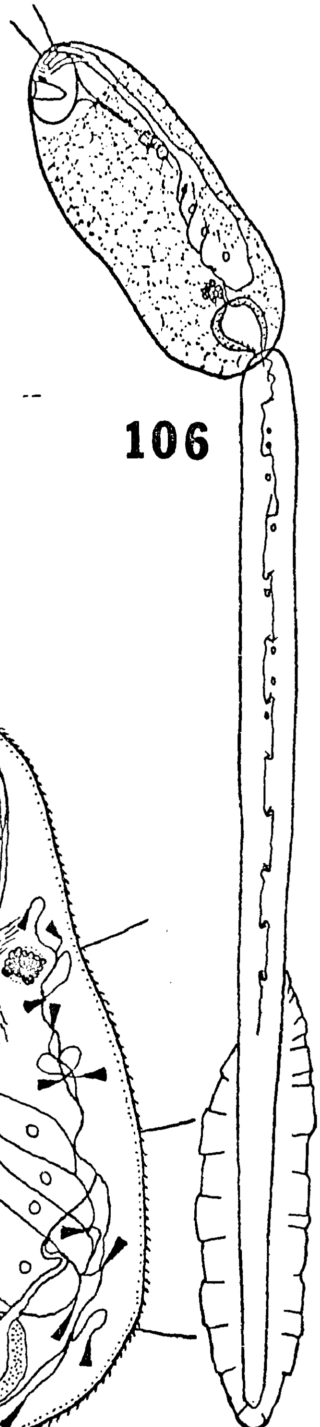

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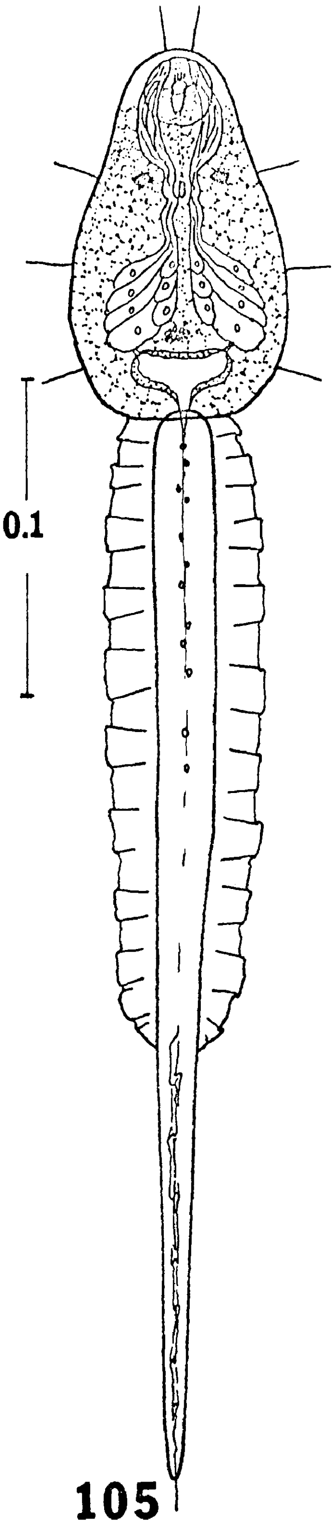

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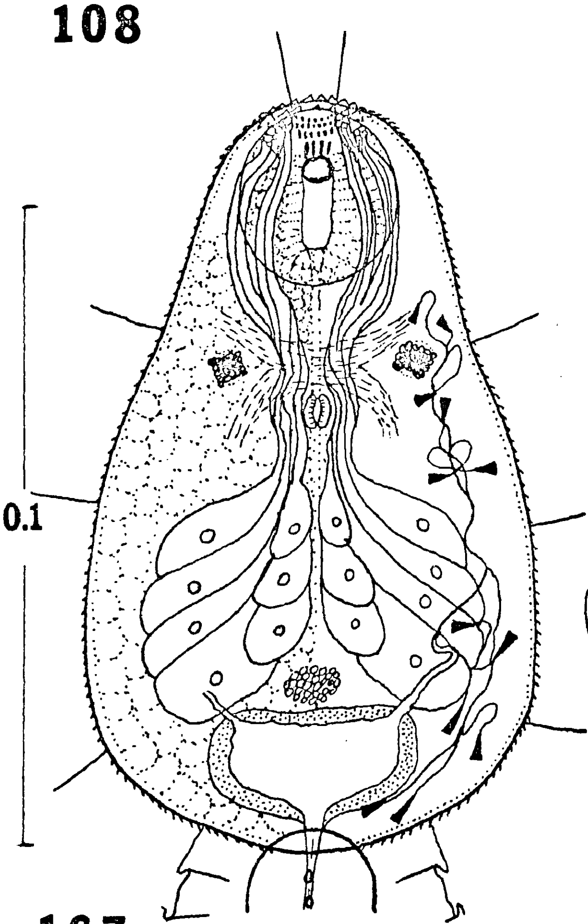

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0.015 long by 0.028 wide. Excretory pore at body-tail junction. Common collecting tubules entering bladder on anterior lateral margin. Flame cell formula 2[(3+3) + (3+3)] = 24. Four or five large spines present in oral crypt, spines on anterior portion of cuticle adjacent to oral sucker large, remainder of body cuticula moderately spinose. Four pairs of lateral setae seen along margin of body. Cercariae positively phototactic, swimming intermittently by figure-eight movement of tail, propelling body forward and somewhat laterad at high speed, then suddenly ceasing and cercaria sinking slowly body-first with tail held ventrad at right angle to body. Cercariae developing in whitish rediae (Fig. 108) in gonad and digestive gland of host snail, heavy infections invading other organs as well, including gills and rectal area. Visceral area of infected snails appearing gray-brown in gross view. Rediae 0.5 to 2.4 long with short rhabdocoele gut less than one-fifth of body length, and birthpore near anterior end at level of termination of gut. Redial pharynx 0.024 long by 0.018 wide.

Host: *Cerithidea pliculosa* (Menke), horn snail

Localities: Yates Bayou, 10 of 89 snails (11.2%); Sportsman's Road, 168 of 1075 snails (15.5%)

Overall Incidence: 178 of 1164 snails (15.3%)

Identity: This cercaria closely resembles, and is probably identical to, the cercaria of Parastictodora hancocki Martin, 1950 from Cerithidea californica in California. The only difference is a slightly larger body size of Cercaria sp. XXIX of 1.1 to 1.4 as compared to 0.7 to 0.9 for P. hancocki. This difference could be due to the fact that C. sp. XXIX was measured alive under moderate cover slip pressure while P. hancocki was measured after fixation. Cercaria cursitans Holliman 1961 from Cerithidea scalariformis is also quite similar but differs in having six rows of spines in the oral crypt as compared to five for P. hancocki and four to five for C. sp. XXIX. The differences would not appear to necessitate specific distinctions among the three forms.

Ecology: This cercaria was often in constant incidence throughout the year and was the most often-encountered of the 11 species of Digenea which parasitize Cerithidea pliculosa, indicating that the host bird is probably an abundant, year around inhabitant of the marsh. Martin (1950) found that the cercariae of P. hancocki encyst on the scales of Fundulus parvipinnis. He succeeded in infecting a baby chick with the metacercariae, which developed into an adult for which he erected the new Genus Parastictodora.

P. Family Opisthorchiidae

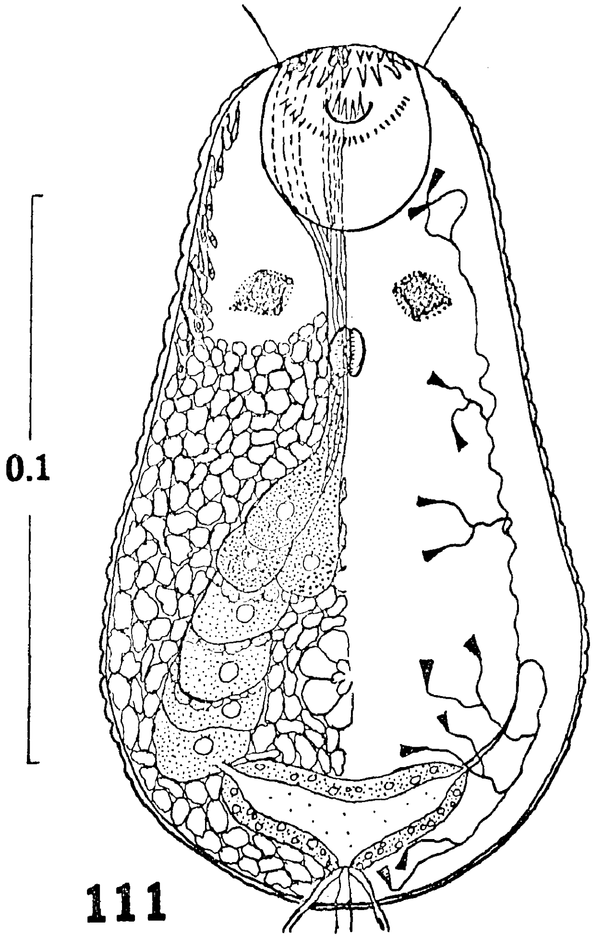
Adult opisthorchiids are parasites in the bile duct and gall bladder (or occasionally in the intestine) of both warm and cold-blooded vertebrates. The suckers are weakly developed and a gonotyl is lacking. The excretory bladder is Y-shaped. Cercariae develop in rediae in marine and freshwater snails. Cercariae are biocellate and may be pleurolophocercous or parapleurolophocercous. Metacercariae encyst in fishes or amphibians and adults occur in carnivorous vertebrates, including man.

Cercaria sp. XXX

(Figures 109 to 112)

Diagnosis: Biocellate pleurolophocercous cercaria, body (Fig. 109) pyriform 0.15 to 0.20 long by 0.06 to 0.08 wide, tail 3.2 to 4.6 long by 0.025 wide at base. Oral sucker circular 0.025 in diameter. Mouth ventral and subterminal, oral crypt with four to five spines. Gut indistinct, pharynx at anterior third of body, 0.012 long by 0.007 wide. Seven pairs of penetration glands present in posterior three-fifths of body, their ducts combining medially and extending in a single bundle anteriad to posterior margin of ventral sucker, separating into paired lateral bundles containing three ducts each and

Figures 109-112. Larval stages of *Cercaria* sp. XXX from *Cerithidea pliculosa*. 109. Left lateral view of tail of cercaria. 110. Ventral view of entire cercaria. 111. Ventral view of body of cercaria, details of excretory system omitted from right side, cystogenous glands omitted from left side. 112. Redia from gonadal area of host.



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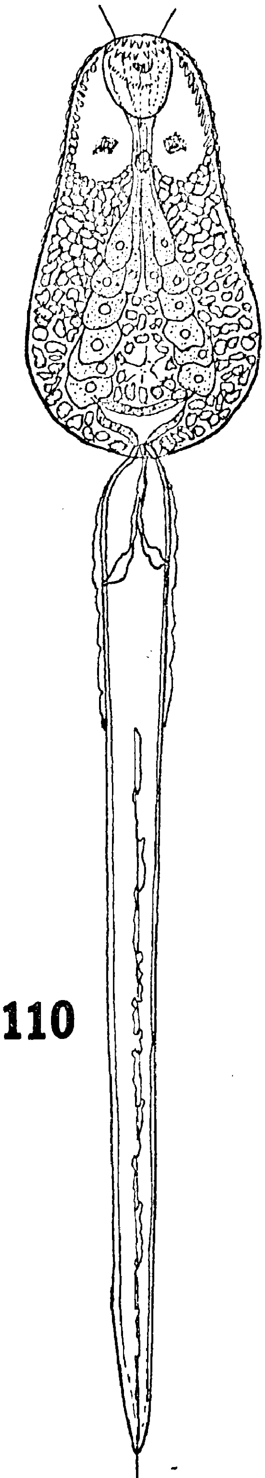

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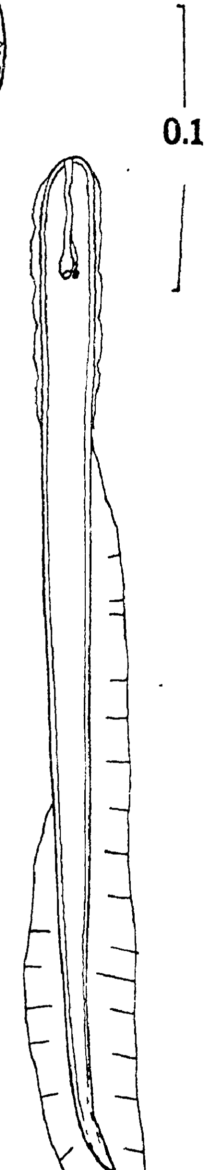

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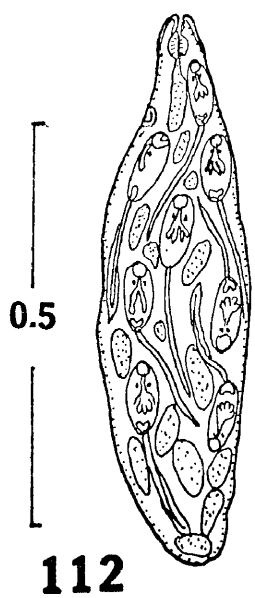

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paired median bundles containing four ducts each. All ducts extending forward dorsal to oral sucker and terminating in a 3-4-4-3 arrangement of pores on anterior margin of oral sucker. Anterior three pairs of penetration glands staining red and posterior four pairs staining pink in neutral red stain. Ventral sucker (?) weakly developed in posterior third of body, 0.015 in diameter. Paired cuboidal eyespots present anterior and lateral to pharynx, and composed of dark brown spherical bodies. Excretory bladder shallow, U-shaped, 0.016 long by 0.042 wide, with excretory pore at body-tail junction. Caudal excretory tubule extending posteriad into tail base, bifurcating 0.03 from body junction and terminating in paired lateral pores 0.05 from anterior margin of tail. Flame cell formula 2[(2+2+2) + (2+2+2)] = 24. Anterior and posterior collecting tubules joining at level of ventral sucker. Common tubules entering excretory bladder on anterior lateral margin. Entire portion of body posterior to pharynx filled with granular cystogenous glands staining red in neutral red stain. Body cuticula moderately spinose, spines pronounced around anterior margin. Anterior portion of tail with cuticular expansion. Dorsal part of tail fin originating on anterior third of tail stem, extending posteriad around tip of tail. Ventral part of tail originating on posterior third of tail stem extending posteriad around tail tip confluent with dorsal fin. Posterior tip of tail stem slightly curved dorsad. Cercariae swimming by figure-eight motion of tail as in *Cercaria* sp. XXIX, with sudden rest pauses. Cercariae positively phototactic. Rediae (Fig. 112) occurring in gonad and digestive gland of host snail and imparting a gross cream color to those organs. Individual rediae 0.68 to 0.75 long by 0.09 to 0.12 wide, pharynx circular, 0.023 in diameter, gut short, one-fourth to one-fifth length of redia. Rediae each containing up to 50 cercariae in various stages of development. Birthpore anterior, near blind end of gut.

Host: *Cerithidea pliculosa* (Menke), horn snail

Localities: Yates Bayou, 4 of 89 snails (4.5%); Sportsman's Road, 62 of 1075 snails (5.8%)

Overall Incidence: 66 of 1164 snails (5.6%)

Identity: This cercaria agrees closely with the description of the cercaria of *Phocitremoides ovale* Martin, 1950 from *Cerithidea californica* in California. The only differences are in the ventral portion of the caudal fin which originates on the posterior third of the tail stem of *Cercaria* sp. XXX and near the level of insertion of the dorsal fin in *P. ovale*, and the presence of a very weakly developed ventral sucker (?) in *Cercaria* sp. XXX not seen in *P. ovale*.

Ecology: This cercaria was found throughout the year in fairly constant incidence, indicating that the final host might be a bird present year around in the marsh. Hutton (1964) reports on three opisthorchiids assigned to the Genus Pachytrema from gulls and ducks in Florida. This report was the only one found concerning the presence of adult opisthorchiids in the Gulf of Mexico. Martin (1950) found that the metacercariae of P. ovale encyst on the scales of Fundulus parvipinnis. He succeeded in infecting baby chicks experimentally and described the adult in the new Genus Phocitremoides of the Opisthorchiidae.

Q. Family Hemiuridae

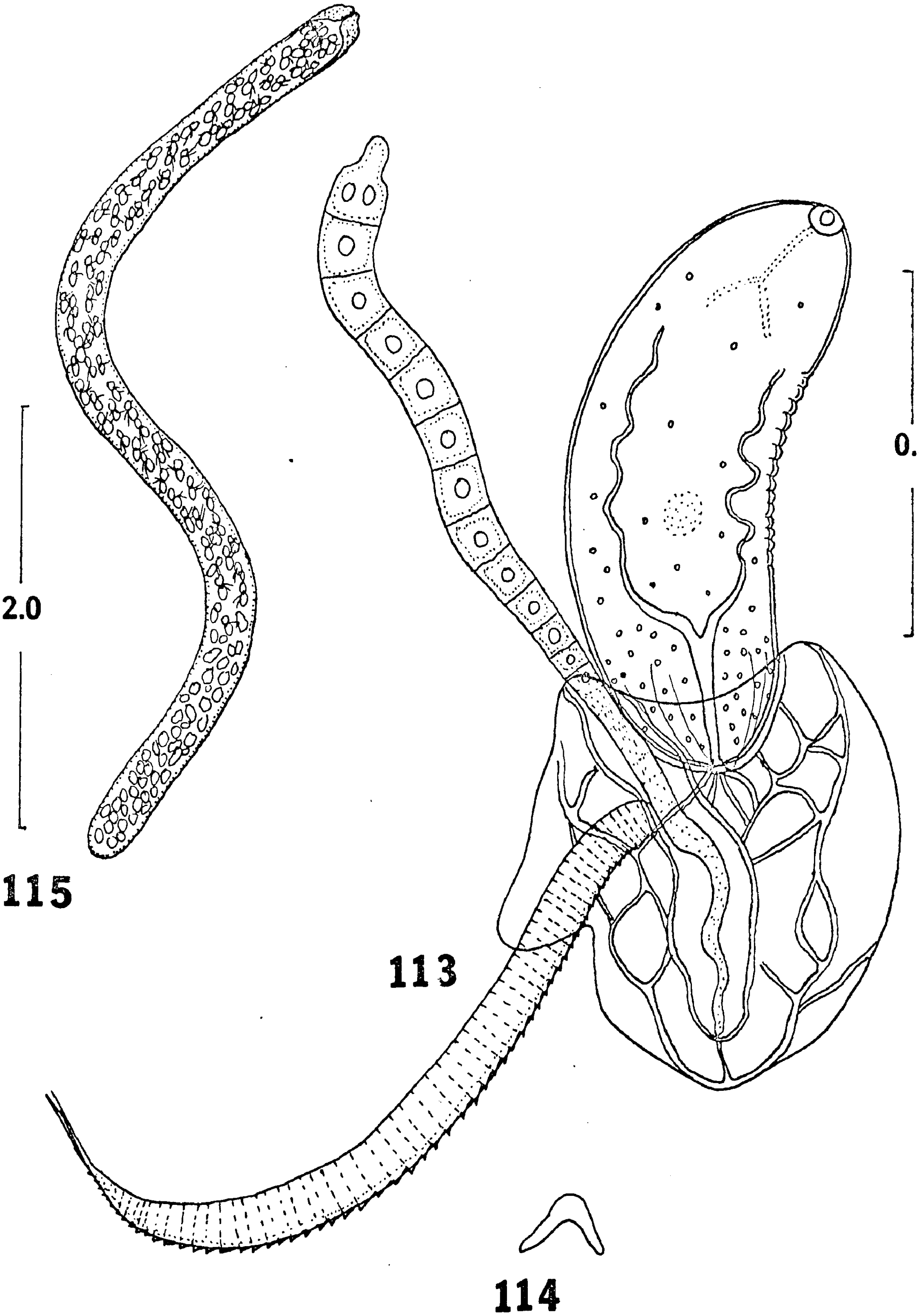
Adult hemiurids are parasites of the esophagus and stomach of marine and freshwater fishes. A few species are found in amphibians and reptiles. In many species, the posterior part of the body "telescopes" into the anterior part which contains the suckers. The excretory vesicle is Y-shaped. Cercariae are of the cystophorous appendiculate type, developing in either sporocysts or rediae in gastropod and scaphopod molluscs. Metacercariae encyst in various planktonic animals, especially copepods, and adults occur in a wide variety of teleost fishes. Yamaguti (1958) lists over 250 species belonging to this family.

<u>Cercaria</u> sp. XXXI

(Figures 113 to 115)

<u>Diagnosis</u>: Cystophorous cercaria (Fig. 113) appendiculate, body 0.40 to 0.45 long by 0.15 to 0.20 wide, tail 0.61 to 0.70 in length, V-shaped in cross section (Fig. 114) and bearing a pair of terminal slightly divergent setae 0.06 long. Cyst-like tail irregular in outline, roughly ovoid, 0.48 to 0.55 in maximum dimension. Delivery tube consisting of 11 to 13 segments, variable in length, up to 0.84 when fully extended. Delivery tube sheath opening on anterior right margin of cyst, extending posteriad and mediad and ending blindly near posterior margin of cyst. Both tail and delivery tube exiting from right side of cyst. Body of cercaria with posterior tip embedded in anterior portion of cyst and apparently anchored there by fibrous structures forming reticulum throughout cyst. Body asymmetrical, curving laterad. Excretory pore terminal at posterior margin of body, bladder Y-shaped, thin, arms extending to anterior third of body. Oral sucker circular, 0.025 in diameter, ventral sucker indistinct, weakly developed, located in posterior half of body, circular, 0.035 in diameter. Gut indistinct, appearing to bifurcate in anterior fourth of body well anterior to ventral sucker. Pharynx not seen. Flame cells not seen. Body cuticula thick and opaque, devoid of spines.

Figures 113-115. Larval stages of *Cercaria* sp. XXXI from *Crepidula plana*. 113. Entire cercaria with body protruding from cyst and delivery tube extruded. 114. Cross section from middle of tail. 115. Sporocyst from gonadal area of host snail.



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Sporocysts (Fig. 115) long and thin, 2.7 to 5.2 in length, by 0.38 to 0.46 wide, birthpore anterior and terminal, color white to transparent, each containing hundreds of cercariae. No swimming or creeping movement of cercariae seen.

Host: Crepidula plana Say, flat slipper limpet

Locality: Galveston Beach, attached to inside aperture of shell of Thais haemastoma (also occupied by the hermit crab Clibanarius vittatus). 1 of 236 snails (0.4%)

Overall Incidence: 1 of 284 snails (0.3%)

Identity: Holliman (1961) lists only 20 known marine hemiurid larvae. This is surprisingly few in view of the large number of described adults (over 250). Cercaria sp. XXXI most nearly resembles Cercaria appendiculata Chubrick, 1952 from Natica clausa, but C. appendiculata develops in a redia whereas no pharynx or gut was seen in the germinal sacs of Cercaria sp. XXXI. C. appendiculata also bears a distinct pharynx, bifurcated gut and ventral sucker, all of which were not seen in Cercaria sp. XXXI, indicating that the latter may be a less than fully mature cercaria. This hypothesis is also based upon the fact that the cercariae did not emerge upon isolation of the host, but were found only after the host was crushed. Nothing of its cercarial morphology is indicative of the specific identity of the adult form.

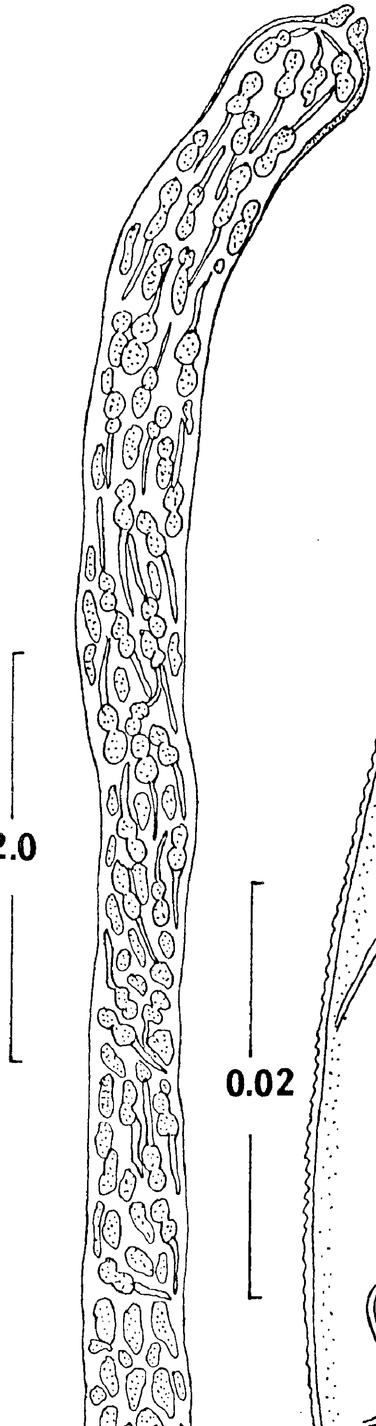
Ecology: The single infected snail was found in December 1972 when the hermit crab was cast up on the beach after a storm. The hermit is a shallow water scavenging species and seldom ventures more than a few hundred yards offshore, whence it returns at low tide to browse on stranded food organisms, hence the host of this hemiurid is probably a fish which ventures quite close to shore.

Cercaria sp. XXXII

(Figures 116 to 119)

Diagnosis: Cystophorous appendiculate cercaria (Fig. 116), cyst consisting of an ovoid distal portion containing body of cercaria 0.048 to 0.052 long, and a spherical basal portion 0.025 in diameter containing delivery tube and sac. Tail 0.09 to 0.16 long, transversely striated with serrated lateral margins and bearing two terminal spines 0.009 in length. Paired lateral tubules or fibers extending through entire tail, terminating at base of spines. Cross section of tail shown in Figure 117. Delivery tube extruding from basal portion of cyst under cover slip pressure, consisting of 11 to 12 segments, entire appendage up to 0.06 in length. Mechanically-excysted body (Fig. 118) 0.05 to 0.052 long by 0.016 wide, oral sucker 0.025 in diameter, mouth terminal. Gut indistinct, pharynx and crura not seen. Excretory bladder oval, 0.024 long by 0.015 wide, excretory

Figures 116-119. Larval stages of *Cercaria* sp. XXXII from *Oliva sayana*. 116. Entire cercaria with cyst intact and delivery tube extruded. 117. Cross section of tail of cercaria. 118. Body of cercaria, further details not observed. 119. Sporocyst from gonadal area of host snail.



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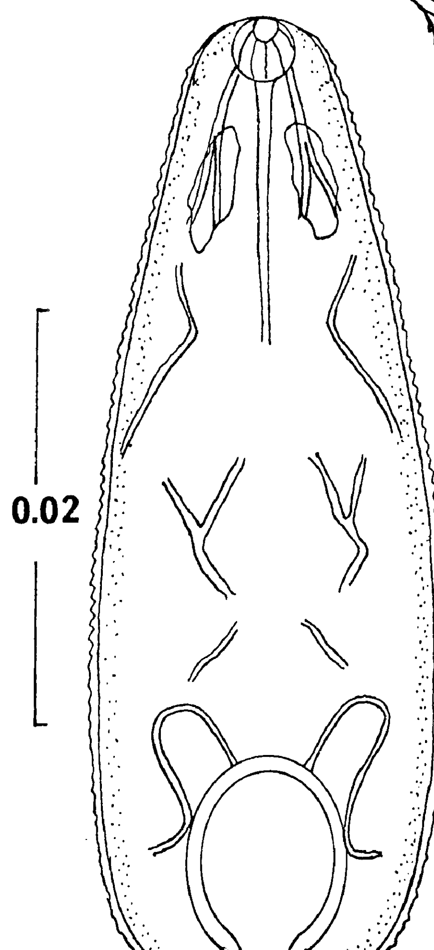

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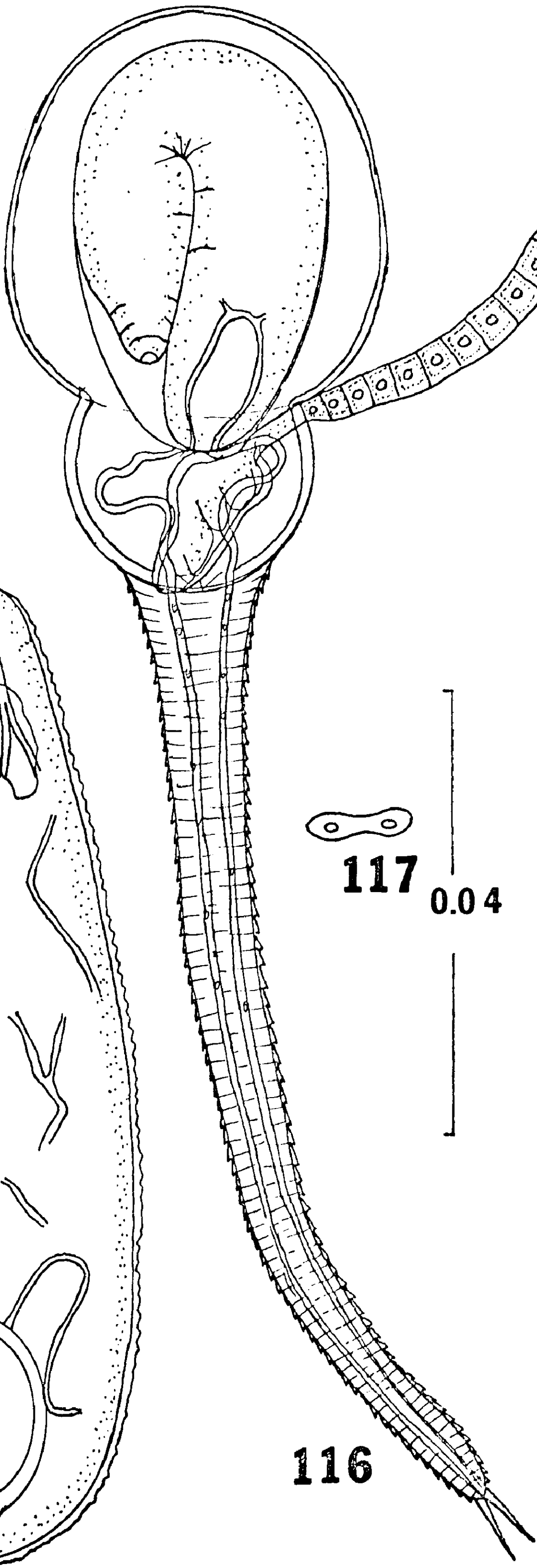

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pore terminal and posterior. Common collecting tubules entering bladder on anterior margin, extending dorsad then laterad, next ventrad and laterad at mid-level of bladder, then becoming indistinct. Flame cells and collecting tubules not seen. Paired glandular (?) bodies staining pink in neutral red stain located posterior to oral sucker. No ducts seen. Ventral sucker not seen. Body cuticula thick, opaque and aspinose. Cercariae developing in elongated sporocysts (Fig. 119) 3.0 to 12.0 in length by 0.5 wide, each containing hundreds of cercariae in various stages of development. Birthpore terminal and anterior. No swimming or crawling behavior observed, cercariae remaining passive on bottom of container.

Host: *Oliva sayana* Ravenel, lettered olive

Locality: East Beach, 1 of 28 snails (3.5%)

Overall Incidence: 1 of 367 snails (0.26%)

Identity: The tail of this cercaria, bearing two terminal spines, is like that of *Cercaria appendiculata* Chubrik, 1952 from *Natica clausa* and also like that of the hemiurid cercaria described above as *Cercaria* sp. XXXI from *Crepidula plana*. This species differs from *C. appendiculata* in that it develops in a sporocyst and not a redia, and the tail extends from the posterior part of the basal portion of the cyst and not from the lateral portion as in *C. appendiculata*. It differs from C. sp. XXXI in that the tail is posterior and not lateral, and it is bilobed in cross section and not V-shaped as in the latter.

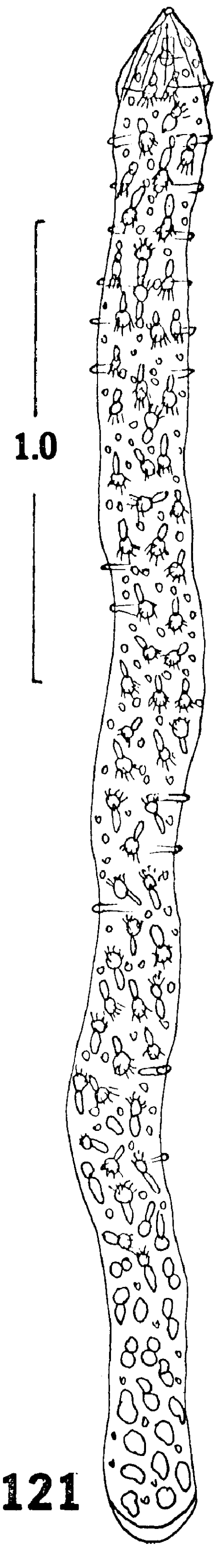
Ecology: This cercaria was found in a snail which was moribund at the time of collection and had washed up on the beach in August 1972 following an outbreak of "red tide" caused by the dinoflagellate *Gonyaulax monilata*. This may account for the fact that the internal features of the body of the cercariae were not fully discernible. Over 300 fresh specimens from other parts of Galveston Beach did not yield cercariae. *Oliva sayana* is a predacious sand-dwelling gastropod living in the shallow coastal waters along the Texas beachfront. The final host therefore is probably a coastal fish which occasionally visits the shallow surf zone.

Cercaria sp. XXXIII

(Figures 120, 121)

Diagnosis: Cystophorous appendiculate cercaria (Fig. 120), body 0.072 to 0.110, elongate pyriform, tail cyst spherical, 0.054 to 0.065 in diameter, bearing two latitudinal rows of eight to nine long curved setae each. Center of cyst bearing sac housing nine-segmented protrusile delivery tube 0.05 long when extended. Mouth terminal, oral sucker indistinct, single row of glandular structures surrounding mouth. Pharynx and intestine lacking, body densely

Figures 120-121. Larval stages of Cercaria sp. XXXIII from Anadara brasiliana. 120. Entire cercaria with delivery tube extruded. 121. Sporocyst from kidney of host clam.



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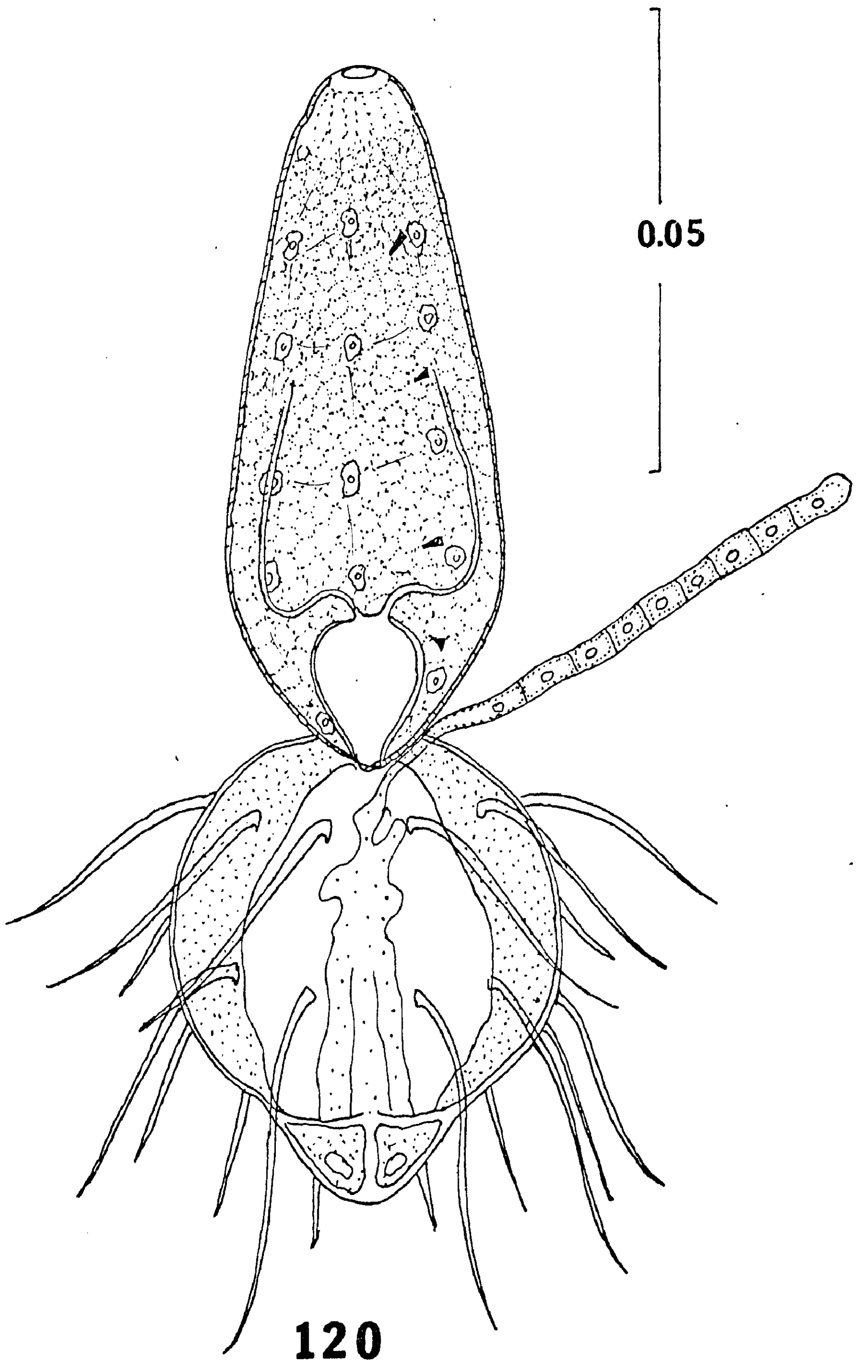

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packed with glandular cells and with a network of larger nucleated cells apparently connected by fibrils forming a meshwork pattern. Excretory bladder inverted pyriform, 0.02 long by 0.015 wide. Excretory pore posterior and terminal. Common collecting tubules entering bladder on anterior margin. Four flame cells seen on each side of body. Further details of excretory system not observed. Body cuticula thick and aspinose. Cercariae developing in whitish sporocysts (Fig. 121) located in nephridium of host clam. Sporocysts very mobile, elongate, 1.3 to 4.8 in length by 0.30 wide. Birthpore terminal and anterior. Anterior end of sporocyst often conical in shape. Sporocyst appearing externally segmented due to cuticular annulations approximately 0.1 apart, concentrated near anterior end. Sporocyst containing hundreds of cercariae, appearing pale orange in color.

Host: *Anadara brasiliana* (Lamarck), incongruous ark

Locality: Galveston Beach, 39 of 358 clams (10.8%)

Overall Incidence: Same

Identity: This is the first known report of a cystophorous appendiculate cercaria developing in a bivalve mollusc. The cercaria most nearly resembles *Cercaria vaullegeardi* Pelseneer, 1906 from *Trochus cinerarius* in Europe which also develops in elongate orange-colored annulated sporocysts, and has a cyst bearing long cuticular setae, but Pelseneer's (1906) figure shows only six setae in a single row whereas C. sp. XXXIII has 16 to 18 in two rows.

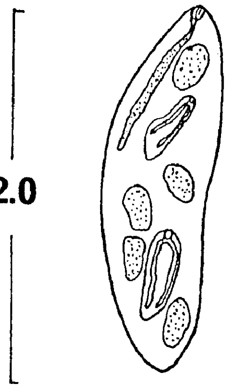
Ecology: Anadara brasiliana is a shallow-burrowing sand-dwelling clam living in, and just beyond, the surf zone along Galveston Beach. Presumably, this habitat must be frequented by the final host which is probably a fish common to the surf zone. The sporocysts do not appear to liberate the cercariae but emerge from the host clam and actively creep on the bottom of the container. The cone-shaped anterior end of the sporocyst might be adapted for burrowing into the substratum, which would also be facilitated by the annular rings which could be used to gain purchase in the substratum.

R. Family Unknown

Cercaria sp. XXXIV

(Figures 122 to 126)

Diagnosis: Monostome cercariaeum (Fig. 123), remaining in parent redia (Fig. 124), body oval to pyriform, 0.44 to 0.51 in length by 0.30 wide, tail absent. Oral sucker circular, 0.06 in diameter, pharynx indistinct, esophagus short, bifurcating in anterior fifth of body into long thick crura extending almost to posterior margin of body. Excretory bladder thin-walled, oval, 0.08 long by 0.04 wide, Figures 122-126. Larval stages of *Cercaria* sp. XXXIV from *Melampus bidentatus*. 122. Immature redia containing unencysted cercariae from gonadal area of host snail. 123. Ventral view of unencysted cercaria, cystogenous glands omitted from left side. 124. Mature redia containing encysted metacercariae from mantle cavity of host. 125. Face and edge views of encysted metacercariae. 126. Excysted metacercaria. Flame cells omitted from right side.



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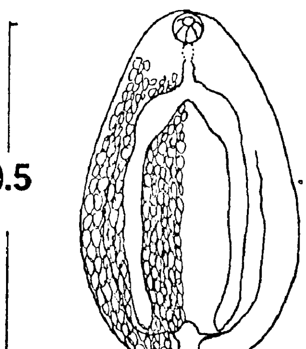

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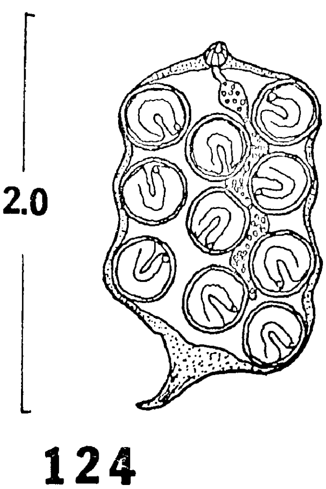

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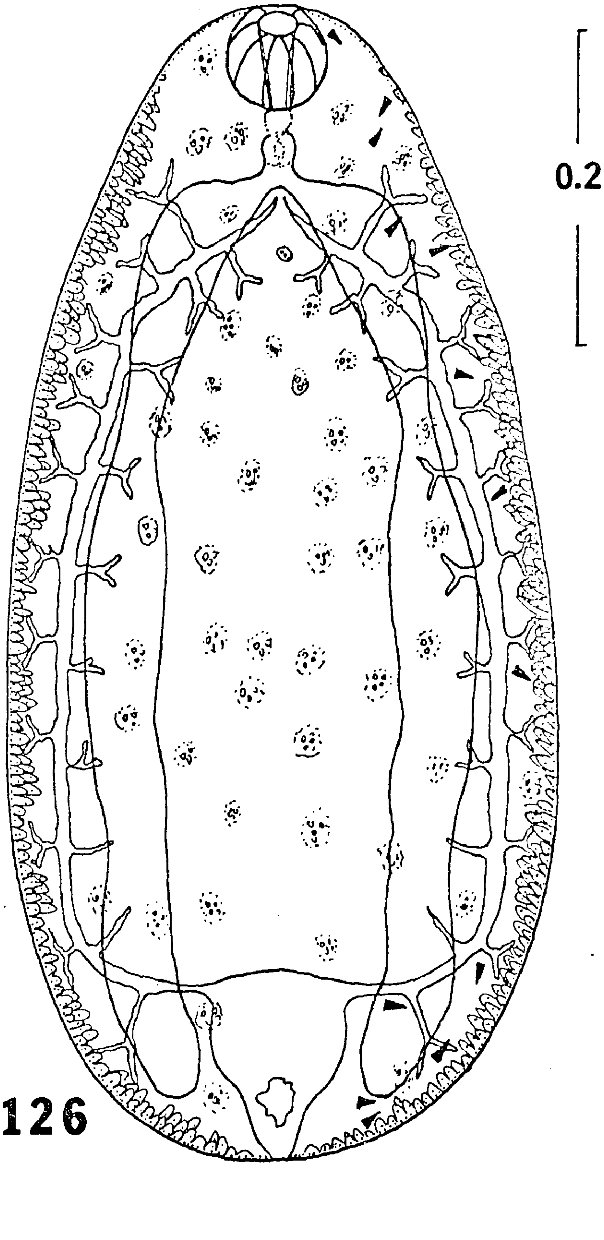

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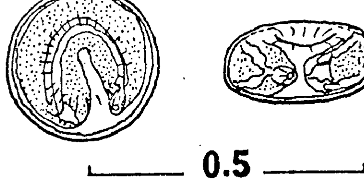

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common collecting tubules entering bladder on anterior lateral margin. Junction of anterior and posterior collecting tubules and flame cell formula not seen. Body posterior to ventral margin of oral sucker filled with granular cystogenous glands. Further details not seen due to difficulty in dissecting cercariae from parent redia. Mature rediae (Fig. 124) sac-like, bearing finger-like cuticular projection on posterior end. Length of redia 1.60 to 1.85 by 0.90 wide, mouth terminal, pharynx circular 0.11 in diameter, gut rhabdocoele, containing dark brown pigment and extending posteriad two-thirds length of redia. Mature rediae bearing up to 13 encysted metacercariae within redial body. Young rediae (Fig. 122) up to 1.75 in length by 0.40 wide with gut extending to body midpoint, containing up to 10 unencysted cercariae in various stages of development. Young rediae inhabiting gonad and digestive gland, mature rediae free in mantle cavity of host snail.

Metacercariae in discoidal cyst (Fig. 125) bearing one concave face, 0.12 to 0.25 in diameter and 0.06 to 0.12 in height. Walls of cyst transparent and thick-walled. Mechanically-excysted metacercariae (Fig. 126) oval to pyriform, 0.52 to 0.84 long by 0.35 wide, mouth ventral and subterminal, oral sucker circular, 0.065 in diameter. Ventral sucker indistinct, possibly represented by a circular primordium 0.024 in diameter on body midline anterior to body midpoint. Prepharynx short, 0.03, pharynx indistinct 0.035 long by 0.030 wide, esophagus indistinct, intestinal crura diverging immediately posterior to pharynx and extending almost to posterior end of body. Remnants of cystogenous glands present on inner margin of body cuticle, staining pink in neutral red stain. Excretory bladder 0.12 long by 0.09 wide, oval, arms of bladder entering on anterior lateral margin of bladder and extending anteriorly to point of bifurcation of intestinal crura, bearing numerous, short, often branched, lateral and medial diverticula. Thirteen pairs of flame cells seen in positions indicated in Figure 126.

Host: *Melampus bidentatus* Say, coffee melampus

Localities: East Lagoon, 1 of 512 snails (0.2%); Yates Bayou, 1 of 104 snails (1.0%)

Overall Incidence: 2 of 616 snails (0.21%)

Identity: The absence of a ventral sucker and the presence of lateral diverticula on the arms of the excretory bladder indicate that this parasite may belong to the family Pronocephalidae, which parasitize turtles as adults. Diamond-back terrapins, *Malaclemys terrapin littoralis*, have been seen in the area where infected snails were taken, and could become infected by ingesting snails directly. Hunter (1961, 1967) described the pronocephalid *Pleurogonius malaclemys* in diamond-back terrapins in North Carolina. Unlike Cercaria sp. XXXIV, P. malaclemys produces monostome cercariae which encyst upon the operculum of the prosobranch snail host Nassarius obsoletus.

Ecology: The two infected snails were found in February and April at Yates Bayou and East Lagoon, respectively. The host snail belongs to a primarily terrestrial family (Ellobiidae) and spends most of its time crawling on emergent salt marsh vegetation, descending at low tide to the exposed bases of the plants and to the debris stranded by the tide. Encystment of the cercaria in the parent redia is therefore apparently an evolutionary adaptation of the parasite to accommodate to the habits of its host by suppressing the free-swimming stage. The final host of this species is probably a bird which feeds directly upon Melampus in the salt marsh. Epstein (1972) originally found this parasite at East Lagoon, Galveston in 2 of 505 M. bidentatus (0.4%). His is the first known report of a cercaria encysting within the parent redia. Members of the families Zoogonidae, Microphallidae and Monorchiidae are known to have larvae which encyst within the parent sporocyst. Maxon and Pequegnat (1949) mention finding metacercarial cysts in Melampus olivaceous in California that "could be readily seen with the binocular microscope" but they did not describe the infection further. It would be interesting to compare those cysts with those from M. bidentatus in Galveston.

VII. CESTODA

Marine molluscs commonly serve as intermediate hosts for several orders of tapeworms whose adults are parasites of the spiral valve of elasmobranch fishes. Unlike trematode larvae, cestode larvae may develop in a wide taxonomic and ecological range of hosts which may or may not include molluscs. Many other groups of animals, especially coelenterates, crustaceans, and fishes are also frequently infected with larval tapeworms. Rays could conceivably become infected by feeding directly upon molluscs by cracking and grinding their shells with their pharyngeal teeth, but sharks are not bottom feeders and are likely infected from plerocercoids in fishes or cephalopod molluscs; however, this does not preclude the possibility of the procercoid stage of shark-parasitic tapeworms occurring in shelled molluscs, which are eaten by teleost fishes which may eventually fall prey to sharks.

A. Order Tetraphyllidea

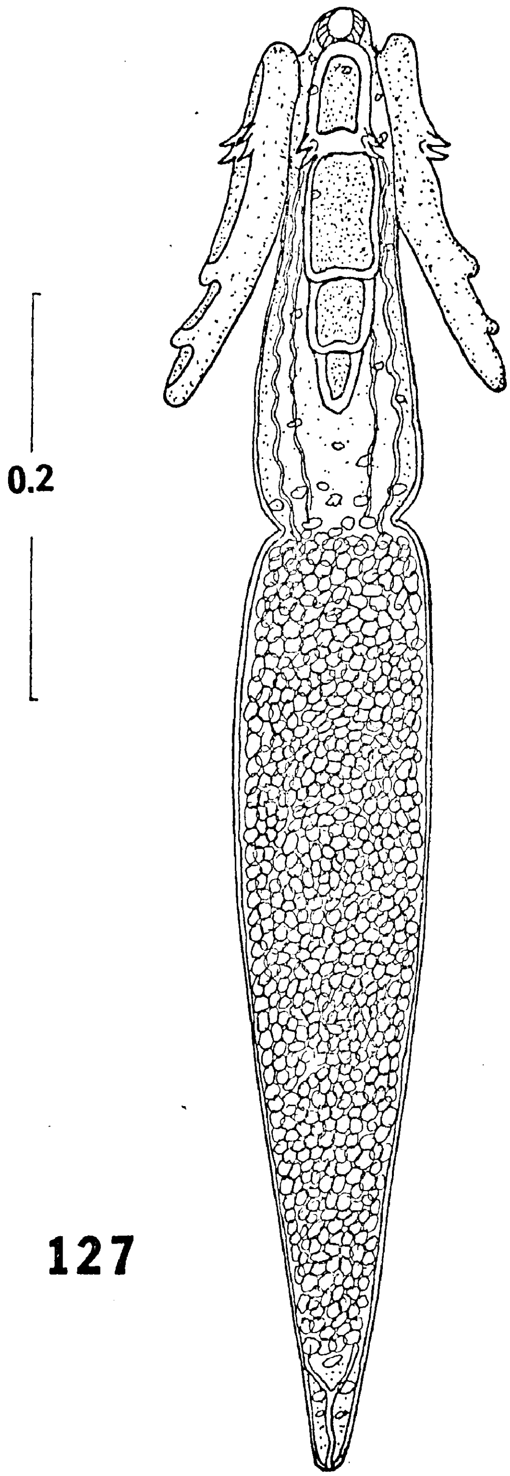
Adult tetraphyllideans are all parasitic in the spiral valve of elasmobranch fishes. The scolex bears four sessile or pedunculate bothridia of varying morphology, and the genital openings of the proglottids are usually lateral. Procercoids and plerocercoids are found in a wide taxonomic and ecological range of marine invertebrates, and plerocercoids are found also in the bodies of fishes.

Scolex sp. I

(Figures 127, 128)

Diagnosis: Elongate unsegmented anteriorly constricted plerocercoid (Fig. 127) up to 0.70 in length by 0.10 wide, with terminal circular myzorhynchus 0.02 in diameter. Anterior end of body bearing four sessile bothridia, each bearing an anterior accessory sucker, a pair of bifid hooks (Fig. 128) and three posterior loculi. Bothridia up to 0.18 in length by 0.04 wide. Caudal excretory bladder 0.03 long, varying in shape from tubular to oval. Two lateral tubules extending anteriad from bladder, hidden by concretions, apparently each bifurcating into total of four tubules, seen anterior to body constriction where concretions are less dense, extending to level of bothridial hooks. Color opaque white posteriorly, transparent anteriorly. Plerocercoid located in alimentary tract of host attached to walls of stomach and intestine by bothridia and myzorhynchus, often found free in lumen. Worms very mobile, crawling anteriad by alternate application and detachment of bothridia accompanied by swelling and contraction of posterior part of body.

Figures 127-128. Plerocercoid stage of *Scolex* sp. I from *Tagelus plebeius*. 127. Entire plerocercoid, fourth bothridium hidden behind rest of scolex. 128. Bifid hook from anterior portion of bothridium.



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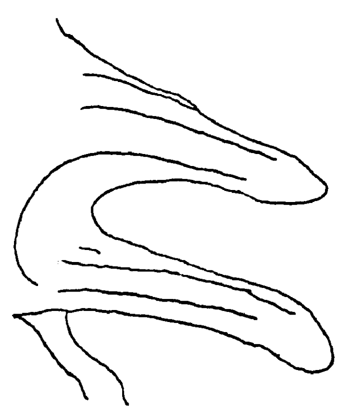


128

Host: Tagelus plebeius (Solander), stout razor clam; Macoma constricta (Bruguiere), constricted macoma

Localities: Sydnor Bayou, East Lagoon and East End Flats

Incidence: 112 of 150 T. plebeius (whose gut was examined) (74.6%) (100% of sexually mature clams examined); 3 of 15 M. constricta

Identity: The pair of bifid hooks on the anterior portion of the bothridium indicate that this parasite belongs to the Genus Acanthobothrium. Henson (1966) in a survey of the elasmobranch cestodes of the Texas Coast found only one species of Acanthobothrium in the Galveston Bay area, A. dujardinii Beneden, 1849 from the sting ray Dasyatis sabina. This ray is common in the marsh area where clams infected with Scolex sp. I were collected, and in all probability these larvae are A. dujardinii.

Ecology: Sting rays are the only elasmobranchs collected or seen from the three localities where Scolex sp. I was found, and stomach analyses of four specimens indicated the presence of numerous cracked shells of Tagelus and Macoma as well as adult A. dujardinii in the spiral valves. Rays commonly undulate their pectoral fins rapidly, excavating shallow depressions in the soft mud substrate causing temporary suspension or liquefaction of the sediment, resulting in the extraction of Tagelus and Macoma from their relatively deep burrows.

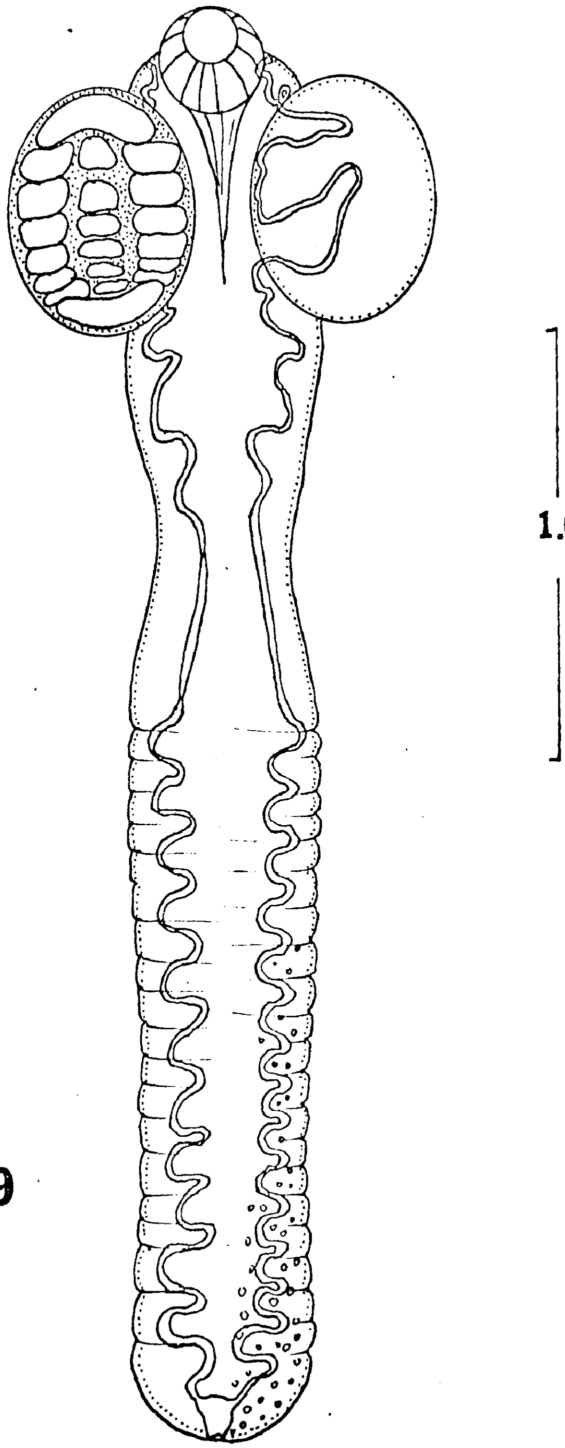
Scolex sp. II

(Figure 129)

Diagnosis: Elongate unsegmented constricted plerocercoid up to 3.2 in length, terminal myzorhynchus present, circular, 0.23 in diameter. Four sessile oval bothridia posterior to myzorhynchus 0.58 long by 0.43 wide, each containing from 18 to 20 loculi in three vertical rows of 6 to 7 loculi each. Caudal bladder ovoid, 0.15 long by 0.11 wide, paired excretory canals extending anteriad from bladder, undulating in posterior half, relatively straight in anterior portion, undulating with wide amplitude at level of bothridia and terminating lateral to myzorhynchus. Widely-scattered small concretions present in posterior half of body. Posterior half of body exhibiting cuticular annulation. Color opaque white. Larvae creeping on substrate by alternate application and retraction of bothridia and by alternate swelling and contraction of posterior half of body. Free plerocercoids found attached to inner wall of stomach and intestine of every sexually mature host clam examined.

Host: Anadara ovalis (Bruguiere), blood ark

Figure 129. Plerocercoid stage of *Scolex* sp. II from *Anadara ovalis*. Entire plerocercoid, loculi omitted from bothridium on right side of figure, excretory canal omitted from bothridium on left. Two other bothridia obscured by rest of scolex. Posterior concretion bodies omitted from left side of drawing.



129

Locality: Galveston Beach

Incidence: 15 of 20 clams (75%)

Identity: The form of the bothridia suggest that this plerocercoid is a larval stage of *Dioecotaenia cancellata* (Linton, 1890) Schmidt, 1969 which occurs in the cow-nosed ray, *Rhinoptera bonasus*. Henson (1966) reported this parasite in *R. bonasus* from Aransas Bay, Texas, and it is likely that it occurs in Galveston also.

Ecology: *R. bonasus* is a large ray which occurs in large schools and appears to be quite migratory. Parker (1965) reports the possibility that they may enter Galveston Bay to spawn in summer time, but most occurrences are from the open Gulf. In late fall, large numbers of cracked shells of the clams *Dosinia discus*, *Anadara brasiliana*, *Spisula solidissima* and *Anadara ovalis* are washed up on the Galveston beaches, which may indicate that a large migrating school of cow-nosed rays has recently passed by close to shore, feeding heavily. The plerocercoid of this parasite is apparently quite host specific since two other species of Arcidae and many other species of bivalves of various families living in the same habitat, just beyond the surf zone, were not found to be infected.

Scolex sp. III

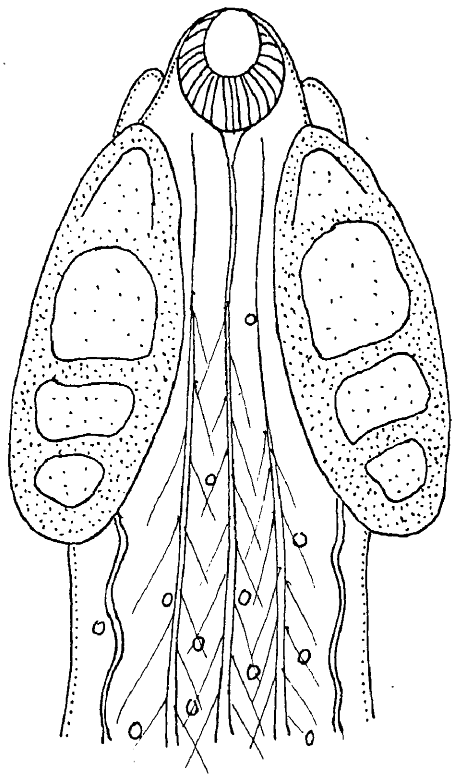
(Figures 130 to 133)

Diagnosis: Elongate unsegmented plerocercoid (Fig. 130) up to 5.0 long by 0.7 wide, myzorhynchus present on anterior end, circular, 0.14 in diameter. Four sessile bothridia (Fig. 131) present posterior to myzorhynchus, 0.50 to 0.60 long by 0.18 wide, containing three distinct loculi posteriorly and a sucker-like area anteriorly which possibly represents an undeveloped accessory sucker. Caudal bladder 0.10 long by 0.05 wide, roughly oval, lateral excretory canals extending anteriad to level of bothridia. Three fiber-like filaments extending length of body, bearing numerous posterior lateral branches in an inverted pinnate arrangement. Posterior three-fourths of body filled with dense concretions. Color transparent anteriorly, opaque white posteriorly in regions of concretions. Plerocercoids attached to inner wall of stomach and intestine of host snail. Earlier stages (Figs. 132, 133) also found free in lumen of gut, possibly recently acquired from feeding. Locomotion effected by alternate application and release of bothridia accompanied by expansion and contraction of body.

Hosts: *Thais haemastoma* (Linné), oyster drill; *Pleuroploca gigantea* (Kiener), horse conch

Figures 130-133. Larval stages of _Scolex_ sp. III from _Pleuroploca gigantea_. 130. Entire body of plerocercoid, two of the four bothridia are hidden behind scolex. 131. Scolex and neck region. 132. Early procercoid. 133. Late procercoid.

0.5



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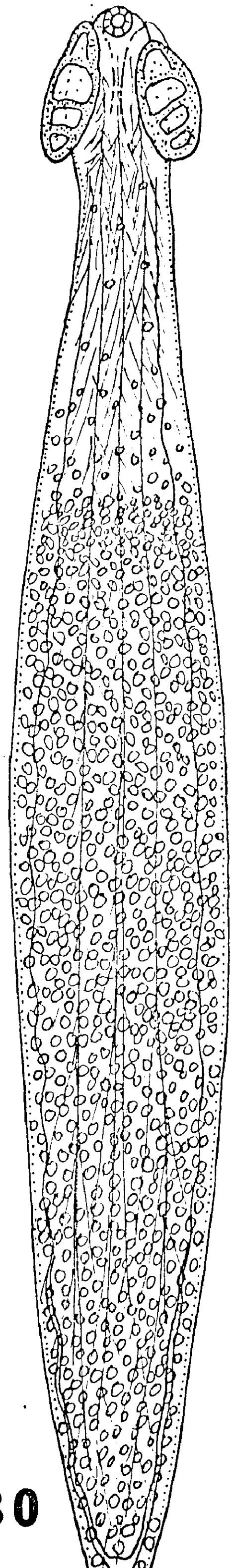
2.0



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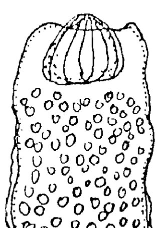

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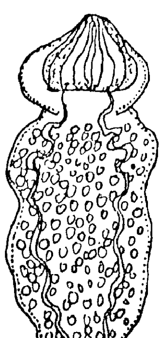


133

0.5

Localities: Galveston Beach and offshore platform, 12 miles offshore.

Incidence: 4 of 4 (100%) Pleuroploca gigantea and 12 of 18 (67%) Thais haemastoma examined

Identity: The arrangement of loculi on the bothridia is similar to that of the genus Acanthobothrium, but no hooks were seen. It is possible that the hooks might develop at a later stage in the snail or not develop until the final host is reached.

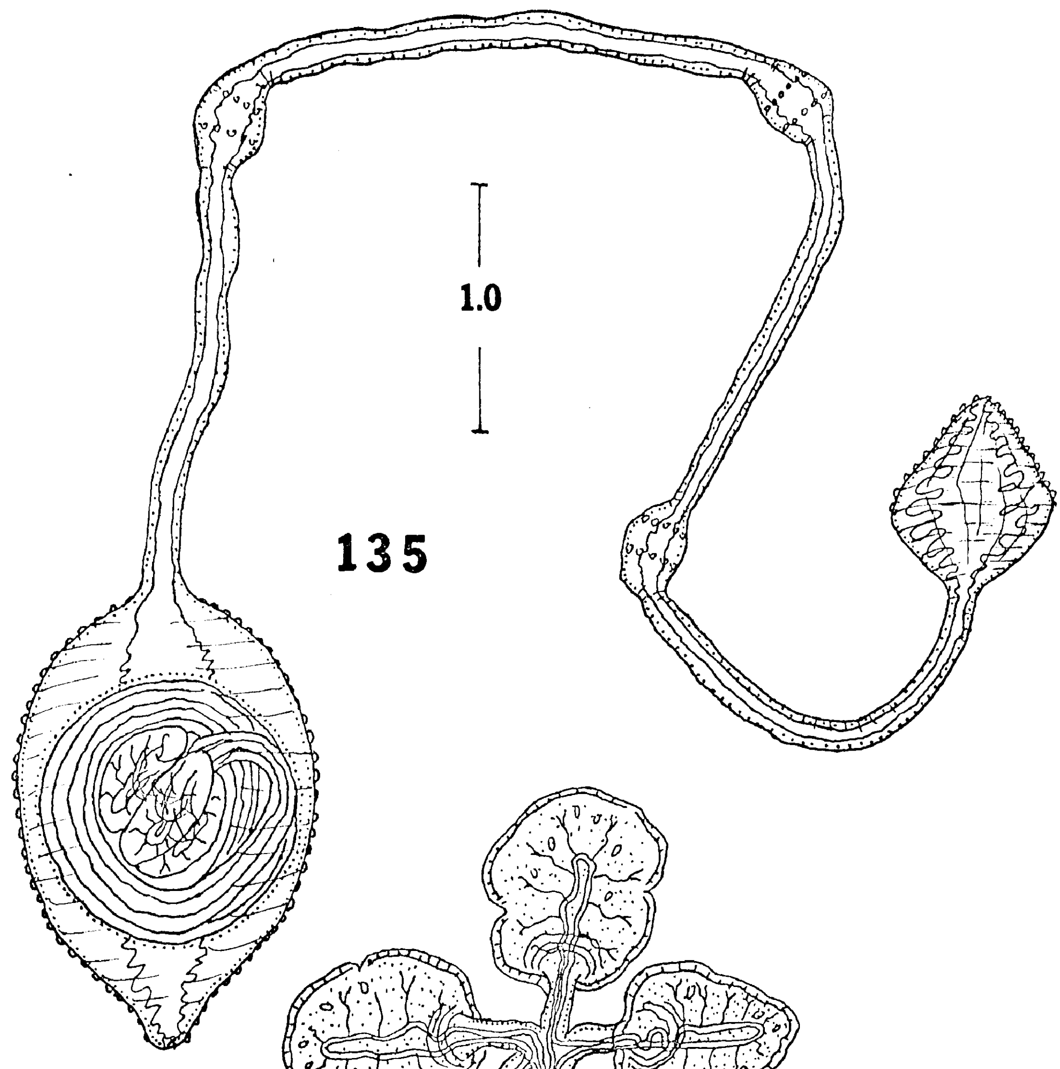
Ecology: Since the large plerocercoids of this species occur in shelled molluscs, there seems to be little doubt that the final host must be a ray capable of cracking the hard shells of these species.

Scolex sp. IV

(Figures 134 to 136)

Diagnosis: Vermiform unsegmented unconstricted plerocercoid (Fig. 134) 3.8 to 4.5 in length by 0.3 wide, myzorhynchus absent, four pedunculate leaf-like bothridia 0.88 to 1.40 long by 0.65 to 1.00 wide on anterior end, each bearing six to eight veins radiating from a central axis dividing face of bothridium into seven to ten compartments. Bothridial peduncles 0.3 to 0.5 long. Caudal bladder 0.1 long, paired excretory canals extending from bladder to a point 0.5 from anterior end. Canals each bifurcating from this point, extending

Figures 134-136. Larval stages of *Scolex* sp. IV from *Donax variabilis*. 134. Entire plerocercoid. 135. Encysted plerocercoid with cyst and anterior triple-jointed extension. 136. Diagrammatic view of arrangement of excretory canals. Dotted lines represent outline of body and bothridia.



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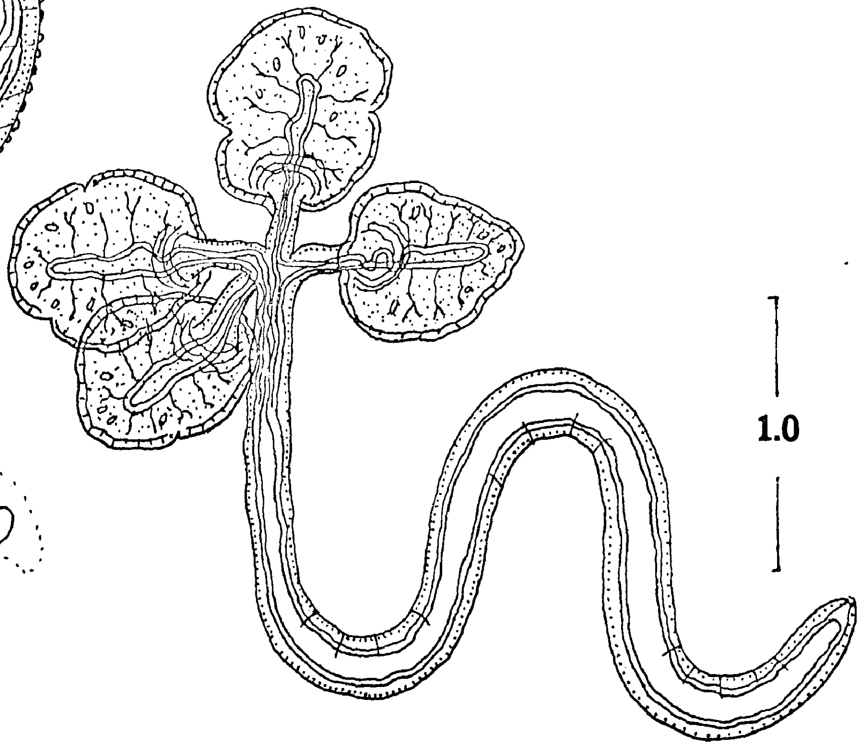

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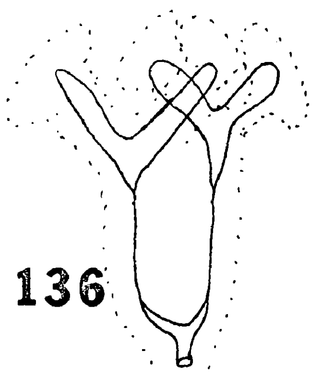

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anteriad, into peduncle and along central axis of bothridium, recurving, returning to base of peduncle then extending into peduncle and central axis of another bothridium, returning to base of peduncle and returning to point of bifurcation of tubules. Thus, each main canal serving two bothridia as shown in schematic diagram (Fig. 136).

Plerocercoid developing in large oval cyst (Fig. 135) 1.6 to 3.8 long by 0.8 to 1.3 wide with 3-jointed anterior vermiform extension 8.0 to 16.0 in length by 0.19 to 0.26 wide, bearing a terminal swelling 0.90 long by 0.80 wide. Distance between joints of anterior extension 0.25 to 0.46. Joints oval, 0.40 wide, each with two transverse rows of white pigmented granules. Cyst body with terminal excretory pore giving rise to two lateral excretory canals extending into anterior extension and terminating in anterior portion of terminal swelling. Cuticula of body of cyst and terminal swelling bearing numerous small papillae. Cuticula of jointed portion devoid of papillae. Plerocercoid coiled in spherical capsule in cyst body 1.0 to 1.1 in diameter. Anterior swelling of cyst embedded in visceral mass of host clam. Body of cyst in mantle cavity. Cyst motionless, anterior extension and terminal swelling very contractile and active. Excysted plerocercoid active, crawling by alternate application and withdrawal of bothridia.

Host: *Donax variabilis* Say, coquina clam

Locality: Galveston Beach, Texas

Incidence: 1 of 584 clams (0.17%)

Identity: The absence of a myzorhynchus and the morphology of the bothridia suggest affinity to the genus *Anthobothrium*. Henson (1966) found five different species of this genus in elasmobranchs of the Texas coast, including one from the stingray, *Dasyatis sabina*, from Galveston. *D. sabina* is common in the shallow surf waters occupied by the clam host of *Scolex* sp. IV and could be the final host.

Ecology: The single infected clam, collected from the wash zone of Galveston Beach in December 1971, was only 19 mm in length and bore ripe ovaries. The parasite, nearly as large as the body of the clam, occupied most of the mantle cavity and must have caused considerable interference to the feeding, respiratory, and locomotor activities of the host. Since the parasite is so large and in such an advanced state of development, it seems likely that the final host would become infected by feeding directly on *Donax*, rather than feeding on a fish which has fed upon *Donax*, therefore the final host is more apt to be a ray than a shark.

Scolex sp. V

(Figure 137)

Diagnosis: Elongate unsegmented unconstricted plerocercoid 1.0 to 1.5 in length by 0.5 wide. Terminal myzorhynchus present, circular, 0.14 in diameter. Four circular sessile bothridia, 0.20 in diameter, posterior and lateral to myzorhynchus. Caudal excretory bladder ovoid, 0.03 long by 0.01 wide, giving rise to four excretory canals, one extending to each bothridium. Body posterior to myzorhynchus filled with concretion spherules. Color of plerocercoid opaque white. Active creeping by alternate application and withdrawal of bothridia and swelling and contracting of body. Plerocercoids free in, and attached to, inner wall of stomach and intestine of host.

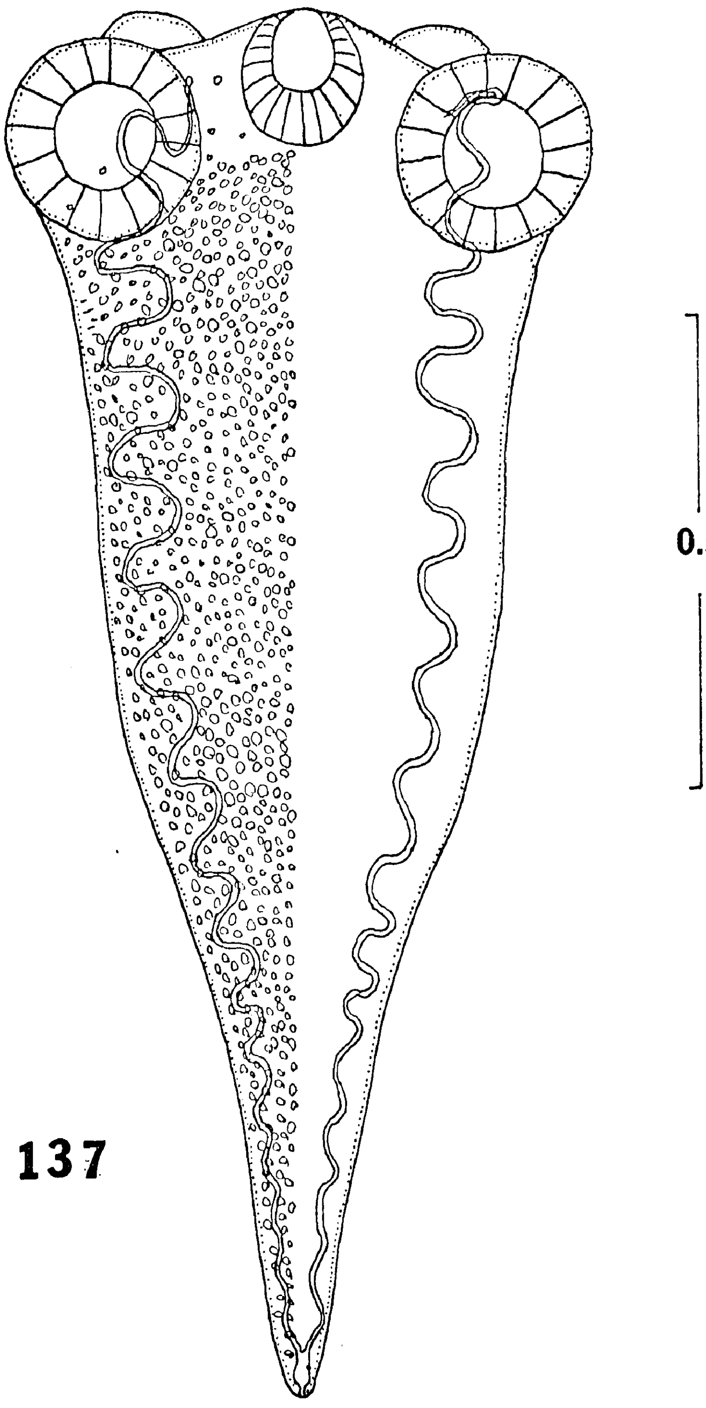
Host: Lolliguncula brevis (Blainville), brief squid

Locality: East Lagoon

Incidence: 16 of 27 squid (59.2%)

Identity: This plerocercoid is referrable to the collective group assembled under the name Scolex pleuronectis Müller, 1788 which encompasses many species of plerocercoids (recovered from the intestines of various marine species) which are not advanced enough to be placed in their proper genus. Most of the species assigned to this group are suspected to be larvae of the order Tetraphyllidea.

Figure 137. Plerocercoid stage of *Scolex* sp. V from *Lolliguncula brevis*. Entire plerocercoid, body concretions omitted from right side of drawing.



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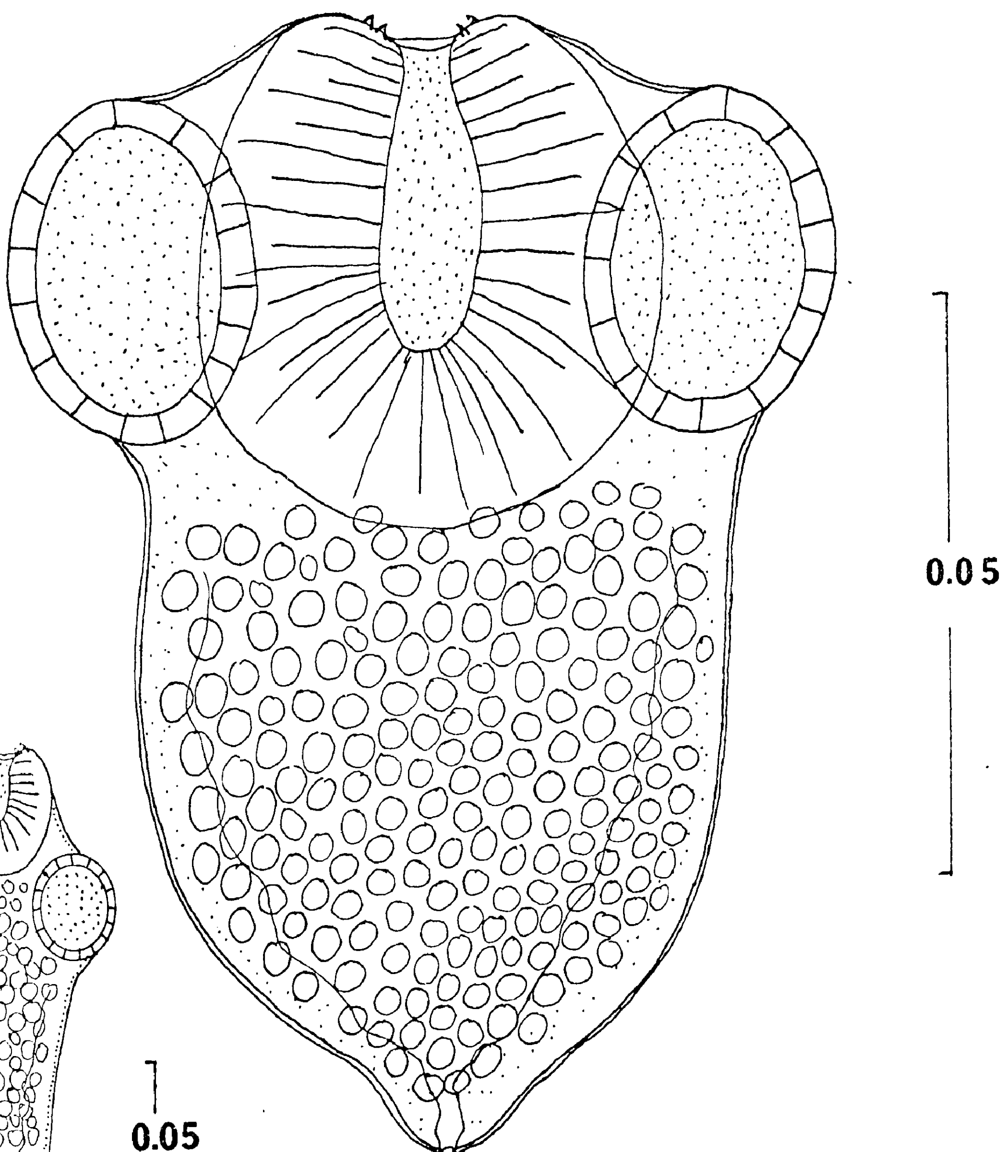
Ecology: Lolliguncula brevis is a predacious carnivore, feeding primarily on small fishes and crustaceans. It is too fast and agile to fall prey to a ray, so the probable final host of this species is a shark which either feeds directly upon the squid, or upon a fish which eats squid. The only sharks common in the inshore area are the black tip shark, Carcharhinus leucas, the bonnet-head, Sphyrna tiburo, and the hammerhead shark, Sphyrna lewini, and one or more of these is probably the final host. Henson (1966) found species of Anthobothrium and Phoreiobothrium in all three of these shark species from Aransas Pass and Corpus Christi, Texas. These hosts were not examined from the Galveston area.

Scolex sp. VI

(Figures 138, 139)

Diagnosis: Globose to elongate unsegmented unconstricted plerocercoid 0.09 to 0.25 long by 0.03 to 0.04 wide. Terminal myzorhynchus large, circular, 0.04 in diameter, bearing four small hooks in circle around orifice. Four oval bothridia, 0.03 long by 0.02 wide, lateral and posterior to myzorhynchus. Caudal excretory bladder oval, 0.005 long by 0.002 wide, four lateral excretory canals extending anteriad from bladder, one to each bothridium. Body posterior to myzorhynchus filled with spherical concretion bodies.

Figures 138-139. Plerocercoid stage of *Scolex* sp. VI from *Janthina janthina*. 138. Plerocercoid in relaxed position. 139. Extended plerocercoid.



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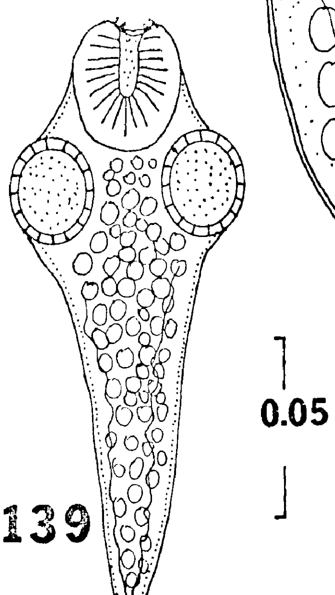

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Overall color opaque white. Plercercoids free in digestive gland of host snail, actively moving by means of bothridia.

Host: Janthina janthina Linne, purple sea snail

Locality: Washed ashore on Galveston Beach

Incidence: 16 of 16 (100%)

Identity: This plerocercoid is referrable to Scolex pleuronectis Müller, 1788 which is a composite species used to place larvae of the Tetraphyllidea which are not advanced enough in development to be classified to genus. This plerocercoid is unique, however, in the possession of four spines in a ring around the orifice of the myzo-rhynchus.

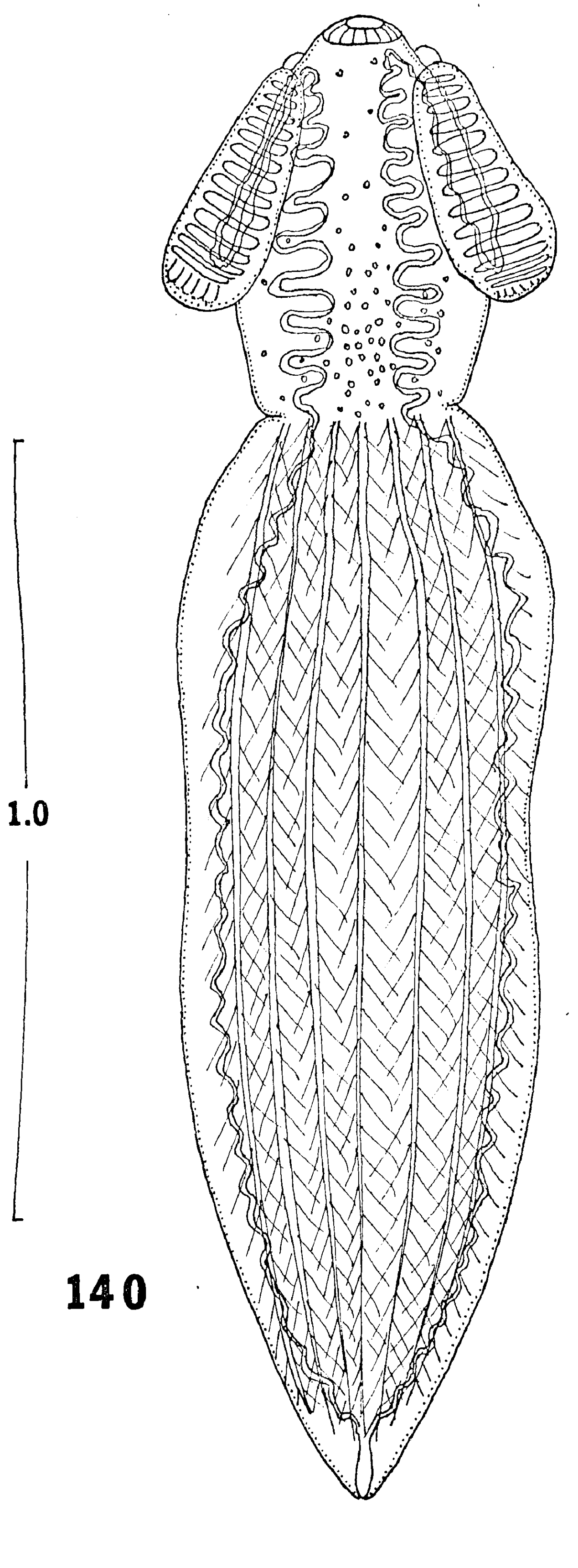
Ecology: Janthina is a pelagic snail which builds a raft of gas-filled mucous bubbles to which it attaches and drifts with the wind and current. The snail feeds on neustonic siphonophores. The final host of this species is probably a shark which feeds on a fish which, in turn, feeds directly upon Janthina.

Scolex sp. VII

(Figures 140, 141)

Diagnosis: Elongated unsegmented constricted plerocercoid 1.5 to 3.5 in length by 0.4 to 0.8 in width, terminal myzorhunchus present, circular, 0.10 in diameter. Four elongate pyriform to oval

Figures 140-141. Plerocercoid stage of *Scolex* sp. VII from *Noetia ponderosa*. 140. Entire plerocercoid. 141. Scheme of arrangement of excretory canals. Dotted line represents outline of body and bothridia.



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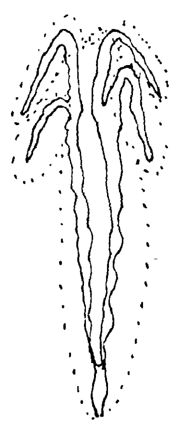

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sessile bothridia 0.15 to 0.25 long posterior to myzorhynchus, bearing up to 13 loculi in a single vertical row. Caudal excretory bladder 0.1 long, I-shaped to oval, giving rise to four lateral excretory canals extending anteriad into bothridia and returning to bladder as shown in Figure 141. Five to eight longitudinal fibers bearing inversely pinnate lateral branches, extending from region of body constriction posterior to bothridia to posterior margin of excretory bladder. Body translucent white anterior to constriction, opaque white posterior to constriction and often filled with concretion spherules. Plerocercoids occurring free in lumen of stomach or intestine of host, or attached to inner gut wall by anterior end. Worms very active, crawling by alternate application and withdrawal of bothridia.

Hosts: This plerocercoid is apparently non-host-specific and was found in the following species of molluscs: Periploma inequale (C. B. Adams), 88 of 268 clams (32.8%); Crepidula plana Say, 243 of 284 snails (85%); C. fornicata (Linne), 86 of 139 snails (61.1%); Atrina seminuda (Lamarck), 110 of 110 clams (100%); Raeta plicatella (Lamarck), 9 of 19 clams (47.8%); Noetia ponderosa (Say), 89 of 89 clams (100%); and Dosinia discus Reeve, 111 of 130 clams (85.3%).

Locality: All infections were found in molluscs collected from Galveston Beach

Incidence: Nearly 100% in each species. Immature molluscs were often not infected.

Identity: The presence of four bothridia with a single vertical row of loculi indicates that this species is a member of the genus *Echeneibothrium*. Henson (1966) found *E. flexile* Linton, 1890 in the stingray, *Dasyatis sabina* in Galveston, and this is probably the adult form of *Scolex* sp. VII.

Ecology: The infected molluscs were collected in the shallow surf zone of Galveston Beach which also is frequented by stingrays (*Dasyatis sabina*). Henson (1966) found *E. flexile* to be one of the most common parasites of the stingray in Galveston (11 of 28 specimens infected) and this correlates with the fact that its suspected larvae are the most common form in the benthic Mollusca of the area.

B. Order Trypanorhyncha

Adult trypanorhynchs are all parasitic in the spiral valve of elasmobranch fishes. The scolex is elongate and possesses two or four simple bothridia and four eversible tentacles armed with recurved hooks. Each tentacle invaginates into an internal sheath which terminates in a muscular bulb. The life cycle is similar to that of the Tetraphyllidea with larvae occurring in various marine invertebrates and fishes.

Scolex sp. VIII

(Figures 142, 143)

Diagnosis: Elongate unsegmented unconstricted plerocercoid 1.70 to 1.85 long by 0.5 to 0.8 wide. Two simple bilobed bothridia present on anterior lateral margin of body, 0.40 long. Four armed eversible tentacles emerging from anterior end of body, bearing oblique rows of uniformly-sized hooks (Fig. 143). Each tentacle retracting into sheath extending from anterior margin of body to muscular bulb located just posterior to body midlevel. Bulb 0.45 long by 0.15 wide. Caudal excretory bladder Y-shaped, lateral excretory canals exiting from anterior margin of bladder and extending forward to anterior margin of body near attachment of bothridia. Body transparent white, containing numerous laterally-oval concretions evenly distributed throughout. Body cuticula mostly smooth excepting a spined area near caudal excretory pore. Worm moving by lateral flexure of body and by feeble application and retraction of bothridia. Plerocercoids located in digestive gland of host clam.

Hosts: *Atrina seminuda* (Lamarck), pen shell; *Donax variabilis* Say, coquina clam

Locality: Galveston Beach, Texas

Figures 142-143. Plerocercoid stage of *Scolex* sp. VIII from *Donax variabilis*. 142. Entire plerocercoid. 143. Armature of extended tentacle near midpoint.

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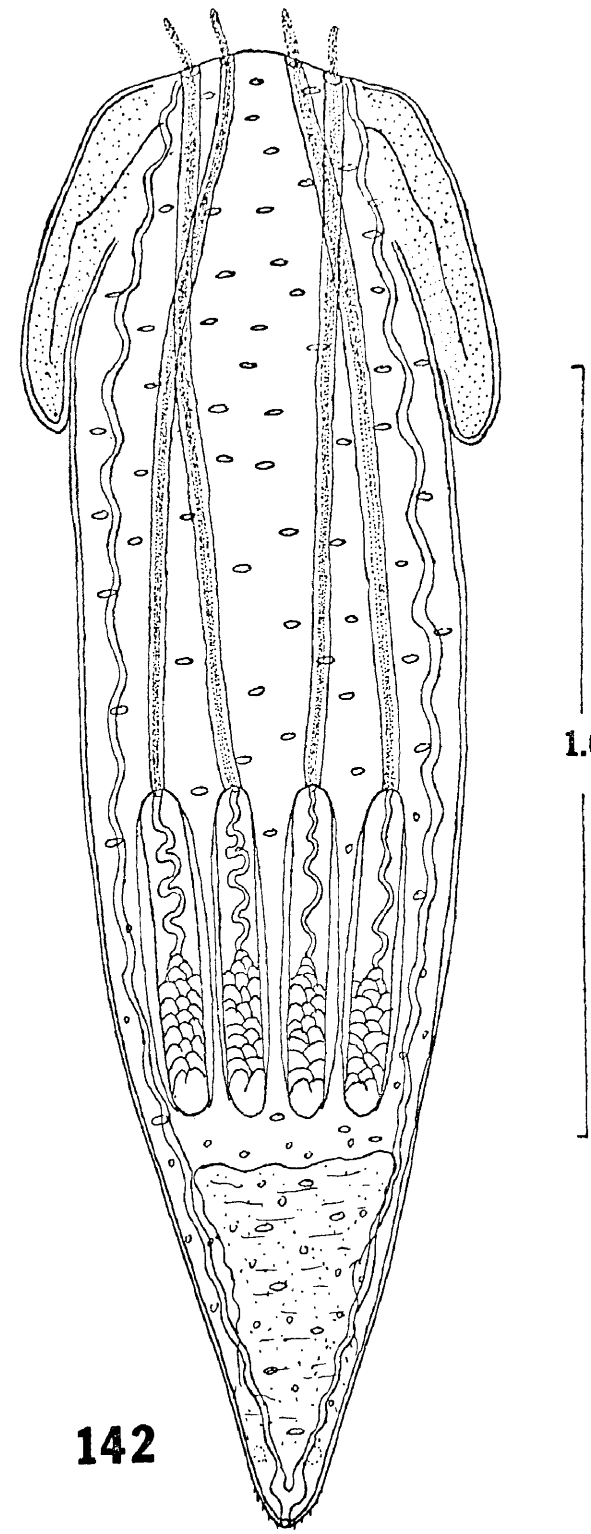

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Incidence: 1 of 110 (1%) Atrina seminuda; 1 of 584 (0.17%) Donax variabilis

Identity: The free-bordered bothridia and oblique rows of similar hooks indicate affinity to the genus Nybelinia of the family Tentaculariidae. Henson (1966) found Nybelinia lingualis (Cuvier, 1817) in Dasyatis sabina, the stingray, from Galveston and it is likely that this plerocercoid is its larval stage.

Ecology: The infected clams were collected in the shallow waters of the surf zone of Galveston Beach which is also frequented by stingrays. D. variabilis lives in the wash zone close to shore and A. seminuda lives just beyond the surf zone in about 2 meters of water. Due to the advanced stage of development of the larva, it probably directly infects the ray which feeds upon the host mollusc. The infected Donax was collected in July and the A. seminuda in November 1972.

VIII. NEMATODA

Many round worms (nematodes) are free-living, but many others are internal parasites of animals or live in or on plants. Most seed plants and most multicellular animals are parasitized by round worms, but there are relatively few reports of parasitic nematodes in marine Mollusca. Members of the free-living Superfamilies Enoploidea, Chromadoroidea and Monhysteroidea are often found in the mantle cavity of marine molluscs, but there is no evidence that they enter into any symbiotic relationship with the mollusc. Only the Spiruroidea (Echinocephalus) and the Ascaroidea (Porrocaecum) contain true parasitic forms known to inhabit marine molluscs.

A. Order Ascaroidea

Adult ascarids are large worms parasitizing the intestinal tract of all classes of vertebrates. The anterior end bears three lips; the pharynx is straight and relatively narrow. Males have two spicules and no gubernaculum, females have two or more parallel uteri and are oviparous producing large numbers of eggs. The life cycle may be direct or include an intermediate host, usually a forage species, either vertebrate or invertebrate.

"Nematode" sp. I

(Figures 144 to 146)

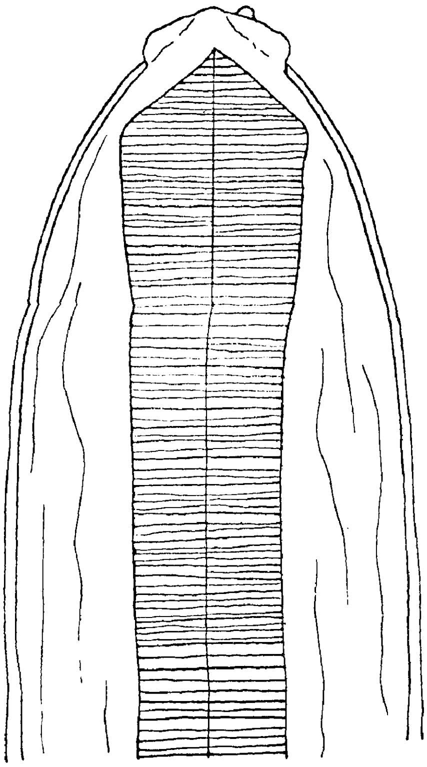
Diagnosis: Body elongate, rounded anteriorly, pointed posteriorly, 3.4 to 5.0 long by 0.12 wide, a single rounded boring tooth (Fig. 145) located on anterior end of body. Esophagus straight, expanded laterally near anterior end, 0.72 long by 0.024 wide. Ventriculus 0.32 long by 0.28 wide, Esophageal appendage projecting posteriorly from ventriculus, 0.38 to 0.53 long by 0.015 wide. Intestinal caecum projecting anteriad from posterior level of ventriculus, 0.12 to 0.18 long, or about one-third the length of the esophageal appendage. Intestine 2.46 to 2.94 long by 0.035 wide. Anus 0.1 to 0.13 from posterior end of body, genitalia undeveloped. Posterior tip of tail weakly annulate and bearing minute papillae (Fig. 146). Worms coiled in delicate sheath in liver and mantle of host.

Hosts: Dinocardium robustum (Solander); Atrina serrata (Sowerby); Atrina seminuda (Lamarck); Crepidula fornicata (Linne); Crepidula plana (Say); Oliva sayana (Ravenel); Pteria colymbus (Röding); Octopus vulgaris (Lamarck)

Identity: The presence of an anterior-projecting caecum and posterior-projecting esophageal appendage from the ventriculus, and

Figures 144-146. Larval stage of "Nematode" sp. I from *Dinocardium robustum*. 144. Anterior fifth of body. 145. Anterior end of body. 146. Posterior end of body.

0.05



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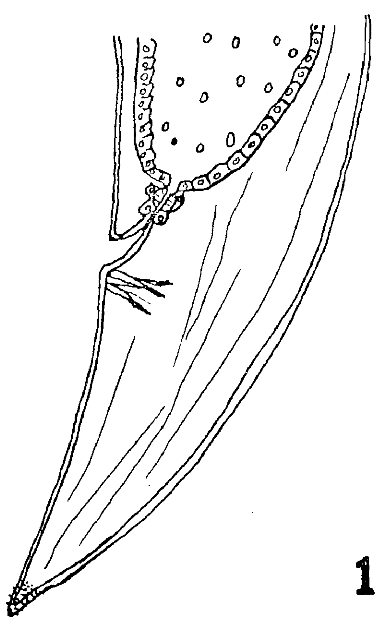

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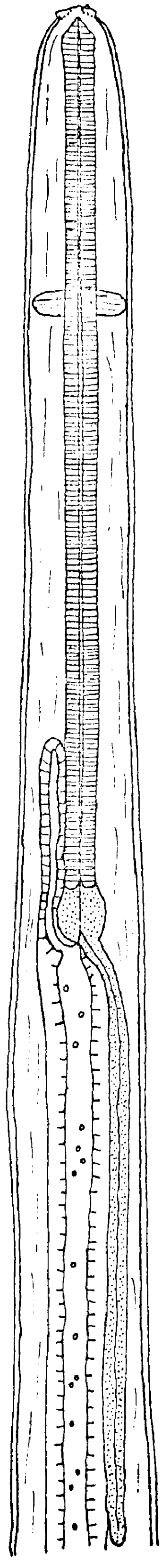

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a boring tooth on the anterior end, indicate that these nematodes belong to the genus *Contracaecum* of the family Anisakidae. Chandler (1935) described *Contracaecum collieri* from the sheepshead minnow, *Cyprinodon variegatus* and *C. robustum* from the long-nosed killifish, *Fundulus similis*, and from the striped mullet, *Mugil cephalus*, in Galveston Bay. The morphology of the boring spine and ecology of the hosts of the latter agree closely with "Nematode" sp. I. *F. similis* and *M. cephalus* are found in schools in the surf zone and beyond, and "Nematode" sp. I is probably the larva of *C. robustum*. Armstrong (1969) found *Contracaecum* sp. 2 in *Fundulus grandis* in Boca Chica, Texas; it closely resembles *C. robustum* and "Nematode" sp. I.

Ecology: *F. similis* could become infected by feeding upon dead or moribund molluscs, or sharing in the kill of a larger predator. *M. cephalus* is primarily a plankton feeder as an adult, and may become infected while supplementing its diet with mollusc carrion. Chandler (1943) observed that: "the species of *Contracaecum* occurring as adults in fishes, unlike those in birds, are strikingly variable with respect to the absolute and relative lengths of the intestinal caecum and esophageal appendix; whereas in the bird species the intestinal caecum is always long and invariably exceeds the esophageal appendix in length, in the fish species the reverse is true in

many instances, and the intestinal caecum may be greatly reduced."
The condition in "Nematode" sp. I indicates therefore that in its
adult form it is a fish parasite.

IX. SUMMARY AND CONCLUSIONS

Three turbellarians, 34 trematodes, 8 cestodes and 1 nematode have been found in the Mollusca examined from the Galveston Bay area (Fig. 1). Of these species (Tables 1 and 2), most appear to be in morphological agreement with previously described species, but others appear to be new and perhaps indigenous (in the sense of being peculiar to the locality), including Cercaria sp. V, a tailless fellodistomatid trematode from Tagelus plebeius, C. sp. VII, a trichocercous fellodistomatid from Rangia cuneata, C. sp. XXI, a renicolid xiphidiocercaria from Cerithidea pliculosa, C. sp. XXIII which encysts in its own redia in Melampus bidentatus, and C. sp. XXXIV, a setose cystophorus appendiculate cercaria of the family Hemiuridae from Anadara brasiliana.

With the exception of the turbellaria, all parasites found in the Mollusca of the Galveston Bay area were immature forms and require passage into a final vertebrate host (often through an intermediate host) in order to attain sexual maturity (Table 3), illustrating the importance of these molluscs in the food web of the area. Most of the parasites found (25 of 46) resemble species whose life cycle is known or suspected to involve a fish as the final host, while a

TABLE 1. List of parasites, hosts, and incidence of infection found in the present study.

Major taxon	Parasite	Mollusc host	Overall incidence
Phylum Platyhelminthes			
Class Turbellaria			
Rhabdocoelida	"Rhabdocoele" sp. I	*Echinochama cornuta*	2 of 3 (66.6%)
Rhabdocoelida	"Rhabdocoele" sp. II	*Modiolus demissus*	15 of 151 (10%)
		Brachidontes recurvus	1 of 305 (0.3%)
		Congeria leucopheata	1 of 264 (0.4%)
Polycladida	"Polyclad" sp. I	*Thais haemastoma*	9 of 107 (8.4%)
Class Trematoda			
Cyathocotylidae	*Cercaria* sp. I	*Cerithidea pliculosa*	8 of 1164 (0.07%)
Schistosomatidae	*Cercaria* sp. II	*Cerithidea pliculosa*	25 of 1164 (2.1%)
Aporocotylidae	*Cercaria* sp. III	*Mercenaria campechiensis*	8 of 116 (6.9%)
Fellodistomatidae	*Cercaria* sp. IV	*Brachidontes recurvus*	1 of 295 (0.33%)
Fellodistomatidae	*Cercaria* sp. V	*Tagelus plebeius*	4 of 1721 (0.23%)
Fellodistomatidae	*Cercaria* sp. VI	*Tagelus plebeius*	18 of 1721 (1.05%)
Fellodistomatidae	*Cercaria* sp. VII	*Rangia cuneata*	210 of 701 (29.9%)
Gymnophallidae	*Cercaria* sp. VIII	*Macoma constricta*	1 of 20 (5%)
Gymnophallidae	*Cercaria* sp. IX	*Donax variabilis*	6 of 584 (1.02%)
Gymnophallidae	*Cercaria* sp. X	*Tagelus plebeius*	9 of 1721 (0.53%)
Bucephalidae	*Cercaria* sp. XI	*Anadara brasiliana*	172 of 358 (48%)
Bucephalidae	*Cercaria* sp. XII	*Brachidontes recurvus*	4 of 305 (1.3%)
Bucephalidae	*Cercaria* sp. XIII	*Rangia cuneata*	60 of 701 (8.5%)
Bucephalidae	*Cercaria* sp. XIV	*Periploma inequale*	4 of 268 (1.5%)

TABLE 1. (continued)

Major taxon	Parasite	Mollusc host	Overall incidence
Echinostomidae	Cercaria sp. XV	Cerithidea pliculosa	14 of 1164 (1.2%)
Echinostomidae	Cercaria sp. XVI	Cerithidea pliculosa	7 of 1164 (0.6%)
Philophthalmidae	Cercaria sp. XVII	Thais haemastoma	22 of 107 (20.5%)
		Cerithidea pliculosa	107 of 1164 (9.1%)
		Littorina irrorata	16 of 1777 (0.9%)
Philophthalmidae	Cercaria sp. XVIII	Littorina irrorata	11 of 1777 (0.62%)
Renicolidae	Cercaria sp. XIX	Cerithidea pliculosa	28 of 1164 (2.4%)
Renicolidae	Cercaria sp. XX	Cerithidea pliculosa	33 of 1164 (2.56%)
Renicolidae	Cercaria sp. XXI	Cerithidea pliculosa	179 of 1164 (14.5%)
Renicolidae	Cercaria sp. XXII	Littorina irrorata	6 of 1777 (0.03%)
Microphallidae	Cercaria sp. XXIII	Cerithidea pliculosa	21 of 1164 (1.8%)
Microphallidae	Cercaria sp. XXIV	Littorina irrorata	2 of 1777 (0.11%)
		Crepidula plana	3 of 284 (1.1%)
Lepocreadiidae	Cercaria sp. XXV	Cantharus cancellarius	2 of 14 (14.3%)
Megaperidae	Cercaria sp. XXVI	Crepidula plana	1 of 284 (0.3%)
Monorchiidae	Cercaria sp. XXVII	Donax variabilis	20 of 584 (3.4%)
Zoogonidae	Cercaria sp. XXVIII	Busycon spiratum	1 of 22 (4.5%)
		Pleuroploca gigantea	1 of 4 (25%)
Heterophyidae	Cercaria sp. XXIX	Cerithidea pliculosa	178 of 1164 (15.3%)
Opisthorchiidae	Cercaria sp. XXX	Cerithidea pliculosa	66 of 1164 (5.6%)
Hemiuridae	Cercaria sp. XXXI	Crepidula plana	1 of 284 (0.3%)
Hemiuridae	Cercaria sp. XXXII	Oliva sayana	1 of 367 (0.26%)
Hemiuridae	Cercaria sp. XXXIII	Anadara brasiliana	39 of 358 (10.8%)
Family uncertain	Cercaria sp. XXXIV	Melampus bidentatus	2 of 616 (0.21%)

TABLE 1. (continued)

Major taxon	Parasite	Mollusc host	Overall incidence
Class Cestoda			
Tetraphyllidea	_Scolex_ sp. I	_Tagelus plebeius_	112 of 150 (74.6%)
		Macoma constricta	3 of 15 (20%)
Tetraphyllidea	_Scolex_ sp. II	_Anadara ovalis_	15 of 20 (75%)
Tetraphyllidea	_Scolex_ sp. III	_Thais haemastoma_	12 of 18 (67%)
		Pleuroploca gigantea	4 of 4 (100%)
Tetraphyllidea	_Scolex_ sp. IV	_Donax variabilis_	1 of 584 (0.17%)
Tetraphyllidea	_Scolex_ sp. V	_Lolliguncula brevis_	16 of 27 (59.2%)
Tetraphyllidea	_Scolex_ sp. VI	_Ianthina janthina_	16 of 16 (100%)
Tetraphyllidea	_Scolex_ sp. VII	_Crepidula fornicata_	86 of 139 (61.1%)
		Crepidula plana	243 of 284 (85%)
		Noetia ponderosa	89 of 89 (100%)
		Atrina seminuda	110 of 110 (100%)
		Dosinia discus	111 of 130 (85.3%)
		Raeta plicatella	9 of 19 (47.8%)
		Periploma inequale	88 of 268 (32.8%)
Trypanorhyncha	_Scolex_ sp. VIII	_Donax variabilis_	1 of 584 (0.17%)
		Atrina seminuda	1 of 110 (1%)
Phylum Aschelminthes			
Class Nematoda			
Ascaroidea	"Nematode" sp. I	_Crepidula fornicata_	3 of 139 (2.2%)
		Crepidula plana	1 of 284 (0.3%)
		Oliva sayana	2 of 367 (0.6%)

TABLE 1. (continued)

Major taxon	Parasite	Mollusc host	Overall incidence
Ascaroidea	"Nematode" sp. I	Atrina serrata	105 of 105 (100%)
		Atrina seminuda	110 of 110 (100%)
		Dinocardium robustum	202 of 202 (100%)
		Pteria colymbus	5 of 18 (27.7%)
		Octopus vulgaris	2 of 2 (100%)

TABLE 2. List of host species examined and their parasites as found in the present study (arranged alphabetically by trivial name)

Mollusc species	No. individuals examined	Parasites found: Turbellaria	Trematoda	Cestoda	Nematoda
Nassarius acutus	158				
Abra aequalis	2				
Tellina alternata	16				
Epitonium angulatum	10				
Haminoea antillarum	1				
Anachis avara	13				
Melampus bidentatus	616		Cercaria sp. XXXIV Cercaria sp. XI Cercaria sp. XXXIII		
Anadara brasiliana	358				
Lolliguncula brevis	27			Scolex sp. V	
Mercenaria campechiensis	116		Cercaria sp. III		
Cantharus cancellarius	14		Cercaria sp. XXV		
Busycon contrarium	26				
Hastula cinerea	164				
Pteria colymbus	18				"Nematode" sp. I
Macoma constricta	20		Cercaria sp. VIII	Scolex sp. I	
Echinochama cornuta	3	"Rhabdocoele" sp. I			
Cyrtopleura costata	83				
Pangia cuneata	701		Cercaria sp. VII Cercaria sp. XIII		
Modiolus demissus	151	"Rhabdocoele" sp. I			
Dosinia discus	130			Scolex sp. VII	
Terebra dislocata	6				
Polinices duplicata	326				
Ostrea equestris	82				
Crepidula fornicata	139			Scolex sp. I	"Nematode" sp. I
Murex fulvescens	2				
Pleuroploca gigantea	4		Cercaria sp. XXVIII	Scolex sp. III	
Janthina globosa	3				
Thais haemastoma	107	"Polyclad" sp. I	Cercaria sp. XVII	Scolex sp. III	
Lyonsia hyalina	10				
Fasciolaria hunteria	1				

TABLE 2. (continued)

Mollusc species	No. individuals examined	Parasites found: Turbellaria	Trematoda	Cestoda	Nematoda
Odostomia impressa	119				
Periploma inequale	268		Cercaria sp. XIV	Scolex sp. VII	
Littorina irrorata	1777		Cercaria sp. XVII		
			Cercaria sp. XVIII		
			Cercaria sp. XXII		
			Cercaria sp. XXIV		
Janthina janthina	16			Scolex sp. VI	
Mulinia lateralis	238				
Chione latilrata	1				
Congeria leucopheata	264	"Rhabdocoele" sp. I			
Littorina lineolata	200				
Chama macerophylla	2				
Litiopa melanostoma	4				
Ensis minor	56				
Macoma mitchelli	17				
Laevicardium mortoni	5				
Teredo navalis	50				
Anachis obesa	166				
Anadara ovalis	20			Scolex sp. II	
Siphonaria pectinata	120				
Phacoides pectinatus	41				
Scyllaea pelagica	55				
Sinum perspectivum	4				
Petricola pholadiformis	4				
Crepidula plana	284		Cercaria sp. XXIV		
			Cercaria sp. XXVI	Scolex sp. VII	"Nematode" sp. I
			Cercaria sp. XXXI		
Tagelus plebeius	1721		Cercaria sp. V		
			Cercaria sp. VI	Scolex sp. I	
			Cercaria sp. X		
Raeta plicatella	19			Scolex sp. VII	
Cerithidea pliculosa	1164		Cercaria sp. I		
			Cercaria sp. II		

TABLE 2. (continued)

Mollusc species	No. individuals examined	Parasites found			
		Turbellaria	Trematoda	Cestoda	Nematoda
Cerithidea pliculosa (cont)			Cercaria sp. XV		
			Cercaria sp. XVI		
			Cercaria sp. XVII		
			Cercaria sp. XIX		
			Cercaria sp. XX		
			Cercaria sp. XXI		
			Cercaria sp. XXIII		
			Cercaria sp. XXIX		
			Cercaria sp. XXX		
Noetia ponderosa	89			Scolex sp. VII	
Neritina reclivata	2				
Brachidontes recurvus	305	"Rhabdocoele" sp. II	Cercaria sp. IV		
			Cercaria sp. XII		
Dinocardium robustum	202				"Nematode" sp. I
Oliva sayana	367		Cercaria sp. XXXII		"Nematode" sp. I
Atrina seminuda	110			Scolex sp. VI	
				Scolex sp. VIII	"Nematode" sp. I
Atrina serrata	105				"Nematode" sp. I
Diplothyra smithii	28				
Spisula solidissima	20				
Busycon spiratum	22		Cercaria sp. XXVIII		
Anadara transversa	40				
Donax variabilis	584		Cercaria sp. IX	Scolex sp. IV	
			Cercaria sp. XXVII	Scolex sp. VIII	
Nassarius vibex	293				
Crassostrea virginica	190				
Octopus vulgaris	2				"Nematode" sp. I
Total	12,131				

TABLE 3. Synopsis of known and suspected (in parentheses) life cycles of helminth parasites having stages in the mollusc fauna of Galveston Bay, Texas

Parasite	Mollusc host	Intermediate host	Final host
"Rhabdocoele" sp. I	Echinochama cornuta	-	-
"Rhabdocoele" sp. II	Modiolus, Brachidontes, Congeria	-	-
"Polyclad" sp. I	Thais haemastoma	-	-
Cercaria sp. I	Cerithidea pliculosa	(Mugil spp.)	bird
Cercaria sp. II	Cerithidea pliculosa	none	bird
Cercaria sp. III	Mercenaria campechiensis	none	fish
Cercaria sp. IV	Brachidontes recurvus	bivalved molluscs	fish
Cercaria sp. V	Tagelus plebeius	T. plebeius	fish
Cercaria sp. VI	T. plebeius	invertebrate	fish
Cercaria sp. VII	Rangia cuneata	invertebrate	fish
Cercaria sp. VIII	Macoma constricta	mollusc	bird
Cercaria sp. IX	Donax variabilis	D. variabilis	bird
Cercaria sp. X	Tagelus plebeius	T. plebeius	bird
Cercaria sp. XI	Anadara brasiliana	(small fish)	predacious fish
Cercaria sp. XII	Brachidontes recurvus	Fundulus	predacious fish
Cercaria sp. XIII	Rangia cuneata	(small fish)	predacious fish
Cercaria sp. XIV	Periploma inequale	(small fish)	predacious fish
Cercaria sp. XV	Cerithidea pliculosa	Crassostrea virginica	bird
Cercaria sp. XVI	Cerithidea pliculosa	Crustacean exocuticle	bird
Cercaria sp. XVII	Thais, Cerithidea, Littorina	encysts on various surfaces	bird

TABLE 3. (continued)

Parasite	Mollusc host	Intermediate host	Final host
Cercaria sp. XVIII	Littorina irrorata	encysts on various surfaces	bird
Cercaria sp. XIX	Cerithidea pliculosa	Fundulus grandis	bird
Cercaria sp. XX	Cerithidea pliculosa	Fundulus grandis	bird
Cercaria sp. XXI	Cerithidea pliculosa	mollusc	bird
Cercaria sp. XXII	Littorina irrorata	mollusc	bird
Cercaria sp. XXIII	Cerithidea pliculosa	crustacean	bird
Cercaria sp. XXIV	Littorina irrorata, Crepidula plana	crustacean	bird
Cercaria sp. XXV	Cantharus cancellarius	invertebrate	fish
Cercaria sp. XXVI	Crepidula plana	(none)	herbivorous fish
Cercaria sp. XXVII	Donax variabilis	in host clam	(Trachinotus carolinus)
Cercaria sp. XXVIII	Busycon spiratum, Pleuro-ploca gigantea	(invertebrate)	fish
Cercaria sp. XXIX	Cerithidea pliculosa	Fundulus, Mugil	bird
Cercaria sp. XXX	Cerithidea pliculosa	Fundulus, Mugil	bird
Cercaria sp. XXXI	Crepidula plana	invertebrate	fish
Cercaria sp. XXXII	Oliva sayana	invertebrate	fish
Cercaria sp. XXXIII	Anadara brasiliana	invertebrate	fish
Cercaria sp. XXXIV	Melampus bidentatus	in redia	(Malaclemys terrapin)
Scolex sp. I	Tagelus plebeius, Macoma constricta	(none)	Dasyatis spp.
Scolex sp. II	Anadara ovalis	(none)	Rhinoptera bonasus

TABLE 3. (continued)

Parasite	Mollusc host	Intermediate host	Final host
Scolex sp. III	*Thais*, *Pleuroploca*	(bottom-feeding fish)	(shark)
Scolex sp. IV	*Donax variabilis*	(none)	*Dasyatis* spp.
Scolex sp. V	*Lolliguncula brevis*	(fish)	(shark)
Scolex sp. VI	*Ianthina janthina*	(fish)	(shark)
Scolex sp. VII	*Crepidula*, *Atrina*, *Dosinia* etc.	(fish)	Elasmobranch
Scolex sp. VIII	*Donax variabilis*, *Atrina* spp.	(none)	*Dasyatis* spp.
"Nematode" sp. I	*Crepidula*, *Atrina*, *Dinocardium*, etc.	(none)	bottom-feeding fish

relatively large number (18 of 46) of the species probably utilize warm blooded vertebrates as the final host.

Qualitative and quantitative variations occurring in the molluscan host fauna of each station preclude a direct comparison of the helminth parasite faunae by stations. The limited year around availability of many molluscan species also precludes analysis of seasonal variations in the parasite populations in many cases.

It is hoped that this study will serve to stimulate further interest in the parasitic helminth fauna of the northwest Gulf of Mexico by providing: (1) a preliminary inventory of the helminth forms present in the local mollusc fauna; (2) information contributing to the knowledge of their often complex life cycles; (3) comparisons (where possible) with identical or closely related species described elsewhere or from other hosts; and (4) information on the ecology and pathology of each parasite with regard to its host and other potential, intermediate and final hosts which may be species of aesthetic, commercial or recreational importance, and (5) information on the ecology of both second intermediate and final host species.

No evidence was found that any of the helminth parasites encountered directly killed their molluscan host, intermediate host, or vertebrate final host. The most severe pathogenic effect appeared to be the destruction of molluscan gonadal tissue by the precercarial stages of most of the trematode species found. The precercarial stages of the two renicolid species (Cercaria sp. XIX and XX) inhabiting the rectum of their molluscan host appeared to occlude the lumen of this organ, but the host molluscs appeared quite healthy. None of the turbellarians, tapeworms or nematodes were observed to cause significant tissue damage to their hosts, although the single enormous tetraphyllidean larva (Scolex sp. IV) from Donax variabilis occupied more than half of the shell cavity volume of the clam. It would therefore be illogical to conclude that elimination of the host molluscs from an area would be beneficial to the faunal community of the area by freeing individuals from mollusc-borne parasites. The close degree of adaptation to and dependence upon the molluscan hosts by these helminths probably represents a climactic stage from a long evolutionary history of association. These helminth parasites are therefore a natural and perhaps essential component of the marine biota of the area. The trematodes producing castration serve to check the population levels of their molluscan hosts, possibly guarding them against overpopulation and insuring adequate habitat and food supply for the maintenance of their normal population levels. Due to the delicate complexity of most of the life cycles of the flukes and tapeworms, their presence and incidence in their molluscan host would probably provide one of the first indications of significant faunal changes occurring in response to human alteration of the coastal environment. Avoidance of polluted waters by a fish, or of altered topography by higher vertebrates could easily prevent the trematode miracida or cestode coracidia produced in the vertebrate from reaching the proper molluscan host in that area. These same environmental alterations could also affect the cycle by excluding or reducing the abundance of the second intermediate host. In either case, these changes would be reflected in a matter of months by a lower incidence or eradication of the corresponding molluscan helminth fauna. Reference intensities of helminth infection could be determined in fairly abundant molluscs such as Cerithidea, Littorina, Tagelus etc. for all seasons in natural undisturbed coastal areas. An index of the ecological condition of similar but disturbed areas could then be obtained by assessing the parasite incidence of one or two molluscs, and comparing it with the reference incidence. If the life cycles of the parasites were better known, the value of the index would be greatly enhanced by providing information as to which specific components of the local fauna have been affected by environmental changes, since most trematodes are quite host specific.

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