Parasites of Puerto Rican Freshwater Sport Fishes

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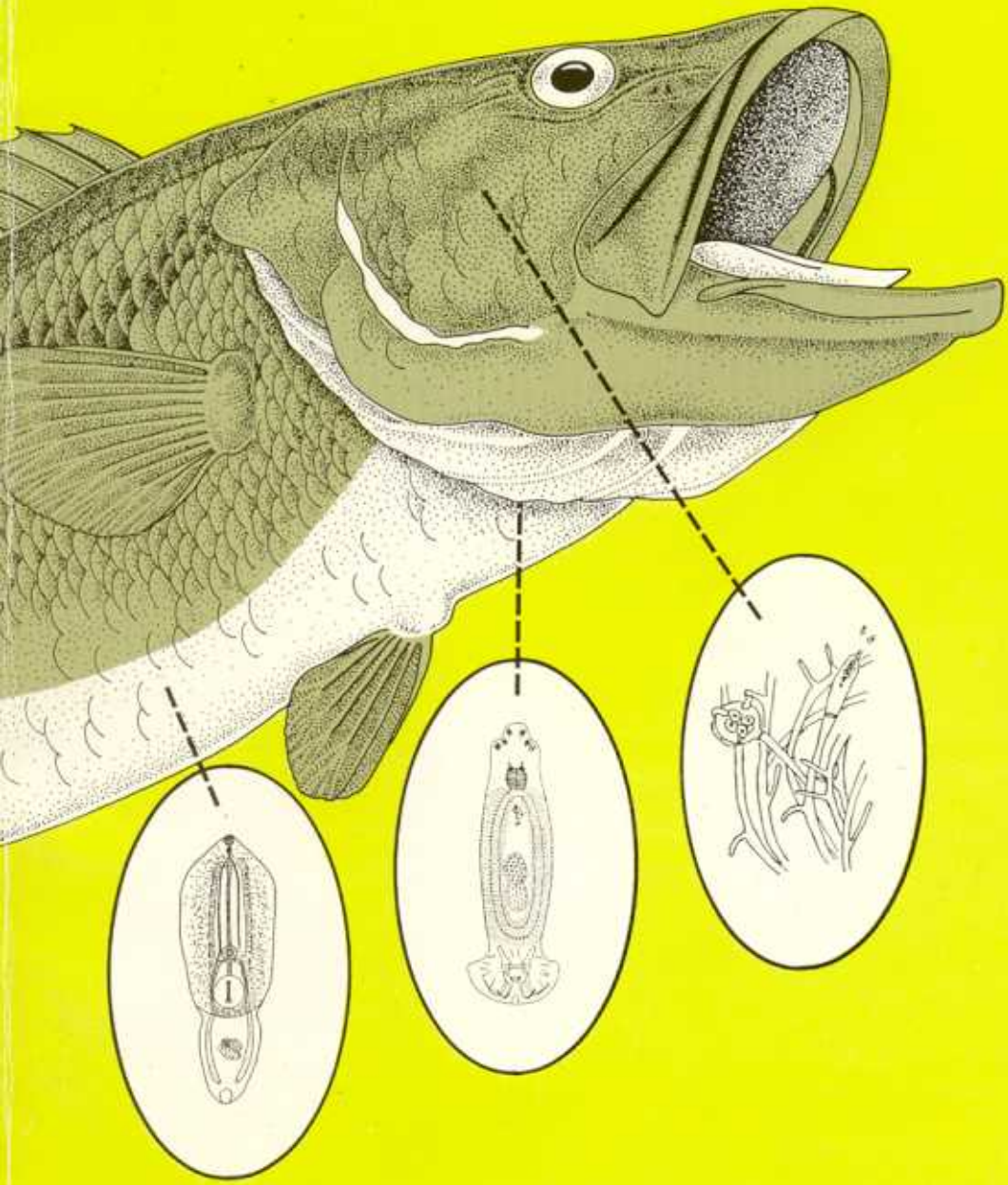

PARASITES OF PUERTO RICAN FRESHWATER SPORT FISHES

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Cover drawing: Largemouth bass with magnification of some of the parasites found on this host in Puerto Rico and their location in the host indicated. Front cover from right to left: *Saprolegnia* spp. (fungus), *Haplocleidus furcatus* (gillworm), *Posthodiplostomum minimum* (grub), continuing on back cover clockwise, *Trichodina fulton*i (protozoan), *Myzobdella lugubris* (leech), *Argulus japonicus* (fish lice), *Epistylis colisarum* (red-sore disease protozoan). Cover by Ms. Gladys Otero

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Key Words: Fish parasites, parasite introductions, parasite ecology, parasite evolution, fish kills, fish diseases, biological control.

CONTENTS

INTRODUCTION

This book is a fish parasite guide for sport fishermen, reservoir managers, fishery biologists, ecologists, scientists, and anyone interested in the health and welfare of freshwater sport fishes. We hope it will encourage the study of the interrelationships between fishes and their intimate parasite partners and point out the unique situation enjoyed by fishes on this tropical island.

Fishes used for examinations in this work were collected by the Department of Natural and Environmental Resources (DNER) personnel or by bass anglers at official tournaments. There was no attempt to make systematic collections. Fishes from the Maricao Fish Hatchery; Carite, Cidra, Garzas, Guajataca, Guayabal, La Plata, Loco, Loiza, Lucchetti, Matrullas, Melania, and Toa Vaca Lakes (map page 152); Joyuda, Mandri and Santa Teresa Lagoons; Añasco, Bucaná, Loiza, Guajataca and the mouth of the Guanajibo Rivers and several other small streams were examined (map page 153). Collection techniques included variable-mesh gill nets, trap nets, seine nets, small and large boat shocker, backpack shocker, and hook and line. Fishes were either placed immediately in plastic bags on ice and examined within 24 hours, or held alive and examined within the next 3 days.

There are approximately 63 species of fishes that live part or all of their lives in Puerto Rican fresh water. We identified approximately 100 species of parasites on or in some of these fishes. The strictly freshwater parasite fauna is depauperate in our island, but the parasites associated with fishes that move between marine and fresh water are rich and diverse. Although the number of truly freshwater parasite species is low, the number of individual parasites on fish can be high in some cases. Outbreaks of parasites have caused some spectacular problems in Puerto Rico, just as parasites occasionally do everywhere. Fish parasites provide readily available examples of many invertebrate phyla which can be used for classroom examinations.

Each parasite species is illustrated, and descriptions of the general characteristics, general biology, methods of control, size, hosts, locations on the host, geographic distribution, damage to hosts, life cycle and reproduction are given. Levels of infections for protista are estimated from skin or fin scrapings or gill clippings viewed with a compound microscope. Five medium power (100X) fields were averaged to determine parasite levels, called very light (<1 per five averaged fields), light (1-5), moderate (6-50), heavy (51-100) or very heavy (100+). These categories are used as number per host (or average of five hosts when possible) for other parasites.

American Fisheries Society (AFS) approved common names

(Robins et al. 1991) of Puerto Rican freshwater fishes are used in the text (for Spanish names see Erdman 1983) with their scientific names listed in the Host-Disease Checklist. (Except for peacock bass which is called peacock cichlid by AFS.) Fishes not occurring in Puerto Rican fresh water are not in the Checklist. Their AFS approved common names are used in the text and their scientific names appear with the first use of their common names. Organisms other than fishes are similarly identified in the text. Any common name can be matched with its scientific name by looking in the Index for the page number in emphasis. Parasite common names are not used except for a few which are widely published and generally accepted.

Samples of most of the parasites of Puerto Rican freshwater sport fishes were deposited in sections of the U.S. National Museum (as detailed in the Acknowledgements). They are indicated in the text by "(USNM plus a number)" or by "(USNM)" alone where a deposition number was not received prior to publication of this book.

Treatments mentioned for fish parasites are not necessarily approved by the U.S. Food and Drug Administration for use on food fishes. Anyone treating fishes is responsible for knowing the currently approved chemicals and methods.

The parasite situation in Puerto Rico and how further introductions of parasites can be avoided is discussed. Diseases of local freshwater fishes (other than parasites) are noted. A form and instructions for sending fish or parasite specimens to us are included. The importance of local parasites, hypotheses concerning exotic parasites, controlling and avoiding fish parasites and the effects of fish parasites on humans are discussed. The Host-Disease Checklist includes the complete classification of local freshwater fishes, a small illustration of each fish, and a list of the diseases we found on each host species. The Bibliography includes some annotations which we hope will be useful.

The freshwater fish parasites of Puerto Rico are in the midst of a huge natural experiment. Fishes from the continental USA, South America, and Africa have repeatedly been brought to the island, and each fish and each shipment has brought its own set of unique parasites. This unnatural mix of fish hosts and unfamiliar parasites is evolving toward some sort of stability. The variety of empty niches on fish hosts should drive some interesting changes. This book provides some of the base-line information necessary to follow this dynamic "experiment" in the future.

We hope that this book will be a useful guide to the parasites of local freshwater fishes. We look forward to receiving reader input concerning these fascinating creatures.

PARASITES OF PUERTO RICAN FRESHWATER SPORT FISHES

PROTOZOA (PROTOZOANS)

Protozoa were once a Phylum in the Animal Kingdom. Now, they are considered a subkingdom with a number of phyla in the Protista Kingdom. In this section, we examine protozoan parasites including members of the Phylum Ciliophora (ciliates), Phylum Mastigophora (flagellates) and Phylum Myxozoa (myxosporidians).

As a group, Protozoa are essentially unicellular, complex organisms, which are usually microscopic. They are similar to the basic animal or plant cell, but differ by having additional morphological and physiological characteristics. Protozoa have one to several nuclei; multiple nuclei can be either identical or divergent. Flagellates usually have few, relatively long flagella for locomotion and one nucleus. Ciliates usually have many, relatively short cilia for locomotion and two types of nuclei. Myxosporidians are characterized by producing spores with 2-6 external valves containing 1-6 (usually 2) polar capsules and 1-2 infective units. Reproduction may be asexual by binary fission, multiple fission, external budding or internal budding; or sexual by fusion, conjugation or autogamy.

Protozoans range from free-living through various forms of commensalism to parasitism in most animals, plants, and even other protozoans. Flagellates and ciliates have a wide range of habits, while all myxosporidians are parasites. Most eat solid organisms or materials (holozoic) or fluid materials (saprozoic), but a few photosynthesize their own energy (holophytic or photo-autotrophic). Parasitic protozoa kill, mutilate and debilitate more people in the world than any other group of disease organisms. Protozoan parasites of fishes, however, are not known to infect humans or even to directly transmit microbial diseases to other fishes, but the damage they produce could allow the entry of secondary infections. Protozoans sometimes kill freshwater or marine fishes in Puerto Rico (Bunkley-Williams and Williams in press; Williams, Bunkley-Williams and Dyer 1994). Many species occur abundantly in fresh water here, consuming dead material in ponds and lakes. Some of these can inhabit fishes under certain conditions, but others are specific pathogens of fishes. In Puerto Rico, we have found protozoa commonly parasitizing the skin, fins, and gills of fishes. Prieto (1991) found *Chilodonella hexasticha* (Kiernik) on all freshwater fishes cultured in Cuba, but we have not seen it here.

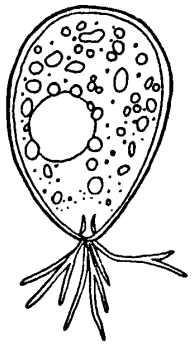
There are more than 65,000 described species of protozoa with half being fossil (useful in identifying oil deposits) and around 10,000 parasitic species (5600 myxosporidians and allies, 2500 ciliates, 1800 flagellates). More than 2400 parasitize fishes. They vary in length from 1 Fm to 7 cm or more, but most are 5-250 Fm. Many thousands of species remain to be described and about one new species is described every day!

References - "Protozoan Parasites of Fishes" (Lom and Dyková 1992), "How to Know the Protozoa" (Jahn, Bovee and Jahn 1979) and "An Illustrated Guide to the Protozoa" (Lee, Hutner and Bovee 1985).

Kingdom Protista (or Protoctista) Taxonomy and Contents . . . . Page

***Piscinoodinium pillulare* (Schäperclaus)**

This parasite kills tropical aquarium and cultured fishes by coating the gills and skin in a condition called "velvet disease". It has the reputation for causing mass mortalities among many species of fishes. Fortunately, this pathogen has not caused problems in Puerto Rico.



Piscinoodinium pillulare

This dinoflagellate should be carefully followed in the future. It has the potential to cause great losses and complications for sport fishes in Puerto Rico. Thus far it has only been found rarely and in small numbers. Relatives of this parasite cause spectacular red tides and ciguatera fish poisoning. The name comes from the appearance of sick fishes which seem to be covered in velvet. It is also called "oodinium disease", "rust disease" or "oodiniasis" from the genus which was formerly called *Oodinium*.

Diagnostic Characters - Clear to golden, relatively large, sub-spherical body with root-like processes.

Records in Puerto Rico - Occurred rarely in low numbers on Mozambique tilapia at the Maricao Hatchery.

Geographic Range - It is widely distributed on tropical aquarium fishes around the world and in tropical fish culture, but has also been found in subtropical waters of Florida. These organisms are rarely studied and are often only tentatively identified to genus. The exact geographic ranges have not been determined. This dinoflagellates is often closely associated with fishes, rather than being natural components of the aquatic environment. It was probably introduced with aquarium fishes.

Life History - The motile flagellated stage finds a fish, loses its flagellum and attaches with root-like processes. There it increases in size and produces numerous (256) new infective stages (gymnospores) by fission.

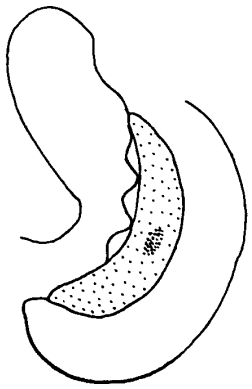
Location in Host - It is found on gill filaments or skin, and rarely penetrates under the skin (subcutaneous tissue).

Size - 12-100 Fm.
Host Specificity - It can infect almost any species of freshwater fish. This disease can attack sport fishes.
Damage to Host - It is not known to cause disease in wild fishes but the potential for harm in hatchery or pond raised fishes is great. Irritation of the gills and skin by velvet disease causes excess mucus production and behavioral changes (lack of feeding, flashing). It has killed aquarium fishes which were being reared in large earthen ponds in south Florida.
Detection - Heavily infected hosts appear to be covered in velvet. Scrapings of skin or clippings of gills must be examined with a compound microscope to confirm the presence of the attached stage. Many species of free-living dinoflagellates can be found on the gills of freshwater fishes in Puerto Rico. A few are rather similar to the infective stage of the velvet disease parasite, but the attached stage is diagnostic.

Many of the free-living dinoflagellates which incidentally occur on the gills of freshwater fishes in Puerto Rico are strikingly beautiful. Some forms occurred so often and in such considerable numbers that we were tempted to consider them fish associates. However, they did not attach on the body or gills as is seen in the velvet disease flagellate, and they appeared to have no effect on the skin or gills of fishes. These forms are worthy of monitoring, but we do not consider their presence harmful to fishes.
Significance to Sportfishing - These parasites can kill or stunt fishes confined in hatchery or culture conditions. This could become a problem in hatchery rearing of sport fishes for restocking. The conditions in Puerto Rico are ideally suited for this parasite. It is surprising that it has not caused more difficulties.
Preparation for Study - These dinoflagellates are usually examined in wet mounts for quick diagnosis or to determine the number present. They can be preserved in 10% formalin for further study. Specimens can be reared by confining fish with light infections in aquaria and sampling them until large numbers of this parasite are found or until an outbreak of velvet disease occurs.
Treatment - Formalin in 15-25 parts-per-million rates may be used in indefinite prolonged treatments in tanks or small ponds. Treatment is seldom practical or necessary in large bodies of water.
Comments - Velvet disease dinoflagellates are relatives to other dinoflagellate species which cause toxic red tide blooms (which kill millions of fishes and other marine or occasionally freshwater organisms) and ciguatera fish poisoning which plagues our island and many tropical regions.

***Trypanoplasma* sp.**

This highly dangerous parasite was isolated from a blue tilapia fish kill in 1974. It may have disappeared for lack of a transfer host. The spread of the leech *Myzobdella lugubris* may allow a resurgence of this pathogen.



Trypanoplasma sp.

Diagnostic Characters - A clear flagellate with a long flagellum at each end.

Records in Puerto Rico - Heavy infections in cultured blue tilapia caused fish kills in Lajas. We have not found this parasite in other tilapias, but cannot be certain that it no longer occurs in Puerto Rico. We suspect that it was introduced along with the fish host.

Geographic Range - Unknown. Similar blood flagellates are found in Europe, Asia and North America in freshwater and occasionally marine fishes.

Life History - Leeches feed on infected fishes and become intermediate hosts. Infected leeches then act as vectors to infect other fishes.

Location in Host - Blood, kidney and other organs.

Size - Cell 3.6 Fm, flagella 21.6 Fm long.

Host Specificity - Unknown. Similar species of blood flagellates prefer one fish species or fish family, while others infect a wide variety of fishes.

Damage to Host - Not well defined, but heavily infected hosts are listless, emaciated, and have sunken eyes.

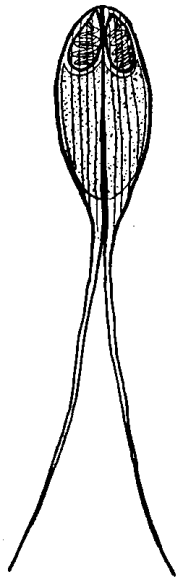
Detection - A drop of blood diluted with a drop of saline can be examined with a compound microscope to see the actively swimming flagellates.

Significance to Sportfishing - Potentially dangerous and damaging parasite. Fortunately, it does not appear to have become established in Puerto Rico. However, the spread of leeches into freshwaters may allow it to be reintroduced in tilapias and to infect sport fishes.

Preparation for Study - Blood is smeared in a thin layer on microscope slides by placing one drop of blood on one end of a slide, touching the back side of a second slide held at a 45E angle to the top of the drop, and drawing the drop across the first slide by pushing the second slide across it. The smear is dried at room temperature and stained with Geimsa.

Treatment - Removal of leeches.

***Myxobilatus mictosporus* (Kudo)**



Myxobilatus mictosporus

This parasite does not kill largemouth bass, but can reduce the productivity of our most important sport fish. Its spread should be controlled.

Diagnostic Characters - It is sperm-shaped with a double tail. The body contains two polar capsules in the anterior end and a single infective unit (sporoplasm) in the posterior end.

Records in Puerto Rico - Rarely found in largemouth bass at the Maricao Hatchery. This parasite is difficult to detect and may be present in other local largemouth bass and *Lepomis* spp. *Acolpenteron ureteroecetes* may occur with this protozoan.

Geographic Range - It is known from the eastern USA, and was probably introduced into Puerto Rico with sunfishes.

Life History - Spores leave the urinary bladder with urine. A fish is infected by eating spores which are dispersed on the bottom. The coiled filament in the polar body may be used to make a break in the intestine. The covering of the spore is digested away in the intestine. The motile stage (sporoplasm) moves through the small hole in the intestinal wall. It may undergo an asexual multiplication in the cells of the intestinal lining, or it may migrate into the blood stream. When it is transferred near the ureter or urinary bladder, it leaves the blood stream and penetrates this organ. A series of complicated asexual multiplications occur and eventually spores are produced. Spores leave the bladder in the urine.

Location in Host - It is found in the urinary bladder and ureter.

Size - Length 43.5-55.0 Fm, body 13.5-20.5 Fm, polar capsules 6.8 Fm.

Host Specificity - It only occurs in sunfishes (centrarchids).

Damage to Host - No associated disease has been noted.

Detection - A wet mount of a small piece of urinary bladder or urine must be examined with a compound microscope. Sometimes the spores cling to the tissue and are not found free in the fluid.

Significance to Sportfishing - It is unlikely to kill sunfishes, but can reduce their productivity. The largemouth bass is the most important sport fish in Puerto Rico; any reduction in the growth or reproductive potential of this fish is extremely significant.

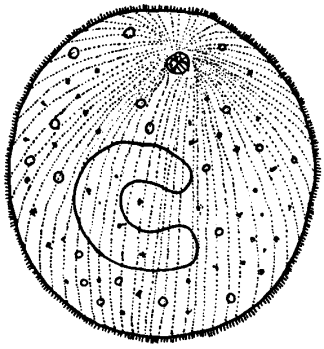
Preparation for Study - These myxosporidians can easily be identified in wet mounts. Samples can be preserved in formalin for further study.

Treatment - There is no method for killing these parasites in the urinary bladder of fishes. Once established in a population, they

cannot be eradicated. Spores on the bottom of ponds have been treated with a variety of chemicals but none have been completely effective. Treatment is not practical in large bodies of water. Infected fishes should be eliminated from the hatchery and the local distribution of this parasite should be determined. If all reservoirs are not infected, the transfer of largemouth bass should be controlled to prevent spreading this parasite.

***Ichthyophthirius multifiliis* Fouquet**

This ubiquitous fish parasite, commonly called "ich", can kill or injure sport fishes held in ponds or hatcheries. Outbreaks in confined fishes are often fatal.



Ichthyophthirius multifiliis

Diagnostic Characters - Ich is a relatively large, round to oval ciliate with an obvious, horseshoe-shaped macronucleus. In advanced infections, macroscopic white spots cover the hosts' body.

Records in Puerto Rico - Light infections occurred in Mozambique tilapia and largemouth bass at Lucchetti and oscars at the Maricao Hatchery. This pest has been involved with fish kills at the Lajas Agricultural Experiment Station. It is frequently found in local aquarium fishes.

Geographic Range - It is known from freshwater fishes around the world and is only excluded above 60-65E northern latitude. This parasite was probably brought into Puerto Rico with the first imported fishes. Ich may have originally come from China, but it was spread around so long ago that we can never be certain of its origin.

Life History - The larger, free-swimming ciliate from the host encysts on the bottom of the pond or tank and divides many times to form up to 1000 small ciliates. These ciliates break out of the cyst, swim up, locate a host, penetrate the skin and enlarge about 50 times. This large protozoan then breaks out of the skin, drops off the host and swims to the bottom to form a cyst. Depending on the temperature, the cycle takes 4-40 days. Optimum temperature is 25-27EC. The life cycle should proceed rapidly in Puerto Rico but in some parts of the island, the water temperatures may occasionally be too warm for optimum reproduction of this parasite!

Location in Host - Skin, fins, and gills.

Size - Infective stage 25-70 Fm, encysted stage 0.05-1.0 mm.

Host Specificity - Ich can attack any freshwater fish.

Damage to Host - The gills are extensively damaged during ich infections, but it is unclear whether the damage is caused by the

protozoan or by secondary bacterial or fungal infection. Hatchery or otherwise confined fishes can be killed by this disease, but low numbers may occur in wild fishes without causing obvious harm. Epizootics are called "ich disease" or "white spot disease".

Detection - White spots on the body of hosts are quite obvious. Large ciliated forms are easily seen in wet mounts of skin or gill scrapings with a compound microscope.

Significance to Sportfishing - This is a very serious pathogen in hatchery and pond culture conditions. Larger bodies of water may be affected if environmental conditions deteriorate. This pest has caused few problems in sport fishes in Puerto Rico, however, it has the potential to disrupt hatchery production and restocking efforts. Without careful diligence, ich disease could cause serious damage or losses in sportfish populations.

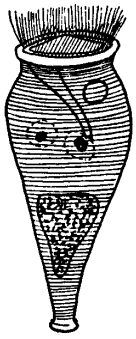
Preparation for Study - Ich can easily be identified in wet mounts. Pieces of gill or skin tissue can be preserved on 10% buffered formalin for future histological examination and confirmation of the disease.

Treatment - Ich disease is very difficult to treat. Infected fishes can be treated with formalin at 15-25 ppm in indefinite prolonged treatments in tanks or small ponds. This does not kill the encysted stages. Raising the temperature of a tank to 32EC for five days may weaken these stages. Treatment is seldom practical or necessary in large bodies of water.

Prevention is the best treatment in small ponds or tanks; avoid adding new fishes. If fishes must be added, quarantine them for a minimum of three days at 24 to 28EC, if no white spots appear then they can be placed in ponds or tanks. Ich outbreaks in larger bodies of water are usually attributed to poor environmental conditions. The best treatment in reservoirs is to improve these conditions.

Apiosoma piscicolum Blanchard

More than one species may be present on local freshwater fishes. This parasite occurred in low numbers on largemouth bass in Puerto Rico. Its propensity for bass make it a potential threat to these valuable fish. *Apiosoma micropteri* (Surber) has been reported from largemouth bass in the eastern USA but is apparently a synonym of *A. piscicolum*.



Apiosoma piscicolum

Diagnostic Characters - It is vase-shaped with a cone-shaped macronucleus in the posterior end of the body. The attachment base is relatively small. A ring of cilia surrounds only the unattached end.

Records in Puerto Rico - Very light infections occurred in 5-10% of largemouth bass in Toa Vaca and Lucchetti,

1 of 4 redeye bass in the Maricao River, 1 of 8 blue tilapia at the Lajas Experiment Station and in two Mozambique tilapia from Mandri Lagoon.

Geographic Range - It is known from North America, Eurasia and South Africa. This parasite was probably brought into Puerto Rico with largemouth bass imported from the USA in 1946.

Life History - Reproduction is by binary fission (asexual) or conjugation (sexual). Teletrochs (free swimming larvae) settle on new hosts.

Location in Host - Gills. It has been reported from gills and skin in other localities

Size - 30-45 Fm long. Reported elsewhere up to 110 Fm long

Host Specificity - Previously known from a great variety of freshwater fishes. Redeye bass, blue and Mozambique tilapia are new hosts.

Damage to Host - It is potentially harmful in large numbers especially to gill tissue where gas exchange may be impeded by the large numbers of parasites physically covering the gills.

Detection - It can be seen in wet mounts of gill filament clippings with a compound microscope.

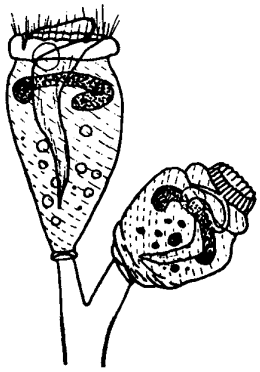
Significance to Sportfishing - It is not known to kill or damage fishes, but may slightly reduce their productivity.

Preparation for Study - These ciliates can be identified in wet mounts.

Treatment - Formalin treatments should control this ciliate.

***Epistylis colisarum* (Foissner and Schubert)**

This sessile protozoan causes red sore disease. Similar ciliates on other local fishes vary in size and shape, and possibly other species of *Epistylis* are present. This parasite is associated with large red sores which are often seen by bass anglers on largemouth bass in Puerto Rico. This disease is quite distressing to fishermen and may cause losses of bass. The same or similar protozoans were found on 10 other species of freshwater fishes and may infect any fish.



Epistylis colisarum

Diagnostic Characters - It is clear, sometimes golden or green if it is covered with dinoflagellates or algae. This parasite has an inverted bell-shaped body on a branched, non-contracting stalk. It is usually found in groups or colonies.

Records in Puerto Rico - It causes large, obvious red sores on Florida largemouth bass in Guajataca and largemouth bass throughout the island. This, or similar ciliates, are also found commonly on peacock bass, all catfishes and tilapias, bluegill, redbreast sunfish, and

threadfin shad. We have also seen *Epistylis* sp. on freshwater shrimp in Puerto Rico.

Geographic Range - It is known from the USA, eastern Asia and aquarium fishes in Germany. This parasite was probably brought into Puerto Rico with largemouth bass imported from Louisiana in 1946.

Life History - Reproduction is by binary fission (asexual) or conjugation (sexual). Teletrochs (free swimming larvae) settle on new hosts.

Location in Host - Skin, sometimes gills.

Size - Individual bells 50-60 Fm long, colony may be visible grossly.

Host specificity - Reported from bluegill, channel catfish, green sunfish *Lepomis cyanellus*, largemouth bass and striped mullet *Mugil cephalus* in the USA, and can probably be found on almost any freshwater fish. Other species have been reported on fish parasitic copepods.

Damage to Host - Scales may be exposed because of catch and release handling, fighting, or nest building. The protozoan attaches to and erodes a hole in the scale. Bacteria associated with this parasite cause inflammation in the skin around the attachment site and the red sores appear. Further bacterial invasion may kill fishes. Some researchers suggest that the ciliate is responsible for the inflammation and bacterial invasion occurs as a secondary infection. Others suggest that the bacteria is responsible for the inflammation and the ciliate is only incidental. Interestingly, one of these pathogens erodes holes in the scales. This characteristic holes-in-the-scales condition does not occur in bacterial lesions of bass when the ciliate is not present.

We believe that this disease is caused by the combined effects of the association between the ciliate and the bacteria. This may be the first known example of a mutualistic (benefiting both) relationship between a parasite of fishes and a bacterial pathogen of fishes. If we are correct, the cooperation produces a synergistic effect which neither pathogen could have created alone. To test our hypothesis, experimental work is necessary to determine if the ciliate, the bacteria, or their combined effect actually causes this disease.

Even when sores are not formed, these ciliates are harmful in large numbers to a variety of fishes especially those in culture facilities or ponds. They may become an added complication during poor environmental conditions or during outbreaks of other pathogens.

Detection - Red sores are large and obvious on largemouth bass. Fish scales in the areas of sores have characteristic holes which can be seen grossly when a loose scale is held up to the light. Protozoans from bass sores and scrapings of fin or skin of other fish species without obvious sores can be seen in wet mounts examined with a compound microscope.

Harm to Humans - The ciliate has not been known to harm humans, but the associated bacteria has been implicated in skin sores on the hands of fishermen and fish handlers. This disease can be serious in humans. The sores can be painful, respond slowly to treatment and

may persist stubbornly. If you have open cuts on your hands, it might be prudent to avoid touching red sores on bass.

Significance to Sportfishing - The ugly sores produced by this parasite-bacterial association are obvious and alarming to fishermen. Some bass die as a direct result of these infections, and these infections may contribute to other diseases that cause catch-and-release deaths. These sores largely occur during the breeding season and may detract from the reproductive success of bass. The affect of this disease on the spawning of largemouth bass warrants additional research. The largemouth bass is an important sport fish in Puerto Rico. Any reduction in the reproduction, growth or size of this fish is extremely significant.

Preparation for Study - These ciliates can easily be identified in wet mounts. Samples can be mounted in glycerine jelly. Identification to species requires more elaborate preparations. A number of relaxation, fixation and staining techniques can be employed, but these are complicated, unpredictable and usually not necessary for routine examinations.

Treatment - Catch-and-release fishing has become a very popular bass tournament technique in Puerto Rico. This has the added advantage of making many bass with red sores available for treatment. A direct (topical) application of an antiseptic (such as iodine) on the wound (lightly dab, do not rub) might help to kill both the ciliate and the bacteria, but this technique needs testing.

***Ambiphrya ameiuri* (Thompson et al.)**

This parasite occurs in the gills of Mozambique tilapia and sometimes on other fishes in Puerto Rico. It is unlikely to cause disease problems.

Diagnostic Characters - This barrel-shaped ciliate has a ribbon-shaped macronucleus through most of the body. The attachment base is expanded. Rings of cilia surround the middle of the body and the unattached end.

Records in Puerto Rico - It occurred rarely and in light to heavy infections on Mozambique tilapia in Lucchetti and Cidra, and in light to heavy infections in the Guanajibo River and Mandri and Santa Teresa Lagoons. It was also found in moderate infections on ladyfish, redear sunfish and tarpon in the Santa Teresa Lagoon.

Geographic range - Found in North America and Europe. It was introduced to Russia on channel catfish and was probably brought to Puerto Rico on exotic fishes from the USA.

Life History - Reproduction is by binary fission (asexual) or conjugation (sexual). Teletrochs (free swimming larvae) settle on new hosts.

Ambiphrya ameiuri

Ecology - This parasite occurs in brackish waters of the Baltic Sea. It appears to range from fresh to brackish water in Puerto Rico.
Location in Host - Gills, skin, and fins.
Size - 80-100 Fm long.
Host Specificity - This species has been reported from bluegill, brown bullhead, channel catfish, grass carp and other fishes. In Puerto Rico it was found most frequently on the Mozambique tilapia but occurs on other species. All hosts in Puerto Rico are new host records.
Damage to Host - This protozoan feeds on waterborne organic particles and does not directly damage the epithelium. It is potentially harmful in large numbers especially to gill tissue where gas exchange may be impeded by the large numbers of parasites physically covering the gills.
Detection - It can be seen in wet mounts of gill filament clippings and skin and fin scrapings examined with a compound microscope.
Significance to Sportfishing - This parasite is not known to kill or damage wild fishes, but may reduce their productivity. It could also be potentially dangerous in hatchery situations.
Preparation for Study - These ciliates can easily be identified in wet mounts.
Treatment - Formalin treatments should control this ciliate.

Trichodinids

These clear protozoans in the genera *Trichodina* and *Trichodinella* are saucer or hat shaped. They were one of the most frequently encountered parasites in our examinations. Trichodinids are distinctive for their ring of chitinoid teeth (denticles), hooked together like plastic pop-beads to form a flexible, crown-like skeleton the center of the cell. The number and shape of teeth and body size are used to distinguish species. Most were brought to Puerto Rico with their exotic fish hosts. They all have direct development on the host with both asexual and sexual reproduction. Thus, population levels can increase rapidly during crowding and poor environmental conditions for the fish hosts. Parasites can then cover gill lamellae and cause gill irritation resulting in death or stunting of fishes. This is particularly important when fishes are in hatchery production for stocking reservoirs or in commercial production. These parasites may be detected and identified in wet mounts of scrapings of skin or fins or in gill clippings examined with a compound microscope. In reservoirs, they are not known to kill or damage sport fishes, but the presence of this ciliate may slightly reduce their productivity. Samples can be mounted in glycerine jelly or preserved in 10% formalin. Exact confirmation of the species requires elaborate preparations. A number of relaxation, fixation and staining techniques can be employed, but these are complicated, unpredictable and usually not necessary for routine examinations. Formalin treatments should control these ciliates.

Trichodina discoidea Davis

This parasite occurs in the gills of channel catfish in Puerto Rico and may eventually be found in sunfishes.

Diagnostic Characters - There are 19-26 denticles in the crown. The outer flange of each crown segment (blade) is paddle-shaped. The skirt (adhesive disk) is as wide or wider than the body.

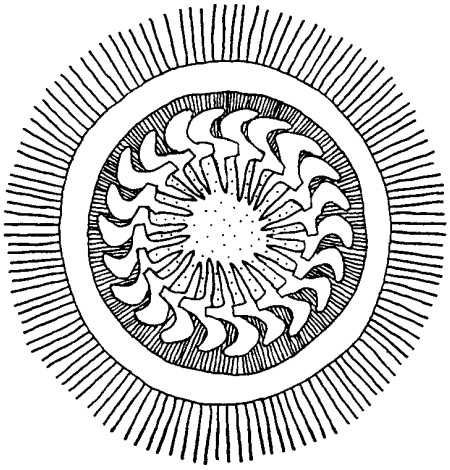
Records in Puerto Rico - Light infections were found on 2 of 3 channel catfish in La Plata. Probably, it can occur on any channel catfish here.

Geographic Range - It is known from the midwestern and southeastern USA. It was probably brought to Puerto Rico with the original shipment of channel catfish in 1938.

Location in Host - Gills.

Size - 36-50 Fm wide.

Host Specificity - It is known from bluegill, other sunfishes and channel catfish.



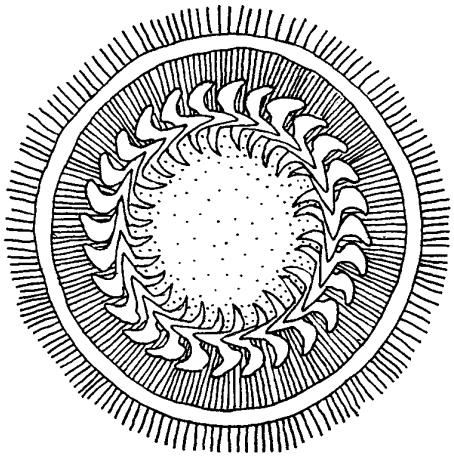
Trichodina discoidea

***Trichodina fultoni* Davis**

This parasite occurs in the gills of bass and occasionally Mozambique tilapia in Puerto Rico.

Diagnostic Characters - The body is relatively large with 25-30 (usually 28) denticles in the crown. Stout, curved upper spines (rays) occur on the denticles. It is similar to *Trichodina pediculus* in size and number of denticles, but the denticle rays are thicker, shorter and curved in *Trichodina fultoni* and the denticle in *Trichodina pediculus* has a distinct step down in its central part.

Records in Puerto Rico - Light infections occur commonly in Florida largemouth bass in Guajataca and largemouth bass around the island. It has also been found in Mozambique tilapia from the Loiza River. Moderate infections occurred in largemouth bass in fry reared at the Maricao Hatchery.

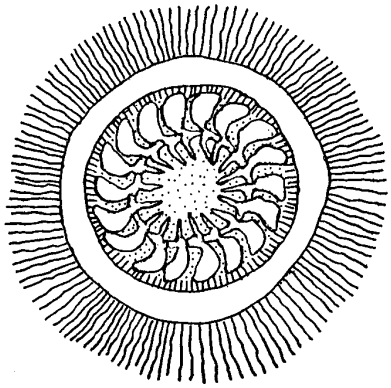


Trichodina fultoni

Geographic Range - North America and Eurasia. This parasite was probably brought into Puerto Rico with largemouth bass in 1946.
Location in Host - Skin of adult and skin and gills of fry of largemouth bass and gills of Mozambique tilapia. Occurs mostly on the skin and fins of fishes in the USA.
Size - 88-104 Fm wide.
Host Specificity - It is known from channel catfish, sunfishes, two other families of fishes, and even a salamander. Since it occurs in two Classes, four Orders and 10 species of aquatic organisms, this parasite has little specificity. We are uncertain why the number of host species infected by this ciliate has been so restricted in Puerto Rico.

***Trichodina microdenticula* Wellborn**

This ciliate has survived and prospered in Puerto Rican waters for more than 30 years. It seems to only parasitize the threadfin shad.
Diagnostic Characters - The body is relatively small with 15-18 denticles in the crown.
Records in Puerto Rico - Light to moderate infections are commonly found in threadfin shad in reservoirs around the island.
Geographic Range - The host native range was from south Florida to Guatemala, and it has been introduced to east and west coast drainages in the USA and elsewhere. The exact distribution of this parasite is unknown. It must have been brought into Puerto Rico in threadfin shad imported from the USA in 1963. This was probably the only introduction.

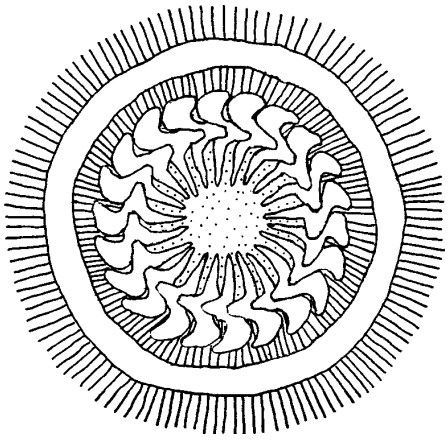


Trichodina microdenticula

Location in Host - Gills.
Size - 22-37 Fm wide.
Host Specificity - This parasite only occurs on the threadfin shad.
Significance to Sportfishing - Threadfin shad were stocked as a food item for largemouth bass. Thus far, this ciliate has not caused any noticeable problems in producing these baitfish. Fortunately, it has not infected other species of fishes here, yet.

***Trichodina pediculus* sensu Wellborn**

Arthur and Lom (1984) separate "*Trichodina pediculus* sensu Wellborn", which occurs on the largemouth bass in North America, from *Trichodina pediculus* (Müller), which occurs on invertebrates and fishes in Eurasia. This apparently new species requires additional study, description and some redefinition. This formerly prudish ciliate seems to be moving to every available host. Its ability to infect hosts seems to have exploded in the new environment. This may be notable as an example of an exotic parasite exploiting open niches, but it could be bad news for sport fishes.



Trichodina pediculus

Diagnostic Characters - The body is relatively large with 22-26 (usually 23) denticles in the crown. Denticles have long, straight upper spines (rays). It is similar to *Trichodina fultoni* in size and number of denticles, but the denticle rays are thicker, shorter and curved in *Trichodina fultoni* and the denticle in *Trichodina pediculus* has a distinct step down in its central part.

Records in Puerto Rico - Light infections occurred on brown bullhead and white catfish in Guayabal; redbreast tilapia in Cidra, Guajataca and La Plata, Mozambique tilapia in Lucchetti, Cidra and Cartagena Lagoon; Florida largemouth bass in Guajataca; largemouth bass in Toa Vaca, La Plata, and Lucchetti; Bluegill in Guajataca and Maricao Hatchery; redear sunfish in La Plata. Moderate infections occurred on fry of largemouth bass reared at the Maricao Hatchery.

Geographic Range - Known from the southeastern USA. This parasite was brought into Puerto Rico in largemouth bass imported in 1915, 1916 or 1946.

Location in Host - Skin, fins and gills.

Size - 61-86 Fm wide.

Host Specificity - Previously reported from largemouth bass and Florida largemouth bass in the USA. All local hosts mentioned above, except these two basses, are new records for this parasite. The *Trichodina* sp. reported from pumpkinseed *Lepomis gibbosus* in Cuba (Arthur and Lom 1984) is probably the same protozoan.

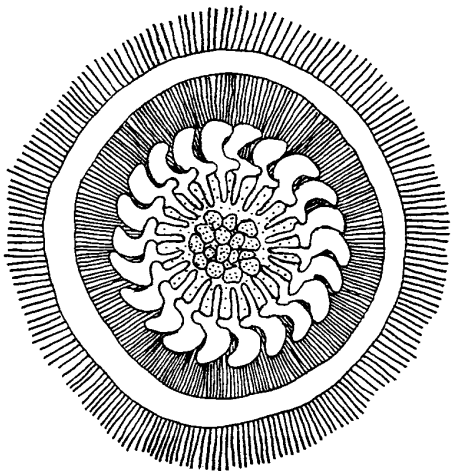
Comments - The great expansion of host species by this ciliate may be part of the "evolution" of our island parasite fauna. This is the sort of movement into open niches that we would expect to see in some opportunistic parasites.

***Trichodina reticulata* Hirschmann and Partsch**

This distinctive and widespread parasite is specific to goldfish, but kills both goldfish and carps in culture.

Diagnostic Characters - The body is relatively large with 23-33 (usually 28) denticles in the crown. It also has a central reticulated mass.

Records in Puerto Rico - Low infections occurred in goldfish from ponds near Mayaguez and aquaria around the island.



Trichodina reticulata

Geographic Range - This ciliate has been spread all over the world and has probably been brought into Puerto Rico repeatedly on goldfish imported for the aquarium fish and ornamental fish trade. The original source of this parasite may have been China, but the goldfish has been shipped freely around the world for so many centuries that this cannot be determined.

Location in Host - Gills. It has been reported mostly on fins and body.

Size - 71-95 Fm wide.

Host Specificity - It is known to parasitize goldfish and other cyprinids, but did not infect local fathead minnows or rosy barbs.

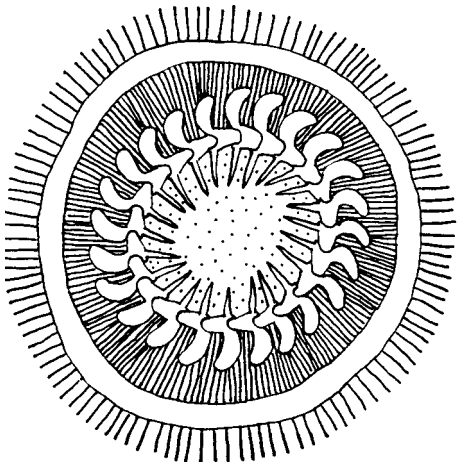
***Trichodina vallata* Davis**

This parasite occurs in the gills of the channel catfish in Puerto Rico. It was introduced from the USA.

Diagnostic Characters - The body is of moderate in size, and has 20-23 (usually 22) denticles in the crown.

Records in Puerto Rico - Light infections occurred on a few channel catfish in La Plata. It probably can occur on any channel catfish in Puerto Rico.

Geographic Range - It is only known from the USA. This parasite was probably introduced to Puerto Rico with channel catfish from the USA in 1938.
Location in Host - Skin. Previously reported from fins, body and gills.
Size - 52-70 Fm. wide
Host Specificity - Only known on channel catfish.

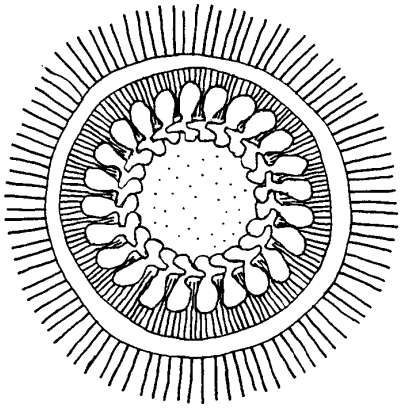


Trichodina vallata

***Trichodina* spp.**

A number of unidentified and possibly some undescribed species exist in Puerto Rican freshwater fishes. They require further study.

Diagnostic Characters - We have examined so few specimens of some trichodinids that we cannot be certain what species they may represent. Others may represent new species.
Records in Puerto Rico - Light infections occurred on a few blue tilapia and guppies from Lajas; channel catfish, common snook and white mullet from the Añasco River; and mountain mullet, Nile and red tilapia in the Maricao Hatchery and tarpon from Urban Pond.
Geographic Range - The distribution of these species cannot be determined until their exact identities are known. Some of these species may have been introduced into Puerto Rico while others may be native.
Location in Host - Skin, fins and gills.
Size - Sufficient variation occurs to suggest that several species exist.
Host Specificity - The host preferences of these species cannot be resolved until their exact identities are determined.



Trichodinella sp.

***Trichodinella* sp.**

This small ciliate was introduced with the oscar and could potentially spread to other fishes. Identification of species in this genus requires access to numer-

ous specimens which must be submitted to a series of complex preparations. We have seen this parasite too rarely and in too few numbers in Puerto Rico to make an exact identification. Prieto (1991) found *Trichodinella epizootica* (Raabe) in Cuban channel catfish.
Diagnostic Characters - This ciliate lacks the inner spine which occurs in the other local trichodinids, and is smaller than the others.
Records in Puerto Rico - Light infections occur on all oscars at the Maricao Hatchery.
Geographic Range - Probably in the wild in Brazil, south Florida and Puerto; and on aquarium oscars around the world. It was introduced into Puerto Rico with this aquarium fish.
Location in Host - Skin.
Size - 21-49 Fm wide.
Host Specificity - Only occurs on the oscar.

CHLOROPHYTA (GREEN ALGAE)

The name "algae" is Latin for "seaweed". Most scientists agree that green algae were the ancestors of all plants. Why this relationship does not place them in the Kingdom Plantae in most modern classifications is enigmatic. They are important for fixing more than a billion tons of carbon each year and being a vital component in the food chain of many organisms. Many of these large seaweeds are commercially important. Some green algae are symbiotic in other organisms and a few occasionally infect fishes. They vary from uni-cellular, colonial to multicellular; from the "slime" that makes you slip on the boat ramp to the larger algae used in aquaria. More than 7000 species have been described. Many different sexual and asexual reproduction systems occur in this diverse phylum. Most are free living, but a few associate with or parasitize other organisms.

Two kinds of algal associations occur in local fishes. The simplest is various algae growing on any exposed hard surface whether bone from a wound, externally attached crustacean parasites or fish tags. Miller and Ballantine (1974) found green algae (and brown algae) growing on the exposed opercular bones of blue tilapia held in sea water. These are not parasites, but the same algae that grow on the bottom of your boat, or on any unprotected surface. The second and more complicated association occurs beneath the surface (epithelium) of the gill filaments or skin of local fishes. These are parasites.
Reference - "Introduction to the Algae" (Bold and Wynne 1985).

Phylum (or Division) Chlorophyta Taxonomy and Contents Page
Class (or order) Chlorococcales
Family Oocystaceae (or Chlorococcaceae)
Chlorella sp. 21

***Chlorella* sp.**

This algae will have to be isolated and cultured before it can be identified. Possibly more than one species or a combination of green and blue-green algae may occur in infections. It was found in wild, not cultured, fishes in Puerto Rico. Such a scenario is opposite that reported in similar algal infections around the world where it has been found in fish kills and in other debilitated fishes in confinement or aquaculture. Its identity, significance and impact require additional study.

Diagnostic Characters - Algae appear as green to gold globular bodies.

Records in Puerto Rico - This parasite occurs rarely and unpredictably. We have seen 12 infections in 9 collections of brown bullhead (1), Mozambique tilapia (1), redbreast tilapia (8), redeye bass (1) and threadfin shad (1), from Cidra, Guayabal, Lucchetti and Toa Vaca, and the Loiza and Maricao Rivers. All but four fishes were in reservoirs and the rest were in rivers. Oddly, we have never seen this parasite in Maricao Hatchery, Lajas aquaculture facility or in commercial tilapia culture facilities. It was associated with a fish kill, and with bacterial diseases in a few fishes, but the majority of infected fishes appeared otherwise healthy.

Geographic Range - The distribution of this parasite cannot be determined until the exact identity is known. Similar parasites have been reported in the USA and around the world. This could be a local algae, or an introduction to Puerto Rico with aquarium fishes.

Life History - Little is known about how these parasites are transmitted or reproduce. In the USA, fishes have been experimentally infected by injection. Offspring (4-16) are produced asexually.

Location in Host - Found between epithelial cells of gill filaments, but in threadfin shad it was under the epidermis (possibly another species).

Size - 6-14 Fm (reported as 7-10 Fm in other fishes).

Host Specificity - Reported from bluegill, kissing gourami, green swordtails in the USA and other fishes around the world. In Puerto Rico it was found mostly in the redbreast tilapia, but also in the Mozambique tilapia, brown bullhead and possibly threadfin shad. It probably can occur in any freshwater fish.

Damage to Host - Damage was not obvious in histological sections of infected gill filaments. More study is necessary to determine the potential of this parasite to injure fishes. Other internal algal infections occasionally cause mass mortalities of fishes in hatchery and fish culture conditions.

Detection - It can be found by examining clippings of gill filaments in a wet mount with a compound microscope.

Harm to Humans - Some algae that produce disease in fishes also cause disease in other animals, including humans. Caution should always be exercised when dealing with a poorly known parasite.

Significance to Sportfishing - This algal parasite requires more study before we can adequately assess its potential to damage sport fishes on the island. It may be involved in some of our persistent fish kills.

Preparation for Study - These parasites can be identified in wet mounts only as a "unicellular algae". This does not even place them in a Kingdom. Gills with algae can be preserved in 10% formalin for later study. Culturing this algae may be the only way to obtain sufficient information to make proper identifications.

Treatment - Chemical treatments are ineffective and ill advised. Shading fishes with algal infections should be attempted.

Comments - Some of the Puerto Rican cases in redbreast tilapia and a brown bullhead were in an area of Cidra where a number of persistent fish kills had recently occurred, or in redbreast or Mozambique tilapias which had other diseases. The deteriorated condition of the local environment or these hosts may have contributed to the initiation of these unusual algal infections. We need to learn if this is a parasite or an aberration caused by abnormal environmental conditions.

Similar algal parasites were found in the USA, Europe and Asia because they killed fishes in culture facilities or small ponds. Our records may be the first reports from wild fishes.

OOMYCOTA (WATER MOLDS AND ALLIES)

These are fungal-like organisms grouped into Phylum Oomycota in the Kingdom Protista (some mycologists place it in Kingdom Fungi). We call them "fungal-like" because the true fungi are now placed in a different kingdom. One, called the potato blight, killed all the potatoes in Ireland and Germany during the 1900s causing the famous Potato Famine. It incited mass migrations of humans. Grapes, salmon and other commercially important products are killed by these organisms. Hundreds of species are known. The exact number is difficult to estimate as many are poorly known or defined. Cell walls of cellulose surround these organisms but do not separate them into segments, except around sexual organs. Branching is irregular. Branches or projections are called hyphae. They produce motile spores with two flagella in zoosporangia. This is the primary means of asexual reproduction and dispersal. Thick-walled resting spores (oospores) are produced by sexual reproduction. Male and female structures are formed on the ends of hyphae. They occur in most freshwater habitats, moist soil and occasionally on plants, attacking tissues and eggs of various organisms. Species in nine genera in Family Saprolegniaceae and one genus in Class Lagenidiales parasitize live fishes. They are largely opportunistic parasites. Food is obtained by extending hyphae into their hosts tissues, releasing digestive enzymes, and absorbing the resulting nutrients.

Reference - "Fungal Diseases of Fish" (Neish and Hughes 1980).

Phylum Oomycota (or Phycomycetes) Taxonomy and Contents

***Saprolegnia* spp.**

Saprolegnia parasitica Coker is the species most commonly noted to attack fishes and fish eggs in fresh water around the world, but other *Saprolegnia* species and similar species in *Achlya* and other genera appear and behave similarly. Individual species are difficult to identify. They are widespread and ever-present, often attacking wounds and eggs of fishes. These fungi can be a persistent problem in culture or poor water-quality conditions and have caused regional mass mortalities.

Diagnostic Characters - The fuzzy or cotton-like appearance of these organisms in wounds of fishes or among egg masses is easily recognized. Microscopically, the clear fungal hyphae are not separated by septa.

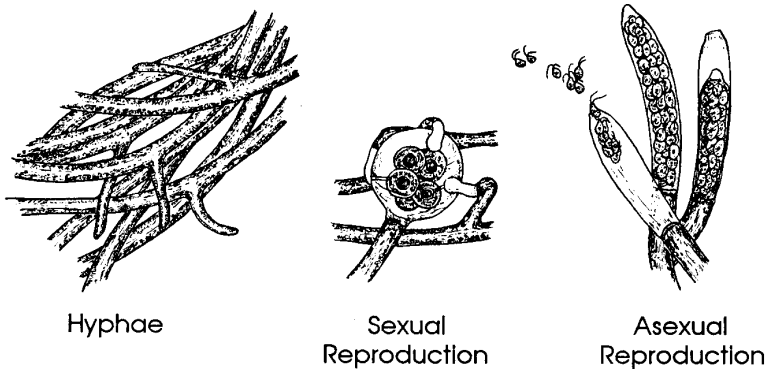
Color - White, occasionally contaminated with algae (green), diatoms (yellow), or sediment (brown).

Records in Puerto Rico - We have seen this disease (saprolegniasis) affecting 3 of 23 largemouth bass and 1 of 14 bluegill in Lucchetti; 8 of 32 Florida largemouth bass and 1 of 3 redbreast tilapia in Guajataca; occasionally in kissing gourami at the Maricao Hatchery and in Mozambique tilapia across the island. It can probably attack any freshwater fish on the island. In one outbreak, 1 of 8 oscars and 33 of 100 Wami tilapia at the Maricao Hatchery were damaged in handling. Two weeks later the oscar and 11 of the tilapia developed saprolegniasis. Often, badly injured fishes suffer *Saprolegnia* spp. infections.

Geographic Range - This species or complex of species is known from around the world. It was probably introduced into Puerto Rico with exotic sport fishes or aquarium fishes, but native species may also exist.

Life History - It usually lives on decomposing materials, but a fish can become infected in a wound or on dead tissue. Dead eggs spread *Saprolegnia* spp. to live ones. Direct development can occur on the host with both asexual and sexual reproduction. A complete life cycle can occur in 1-2 days, depending on the water temperature. The infection is spread from fish to fish by spores, not by direct contact with fungal hyphae on an infected host.

Location in Host - Usually on the body, but sometimes on fins, rarely gills, or very rarely internal.



Saprolegnia spp.

Size - The white fungal mass (mycelium) may be several centimeters in diameter. Microscopically, the hyphae are 20 Fm wide.
Host Specificity - It can attack any freshwater fish.
Damage to Host - Every egg mass and many fishes infected by this fungus will die unless treated. As the infection progresses, the host becomes less active, changes behavior, and may be eaten by predators. Regional mass mortalities have occurred in the USA and Europe. It does not produce toxins. Damage is caused by hyphal growth. Bacteria may associate with fungus in wounds and internally causing additional damage to the host.
Detection - An obvious, white fuzzy mass occurs on fish or eggs. It can be identified to Order in wet mounts with a compound microscope.
Significance to Sportfishing - Largemouth bass from catch-and-release tournaments may be susceptible to fungal infections. Dab treatments of antiseptics might also be useful in treating wounds on released bass to prevent fungal infection. Both the wounds and the stress of catching and handling make bass susceptible to saprolegniasis.

These fungi also seem to become particularly important in hatchery culture and in times of low water quality. This may make the production of eggs and young sport fish for restocking more difficult. Infections may intensify fish kills in wild sport fish populations when reservoir water levels are low or excessive weeds are present.
Preparation for Study - Isolates from fish or eggs can be reared in the laboratory. *Saprolegnia* spp. is probably the only fish parasite that grows equally well whether its host is dead or alive.
Treatment - Salt at 30 grams/liter may be used as a treatment or 25 ppm formalin. Dead eggs should be removed from cultured egg masses to prevent further infection. Spores, particularly the thicker-walled

ones produced by sexual reproduction, may be resistant to treatments. This makes control or eradication more difficult.

PLATYHELMINTHES (FLATWORMS)

Flatworms form a phylum of soft-bodied, bilaterally symmetrical, flattened, worm-shaped animals. Usually each worm has a set of both female and male organs (hermaphroditic). They either have a primitive blind gut and a mouth, or absorb nutrients through their bodies. They respire through their skin and possess specialized cells that secrete ammonia waste products. There are about 20,000 species of flatworms including the gillworms, flukes and tapeworms.

Phylum Platyhelminthes Taxonomy and Contents . .. . Page

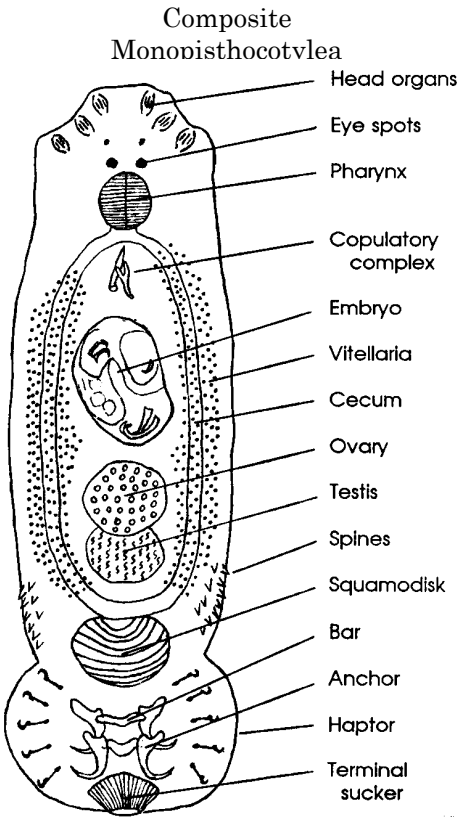
MONOGENEA (GILLWORMS)

The name "monogenea" means born once, and refers to the simple life cycle. In heavy infections they can kill captive fishes and occasionally wild ones. More than 1500 species have been described, but this is probably only a small percentage of those existing. Adults range from 30 Fm to 2 cm in length and are transparent, creme or pink. Gillworms have a distinct attachment organ on their posterior end (haptor) with hardened anchors or specialized clamps with which to pierce the epithelium and hold on to the host. Sclerotized marginal hooks often surround the haptor, and bars, disks, scales or hooks may occur on or near the haptor. The head sometimes has eye spots and specialized holdfast organs. Most reproduce by laying eggs that hatch ciliated larvae (onchomiracidia) and quickly mature and attach to the host. Some have a uterus and produce an easily seen embryo that emerges almost mature with another developing embryo already inside it. Since no stages on intermediate hosts are necessary, they can reproduce rapidly. When reduced water levels or intensive culture crowds fishes together and allows most gillworm offspring to survive, they can quickly begin to kill fishes. Gillworms are permanent parasites in the gills, mouths or on the bodies of fishes. Some occur in the nares, pockets in the lateral line or rarely in the gut of fishes. Some species occur in the urinary bladder of fishes, frogs or turtles. They generally feed on mucus or epithelial cells sloughed from the gills or skin. Simple gillworms are common on fishes in all aquatic environments.
Reference: "How to Know the Trematodes" (Schell 1970).

Class Monogenea Taxonomy and Contents ..... **Page**

Monopisthocotylea

Monopisthocotylea have simple attachment organs, usually a haptor with 1-2 pairs of anchors with interconnecting bars. These worms are generally much smaller than Polyopisthocotylea. Capsalids are an exception, with worms as large as 0.5 cm, but they still have simple haptors.



These parasites can normally be found in wet mounts of skin scrapings or clippings of gills observed with a compound microscope. Absence in samples does not assure that fishes are free from these parasites. Gillworms are usually small and when they occur in low numbers, they can often be difficult to detect. Parasites can be relaxed in 1 part formalin to 4000 parts freshwater until dead, fixed in 10% formalin and mounted in glycerine jelly. Relaxed specimens can be stored in 10% formalin.

Our examinations of adult wild fishes suggest that these worms usually do little physical damage in reservoir environments even with infections of 500 or more worms per fish. Under extreme environmental conditions (water draw-downs, drought, poor water quality or turn-overs) they could contribute to mortalities. They are more of a problem in hatchery rearing of fishes for stocking, where crowded conditions, poor water quality and low water flow rates can enhance the buildup of worms on the gills.

In heavy infections, attachment of worm hooks causes skin or gill irritation and a heavy production of mucus. Skin may have white patches especially behind the fins, gills may thicken. Fishes may exhibit flashing behavior and scrape their bodies on the sides of the tank. Swimming may alternate between wildly active and lethargy. Secondary bacterial infections can enter areas of damage, further weakening the fish.

If treatments become necessary, formalin at 250 parts per million

(ppm) for one hour will remove most parasites. A follow-up treatment not less than three days later may be necessary. Some fishes may be sensitive to that level of formalin; they may be treated at 167 ppm and the treatment repeated every other day until parasites are gone. A variety of chemicals can be employed in aquaria, hatcheries or small ponds (Hoffman and Meyer 1974, Post 1987). Treatment in reservoirs or streams is usually impractical or impossible. Increasing the water flow rate in hatchery situations may flush out early stages of gillworms in the water and slow their accumulation on the gills. It should be noted that no treatment will eliminate all parasites, some will always remain. Treatments reduce the numbers to tolerable loads for fishes. It is almost impossible to eliminate gillworms from a system, once infected. This should be kept in mind when importing fishes to new areas.

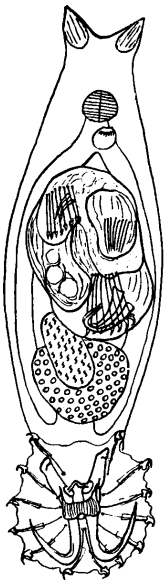
Competition and interaction among parasites is complex. In the native habitat of fish hosts so many species of parasites occur on the gills that examining competition between two species is almost impossible. In Puerto Rico, this situation has been simplified. Largemouth bass have fewer gillworm species (*Clavunculus bursatus*, *Actinocleidus fusiformis*, and *Haplocleidus furcatus*). With fewer species, natural competition between species may be more easily studied. The very recent introduction of *Onchocleidus principalis* on Florida largemouth bass may complicate this situation. Even if the new gillworm spreads to most local basses, the mix of parasite species will still be rather simple. The same simplified competition occurs in gillworms found in *Lepomis* spp. (*Haplocleidus furcatus*, *Onchocleidus ferox* and *Actinocleidus gracilis*); and tilapias (*Cichlidogyrus tilapiae* and *Gyrodactylus cichlidarum*). The three gillworms on the largemouth bass usually occur on every bass, while the three gillworms on the local *Lepomis* spp. often occur alone, or in two-species combinations. *Haplocleidus furcatus* is the most successful of all these parasites, occurring much more often and in higher numbers than any of the others on Puerto Rican centrarchids. Knowledge of competitions obtained in our simplified environment may have applications in fish management, hatchery or aquaculture production of these fishes in the USA and Africa.

The seasonal change in the numbers of gillworms on the largemouth bass in the Maricao Hatchery and Guajataca Lake was examined by Pomales and Williams (1980). Williams and Williams (1993) found higher numbers of these worms in lowland reservoirs than in upland reservoirs. A greater understanding of the biology of these parasites may aid in developing control and eradication methods.

***Gyrodactylus cichlidarum* Paperna**

This small, but dangerous worm lives on the body of tilapia. Under crowded conditions or poor water quality, its direct reproduction allows it to quickly overpopulate hosts causing kills.

Gyrodactylus cichlidarum



Diagnostic Characters - This small gillworm has one pair of anchors and a prominent shield across the top of the anchors. A large embryo is visible in the body of the adult.

Records in Puerto Rico - Very heavy infections were found on blue tilapia during an epizootic at the Lajas Agricultural Experiment Station and moderate infections occurred on Mozambique tilapia at Lucchetti.

Geographic Range - Originally found in Africa and western Asia but now introduced in many areas of the world with tilapias. This worm was probably introduced to Puerto Rico in 1988 with stocks of blue tilapia from Auburn University. This case illustrates the risks involved in reintroducing fishes and inadvertently introducing additional parasites. This worm is a particularly dangerous parasite that did not occur in Puerto Rico. The advantages of genetic improvement of stock must be weighed against the risks of bringing in new, possibly very dangerous parasites, before reintroductions are made.

Location in Host - It has been reported from the gills and skin of fishes in Africa, but we found it on the skin and fins of tilapias in Puerto Rico.

Size - 0.3-0.4 mm long.

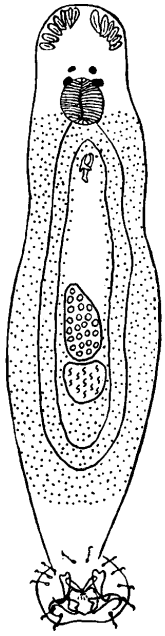
Host Specificity - This parasite has been reported on a variety of tilapias and other cichlids in Africa. Its limited host specificity may allow it to attack all tilapias, peacock bass, oscar, and possibly other cichlids here.

Significance to Sportfishing - This gillworm may be dangerous for peacock bass because of its attraction to cichlids in general and because this species lost its native gillworms when introduced.

Comments - Our first examination of this parasite in Puerto Rico was due to an epizootic of blue tilapia held in an aquaculture facility. This parasite produces an almost mature offspring which attaches immediately to the parent's host. Thus, large numbers of parasites can build up on a host in a short period of time. Individuals are spread from fish to fish by direct contact. This monogenean can be extremely damaging in hatchery, culture or aquarium situations.

***Actinocleidus fusiformis* (Mueller)**

Actinocleidus fusiformis



Placed in the genus *Syncleithrum* by some authors, this distinctive worm is found commonly on all local populations of largemouth bass. It has killed local hatchery bass.

Diagnostic Characters - Bars on the anchors are joined in the center. The upper bar is broad and fan-shaped.

Records in Puerto Rico - Moderate infections occurred on most largemouth bass in the Maricao Hatchery, 6 of 12 from La Plata, 11 of 23 from Lucchetti and 19 of 32 Florida largemouth bass from Guajataca. Probably every population of largemouth bass in Puerto Rico has these parasites (USNM). This worm shares the gills of largemouth bass with *Clavunculus bursatus* and *Haplocleidus furcatus*.

Geographic Range - It is found throughout the USA wherever largemouth bass occur. These parasites apparently came to Puerto Rico with shipments of bass from the USA in 1946.

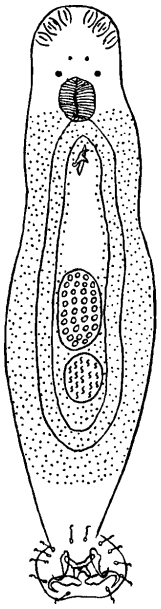
Location in Host - Gill filaments.

Size - 0.60-0.72 mm long.

Host Specificity - Reported on largemouth, spotted *Micropterus punctulatus* and smallmouth *Micropterus dolomieui* basses in the USA. In Puerto Rico it occurred on largemouth but not redeye bass.

Damage to Host - Epizootics have been caused by this gillworm in hatchery-reared largemouth bass fingerlings in Puerto Rico.

Actinocleidus gracilis



***Actinocleidus gracilis* Mueller**

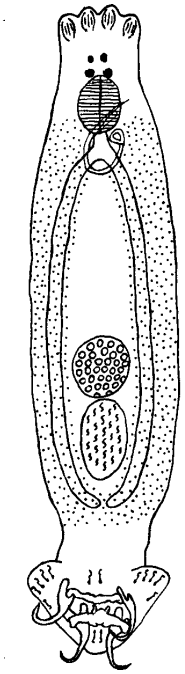
When introduced into Puerto Rico, these common gillworms spread from bluegill to two new hosts, redbreast and redear sunfish, .

Diagnostic Characters - Bars on the anchors are joined in the middle. Both are narrow and notched near their ends.

Records in Puerto Rico - Low numbers occurred on all *Lepomis* spp. at the Maricao Hatchery and 3 of 7 redbreast sunfish in Cidra, 7 of 12 bluegill in

Guajataca and 8 of 14 in Lucchetti, 3 of 6 redear sunfish in Guajataca and 4 of 6 in La Plata. Probably found in all populations of *Lepomis* spp in Puerto Rico (USNM).
Geographic Range - This species is found in the southeastern USA. It was apparently brought into Puerto Rico with bluegill in 1915.
Location in Host - Gill filaments.
Size - 380-500 Fm long.
Host Specificity - Known from bluegill, dollar sunfish *Lepomis marginatus*, and green sunfish in the USA. Redbreast and redear sunfish are new host records. This gillworm prefers *Lepomis* spp.

***Ancyrocephalus* sp. a**

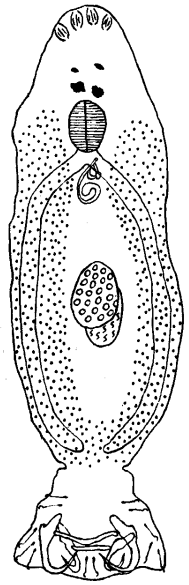


This apparently new species is the only native gillworm in local freshwater fishes. It may be one of only two locally endemic fish parasites.
Diagnostic Characters - It has a wedge-shaped haptor, anchors that differ in size and shape, and bars that are similar in shape. The copulatory complex is loop-shaped.
Records in Puerto Rico - Moderate numbers of worms occurred in all mountain mullet at the Maricao Hatchery (USNM). It is probably found in populations of this host in local upland streams.
Geographic Range - A native parasite of Puerto Rico. The host occurs from North Carolina on the eastern USA coast through the Gulf of Mexico, Mexico, Central and northern South America, and the Caribbean, but this parasite may not occur outside of Puerto Rico (endemic).
Location in Host - Gill filaments.
Size - 375-510 Fm long.
Host Specificity - Only on mountain mullet.

***Ancyrocephalus* sp. b**

This is apparently a new species, which is surprising since the oscar is a popular aquarium fish and has been shipped around the world.
Diagnostic Characters - The haptor has two pairs of similar anchors and two V-shaped bars.
Records in Puerto Rico - Moderate numbers occurred on every oscar at the Maricao Hatchery (USNM).

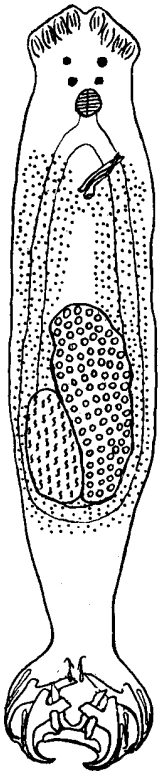
Geographic Range - It occurs naturally in Brazil and has been widely introduced on oscars used in the aquarium trade and in ornamental fish ponds. This exotic parasite has probably been brought into Puerto Rico with every shipment of this aquarium fish. This fish has become established in south Florida but only occurs in a few ponds in Puerto Rico.
Location in Host - Gill filaments.
Size - 315-465 Fm long.
Host Specificity - Found only occurs on oscars.



Ancyrocephalus sp. b

***Cichlidogyrus tilapiae* Paperna**

This parasite occurs on all tilapia in Puerto Rico and is the only gillworm on these hosts. It has fewer hosts in its native African range.
Diagnostic Characters - The two haptoral bars have two additional articulated pieces.



Cichlidogyrus tilapiae

Records in Puerto Rico - This worm occurred commonly on all tilapia at the Maricao Hatchery and on 5 blue tilapia from Guajataca; 3 of 12 Mozambique tilapia from Lucchetti and 3 of 5 from Guayabal, 4 from Loco, 4 of 5 from Toa Vaca and 5 of 6 from Cidra; 2 of 6 redbreast tilapia from Lucchetti, 1 of 3 from Guayabal, 1 of 6 from Loco, 1 of 2 from Toa Vaca, 4 from Cidra, 2 of 3 from Guajataca and 1 of 4 from La Plata. Levels of infection were 1-7 in blue tilapia, 0-8 in redbreast tilapia and 0-55 in Mozambique tilapia. This parasite probably occurs in all populations of all species of tilapias in Puerto Rico (USNM).
Geographic Range - It occurs naturally in Africa and has been widely introduced on exotic tilapias. It has also been reported on the Mozambique tilapia in Colombia. These exotic parasites were probably brought into Puerto Rico (and Colombia) with stocks from Auburn University in 1958 (Mozambique tilapia) and 1963 (redbreast tilapia).
Location in Host - Gill filaments.
Size - 375-595 Fm long.
Host Specificity - This gillworm occurred naturally on fewer and different species of tilapia in Africa. It has spread to every species of tilapia in Puerto Rico.

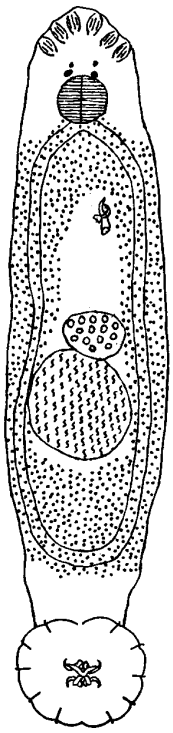
***Clavunculus bursatus* (Mueller)**

Only one or two of these largest gillworms occur per fish, on local *Micropterus* spp. Oddly, they are found on the gill arches instead of the filaments.

Diagnostic Characters - The haptoral bars and anchors are small and hidden in the middle of the haptor. Its body is larger than other three gillworm species found on local *Micropterus* spp.

Records in Puerto Rico - This worm occurs on most largemouth and Florida largemouth bass at Maricao Hatchery and redeye bass in Maricao River, 8 of 32 Florida largemouth bass in Guajataca, 1 of 4 largemouth bass in Loco, 10 of 11 in Toa Vaca, 6 of 12 in La Plata and 9 of 23 in Lucchetti. It probably can be found in every population of largemouth bass in Puerto Rico (USNM). Usually, 1-2 worms are found per adult host, but occasionally none or up to 5 may occur. Up to 12 worms may occur on fry or young fish reared at the Maricao Hatchery. Found in combination with *Haplocleidus furcatus* and *Actinocleidus fusiformis*.

Geographic Range - Its original distribution was the eastern USA. This parasite probably came to Puerto Rico with shipments of largemouth bass from the USA in 1946.



Clavunculus bursatus

Location in Host - Occur on the gill arches and rakers in adult bass, usually on the first and second arches. Sometimes found in the throat or mouth. Also found in aggregations up to 10 worms behind the upper jaw on the roof of the mouth in fry or young bass.

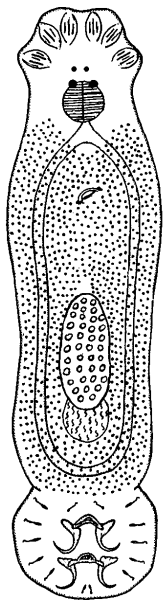
Size - 0.65-1.60 mm long.

Host Specificity - In Puerto Rico, it only occurs in the largemouth bass. In the USA, this parasite has been reported on largemouth, smallmouth and spotted basses and the bluegill and green sunfish. Why it is not found on the bluegill in Puerto Rico is not known.

***Cleidodiscus pricei* Mueller**

Sometimes placed in genus *Ligictaluridis*, this exotic parasite occurs on every catfish in Puerto Rico.

Diagnostic Characters - It has prominent eye spots, relatively large anchors and a raised narrow shield on one bar.

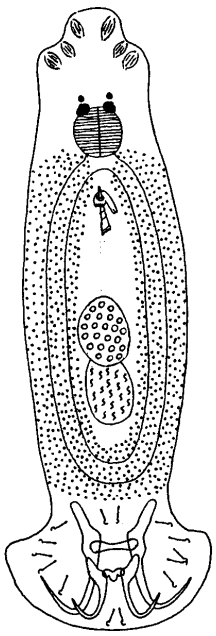


Cleidodiscus pricei

Records in Puerto Rico - A great variation of infection occurred with 1-96 worms on channel catfish, 41-307 on white catfish and 1-145 on brown bullhead (USNM).
Geographic Range - It occurs naturally in the eastern USA and Canada, but has been introduced to California and Russia on the channel catfish and to Europe on bullheads. In Puerto Rico, it appears to occur throughout the range of the catfish (the lower streams and all reservoirs). This parasite was probably brought into Puerto Rico with these hosts in 1915, 1938 and 1946.
Location in Host - Gill filaments.
Size - 335-530 Fm long.
Host Specificity - Only occurs on ictalurids.
Damage to Host - This worm has done little damage in Puerto Rico, however, it has been responsible for epizootics in culture and hatchery situations elsewhere.
Comments - The rather similar *Cleidodiscus floridanus* Mueller is very abundant and very successful on bullhead catfish in eastern North America. Why this worm was not introduced to Puerto Rico as well is a mystery. Some authors believe that these gillworms are the same species.

***Haplocleidus furcatus* Mueller**

This parasite is highly successful in Puerto Rico occurring on largemouth bass and all the other sunfishes. It can kill hatchery fishes.
Diagnostic Characters - It is a small gillworm with pairs of hooks that are quite different in size. The accessory piece of the copulatory organ is Y-shaped and the associated cirrus is straight.
Records in Puerto Rico - Collected from all *Micropterus* spp. (basses) and *Lepomis* spp. from the Maricao Hatchery and adjacent river, and every reservoir where these fishes were examined (USNM). Usually light to heavy infections occurred on largemouth bass with light infections on other sunfishes. Two other worms share the gills of the largemouth bass in Puerto Rico, *Clavunculus bursatus*, and *Actinocleidus fusiformis*. *Onchocleidus ferox* and *Actinocleidus gracilis* often occur together with



Haplocleidus furcatus

this worm in Puerto Rican *Lepomis* spp. Total infection levels, number of worms per fish, in largemouth bass were 0-509 worms, redeye bass 0-2; 9-143 in redear sunfish and 0-60 in bluegill. Most of the worms in these infections were *Haplocleidus furcatus*.

Geographic Range - Originally, it was found in the eastern USA, but it has been transferred across the entire USA and into Canada. This parasite was either brought into Puerto Rico in *Lepomis* spp. in 1915 and 1957, or largemouth bass in 1946. It occurred on the Florida largemouth bass recently brought into Puerto Rico.

Location in Host - Gill filaments. More worms occur on the filaments of the first and second gill arches.

Size - 540-696 Fm long.

Host Specificity - This parasite has been reported on largemouth, redeye, smallmouth, spotted and Suwannee basses *Micropterus notius* and 5 species of *Lepomis* in the eastern USA. It occurred on all sunfishes in Puerto Rico.

Damage to Host - Epizootics have occurred in largemouth bass fingerlings at the hatchery in Puerto Rico.

***Murraytrematoides* sp.**

This new species of gillworm tolerates fresh water to marine salinities (euryhaline).

Diagnostic Characters - Three bars are present on the wide haptor. No spines occur on the body.

Records in Puerto Rico - Light to moderate infections occurred on timucu in brackish and coastal fresh waters (USNM).

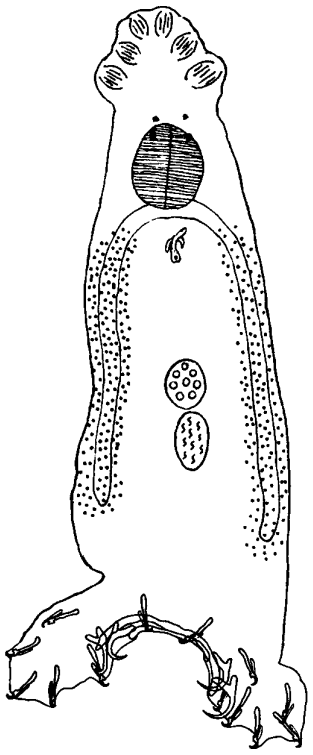
Geographic Range - Only known from Puerto Rico, but unlikely to be an endemic parasite on such a wide ranging euryhaline host.

Ecology - Little is known about this parasite species but other euryhaline needlefish carry their gillworms as far as 350 km inland in U.S. rivers (Williams and Rogers 1972).

Location in Host - Gill filaments.

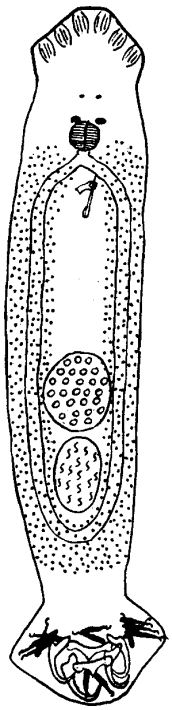
Size - 350-425 Fm long.

Host Specificity - It has only been found on timucu.



Murraytrematoides sp.

***Onchocleidus ferox* (Mueller)**



Onchocleidus ferox

Parasitizes all *Lepomis* spp. in Puerto Rico, but was not found in the closely related largemouth bass. The redbreast sunfish is a new host.

Diagnostic Characters - This is a small gillworm with elongate thin anchors and relatively large marginal hooks.

Records in Puerto Rico - Light infections occurred in bluegill, redbreast and redear sunfish at the Maricao Hatchery and every reservoir where these sunfish are found. *Haplocleidus furcatus* and *Actinocleidus gracilis* share the gills of *Lepomis* spp. with this worm, but it often occurs alone or with only one of the other species. (USNM).

Geographic Range - Originally, it was found in the eastern USA and Canada. This exotic parasite was probably introduced in Puerto Rico with shipments of *Lepomis* spp. in 1915 or 1957.

Location in Host - Gill filaments.

Size - 250-402 Fm long.

Host Specificity - It has been reported from bluegill, redear sunfish, spotted bass, and 8 other species of *Lepomis* in the USA. Redbreast sunfish is a new host record.

***Onchocleidus principalis* Mizelle**

This parasite was recently brought into Puerto Rico on a shipment of Florida largemouth bass. It quickly spread to other bass at the hatchery.

Diagnostic Characters - This gillworm has a copulatory organ that resembles a corkscrew and the marginal hooks are thinner than those found in *Onchocleidus ferox*.

Records in Puerto Rico - Light to moderate infections occurred in 22 Florida largemouth bass and 10 largemouth bass examined at the Maricao Hatchery in December 1993 (USNM).

Geographic Range - This parasite was originally found in the eastern USA, but is now found throughout the USA wherever bass have been transferred and in England. It was imported in stocks of Florida Largemouth Bass from a hatchery in Louisiana in July 1992. This gillworm infected other largemouth bass at Maricao and possibly at Sabana Grande, and may spread to largemouth bass throughout Puerto Rico.

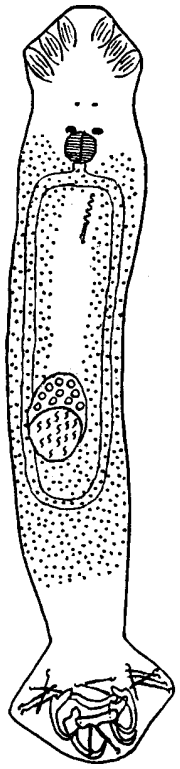
Location in Host - Gill filaments.

Size - 480-660 Fm long.

Host Specificity - It is known from largemouth, smallmouth and spotted basses in the USA. All three species of gillworms previously

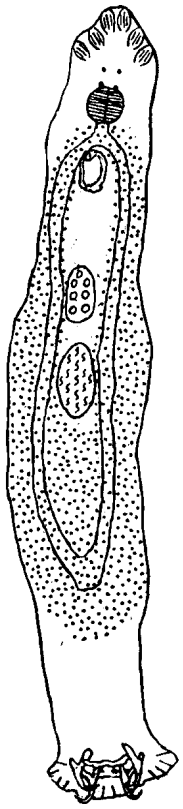
found on Puerto Rican largemouth bass were also found in the imported Florida bass. Whether these parasites came from the Puerto Rico bass or were reintroduced with the Florida bass cannot be determined as they were held together at the hatchery.

Significance to Sportfishing - An additional gill parasite for the largemouth bass provides another opportunity for gillworms to cause problems in the hatchery and possibly in the reservoirs. Future parasite introductions can be avoided (see Avoiding New Parasites page 124).



Onchocleidus principalis

***Pseudohaliotrema mugilinus* Hargis**



Pseudohaliotrema mugilinus

This worm may be a synonym of *Ancyrocephalus vanbenedenii* (Parona and Perugia), but we will use the present name until these worms can be directly compared. This native euryhaline parasite probably inhabits every white mullet entering coastal fresh waters.

Diagnostic Characters - The two haptoral bars touch, but are not fused. One bar has a butterfly-shaped middle section.

Records in Puerto Rico - This parasite was consistently found in moderate infections on every white mullet we examined from marine, brackish and coastal fresh waters (USNM). It occurs in combination with *Metamicrocotyla macracantha*.

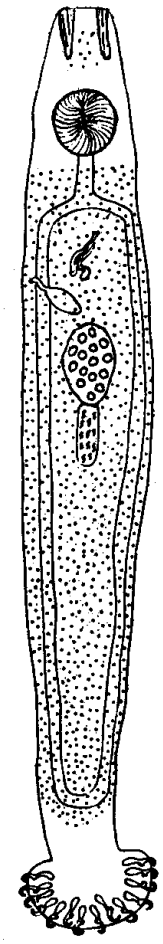
Geographic Range - It is known from the Gulf of Mexico and Caribbean and is a native parasite.

Location in Host - Gill filaments.

Size - 0.63-1.02 mm long.

Host Specificity - It only occurs on white and striped mullet.

***Acolpenteron ureteroecetes* Fischthal and Allison**



Acolpenteron ureteroecetes

This worm occurs in local largemouth bass and is of interest because the urinary bladder is an unusual location for a gillworm.

Diagnostic Characters - It has 14 small marginal hooks and no large anchors or bars on the haptor.

Records in Puerto Rico - Occasionally occurred in all *Micropterus* spp. at the Maricao Hatchery and adjacent river (USNM). In Puerto Rico, fish are usually infected with 1-6, but sometimes up to 12 worms. As many as 50 per host have been reported in the USA. *Myxobilatus mictosporus* may occur with this worm.

Geographic Range - It was originally found in all basses in the eastern and central USA, but has been spread around the world wherever these fish were introduced. This parasite was probably introduced to Puerto Rico with largemouth bass from the southeastern USA .

Location in Host - Urinary bladder and ureter.

Ecology - In the southern USA, it is limited to streams and lakes with rocky bottoms.

Size - 0.46-0.81 mm long.

Host Specificity - It has been reported in Guadalupe *Micropterus treculi*, largemouth, shoal (an undescribed *Micropterus* sp.), smallmouth, spotted and Suwannee bass and redbreast sunfish in the USA. Redeye bass is a new host record.

Damage to Host - It usually causes little damage; however, epizootics of this parasite killed hatchery-held largemouth bass fingerlings in South Africa.

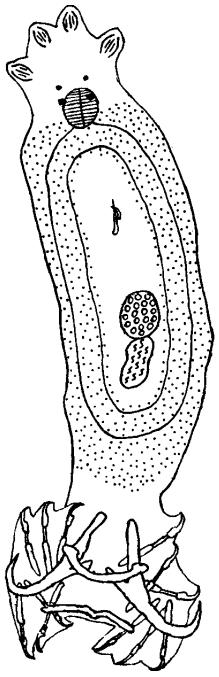
Detection - This worm can be carefully teased from urinary bladder tissues using a dissection microscope. Squeezing urine samples from live fish does not detach this worm from the wall of the bladder and is not an effective examination method.

Treatment - No treatment is possible with internal gillworms.

***Dactylogyrus* sp.**

This, apparently new species, is possibly the most widely distributed undescribed species of gillworm. It occurs here on exotic populations of rosy barb.

Diagnostic Characters - One of the haptoral bars is U-shaped. The anchors have one short and one long root.

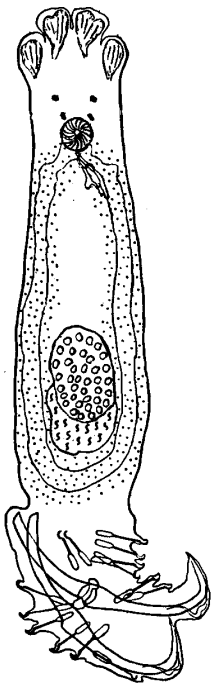


Dactylogyrus sp.

Records in Puerto Rico - Moderate infections occurred on rosy barb at the Maricao Hatchery (USNM). Probably occurs in all populations of rosy barb in Puerto Rico.
Geographic Range - Probably a native parasite of this host in northern India. Spread around the world in the tropical fish trade. It may be a new species but this is difficult to believe on such a popular aquarium fish.
Location in Host - Gill filaments.
Size - 260-300 Fm long.
Host Specificity - Only occurs on rosy barb.

***Dactylogyrus anchoratus* Dujardin**

This parasite was brought to Puerto Rico with aquarium goldfish and has fortunately not spread to other fishes. A number of other species in this genus occur on goldfish around the world. Repeated introductions may bring many of them to Puerto Rico, and unlike this worm, they may spread to other fishes.

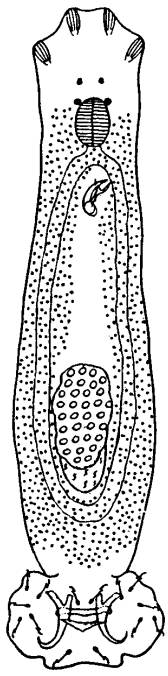


Dactylogyrus anchoratus

Diagnostic Characters - It has one haptoral bar and a pair of large, rather slender anchors with one root extremely elongate and the other reduced.
Records in Puerto Rico - It was common in light to moderate infections on goldfish at the Maricao Hatchery (USNM).
Geographic Range - This gillworm has been introduced around the world with goldfish used in the aquarium trade and for ornamental fish ponds. The temperate goldfish has never become established in tropical Puerto Rico, although it has been introduced many times. The range of this parasite includes at least Canada, Israel, Japan and the USA. This exotic parasite has probably been brought into Puerto Rico with every shipment of aquarium stocks of this host.

Location in Host - Gill filaments.
Size - 326-388 Fm long.
Host Specificity - It is known from goldfish and common carp *Cyprinus carpio* around the world, but has only been found in goldfish in Puerto Rico.

***Dactylogyrus bifurcatus* Mizzelle**



Dactylogyrus bifurcatus

This parasite occurred in fathead minnows stocked in Puerto Rican reservoirs for 20 years until the minnow (and its gillworm) died out. This is a notable example of the rare loss of an established exotic parasite.
Diagnostic Characters - It has two separate bars and one is triangular-shaped. The roots of the anchors are approximately equal.
Records in Puerto Rico - Light infections occurred commonly in fathead minnows that were stocked in reservoirs and ponds from 1957 through 1975. This host was reared and held at the Maricao Hatchery and Lajas Agricultural Experiment Station and is now presumed to have become extinct in Puerto Rico (extirpated) in 1976 or 1977. It was in the Lajas Valley irrigation canal system in 1975 (USNM).
Geographic Range - Its host occurs naturally from northern Mexico through Canada, and has been widely introduced for use as a bait or forage fish. We cannot be certain of the range of this parasite. It was brought into Puerto Rico with stocks of fathead minnows from Welaka, Florida, USA 24 June 1957. Apparently, this was the only introduction of this host and parasite.
Location in Host - Gill filaments.
Size - 254-492 Fm long.
Host Specificity - It only occurred on the fathead minnow in Puerto Rico, but is also known from other species of minnows in the USA.
Damage to Host - This parasite and the tapeworm *Bothriocephalus acheilognathi* may have played a role in removing this useful bait fish from Puerto Rico.
Comments - Rarely do humans introduce a new exotic parasite, allow it to become established over a period of decades, then as abruptly, find that it has disappeared. Usually, there is little hope in controlling these types of parasites, but this is a rare example of a loss.

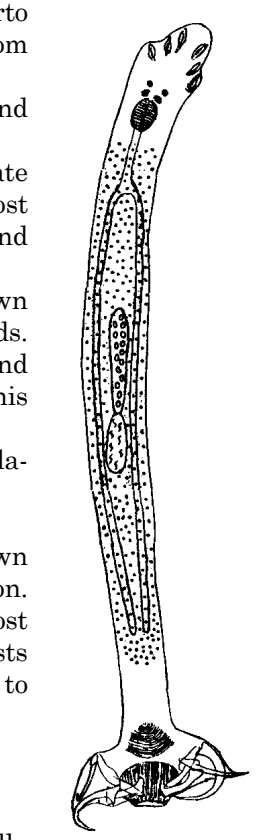
***Diplectanocotyla gracilis* Yamaguti**

This is a common parasite of tarpon in Puerto Rico, but was previously known only from Indonesia.

Diagnostic Characters - It has squamodisks and a large, terminal sucker on the haptor.

Records in Puerto Rico - Light to moderate infections of this gillworm were found on almost every tarpon we examined in marine, brackish and coastal fresh waters (USNM).

Geographic Range - It was previously known from Indonesia. We are not aware of other records. This would be a considerable range extension and would suggest a circumtropical distribution for this parasite.

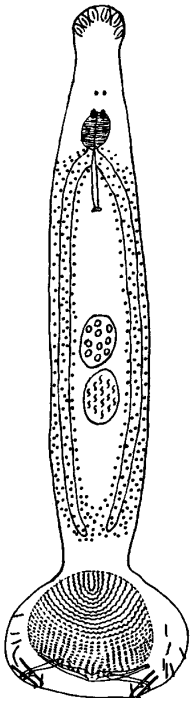


Diplectanocotyla gracilis

Location in Host - Gill filaments.

Size - 0.45-1.0 mm long.

Host Specificity - Known from another species of tarpon. This appears to be a new host record for tarpon and suggests this parasite may be limited to fishes in the tarpon family.



Diplectanum collinsi

Diplectanum collinsi (Mueller)

This worm was originally placed in the genus *Lepidotes* because it was found in freshwater. The gillworm is actually of marine origin, but enters freshwater with many of its hosts. It needs to be redescribed. The discovery of this worm solves a 60-year-old mystery.

Diagnostic Characters - Squamodisks occupy most of the wide haptor. The haptoral bar is boomerang-shaped and both pairs of anchors have elongate bases.

Records in Puerto Rico - Light to moderate infections occurred on striped and yellowfin mojarras (USNM). It may also occur on other local mojarras.

Geographic Range - It has been reported from Florida. Puerto Rico is a new Caribbean record, but this species of gillworm probably occurs throughout the region.

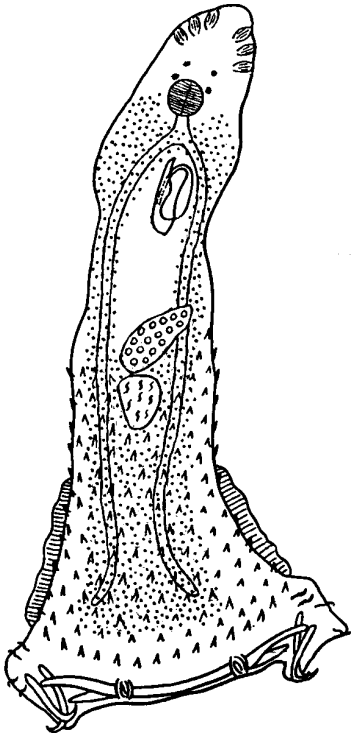
Location in Host - Gill filaments.

Size - 635-675 Fm long.

Host Specificity - It is only known from mojarras. This worm was supposedly described from the striped bass *Morone saxatilis*, an

important sport fish. Actually, it came from a striped mojarra which occurred in the same collection with striped bass. A data recording error contributed to an approximately 60 year mystery of why this gillworm could never be found on the striped bass.

***Rhabdosynochus rhabdosynochus* Mizelle and Blatz**



Rhabdosynochus rhabdosynochus

This fresh to saltwater spiny gillworm occurs on most snooks throughout their host ranges.

Diagnostic Characters - Spines are present on the entire lower half of the body. The posterior end of the body gradually widens to form the haptor. The relatively small, thin anchors are found on either corner of the haptor with three elongate bars in between.

Records in Puerto Rico - Light to moderate infections occurred in all common and swordspine snook examined in fresh and brackish waters (USNM).

Geographic Range - It is known from Florida. Puerto Rico is a new Caribbean record, but the species probably occurs throughout the Gulf of Mexico and Caribbean.

Location in Host - Gill filaments.

Size - 220-340 Fm long.

Host Specificity - It was reported only from the common snook. The swordspine snook is a new record for this parasite. It may also occur on the fat and tarpon snooks.

***Neobenedenia melleni* (MacCallum)**

This rather large capsalid has a reputation as a killer of fishes throughout the Western North Atlantic. It has destroyed commercial tilapia enterprises in salt or brackish waters in the Bahamas, Jamaica and Puerto Rico. This parasite blinds groupers held in public aquaria. It can be so abundant on a fish that the worms look like the scales.

Diagnostic Characters - It is a relatively large, almost circular, flat worm with a separate circular haptor. The haptor is much more narrow than the body.

Records in Puerto Rico - This native parasite has been found in great numbers on blue, Mozambique and red tilapia in culture situations (USNM).

Geographic Range - It is known throughout the tropical and subtropical western Atlantic, including Bermuda. It was transported to New York Aquarium and other facilities on tropical marine fishes.

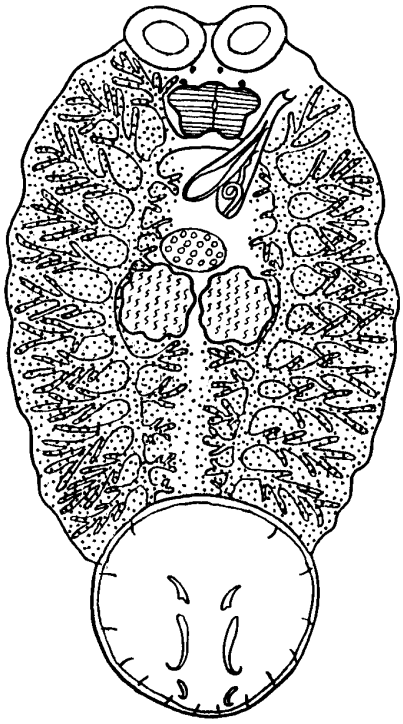
Location in Host - Eyes, skin, rarely gill chamber.

Size - up to 5 mm long.

Host Specificity - It can attack almost any fish confined in seawater. Interestingly, exotic tilapias have almost no resistance to this worm.

Damage to Host - Massive infections cause death in culture conditions. Tilapias cultured in marine or brackish water in the Caribbean can be quickly killed by this parasite. Damage to wild fishes is not known.

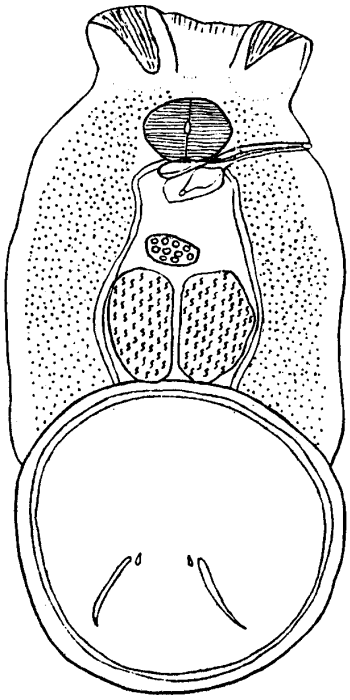
Treatment - This worm has been treated successfully with formalin and also with prolonged exposure to freshwater. Exclusion of this worm from several large-scale culture projects was all but impossible. Treatments with chemicals or freshwater proved too expensive. Some cage culture projects found they could move the cages to greater depths and avoid most of the worms.



Neobenedenia melleni

Comments - This worm is devastating to fishes held in marine or brackish water, but cannot withstand long exposure to freshwater. It is only included because of the famous problem experienced with attempts to rear "freshwater" tilapias in seawater. More is known about the damage caused to New York aquarium fishes and to commercial tilapia, susceptibility, immune response, life cycle, than almost any marine-brackish gillworm, but almost nothing is known about its normal existence. Information about this parasite was recently summarized (Dyer, Williams and Bunkley-Williams 1992).

***Neobenedenia pacifica* (Guberlet)**



Neobenedenia pacifica

This relatively large marine capsalid is carried into fresh waters by the white mullet. It has not previously been reported on this host or in the Atlantic.

Diagnostic Characters - It is a relatively large, almost circular flat worm with a separate, circular haptor. The haptor is as wide as the body.

Records in Puerto Rico - Approximately of white mullet examined from the Bucaná River had 1-2 worms. It is probably found in white mullet in all marine, brackish and coastal freshwaters waters (USNM).

Geographic Range - Oddly, this parasite has only previously been reported from the Pacific. We have no evidence to suggest an exotic introduction, although Pacific marine fishes have been introduced in Panama and Barbados.

Location in Host - Skin.

Size - up to 4 mm long.

Host Specificity - It was previously known from striped mullet. White mullet is a new host record for this parasite.

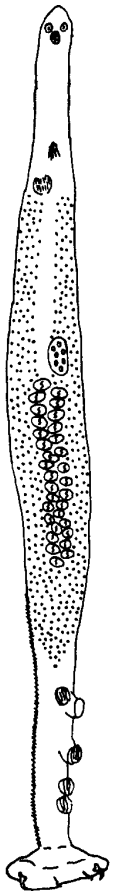
Damage to Host - A superinfection occurred on the skin of one adult white mullet in a sample of 89. This infection would have probably killed the fish. This is a rare example of a superinfection in a free ranging fish.

Polyopisthocotylea

These worms are generally much larger than Monopisthocotylea and usually can be easily seen with the naked eye. Capsalids are as large, but they have simple haptors. Polyopisthocotylea have intricate attachment organs with a series of complicated clamps or suckers often on extensions of a complex haptor. These worms generally feed on blood. They produce fewer eggs than Monopisthocotylea and usually occur in much lower numbers on the host. Where 50-100 Monopisthocotylea may occur on a host, 1-2 Polyopisthocotylea might occur on the same host. Polyopisthocotylea tend to be more common in the marine environment. The few that do occur in freshwater are usually on hosts of marine origin. They do not increase in numbers rapidly, but those that feed on blood can severely damage their hosts with even slight increases in numbers. Usually marine hosts are not held in hatchery or culture conditions in Puerto Rico where worms can

cause problems. They could become a problem if restocking of marine sportfish, as is being studied in Florida, is ever attempted here.

Worms can be relaxed in dilute formalin solutions and cleared and mounted in glycerine jelly as described for the Monopisthocotylea, but, they can also be placed under a microscope coverslip on a slide and bathed in 5% formalin so that they can be fixed flat. They may also be stained and permanently mounted as described for digeneans. Fishes infected with these worms can be treated with formalin as described for the Monopisthocotylea above.



Protomicro cotyle mirabilis

***Protomicrocotyle mirabilis* (MacCallum)**

This long, asymmetrical worm had not been reported in horse-eye jack or from the Caribbean.

Diagnostic Characters - It has an elongate body with four clamps which appear to be on the side of the body, anterior of the haptor.

Records in Puerto Rico - A few worms were found on almost every crevalle and horse-eye jack examined in local marine, brackish and coastal freshwaters (USNM).

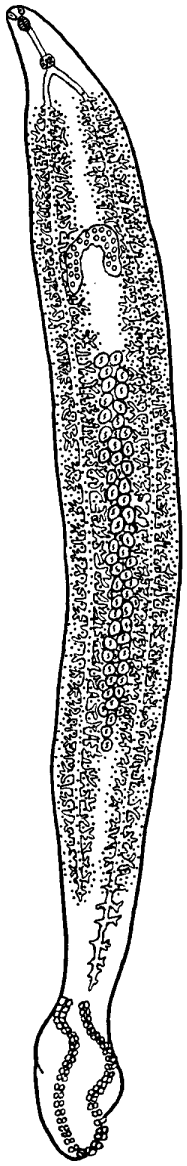
Geographic Range - Oddly, this native parasite has not been previously reported south of the Gulf of Mexico. It is, at least, found in the Caribbean, Gulf of Mexico and Atlantic coast of the USA, and probably beyond these areas.

Location in Host - Gill filaments.

Size - up to 5.5 mm long.

Host Specificity - It was known from crevalle jack, but horse-eye jack is a new host record for this parasite. Possibly, it only occurs on jacks in genus *Caranx*.

***Metamicrocotyla macracantha* (Alexander)**



Metamicrocotyla macracantha

This largest gillworm on local mullets had not been reported from white mullet or the Caribbean.

Diagnostic Characters - It has a very elongate body with 152-213 testes and 23-25 clamps in two rows along the haptor.

Records in Puerto Rico - Light infections occurred on almost every white mullet examined (USNM).

Geographic Range - It was previously known from the eastern Pacific and Gulf of Mexico. Puerto Rico was a new geographic record for the Caribbean (Garcia-Sais and Williams 1985).

Location in Host - Gill filaments.

Size - up to 12.5 mm long.

Host Specificity - It had been reported from the striped mullet. The white mullet was a new host for this parasite (Garcia-Sais and Williams 1985).

***Allopyragraphorus hippos* (Hargis)**

This symmetrical worm had not been reported from the horse-eye jack or the Caribbean.

Diagnostic Characters - It has a relatively short body. The many clamps are almost evenly distributed on its fish-tail-shaped haptor.

Records in Puerto Rico - A few worms occurred on almost every crevalle and horse-eye jack examined (USNM).

Geographic Range - Oddly, this worm has not been previously reported south of the Gulf of Mexico. Its range is probably at least Caribbean, Gulf of Mexico and Atlantic coast of continental USA, and possibly beyond these areas.

Location in Host - Gill filaments.

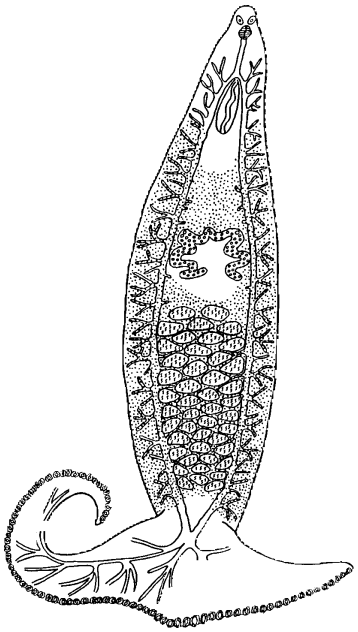
Size - 2.9-3.3 mm long.

Host Specificity - Previously known from crevalle jack. Horse-eye jack is a new host record for this parasite. Possibly, it only occurs on jacks in genus *Caranx*.

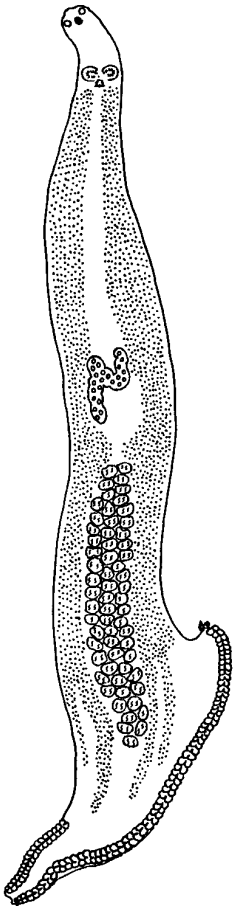
***Cemocotyle noveboracensis* (Price)**

This worm, with an unbalanced line-up of clamps, had not been reported from the horse-eye jack or from the Caribbean.

Diagnostic Characters - The haptor is wrapped around the posterior body with 43-57 clamps on one side and 15-17 on the other. Slightly more clamps were found on the long side in local specimens than had been reported previously.
Records in Puerto Rico - A few worms occurred on almost every crevalle and horse-eye jack examined in local marine, brackish and coastal fresh waters (USNM).



Allopyragraphorus hippos



Geographic Range - This worm had not previously been reported south of the Gulf of Mexico. Its range is probably at least Caribbean, Gulf of Mexico and Atlantic coast of USA, and possibly beyond these areas.
Location in Host - Gill filaments.
Size - up to 4.5 mm long.
Host Specificity - Previously reported from crevalle jack. Horse-eye jack is a new host record for this parasite.

Cemocotyle noveboracensis

DIGENEA (GRUBS AND FLUKES)

Flukes, digeneans (formerly digenetic trematodes) form a class of flatworms. Flukes reproduce as adults and again as larvae, hence the name "di-genetic" or two births. They cause serious and fatal diseases in many animals including humans. Bilharzia (*Schistosoma mansoni* Sambon) in humans is an example in Puerto Rico. Digeneans are important fish parasites with fishes serving both as intermediate (grubs) and final hosts (flukes). More than 9000 species have been described. Adults range in size from <0.2 mm to >10 cm. One of the largest occurs in the stomachs of local wahoo *Acanthocybium solandri*, an important marine sport fish. Flukes usually look like typical flatworms with a mouth in the head region, blind gut, and reproductive and other organs in the trunk region. Unlike generalized flatworms, they have two sucker-like holdfast organs. One is located around the mouth (oral sucker) and the other is usually in the middle of the worm on the same (ventral) side (ventral sucker or acetabulum). Great differences in shape, size and orientation of structures occur in different species. Flukes have a complex life cycle with 2-3 intermediate hosts, possible transfer hosts and a final host. In a typical life cycle, eggs from the body of the fluke pass out the intestine of the final (definitive) host. The eggs hatch into a swimming ciliated larva (miracidium) that infects the first intermediate host, usually a snail. Each (sporocyst) asexually produces many larval parasites (rediae) which in turn produce many swimming infective larvae (cercaria) that leave the snail. They infect the second intermediate host, encyst, and become metacercaria. If the appropriate final host eats this infected host, the metacercaria is digested out and becomes an adult fluke. Each fluke has a set of female and male organs (hermaphroditic) but reproduction still requires two worms. Flukes are permanent parasites in most marine fishes, and in many freshwater fishes, amphibians, reptiles, mammals and birds. Larval stages occur in a variety of invertebrates and vertebrates. Flukes usually occur in the intestine, stomach or mouth, or occasionally lungs and other organs. Larval forms occur in almost any tissue. We list the grubs and flukes known from freshwater fishes in Puerto Rico in the classification below, but separate the species accounts by considering all of the larval(*) grubs first (page 49), and the adult flukes second (page 55).
Reference "How to Know the Trematodes" (Schell 1970).

Class Digenea Taxonomy and Contents . . . . . **Page**

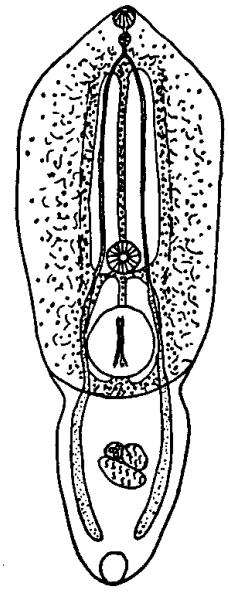
*Larval forms.

Metacercaria (grubs)

We have identified six species of grubs in three orders and five families from freshwater fishes in Puerto Rico. Most of these worms become adult flukes in fish-eating birds, but one occurs in marine fishes. Fortunately, the highly damaging eye-dwelling grubs (*Diplostomulum* spp.) appear to be absent from Puerto Rico. Prieto (1991) found eye grubs in Cuban tilapia and carps in cultivation, and largemouth bass and other sunfishes in reservoirs. Some grubs may live in a fish for up to four years. The yellow grub is the only local fluke in fishes that may parasitize humans but it is killed when the fish is cooked. No treatment of grubs in fishes is possible. Screening birds from production ponds should reduce their numbers in pond fishes. Grubs can be found in the skin, muscle, mesenteries or internal organs

of fishes. Sometimes they are clearly visible under the skin of live fishes without the aid of magnification. Grubs may appear as dark spots in small or relatively translucent fishes, especially with light behind their bodies. Thin fillets can be held up to a light to search for opaque spots, indicating metacercaria. This technique is called "candling". Grubs in the viscera and in the gills are easily visible during necropsies when observed with a dissection microscope. The relatively small grubs are hidden in the flesh of fishes and are unlikely to be noticed by fishermen. Larger grubs may appear aesthetically undesirable to anyone cleaning their catch, indirectly discouraging sportfishing. Grubs in the ovaries limit reproduction. Heavy infections reduce growth rates, increase mortalities and make sportfish production more difficult.

***Posthodiplostomum minimum* (MacCallum)**



Posthodiplostomum minimum

The life cycle of this bird fluke called "white grub" probably was completed only after exotic fishes were imported to Puerto Rico. We are not aware of any other instance where a life-cycle was introduced for an existing native parasite. White grubs did not occur here in the high numbers often noted in the USA. The subspecies (*P. minimum centrarchi*) occurs in sunfishes (centrarchids); the subspecies (*P. minimum minimum*) occurs in minnows and carps (cyprinids), and unnamed subspecies occur in other fishes.

Diagnostic Characters - The white color, relatively large size and usual location in viscera, distinguishes this worm.

Records in Puerto Rico - The sunfish subspecies was found in a bluegill and 6 of 7 redbreast sunfish from Cidra, a bluegill and redear sunfish from the Maricao Hatchery and 1 of 33 Florida largemouth bass from Guajataca. Usually 1-2 cysts were found per host. We have only found one grub in hundreds of largemouth bass although it occurs commonly in this fish in the USA. We have also examined sunfishes from La Plata, Guayabal and Lucchetti and we have not found this grub in these lakes although fish-eating birds and sunfishes are present. Possibly the appropriate mollusk intermediate hosts are lacking or a certain abundance of sunfishes is necessary. In the USA, parasite burdens of hundreds of worms per fish are seen, in contrast to the light burdens observed in Puerto Rican fishes.

Two of eight guppies taken from a stream just west of Lajas were parasitized by 8-10 of an unknown subspecies. Four species of minnows and carps occur in Puerto Rico, but none have been found infected by the minnow subspecies of this grub. This suggests that this subspecies does not occur in local fish-eating birds.

Geographic Range - The sunfish subspecies is known from the USA, Canada and Cuba. It can probably be found in any of the Caribbean islands with sunfishes introduced from the USA. The minnow subspecies is reported from the USA, Canada and Mexico. This grub was involved in a most peculiar form of exotic introduction in Puerto Rico. Herons have been bringing the adult fluke of this grub to Puerto Rico probably for thousands of years. Parasite eggs have been raining down into local fresh waters. Until 1915, those eggs were wasted. With the introduction of sunfishes to Puerto Rico from the southeastern USA, and the release of guppies from the aquarium trade, the life cycle was completed. The bird final host and appropriate mollusk first intermediate hosts were apparently already here. All that was necessary was to add the second intermediate fish host. The parasite was a natural native species, but its life cycle was introduced.

Life History - Great blue heron *Ardea herodias*, green heron (or green-backed heron) *Butorides striatus*, great egret *Casmerodius albus*, little blue heron *Egretta caerulea*, snowy egret *Egretta thula* and black-crowned night heron *Nycticorax nycticorax* are final hosts. It is surprising that this grub is not more successful and abundant here. In the continental USA, the tadpole physa *Physa gyrina* serves as an intermediate mollusk host.

Location in Host - Grubs are encysted in the internal organs or mesenteries. Adults are in the intestine.

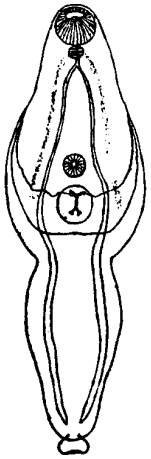
Size - Grubs 1.0-1.5 mm, adults 3-5 mm long.

Host Specificity - White grubs can be found in almost any freshwater fish in the USA. The sunfish subspecies occurred in all local sunfishes, except redeye bass. An unknown subspecies occurred in guppies. In livebearers, the white grub has been reported from shortfin molly *Poecilia mexicana* in Mexico and western mosquitofish in Tennessee (USA).

Damage to Host - Heavy infections in muscle have caused mortalities. Infections in internal organs should also cause injury. The heart of some heavily infected fishes looks like a popcorn ball with white cysts completely covering it.

Uvulifer ambloplitis (Hughes)

This metacercarial stage causes superficial black spots in the skin and fins and rarely damages wild fishes, but frequently offends or disturbs fishermen. Large numbers of grubs sometimes attack



Uvulifer ambloplitis

culture and hatchery fishes ("black grub" or "black spot disease") causing fishes to be unmarketable.

Diagnostic Characters - The black color, relatively small size and usually prominent location in the fins or skin of the host is characteristic.

Records in Puerto Rico - One to 10 grubs were found in 8 river and 3 sirajo gobies from Bucaná River, and 2 in 1 of 3 redeye bass from Maricao River. It appears limited to upland streams in Puerto Rico. Possibly the temperatures in reservoirs and lower streams are too warm for this temperate parasite.

Geographic Range - Black grub is common in much of North America and may occur on many fishes in some areas.

Life History - The belted kingfisher *Ceryle alcyon* is the final host. In the USA, marsh rams-horn *Planorbella trivolis* or bellmouth rams-horn *Planorbella campanulatum* serve as the mollusk intermediate hosts. Two local species of rams-horn probably serve as intermediate hosts.

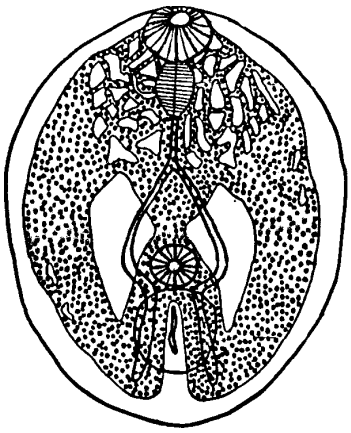
Location in Host - Black grub occurs in muscle and fins of fishes in the USA. In Puerto Rico, one was in muscle just under the skin and the rest were in fins. Adults are found in the intestine of birds.

Size - Grubs 0.36-0.39 mm, adults 1-2 cm long.

Host Specificity - It may encyst in any freshwater fish. Gobies are a new family of hosts for this grub.

Damage to Host - Usually, only a few cysts occur on each fish. Superinfections are rarely found in nature. In pond culture, where birds are not excluded, very high levels may occur and damage fishes. Heavy infections have caused reduced fat and body condition, increased oxygen consumption and poor over-winter survival.

Reference - Brokaw (1972).



Neogogatea pandionis

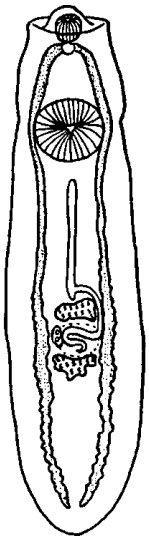
***Neogogatea pandionis* Cable and Rausch**

This grub was not previously found in fishes. It may become more abundant as its final host expands its range on the island.

Diagnostic Characters - This rather nondescript, white to translucent grub has a large, W-shaped excretory bladder. Recognizing this character requires the use of a microscope.
Records in Puerto Rico - One grub was found in a guppy from the Yauco River above Lucchetti (USNM 83026). The osprey *Pandion haliaetus*, final host for this fluke, is becoming more abundant in Puerto Rico. It will be interesting to see if this grub becomes more common in local fishes.
Geographic Range - It occurs in eastern North America, but the exact range is not known.
Life History - The osprey is the final host.
Location in Host - It encysts in muscle or occasionally viscera of freshwater fishes.
Size - Grubs 1.0-1.5 mm, adults 2-3 mm long.
Host Specificity - Unknown. This species of grub has not been previously noted from fishes, but a species in the same genus occurs in North American freshwater fishes.

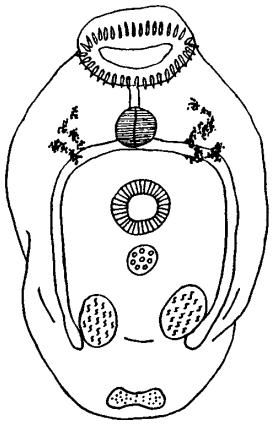
***Clinostomum complanatum* (Rudolphi)**

This parasite, commonly called yellow grub, occurs in such high abundance in the organs of two local, large sleepers that it may reduce their numbers in streams of western Puerto Rico. It could parasitize humans. This worm causes serious problems in USA fishes.
Diagnostic Characters - The yellow color and relatively large size identify this grub.
Records in Puerto Rico - Most fat sleepers and bigmouth sleepers in the streams of western Puerto Rico have heavy infections of yellow grubs. One cyst occurred in a channel catfish from Lucchetti. Why this grub is limited to western Puerto Rico is unclear. The intermediate hosts (snails and fishes) and final hosts (herons) are found throughout the island.
Geographic Range - It is widespread in the old and new world. Apparently, it is a bit more abundant in the northern half of its range in North America.
Life History - In the USA, rams-horn *Helisoma* sp. serves as the mollusk first intermediate host. Two local species of rams-horn probably serve as intermediate hosts in Puerto Rico. Adults are found in the mouth of herons (great blue heron, green heron, great egret, little blue heron, black-crowned night heron).
Location in Host - It was found in livers and ovaries of sleepers and in the liver of a channel catfish.



Clinostomum complanatum

Size - Grubs 4-6 mm, adults 3.5-6.6 mm long.
Host Specificity - It may encyst in any freshwater fish. Both bigmouth and fat sleepers are new host records. Sleepers are also a new host Family for this parasite
Damage to Host - This grub damages hatchery and culture fishes in the USA. The livers and ovaries of local sleeper were heavily infected.
Harm to Humans - This worm can incidentally infect humans by migrating into the trachea (Hoffman 1967). Human infections by a similar species have been reported in India and Japan. This potential should be sufficient to discourage the use of freshwater fishes in raw-fish dishes. Cooking kills these parasites.
Significance to Sportfishing - Sleepers are used as food fishes and sport fishes in Puerto Rico. These grubs occur in such high numbers in sleepers that these fishes may become increasingly scarce in the streams in western Puerto Rico.



Echinochasmus donaldsoni

***Echinochasmus donaldsoni* Beaver**

This grub occurs commonly on a variety of sport fishes in Puerto Rico.
Diagnostic Characters - This small grub parasitizes the gills and is bent double in the cyst. The spines are less developed than in *Stephanostomum* sp.
Records in Puerto Rico - One to 2 cysts occurred in the gills of 3 of 5 bigmouth sleepers from the Loiza River, 6 of 12 bluegill in Guajataca and 3 of 14 in Lucchetti, 1 of 32 Florida largemouth bass and 1 of 6 redear sunfish from Guajataca, three mountain mullet at the Maricao Hatchery, 1 redeye bass from Maricao River and 1 western mosquitofish in Lajas. This parasite will probably be found in many other local fishes.
Geographic Range - It has been reported from eastern North America, but the exact range is not known.
Life History - The mud amnicola *Amnicola limosa* and boreal marstonia *Marstonia lustrica* serve as mollusk first intermediate hosts in the USA. The final host is the pied-billed grebe *Podilymbus podiceps*.
Location in Host - Encysted in the gills.
Size - Grubs 0.26-0.32 mm, adults 1.75-2.25 mm long.
Host Specificity - It encysts in a variety of freshwater fishes and amphibians.

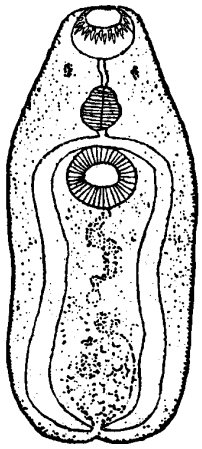
***Stephanostomum* sp.**

This grub seldom infects freshwater fishes because the life cycle is limited to the marine environment. We have not determined the species of this grub because several species in this genus occur in local marine fishes and their life cycles have not been described.

Diagnostic Characters - This grub can easily be identified by the white to opaque color and the spines around the oral area.

Records in Puerto Rico - One cyst was found in a burro grunt near Humacao. We have also found this grub in a variety of near-shore marine fishes. It probably can be carried into freshwaters by any local euryhaline host.

Life History - Encystment in a fish which moves into fresh water is a "dead end" for the life cycle. The first intermediate mollusk host and final fish host are marine.

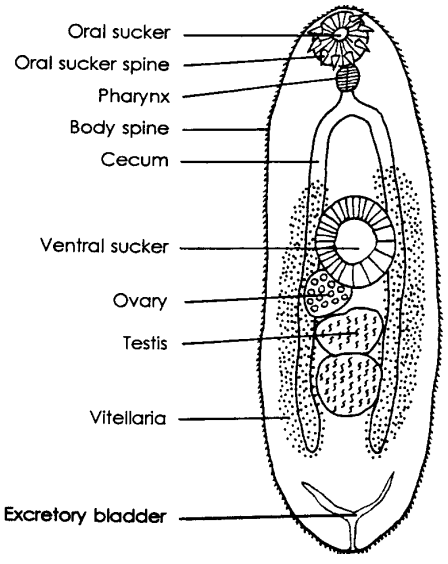


Stephanostomum sp.

Location in Host - It encysts in the muscle or occasionally the viscera.

Size - Grubs 0.5 mm long, adults 1-7 mm long.

Host Specificity - None. Apparently cercariae can encyst in any marine or freshwater fish.



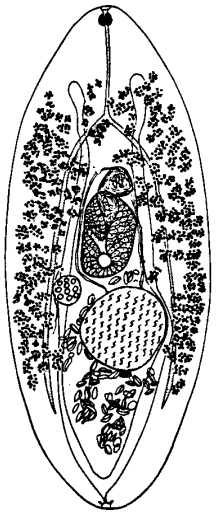
Composite Digenea

Adult Digenea (flukes)

Flukes do not occur in strictly freshwater fishes in Puerto Rico. Only marine forms that are carried into fresh water with euryhaline fishes are found. These hosts were infected in saltwater and the life cycle of the worms is completed there. Even in the marine ecosystem, their biology has received little attention and none of these life cycles are known. If these fishes stay in fresh water, their flukes will be lost in a few weeks. Sizes can vary considerably depending on age, condition and how well they are relaxed when preserved. Many of these worms have only been measured once or twice and

usually from very few specimens, thus their real sizes are not known. These flukes occur in such low numbers that they are unlikely to cause any serious damage to their hosts. A dissection (necropsy) is necessary to find these worms. None are known to harm humans. They may cause a slight decrease in the productivity of their hosts, but this should not be significant for local sportfishing. These fishes are not held for aquaculture or aquarium purposes in Puerto Rico and thus treatment is not necessary. Additional study of their biology and significance in the environment would be highly desirable.

***Bivesicula tarponis* Sogandares-Bernal and Hutton**



Bivesicula tarponis

This worm is occasionally found in tarpon entering fresh water.

Diagnostic Characters - The body has fine spines and the oral sucker is bowl-shaped.

Records in Puerto Rico - Low numbers were found in tarpon in the Joyuda Lagoon, but not in tarpon in the coastal areas of south central, eastern or northern Puerto Rico. This parasite does not occur in every host, but can probably be found in most coastal fresh waters.

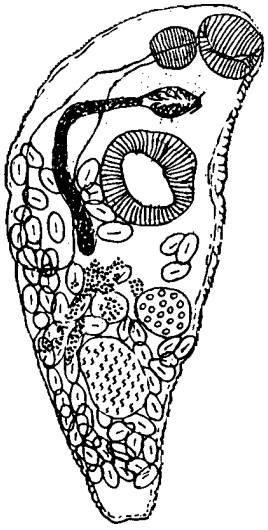
Geographic Range - This worm was previously reported from the Gulf of Mexico. This record is a new locality for the fluke in the Caribbean.

Location in Host - Intestine.

Size-1.5-2.5 mm long.

Host Specificity - It has only been found in tarpon.

***Haplosplanchus mugilis* Nahhas and Cable**



Haplosplanchus mugilis

This worm is an occasional parasite of white mullet, but was previously not reported from Puerto Rico.

Diagnostic Characters - The oral sucker is almost as large as the ventral sucker. Two intestinal ceca occur.

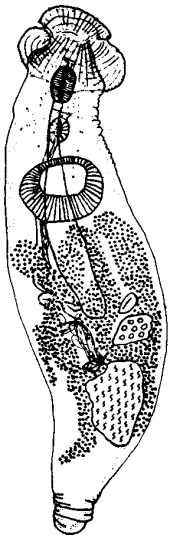
Records in Puerto Rico - It occasionally occurs in moderate infections in white mullet along coastal areas (USNM 83007).

Geographic Range - *Haplosplanchus mugilis* was reported in

Curaçao. Puerto Rico is a new locality record. It probably occurs throughout the Caribbean.
Location in Host - Intestine.
Size - 0.8-1.2 mm long.
Host Specificity - The fluke has only been reported in white mullet.

***Hymenocotta manteri* Overstreet**

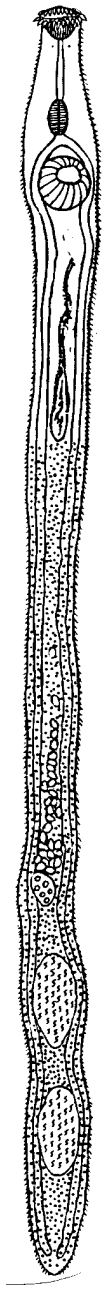
This parasite occurs commonly and in very heavy infections in local white mullet, but has not been reported before from the Caribbean.
Diagnostic Characters - The oral sucker is disk-shaped or contracted into a cup-shape. Two intestinal ceca occur.
Records in Puerto Rico - Fifty to 220 worms occurred in white mullet in the Bucaná River east of Ponce (USNM 83020-22,24) and on the east coast of Puerto Rico. Probably any coastal fresh water area may harbor *H. manteri*.
Geographic Range - It was previously reported from south Florida. The Caribbean is a new locality record for this worm.
Location in Host - Intestine and pyloric ceca.
Size - 0.9-1.6 mm long.
Host Specificity - Already reported from the striped mullet; the white mullet is a new host record. It seems to prefer mullets, but we have seen the worm once in a snapper.



Hymenocotta manteri

***Stephanostomum ditrematis* (Yamaguti)**

First reported in a Japanese surfperch, it is an elongate worm found in a variety of jacks around the world. Those worms found in surfperch and the ones found in jacks, probably represent two or more species.
Diagnostic Characters - Very long, thin worm with 36 spines around the oral sucker.
Records in Puerto Rico - Eight worms occurred in a crevalle jack in the Bucaná River east of Ponce (USNM 83023). Probably any coastal fresh water may have *S. ditrematis* in crevalle or horse-eye jacks.
Geographic Range - It has been reported from around the world, and from Bimini, Curaçao, Florida and Jamaica in the West Indies. This is the first record of the worm in Puerto Rico, but it probably occurs throughout the Caribbean.
Location in Host - Intestine.

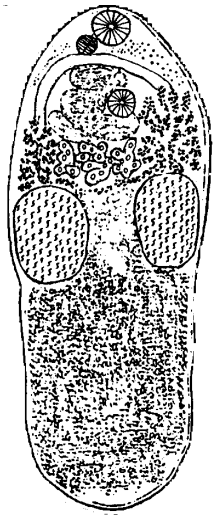


Stephanostomum ditrematis

Size - 3.2-6.0 mm long.
Host Specificity - The name *Stephanostomum ditrematis* may represent more than one species of worm, but probably, only one of them occurs on jacks. This unusual parasite requires additional taxonomic study.

***Paracryptogonimus centropomi* Siddiqi & Cable**

This worm can heavily infect local snook. It has only been found in Puerto Rico, but is probably not endemic.



Paracryptogonimus centropomi

Diagnostic Characters - This is a broad worm with a ventral sucker that is smaller than the oral sucker. The ovary is very wide and has dendritic lobes.
Records in Puerto Rico - Two to 100 worms were found in common snook from Urban Pond, Villa Carolina, and the Añasco River, Mayaguez (USNM 82987). Probably any snook in coastal fresh waters may have this parasite.
Geographic Range - Previously, it was reported from the swordspine snook in Puerto Rico. This worm probably occurs throughout the Caribbean.
Life History - A larval stage of this fluke may be "*Cercaria caribbea* XIV Cable" (Cable 1956) which is found in the variable bittium *Bittium varium*, a marine snail.
Location in Host - Intestine.
Size - 0.4-0.9 mm long.
Host Specificity - It has only been found in snooks.

***Brachyphallus parvus* (Manter)**

This worm has been brought into fresh waters in tarpon and ladyfish, but occurs in a variety of local marine fishes.

Diagnostic Characters - It does not have a tail. The large ventral sucker is more than 3/4 the width of the worm, and is about one ventral-sucker width away from the oral sucker. The testes are larger than the oral sucker.

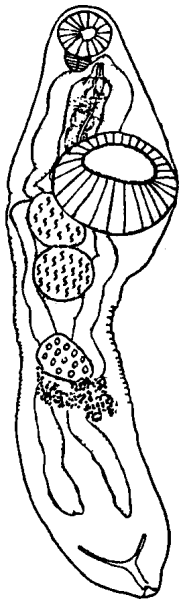
Records in Puerto Rico - One fluke was found in a ladyfish from the Bucaná River, and two in a tarpon from the Añasco River, Mayaguez. This worm probably can occur in any local euryhaline fish.

Geographic Range - This fluke was previously reported in a great variety of marine fishes from Florida through the Gulf of Mexico to Brazil. This worm has only been reported from Puerto Rico in the Caribbean, but probably occurs throughout the region.

Location in Host - Stomach.

Size - 0.5-1.2 mm long.

Host Specificity - None.



Brachyphallus parvus

***Lecithochirium monticellii* (Linton)**

This rather large and common marine fluke is occasionally carried into fresh water in the stomachs of euryhaline fishes.

Diagnostic Characters - The tail is short. The large ventral sucker is about one ventral-sucker width away from the oral sucker. The testes are smaller than the oral sucker.

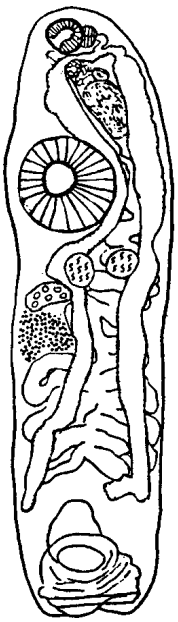
Records in Puerto Rico - One to 2 worms rarely occurred in the lined sole in the Añasco River near Mayaguez and 1 in 8 liza in the Guajataca River. It can probably occur in any local euryhaline fish.

Geographic Range - It was previously reported from a great variety of marine fishes from Woods Hole, Massachusetts, Bermuda, Florida, Gulf of Mexico and Puerto Rico. This worm probably occurs throughout the Caribbean.

Location in Host - Stomach.

Size - 1.2-5.4 mm long.

Host Specificity - None. The liza is a new host record for this parasite.



Lecithochirium monticellii

CESTOIDEA (TAPEWORMS)

Tapeworms or cestodes form a large class of the flatworms or platyhelminths. The common name comes from the long series of body segments which resemble a tape measure. They are always of interest because they can reduce growth and affect reproductive success of fishes, and some that could harm humans occur as immatures in fishes. More than 5000 species of cestodes are known. Adults range from less than a millimeter to more than 30 meters in length. Tapeworms usually consist of a chain of segments (proglottids) each with a set of reproductive organs. The segments are continuously budded in the anterior portion of the body or neck, and enlarge and mature as they slowly move posteriorly. The scolex or "head" on the anterior end is armed with various suckers, hooks and or bothria (sucking grooves) to attach to the host's intestine.

Eggs may be laid through pores or a whole mature segment, filled with eggs, may separate and pass out the intestine of the vertebrate host. Eggs hatch into ciliated (coracidium) or unciliated (hexacanth or oncosphere) larvae which are eaten by the first intermediate host (insect, crustacean or annelid) and become elongated procercoids. This host is then eaten by a vertebrate (second intermediate host) and the larvae develop into partially differentiated plerocercoids or plerocerci. Hexacanths develop into variously shaped cysticercoids in diverse invertebrates. Plerocercoids can be transferred directly between fishes and greatly concentrated or increased in numbers by feeding the viscera of one host to another. We have seen this practice cause a superinfection in caged red hind *Epinephelus guttatus* in Puerto Rico. If viscera must be used as fish food, it should be frozen for several days to kill parasites. The final or definitive vertebrate host eats the second intermediate host and the adult tapeworms develop in the intestine.

Most tapeworms have both sexual organs in either the same individual or each proglottid; a few tapeworms have separate sexes. Tapeworms occur in all kinds of vertebrates, in all habitats around the world. All tapeworms are permanent parasites. Nutrition is absorbed through their body wall, their intestine has been lost.

Larval tapeworms can be preserved in steaming, 5% formalin. Identification below order is very difficult in most larvae. Study of the entire life cycle of a tapeworm may be necessary to determine the identity of a larval form. Such work is difficult and requires luck.

Di-N-butyl tin oxide and di-N-butyl tin dilaurate can be used at 0.5-0.6% of the diet for three days to remove tapeworms in the intestine of brood stock or valuable fishes. No treatment is known for encysted forms. Drying ponds and treating them with unslaked or chlorinated lime will eliminate worms. Reintroduction of infected fishes should be strictly avoided.

One species of adult and four species of larval tapeworms, which

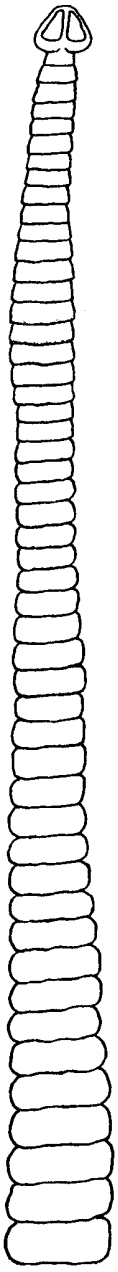
occur as adults in aquatic birds, amphibians, fishes or sharks, are found in Puerto Rican freshwater fishes. A necropsy is necessary to find the larvae in the organs and mesenteries. Some cestodes of other animals can infect humans; however, none of those in Puerto Rican fishes are known to infect humans.
Reference - "CRC Handbook of Tapeworm Identification" (Schmidt 1986).

Class Cestoidea (or Cestoda) Taxonomy and Contents. Page

*Larval forms.

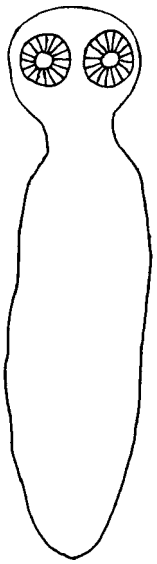
Tetraphyllidean larvae

A variety of larval tapeworms from sharks and rays may occur in fishes that move from marine to fresh water. These tetraphyllidean larval forms or plerocercoids usually cause little harm unless they occur in very high numbers.
Diagnostic Characters - It is a small, white, ovoid worm with a short neck. The anterior attachment (scolex) has four suckers around a bulb and a terminal sucker with no hooks. These tapeworm larvae very actively contract and relax when alive. These plerocercoids cannot be identified to genus or species because they possess few diagnostically useful characters.
Records in Puerto Rico - Low numbers commonly occur in white mullet from coastal fresh waters and in lower elevation rivers. They may also occur in other euryhaline fishes.
Geographic Range - Similar larval tapeworms occur throughout the Caribbean, West Indies and Atlantic.



Bothriocephalus acheilognathi

Location in Host - Larval forms occur in internal organ and mesentery cysts or free in the intestine of bony fishes. Adults occur in the stomach, intestine or spiral valve of sharks and rays.
Size - 1-2 mm long.
Host Specificity - They occur in white mullet or any other coastal bottom fishes. We cannot be certain how many species of tapeworms may be represented in the mullet.
Damage to Host - These larval tapeworms usually occur in low numbers and probably do little damage to the host, but up to 4500 worms per fish have been reported in the intestines of small white and striped mullets in the Gulf of Mexico. This number would probably kill or stunt these fishes.



Tetraphyllidean larvae

Significance to Sportfishing - These larval tapeworms probably have little effect on local fishes.

***Bothriocephalus acheilognathi* Yamaguti**

This well-known exotic parasite, called the Asian tapeworm, caused mass mortalities of carps in Europe and bait minnows in the USA and may damage fishes in Puerto Rico.
Diagnostic Characters - The scolex is heart-shaped with an apical disk and lateral bothria. The body is white and lacks a neck. Segments do not overlap each other. Posterior segments become gravid before detaching.
Records in Puerto Rico - Present in 2 of 6 guppies at the Maricao Hatchery, 3 of 4 guppies in the Maricao River and 6 of 8 guppies in a small stream west of Lajas. In Maricao, only one adult worm occurred in each fish, but in Lajas 1-3 were found.
Geographic Range - Originally in Asia, it was introduced and established in Europe, USA, and around the world wherever grass carp have been shipped. This worm probably was introduced in grass carp brought into Puerto Rico on numerous occasions since 1972 and is

now established and independent of its original host.
Life History - Most tapeworms require three hosts for development. The Asian tapeworm has a short, two-host cycle, allowing it to more easily become established in many areas around the world. The final host eats the copepod (first intermediate host) and the procercoid develops directly into the adult in the intestine. This worm is a warm-water species, the life cycle proceeds fastest at 25EC.
Location in Host - Intestine.
Size - 8-32 cm long.
Host Specificity – It can use many species of copepods as intermediate hosts and can infect a variety of fishes. It may prefer carps and minnows (Cyprinidae) slightly more than other fishes, but has been found in guppies, channel catfish, and other fishes in the USA, barbs in South Africa and tilapia in Cuba. It may have contributed to the loss of the fathead minnow from Puerto Rico and may eventually attack a variety of local fishes, but guppies seem to be the preferred host here.
Damage to Host - This worm extensively damaged carp culture in Europe and bait-fish culture of fathead minnows and golden shiners *Notemigonus crysoleucas* in the USA. Up to 362 worms per host have been found and 5-10 worms per fish can kill fishes less than a year old. The head or scolex of the worm damages the intestinal mucosa and it may produce a toxin that further weakens the fish. Tropical aquarium fishes are killed if they eat copepods infected with this larval tapeworm. This parasite causes more damage in subtropical and tropical regions. It also seems to do extensive damage when it is first introduced into a new area.
Detection - Segments of this tapeworm may be noted on the bottom of culture tanks, but usually a necropsy is necessary. Very low levels of infection can occur, thus sub-sampling cannot be used to test for the presence of this parasite in transferred stocks.
Significance to Sportfishing - This highly adaptive and damaging parasite may cause significant problems in local sport fishes. Local tilapias may eventually be attacked as they were in Cuba. Guppies are eaten by largemouth bass and are used as live bait for this important sport fish. This baitfish could transfer the Asian tapeworm to largemouth bass.
Preparation for Study - This tapeworm is so distinctive that it can be identified in a simple wet mount.

***Proteocephalus ambloplitis* (Leidy)**

This worm, called the bass tapeworm, did not become established in Puerto Rico in 1946 with the first successful introduction of largemouth bass, but a recent reintroduction of this fish gave it a second chance. These imported fish were destroyed, but we cannot be

certain that this tapeworm did not escape. This parasite would reduce growth and sterilize largemouth bass, and its larval forms could infect any freshwater fish in Puerto Rico.

Proteocephalus ambloplitis

Diagnostic Characters - Found in tissues of fishes, the off-white larvae vary in size and have four spherical suckers and a smaller apical sucker on the scolex (head).

Records in Puerto Rico - It was not seen in Puerto Rico until we found encysted larvae (plerocercoids) in five Florida largemouth bass at the Maricao Hatchery, 3 December 1993. The infected fish had been brought into Puerto Rico from Louisiana in July 1992 for experimental purposes, stocked at a farm near Sabana Grande, then moved to the Maricao Hatchery. We obtained permission to attempt to eradicate this parasite, destroyed all remaining infected fish, and sterilized the affected pond at the hatchery on 26 January 1994. Despite these efforts, the bass tapeworm may have become established in areas around the hatchery or the fish farm. The spread, or hopefully disappearance, of this tapeworm should be carefully monitored. The Maricao Hatchery produces and distributes largemouth bass all over Puerto Rico, possibly providing a potential distribution point for this parasite. We will monitor batches of largemouth bass fingerlings produced by the hatchery to ensure that this dangerous parasite is not present.

Geographic Range - Originally from the eastern USA, this worm has been introduced and established along with the largemouth bass in the state of Washington (USA) and British Columbia (Canada) where immature stages of this tapeworm have harmed economically important trout (Salmonidae). The largemouth bass has been introduced into 25 countries. Puerto Rico is the first location outside continental North America in which the bass tapeworm may have become established. The parasite probably entered Puerto Rico with largemouth bass in 1915, 1916 and more abundantly in 1946, but never became established. Possibly the appropriate invertebrates or the necessary small fishes did not exist in Puerto Rico then to complete the life cycle. Williams and Sindermann (1992) suggested that the more introductions that are made in an area, the more likely the environment is to become predisposed to supporting complex life cycles of exotic parasites. We suspect that the appropriate intermediate hosts may now be present and the life cycle of this worm can now be completed in Puerto Rico. If released, this worm could become established. Reintroductions of exotic fishes multiply the odds of serious parasite and disease problems.

Life History - The adult lives in the intestine of the fish. The eggs are eaten by a copepod and develop into larvae (procercoids). The infected copepod is eaten by a small fish where the parasite penetrates the gut and develops into a second larval stage (plerocercoid) in the organs or mesenteries. The plerocercoid is not host specific and can develop in any freshwater fish, even in small largemouth bass. Finally, a largemouth bass eats an infected small fish and the adult cestode develops in the intestine.

The fish at the hatchery were infected with the plerocercoid. If any of these fish escaped from the fish farm or the hatchery and were eaten by another largemouth bass, then the life cycle could have been completed and this parasite could become established. If these bass had been stocked in reservoirs, this highly damaging parasite would surely have been eaten by a fish host and this parasite introduced. Fortunately, this disaster may have been avoided. Interestingly, after 1.5 years encysted in these hosts, only about a third of these larval tapeworms had died. This plerocercoid is reported to be able to migrate back into the intestine of spotted bass and mature into adults. Fortunately, this did not happen in these imported largemouth bass.

Location in Host - Adult in intestine. Larval form in organs and mesenteries.

Size - Plerocercoids 5-15 mm; adults up to 15 cm long.

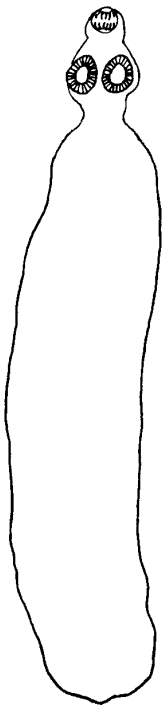
Host Specificity - Larval forms of this tapeworm can infect the tissues of any freshwater fish and can even be found in amphibians and reptiles. The adults usually occur in largemouth bass.

Damage to Host - Immature stages (plerocercoids) migrating through viscera cause damaging adhesions. If these larvae migrate through a vital organ (brain, heart, eye) they can kill the fish and migration through a gonad (producing fibrosis) can cause sterility. This damage may be more severe in fishes with no prior exposure, or resistance. Larval bass tapeworms greatly complicate largemouth bass production in hatcheries, and may reduce the natural reproduction of this fish. Largemouth bass grow rapidly, and a high number remain at large sizes in Puerto Rican reservoirs. Part of this success may be due to an environment virtually free of their normal parasites from their native waters. If the destructive bass tapeworm becomes widespread locally, this high productivity must become at least slightly, and possibly significantly, reduced.

Significance to Sportfishing - This parasite could make the most important freshwater sport fish in Puerto Rico, the largemouth bass, more difficult to rear for stocking, less rapid growing, and smaller in size. It could injure any or all freshwater fishes on the island.

***Ophiotaenia* sp.**

A disease caused by this worm and the next worm may provide a natural, biological control for tilapias. The circumstances which allowed these worms to reduce the condition and numbers of Mozambique tilapia in a reservoir should be thoroughly investigated. We are unable to match this larval form with any known local adult tapeworm. It could occur in the gut of a frog or caiman.



Ophiotaenia sp.

Diagnostic Characters - It is a small, white, ovoid worm with a short neck. The anterior attachment (scolex) has four suckers around a bulb and a terminal sucker without hooks. It very actively contracts and relaxes when alive.

Records in Puerto Rico - Moderate to very heavy infections were found in Mozambique tilapia in Lucchetti and the Loiza River. Possibly, it can be found in populations of this fish in other reservoirs or rivers across Puerto Rico.

Geographic Range - Unknown.

Life History - Unknown.

Location in Host - Liver, spleen and mesenteries.

Size - 1.2 mm long.

Host Specificity - These larvae appear to occur only in the Mozambique tilapia. This specificity in a presumably non-specific larval form is puzzling. It is very likely related to the feeding patterns and habitat preferences of the Mozambique tilapia rather than any host specificity of the parasite (see next worm).

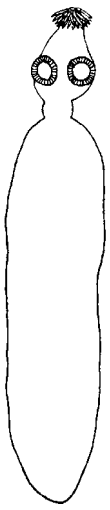
Damage to Host - Very heavy infections of larvae occurred in the internal organs of some Mozambique tilapia, apparently causing starvation and death. This parasite seems to have reduced the numbers of Mozambique tilapia in Lucchetti and may act as a biological control for this fish. A pathogen that only damages Mozambique tilapia might be useful in areas where this fish needs to be limited.

Significance to Sportfishing - These parasites have reduced the number of this fish in Lucchetti and possibly other lakes. However by eliminating some of their population, the remaining fish may be able to grow larger and have a higher condition factor. This parasite and *Ophiovalipora minuta* might have a positive effect on sportfishing in Puerto Rico by limiting the number of Mozambique tilapia. These parasites also might be used in areas where the Mo-zambique tilapia is undesired. More study is needed to understand this condition and to evaluate it as a possible biological control.

***Ophiovalipora minuta* Coil**

A disease caused by this worm and the preceding have reduced the numbers of Mozambique tilapia here. *Ophiovalipora lintoni* (Olsen) from the green heron and *Ophiovalipora nycticoracis* Yama-guti from the black-crowned night heron may also occur.

Diagnostic Characters - It is a small, white to pink, ovoid worm with a short neck. The anterior attachment (scolex) has four suckers around a bulb and a terminal knob with a crown of hooks (two rows). It actively contracts and relaxes when alive.



Ophiovalipora minuta

Records in Puerto Rico - Heavy infections occurred in Mozambique tilapia in Lucchetti, Melania and the Loiza River. Light infections were found in redbreast tilapia in Cidra; 2 of 8 guppies had one worm each from the Maricao Hatchery and one worm occurred in a fat sleeper from a small stream just west of Lajas. Possibly, it can be found in populations of these fishes in other reservoirs or rivers across Puerto Rico.

Geographic Range - Known from freshwater fishes in the USA, its final host, green heron, is found in temperate North America, through the West Indies, into northern South America. The exact range of the tapeworm is not known.

Life History - Eggs pass out of the heron, are eaten by a freshwater crustacean, possibly a copepod, and develop into a procercoid. When the crustacean is eaten by a fish, a plerocercoid develops in the organs of the fish. Finally, a green heron eats the infected fish and the worm develops into an adult.

Location in Host - Found in the visceral organs, intestinal wall and mesenteries in Puerto Rican fishes, but it has only been reported from the gall bladder of fishes in the USA.

Size and color - Two encysted larval stages are 0.9-1.2 mm (white) and 2.8 mm (pink) long.

Host Specificity - These larvae appear to prefer Mozambique tilapia, but also occur in redbreast tilapia, guppy and fat sleeper. This partial specificity in a presumably non-specific larval form is puzzling. It is very likely related to the feeding habits and habitat preference of the Mozambique tilapia. This larval worm occurs in the largemouth bass, spotted bass and western mosquitofish in the USA. The redbreast tilapia, guppy, fat sleeper and Mozambique tilapia are new host records for this parasite.

Damage to Host - Very heavy infections appeared to cause star-vation and death in the Mozambique tilapia. Possibly, migration of numerous parasites through the intestinal wall and encystment in the liver caused the host problems in digesting and absorbing food. The double

infection of this worm and *Ophiotaenia* sp. seems to have caused a reduction of the numbers of Mozambique tilapia in Luc-chetti. This could also be occurring in other reservoirs.

Significance to Sportfishing - See previous worm.

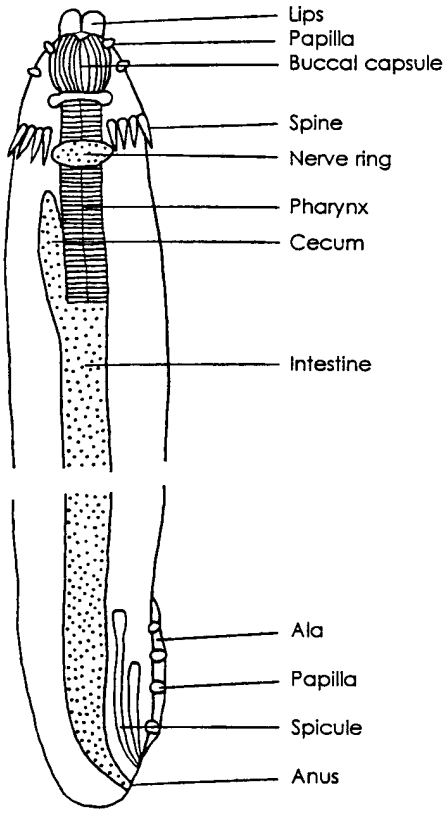
NEMATODA (ROUNDWORMS)

Roundworms, threadworms or nematodes form a phylum. They, along with flatworms and thornyheaded worms, are sometimes called "helminths". Roundworms cause serious diseases and even death in humans. The recent resurgence in popularity of Japanese raw-fish dishes has caused an increase in the number of fish-nematode-related illnesses around the world. Modern refrigeration of fish catches has also allowed nematodes, that would have been discarded by quick cleaning, to migrate from the gut and mesenteries into the edible flesh. The unwise game of "live fish swallowing" has produced severe gastric distress in humans when nematodes from fishes burrowed through the intestinal wall into the body cavity of humans. Treatment requires surgical removal. More than 12,000 species have been described of the more than 50,000 species that probably exist. They are one of the most abundant groups of multicellular organism on earth, both in total numbers of individuals and in number of species. Roundworms occur in such high numbers in almost all vertebrates and invertebrates that it has been suggested that the shapes of all living animals could be seen from space by merely seeing the mass of worms in each animal.

Most free-living forms are small to microscopic, but parasitic forms are large, up to 8 meters long. Roundworms, as the name implies, are circular in cross-section. The body is non-segmented, elongate and slender, often tapered near the ends, and covered with cuticle. Three to six lips of various shapes surround the mouth. The digestive tract is complete, musculature has longitudinal fibers, and a pseudocoel (false body cavity) is present. A nerve ring is usually visible in the anterior end of the body. Sexes are separate. The male has a cloaca, a pair of chitinized copulatory structures (usually spicules), often with a variety of papillae, alae, suckers in or on the posterior end. All of these male structures are important in identifying species. Eggs are released in the intestine of fishes, or through holes in the skin in tissue-dwelling roundworms, into the water. Some eggs already contain developed roundworms, while others are expelled while less developed. Some worms are eaten by fishes and develop directly into an adult. Usually, larvae must go through 2-5 molts in one or more crustacean and/or fish intermediate hosts. They are found in all marine, freshwater and terrestrial habitats. Flying insects, birds and bats take them into the skies.

Three adult and four encysted larval roundworms occur in local freshwater fishes. All three adult species were introduced to Puerto Rico on fishes. None have become a problem, but one has the potential to cause extensive damage.

None of the nematodes found in Puerto Rican fishes are known to normally infect humans. Neverthe-less, consuming live round-worms is ill advised as these parasites can cause consi-derable gastric distress or even penetrate the wall of the stomach or intestine. Those found in the muscle of edible sport fishes are of particular interest as they are likely to be consumed by humans. Thorough cooking will kill all roundworms in fishes. Raw-fish dishes should never be made with any freshwater species.



Composite roundworm

A necropsy is necessary to find the larvae in the internal organs, muscle and mesenteries and the adults in the stomach and intestine of fishes. Roundworms should be relaxed in acetic acid and stored in a mixture of 70% ethanol with 5% glycerine. Adult roundworms which live in the tissues of fishes are exceedingly delicate and tend to explode if placed in fresh water or preservatives. These small worms can be placed in a steaming 0.8% saline and 5% formalin solution. Once fixed (15 minutes for small worms up to 24 hours for large ones), worms can be rinsed in fresh water, and slowly transferred into gradually increasing concentrations of ethanol, until stored in a mixture of 70% ethanol and 5% glycerine. Nematodes are usually examined in wet mounts. Semipermanent mounts may be prepared using glycerine jelly. Identification below genus is difficult in most larval species. Study of the entire life cycle of a roundworm may be necessary to determine the identity of larvae.

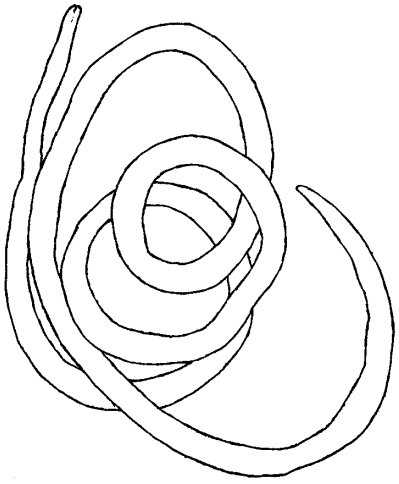
No treatment is possible for roundworms in the body cavity or tissues of fishes and is seldom necessary for intestinal forms. Worms that perforate the intestine of humans must be surgically removed.

*Larval forms.

***Eustrongylides ingotus* Jagerskiold**

This large, fat worm can do severe damage to fishes. It is surprisingly rare in Puerto Rican fishes though it may be more common as an adult in aquatic birds. Determining the cause of its rarity in island fishes might be of interest, as this parasite could cause significant problems in sport fishes. This species could also be *Eustrongylides perpapillatus* Jagerskiold, which has been reported in Brazilian herons, or *Eustrongylides wenrichi* Canavan, which has been reported in North American ducks. A number of other species in this genus occur around the world in fish-eating birds. Although larval worms are difficult to identify, we believe that this worm is *E. ingotus*. The known geographic range of this worm and kinds of birds available in Puerto Rico also agree with our identification.

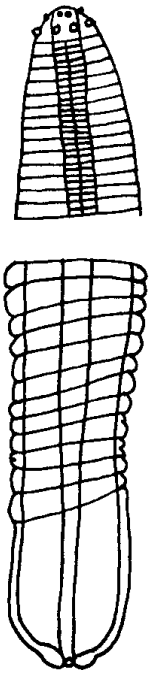
Diagnostic Characters - Larvae are large, red, thick worms with coarse striations. Two rings of papillae (small projections) are on the anterior end, and the anus is in the center of the posterior end.



Eustrongylides ingotus
whole worm

Records in Puerto Rico - One worm was found in a guppy from a pond in Mayaguez, although it probably occurs in more species of fishes and localities in Puerto Rico.

Geographic Range - This parasite encysts in a variety of freshwater fishes from Europe, Japan, New Zealand and North America. The Caribbean Region is a new locality record.



Eustrongylides ingotus
anterior and posterior

Life History - Adults occur in herons and other fish-eating birds. Freshwater worms related to earthworms, *Limodrilus* sp. (Oligochaeta), are the first intermediate hosts. When they are eaten by a fish, the larval roundworms are digested out, penetrate the tissue of the fish or frog host and encyst. After sufficient development in the fish, and when the fish is eaten by a bird, the larval roundworm becomes an adult.

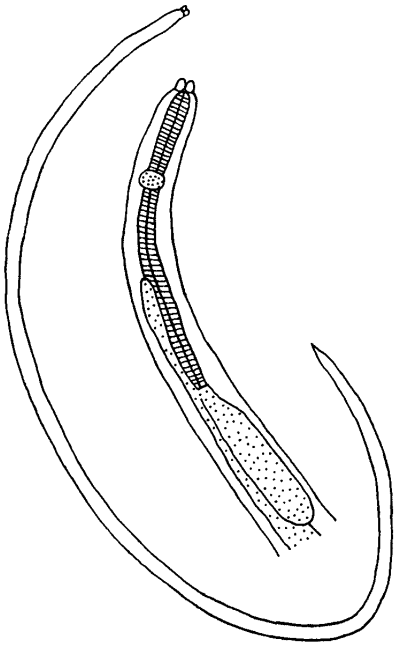
Location in Host - Larvae are in the body cavity or musculature of fishes or frogs; adults in the proventriculus of fish-eating birds.

Size - Up to 10 cm long (in fishes).

Host Specificity - Larvae occur in a variety of freshwater and euryhaline fishes. Although we have only found this worm in the guppy in Puerto Rico, it will probably eventually be found in many other fishes. Adults parasitize fish-eating birds, and possibly reptiles and mammals. The guppy is a new host record and Atheriniformes a new host Order for this parasite. *Eustrongylides* sp. has been reported from atherinids, cyprinodontids and poeciliids, including western mosquitofish.

Damage to Host - This large worm is very damaging to its host. Incapacitating the host may be advantageous to this parasite. Slow or sick fishes are much more likely to be eaten by birds. Modification of the host's behavior may only occur after the larval nematode is sufficiently developed to be able to mature in the final host. This parasite has caused mortalities of ducks, fish kills, and has also killed snakes. *Eustrongylides* sp. in western mosquitofish killed mergansers (ducks). Domestic cats become parasitized if they are fed infected fish.

Detection - Larval roundworms sometimes cause obvious bulges or distortions in the body of infected fishes, may cause unusual swimming behavior, and may rupture the body cavity and kill the host. Not all infections cause such dramatic disease signs and a necropsy of fish may be necessary to find less developed larval forms.



Contracaecum spiculigerum

Harm to Humans - This large roundworm can produce serious symptoms in humans. It infected humans who ate sushi (raw fish), and it perforated the intestine of humans who swallowed live fishes. This parasite is killed by cooking.

Significance to Sportfishing - These worms can kill small fishes and significantly harm larger fishes. It is relatively rare in Puerto Rico and therefore does little damage to sportfishing. Efforts to understand what maintains these unusually low infection levels could be of value in determining biological control methods for this damaging parasite to protect sport fishes elsewhere.

***Contracaecum spiculigerum* (Rudolphi)**

This worm can complete its life cycle in freshwater or saltwater fishes. It can be brought into freshwater by euryhaline herrings but it also occurs in strictly freshwater fishes with little effect.

Diagnostic Characters - This large red worm has convoluted lips. A cecum projects forward (anteriorly) at the junction of the pharynx and intestine .

Records in Puerto Rico - One worm was found in a Florida

largemouth bass from Louisiana held at the Maricao Hatchery (USNM), and in 1 of 8 liza from the Guajataca River; 2-6 worms were collected from 2 redeye bass in the Maricao River. Light infections occur in scaled sardine and Atlantic thread herring in coastal fresh waters. The adult commonly occurs in double-crested cormorant *Phalacrocorax auritus*, herring gull *Laurus argentatus*, brown pelican *Pelican occidentalis*, reddish egret *Egretta rufescens* and possibly other local fish-eating birds. It is conceivable that the worm in the Florida largemouth bass was brought to Puerto Rico from Louisiana, but the fish could have easily been infected here. This roundworm occurs commonly in coastal marine fishes, but is less common in local freshwater fishes.

Geographic Range - It occurs around the world (cosmopolitan) in fish-eating birds including North America, West Indies, and Mexico.

Life History - Eggs pass out through the intestine of birds. Larvae or eggs are ingested by crustaceans and develop. These crustaceans are consumed by fishes and the larval roundworms migrate through the gut and encyst in mesenteries. When an infected fish is eaten by a suitable bird, the roundworm matures in the digestive tract.

Ecology - The life cycle can, apparently, be completed in freshwater or marine environments. Brown pelicans are becoming established in inland reservoirs and may spread this parasite to additional freshwater fishes (Williams, Bunkley-Williams and López-Irizary 1992).

Location in Host - Encysted in the mesenteries of fishes. Adults in the digestive tract of birds.

Size - Larvae encysted in fishes 6-8 mm long.

Host Specificity - The larval forms seem to have little specificity, occurring in a variety of freshwater and coastal marine fishes. The redeye bass and liza are new host records for this parasite.

Damage to Host - These worms usually occur in low numbers and cause little damage. Heavy infections injure or kill fishes.

Significance to Sportfishing - The light infections in freshwater fishes probably cause little harm. This parasite may be more important in marine sport fishes.

***Camallanus cotti* Fujita**

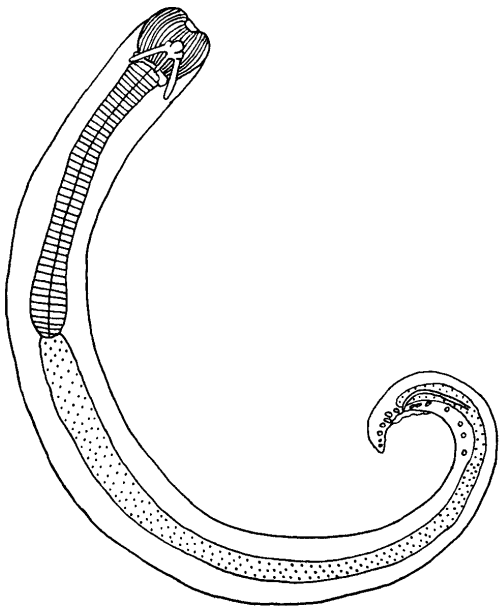
This highly damaging worm was brought into Puerto Rico in aquarium fishes. It has readily become established in many areas around the world and mortalities of fishes have resulted. Care should be taken to avoid the establishment or spread of this dangerous parasite among island fishes.

Diagnostic Characters - It is a small roundworm with a clamshell-shaped buccal capsule in the anterior end.

Records in Puerto Rico - It was found in captive guppies, but this worm is probably not established in the wild in Puerto Rico.

Geographic Range - It was originally described from Japan, but

spread around the world in ornamental fish culture. This roundworm has been recorded from Australia, Europe, Malaysia and USA and could appear anywhere aquarium fishes are sold.



Camallanus cotti

Life History - The exact life cycle is unknown, but this worm seems to be rather adaptive, or generalized in its intermediate host requirements. This makes the parasite very dangerous because it may easily become established in Puerto Rico.

Location in Host – Intestine.

Size - Male 2.4-3.5 mm, female 4.7-6.7 mm long.

Host Specificity - Known from many species of fishes.

Damage to Host - The attachment in the intestine of the host causes some damage. Heavy infections could be detrimental to hosts or cause mortalities.

Significance to Sportfishing - The guppy is widespread, abundant and used as live bait for largemouth and peacock bass. This dangerous and adaptive parasite could spread across the island and attack some of our most important sport fishes.

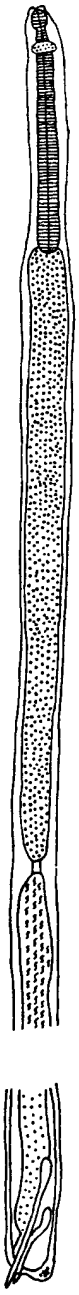
***Philometroides* sp. of Crosby and Rogers**

This worm is being described as a new species. It is a rather destructive roundworm which causes the eyes of bluegill to bulge. It has survived in low numbers from early introductions of bluegill.

Diagnostic Characters - It has an elongate red body with rounded ends. The esophagus is bulbous at the anterior end.

Records in Puerto Rico - Light infections occurred in bluegill at Maricao Hatchery, but it may be more widespread in Puerto Rico.

Geographic Range - Known from the southeastern USA, it has been confused with other similar roundworms in the past. The local distribution of this parasite must be determined before any possibility of eradication can be considered.
Life History - Unknown.
Location in Host - The adult is found in tissues behind the eye. Immature worms may be found migrating through muscle or other tissues.
Size - Female 3.3-12.2 mm, male 2.5-3.4 mm.
Host Specificity - It only occurs in bluegill.
Damage to Host - Migrating immature stages are particularly destructive. Adults usually do little damage, but can cause exophthalmia (bulging eyes) and injure the eyes.
Detection - Removal of the eyes is necessary to find the adults in the tissues. Immature worms are rather difficult to find. "Candling" thin sections of muscle tissue by holding in front of a bright light may reveal the larvae as dark regions. Ascertaining that stocks are free of this parasite is difficult.
Significance to Sportfishing - The amount of damage this parasite causes to the production, survival and growth of bluegill in Puerto Rico has not been determined. Since cleaning food fishes does not require the removal of fish eyes, this parasite usually remains hidden and practically unknown. A hatchery stock free of this parasite could be established from local fish by screening for this worm and used to stock new reservoirs and for future restocking.



Philometroides sp.

Tetrameres fissispina **(Diesing)**

This roundworm causes a serious disease in domestic fowl. It is seldom found in fishes.
Diagnostic Characters - Larval forms have a short, clear vestibule between the mouth and pharynx. The pharynx is long (more than a third of the worm's length); the anterior is twisted, narrower and less dark than the posterior part.
Records in Puerto Rico - Light infections were found in bigmouth sleeper in the Loiza River east of San Juan (USNM).
Geographic Range - This roundworm is a very common parasite of water fowl in Africa, Asia,

Europe, Oceania North and South America.

Life History - Eggs pass out the intestine of a bird and hatch after being eaten by a variety of freshwater or marine invertebrates. Larvae are infective in 7-18 days. After the invertebrate is eaten by the final (bird) host, the worm becomes mature in 18 days. Larvae survive if eaten by freshwater or marine fishes (transfer hosts). The local final host may be the herring gull.

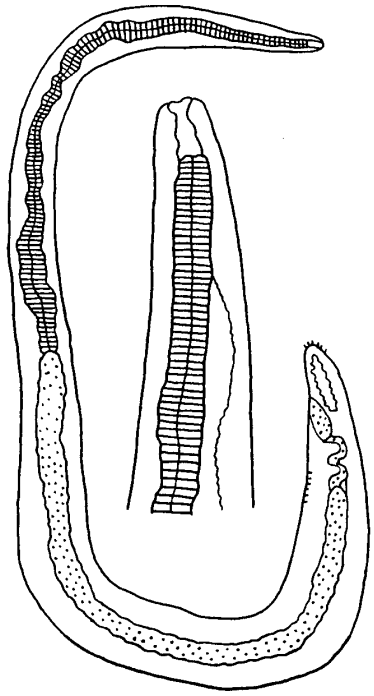
Location in Host - Larvae are in the skin, muscle, internal organs and mesenteries of fishes. Adults are in a bird proventriculus.

Size - Larval forms in fishes 1.8-2.0 mm long.

Host Specificity - None. The bigmouth sleeper is a new host record for this parasite.

Damage to Host - High numbers can kill fishes. This parasite is a potentially very serious threat to commercial poultry.

Significance to Sportfishing - These sleepers are used as food and sport fishes in Puerto Rico, but this parasite occurs too seldom to be important.



Tetrameres fissispina

***Spinitectus carolini* Holl**

This small, highly ornamented worm usually does little harm to fishes. It is an exotic parasite that has, thus far, been limited to upland streams in Puerto Rico. It could be a potential problem for sport fishes, particularly sunfishes.

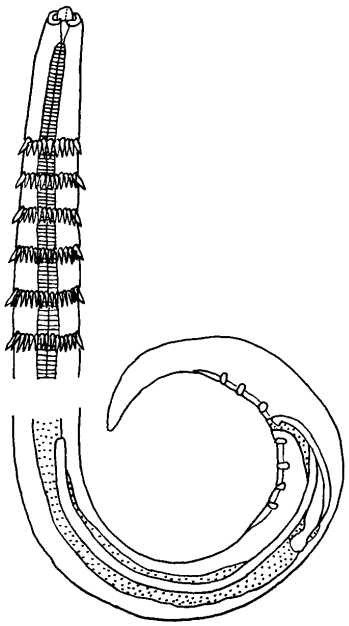
Diagnostic Characters - Rings of large spines, decreasing in size posteriorly, are found on the body.

Records in Puerto Rico - Three to 17 worms were found in a mountain mullet in the Yauco River (USNM 83026) and two from the Maricao Fish Hatchery. This parasite is probably common in upland streams.

Geographic Range - Known east of the rocky mountains in the USA and Canada, it was probably introduced into Puerto Rico with southeastern USA freshwater fishes, possibly in 1958, along with the redeye bass which was stocked in upland streams. This is the first

known introduction of this parasite.

Life History - Eggs are shed into the intestine of fish, pass into the water, and are eaten by immature aquatic insects. Larval stages develop in the muscle of the insect. When the insect is eaten by a fish, the parasites become adults. This is one of the few exotic parasites with complex life cycles, involving intermediate hosts, that have become established in Puerto Rico. Study of the local life cycle would be of interest to see how it compares with that found in the native environment.



Spinitectus carolini

Ecology - These roundworms appear to occur only in upland streams, but not in reservoirs in Puerto Rico. They are known from reservoirs and almost any other habitat in the USA. The higher temperatures in local reservoirs and lowland streams may limit the distribution of this non-tropical parasite

Location in Host - Intestine and stomach.

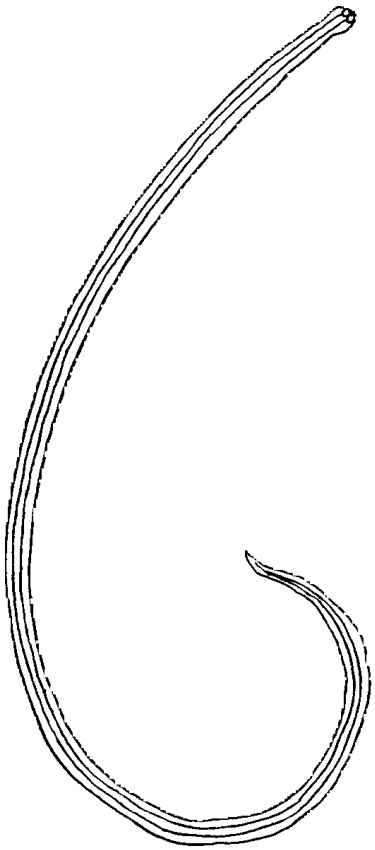
Size - Female 5.8-10.0 mm, male 5.2-10.8 mm long.

Host Specificity - It is known from a wide variety of hosts including almost all species of sunfishes in the USA. The mountain mullet is a new host record and Mugilidae is a new family for this parasite.

Damage to Host - This worm usually occurs in low numbers and does little damage to the host; however, large numbers of worms can stunt or kill fishes. We have seen the hooks of this worm damaging the intestinal lining of freshwater fishes in the southeastern USA.

Significance to Sportfishing - Sunfishes (largemouth bass, bluegill, redear sunfish, redbreast sunfish and redeye bass) are very important sport fishes in Puerto Rico. The importation of an exotic parasite that prefers these fishes is unfortunate. Since this worm has not become established in the island reservoirs, its impact has been very low. As long as it remains in stream fishes, it has the potential to spread into the reservoirs or hatchery and cause serious problems for sport fishes.

Skin blister roundworm



Skin blister roundworm

This undetermined species of minute worm caused raised nodules on the skin of a white catfish. They have been called "skin blisters" but they do not contain fluid. Other workers have identified it as *Contracaecum* sp. but it does not appear to fit into this genus. Members of the genus *Cystoopsis* may also cause skin "blisters" in fishes.

Diagnostic Characters - This is an extremely small roundworm forming raised nodules on the skin. Several larval roundworms are found in each cyst.

Records in Puerto Rico - These worms were found in 24 skin nodules on a white catfish from Guayabal. It is probably much more widespread.

Geographic Range - This disease has been reported from the eastern USA, but only in channel catfish. It was possibly imported into Puerto Rico with the channel catfish in 1938.

Life History - Unknown. These larvae are much smaller than other encysted larval roundworms reported from fishes. It could be an accidental infection by a larval form that should develop in an invertebrate.

Location in Host - Skin.

Size - 2-3 mm long.

Host Specificity - It was previously known from the channel catfish. The white catfish is a new host record.

Damage to Host - Although the shallow wounds are usually superficial, they can provide an entrance for pathogenic bacteria and cause more extensive damage. Each blister holds three or more nematodes.

Detection - Scraping and dissecting lesions can confirm the presence of this parasite.

Significance to Sportfishing - All catfish are important sport fishes. This disease has thus far not occurred often enough in Puerto Rico to cause much damage. It has the potential to deform or damage sport fishes.

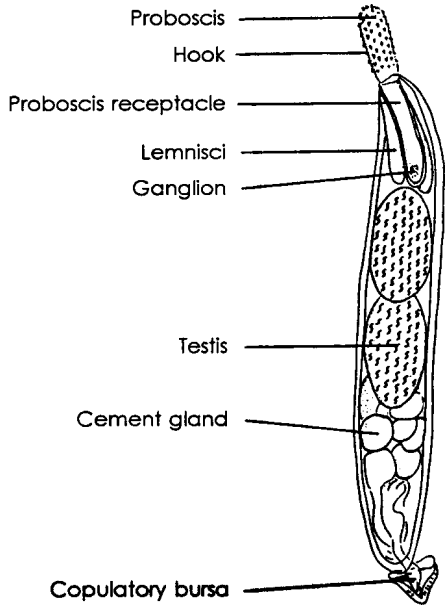
Preparation for Study - We have prepared histological sections of these lesions and sent samples to roundworm and histology specialists, but have not been able to identify this worm. This condition has been recognized by those studying channel catfish diseases in the USA, but the nematode has not been identified. Infected fishes might be held alive until this roundworm could develop and express more diagnostic characters.

ACANTHOCEPHALA (THORNY-HEADED WORMS)

These worms form a small phylum in the Animal Kingdom. The name "acanthocephala" means thorny headed. Acanthocephalans are all permanent parasites in the intestine of most vertebrates, including humans. More than 700 species are known. Adult females vary from 1 mm to longer than 1 m, but are usually about 2 cm long. Males of the same species are typically smaller than females. They may be white, yellow, orange or red in color (*Pomphorhynchus lucyae* Williams and Rogers seems to absorb orange pigments from crayfish in the intestine of southeastern USA freshwater fishes). They are bilaterally symmetrical, unsegmented, or only partially segmented externally, and unsegmented internally. They attach in the gut of their host with a globular or cylindrical, protrusible, thorny proboscis. The proboscis pops out like an everting plastic glove, and the thorns fold out and lock like a compact umbrella. Muscles invert the proboscis, and a hydraulic system (lemnisci) pop it back out. Some species have thorns on the body as well. Sexes are separate, fertilization is internal, and embryos develop in the body of the female. Shelled larvae (acanthors) are shed through the intestine of the host, eaten by a crustacean, insect or mollusk intermediate host, and develop into an acanthella then to an encysted cystacanth larval stage. When the final host consumes an infected intermediate host, the cystacanth develops into an adult in the intestine. Adults absorb nutrients from the gut contents of their hosts. Proboscis hooks cause some mechanical damage, but this is only serious in a heavy infection. Treatments are seldom necessary and fortunately, natural infections usually consist of only a few worms per host. These worms rarely harm humans since they are usually discarded with the intestine when fishes are cleaned and cooking kills these parasites.

A necropsy is necessary to find these worms in the intestine. Acanthocephalans in Puerto Rican fishes can be identified in wet mounts for routine examinations. For more detailed study, the proboscis must be fully everted before preserving. Worms must be refrigerated in distilled or fresh water for 12-24 hours before preserving in 5% formalin. The thick cuticle of these worms does not allow alcohol solutions or stains to readily penetrate. The cuticle must be pierced before dehydrating in alcohol solutions and staining.

Acanthocephalus alabamensis Amin and Williams



Acanthocephalus alabamensis

This is an uncommon and probably unimportant parasite in Puerto Rico, but it is interesting because it is the first example of a thorny-headed worm ever known to be introduced to a new geographic location.

Diagnostic Characters - They are small worms which lack giant nuclei in the outer wall. The proboscis is covered with small hooks.

Records in Puerto Rico - A light infection was found in three redeye bass from the Maricao River. It may be limited to higher elevation streams which have lower water temperatures.

Geographic Range - Known from Alabama and Georgia, apparently, this worm was introduced with some, if not many, of the fishes imported from the southeastern USA between 1930 and 1950 and the life cycle was established in Puerto Rico.

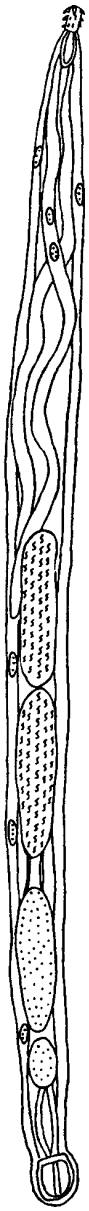
Life History - Larvae, similar in appearance to adults, occur in free-living freshwater amphipods, copepods or isopods. There is no second intermediate host.

This is the first example of a thorny-headed worm that has become established in a new geographic region. This particular worm has a less complicated (two host) life cycle that might be more easily completed in a new environment. Possibly so many fishes, and inadvertently, so many invertebrates, have been introduced from the southeastern USA to Puerto Rico, that parasite life cycles involving

multiple hosts can now become established.
Location in Host - Intestine.
Size - Female 3.7-6.7 mm, male 1.6-3.2 mm long.
Host Specificity - It occurs in a variety of southeastern USA freshwater fishes, including redeye bass. It appears to have little specificity.
Harm to Humans - Humans who eat raw fishes have been parasitized by species from this genus in North America and Indonesia. Cooking kills these parasites.
Significance to Sportfishing - This worm usually occurs in light infections and would probably do little harm to sport fishes if it were common here.

***Floridosentis mugilis* (Machado-Filho)**

A very common and persistent parasite in local mullet. It is an exception to the normal occurrence of these worms in predators.
Diagnostic Characters - These large white worms have large globs (giant nuclei) in the outer wall. The proboscis has a few large hooks.
Records in Puerto Rico - Light to moderate infections were found in all white mullet from the Bucaná River and in all coastal fresh waters of Puerto Rico (USNM). White mullet in Puerto Rico almost invariably have this parasite.
Geographic Range - It is known from the Gulf of Mexico through the West Indies to Brazil, and in the Gulf of California.
Life History - Unknown. Most known life cycles of thorny-headed worms involve at least one small invertebrate and at least one large invertebrate or vertebrate intermediate host. Since this host eats only small invertebrates, its life cycle may be more abbreviated. White mullet which remain for months in local fresh water, lose their flukes but not their thorny-headed worms (Garcia-Sais and Williams 1985). This suggests that either the life cycle of this thorny-headed worm occurs in both freshwater and marine hosts, or that *Floridosentis mugilis* survives longer than the flukes in the mullet.
Location in Host - Intestine.
Size - Females up to 25 mm, males to 18 mm long.
Host Specificity - It only parasitizes white and striped mullet.



Floridosentis mugilis

HIRUDINIDA (LEECHES)

Leeches form one of the classes of segmented worms or annelids. The most familiar member of this phylum is the earthworm. Leeches are often called "bloodsuckers" for their feeding habits. They are sometimes used as hook-and-line bait for fishes! Predacious leeches have also been used to control snails that cause swimmers itch (the cercaria of a bird fluke which attack and irritate the skin of humans). More than 300 species of leeches have been described. Adults vary from 0.5-45 cm in length, although they vary greatly in size and shape due to powerful muscle contractions and enlargement during feeding. Leeches have a pigmented (sometimes brightly colored), dorso-ventrally flattened (depressed) body made up of 34 segments, which may be further subdivided by shallow creases or lines into annuli. One sucker occurs on the posterior end of the body and usually another is found on the anterior end surrounding the mouth. A poorly formed, saddle-shaped mid-portion (clitellum) functions in copulation and cocoon formation. The body cavity (coelom) is reduced to a few channels. Eggs are usually deposited in cocoons formed of epithelial tissue and mucus. Development is direct (no larval stages). Their complex reproductive systems contain both sexual organs (hermaphroditic). Leeches occur in fresh, brackish and marine waters, and also in moist conditions on land around the world except in Antarctica. They can crawl, attach with their suckers, and many are able to swim. Leeches are permanent to temporary ectoparasites, predators or scavengers. Parasitic forms feed on whole blood of crustaceans, fishes, amphibians, reptiles and mammals. They are often vectors of pathogenic protozoa, roundworms and tapeworms. They have been accused of spreading lymphocystis disease and bacterial diseases among fishes.

Several large leeches in fresh water attack mammals, including humans, in Puerto Rico. A few small and attractively marked predacious leeches feed on snails, but we found only one species parasitizing Puerto Rican freshwater fishes.

Phylum Annelida Taxonomy and Contents . . . . . **Page**

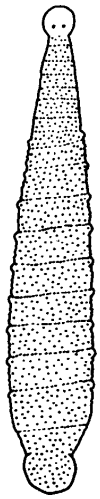
Myzobdella lugubris Leidy

This exotic leech may eventually parasitize freshwater sport fishes throughout Puerto Rico. This introduction was unfortunate because it is highly damaging and may carry microbial diseases.

Diagnostic Characters - The body is smooth and wider near the posterior end. The posterior sucker is distinct from the body, concave and more narrow than the widest part of the body. It is the only leech

found on fresh and brackish water fishes in Puerto Rico.

Records in Puerto Rico - At the Santa Teresa Lagoon near Humacao, very heavy infections occurred on siri crabs *Calinectes bocourti* and blue crabs *Calinectes sapidus* and one to two leeches per fish were found on redbreast tilapia, tarpon and white mullet (Williams, Bunkley-Williams and Burreson 1994). One leech was collected off a swordspine snook from the Añasco River. When we first encountered this leech at the Santa Teresa Lagoon, we thought it was a recent and isolated introduction, but a local biologist remembered seeing leeches there in 1968; and later we found a specimen on the western end of the island. We expect it can invade all fresh and brackish waters, because it attacks inland freshwater fishes in the USA.



Myzobdella lugubris

Geographic Range - It is recorded across the entire USA and into Canada. Not previously found south of Florida, this was a range extension of 1700 km and a new Caribbean record (Williams, Bunkley-Williams and Burreson 1994).

Life History - Adults usually leave the host and deposit cocoons from which 1-2 mm free-swimming young emerge. In brackish water, leeches attach cocoons to siri and blue crabs. It will be interesting to see if it will parasitize freshwater crabs or shrimp in Puerto Rico.

Ecology - This leech has been found in all fresh and brackish water habitats (0-22, usually below 15 ppt, salinity), it is killed by full-salinity sea water. It prefers warm water (21-30EC, few in 16-20EC, seldom cooler). Many variations in host preference, incidence, and abundance have been reported from different habitats.

Location in Host - Skin or fins, rarely mouth or gills of fishes; legs or shell of crabs or shrimp.

Size - 1-40 mm. long. It may attach at a very small size. Adult size is more dependent on how recently and how much blood it has consumed than on the age of the leech.

Host Specificity - Blue and siri crabs, grass shrimp *Palaemonetes pugio*, striped mullet, southern flounder *Paralichthys lethostigma*, killifish *Fundulus* spp. and white catfish are preferred, but a great variety of hosts are known. Any Puerto Rican sport fish could be attacked. The redbreast tilapia (Williams, Bunkley-Williams and Burreson 1994) and swordspine snook are new hosts for this parasite. It was probably introduced from the southeastern USA. No leeches capable of attacking brackish and freshwater fishes, crabs and shrimp previously existed in Puerto Rico.

Damage to Host - Mass attacks killed siri and blue crabs in

Puerto Rico, and white and channel catfish in the USA. Local, native crabs and shrimp, and some exotic sport fishes have no previous exposure to or defense against this leech and may be highly vulnerable. Fishes wounded by leeches often become infected with *Saprolegnia* spp. Leeches carry and transmit a variety of protozoan and microbial diseases. It could have spread the blue tilapia *Trypanoplasma* sp. epizootic across the island, and may transmit new blood diseases from aquaculture or aquarium fishes.

Detection - It is easily seen externally on fishes, crabs and shrimp.

Harm to Humans - The body leech has attached to humans in Puerto Rico, but has not attempted to feed.

Significance to Sportfishing - Eventually this leech may cause extensive losses of and damage to sport fishes. Fishermen may also be offended by the wounds caused by these leeches.

Preparation for Study - Leeches may be relaxed in 15% ethanol or refrigerated until the leech does not respond to touch. They can then be preserved in 5% formalin, or 70% ethanol (151 proof rum will do).

Treatment - Knowing why this leech has not invaded local fresh waters more rapidly, might be useful information in determining methods of control. The erratic raising and lowering of local reservoirs may expose the deposited cocoons of leeches and limit their numbers.

CRUSTACEA (CRUSTACEANS)

Crustaceans are one of the phyla of animals with hard, segmented shells (exoskeletons). They are largely aquatic, while the insects and arachnids are mostly terrestrial. They generally have two pairs of antennae; respire through gills or the body surface; and, anteriorly or throughout, have paired, segmented, usually biramous appendages. More than 36,000 species have been described including copepods, branchiurans and isopods.

Phylum (or Class) Crustacea Taxonomy and Contents . Page

COPEPODA (COPEPODS)

Copepods form a class in the crustaceans. The common name copepod means "oar-foot". They are found in fresh and sea water. A new species of copepod was just described from the water held by bromeliads high in the trees of Puerto Rico. Most copepods are free-living and are very important food items for a variety of aquatic life.

Approximately 10,000 species have been described. They range from 0.5 mm to 25 cm, but most are less than 1 cm long. Body shapes vary tremendously from generally cylindrical to flattened or saucer shaped. The body is divided into a head, that is fused with the first or second thoracic segments (cephalothorax), thorax and abdomen. The thorax usually has five segments; and the abdomen three to five segments. One pair of thoracic appendages is modified into mouthparts, and five pairs are unmodified. The abdomen has no appendages, and usually terminates in a bifurcate tail (caudal rami).

In parasitic forms, the life cycle is direct, but typically involves a series of planktonic stages off the host. Sexes are separate with males often much smaller than females. Copepods ordinarily occur on the gills or skin of fishes, but may burrow into the flesh or head sinuses, or crawl into the nose (nares) or eyes (orbits). They also associate with or parasitize a variety of invertebrates. We found one damaging a basket sea star in Puerto Rico (Williams and Wolfe-Walters 1990). Fish-parasitic copepods are not known to attack humans. Those on fishes are permanent parasites, feeding on mucus, sloughed epithelial cells and tissue fluids. Copepods have not been found to directly transmit microbial disease, but the wounds they cause may provide entry points for diseases. Parasitic copepods are quite rare on inland fishes. Most of those in fresh water have been carried in from the saltwater environment by their euryhaline hosts. Collected specimens can be preserved and stored in 70% ethanol and mounted in glycerine jelly.

The best treatment for copepod parasites is prevention - do not introduce infected fishes to the system. Salt is effective as a 30 second dip at 3-5%. Fishes sensitive to salt can be treated at 0.8-1.1% salt as a bath for three days. Ponds can be drained and dried to eliminate all developmental stages. For chemical treatments see Post (1987) or Hoffman and Meyer (1974). Many pond treatments that are effective against copepods, especially tissue-copepods, have not been approved by the Food and Drug Administration for use on fishes, or for use on food fishes because they are very toxic to humans and to fishes, especially largemouth bass. Additionally, these compounds not only kill the parasitic copepods but also kill the free-living planktonic copepods. Treatment of wild fishes in reservoirs or streams is seldom practical.

Class Copepoda Taxonomy and Contents ..... **Page**

***Bomolochus nitidus* Wilson**

This small marine copepod is apparently quickly killed by fresh water, but it can be seen on mullet entering coastal fresh waters. It is unlikely to cause problems.

Diagnostic Characters - An extremely small, beige copepod, its large first antennae are covered with numerous setae. The second antennae are not formed into long arms.

Records in Puerto Rico - One to two copepods were found in approximately 3% of the white mullet and liza examined from the lower reaches of rivers in Puerto Rico (USNM). This species is either uncommon or quickly removed by freshwater exposure.

Geographic Range - It is reported from North Carolina to Florida along the Atlantic coast of the USA. Puerto Rico is a new locality record for the Caribbean. This parasite was probably not introduced, but occurs naturally throughout the region.

Location in Host - They appear as darker spots on the inside of the opercular flap and lining of gill chamber. Sometimes these copepods are found on gills, but this may be due to movement after host death.

Size - Female 1.5-2.0 mm long.

Host Specificity - Previously reported from striped mullet, the white mullet and liza are new host records.

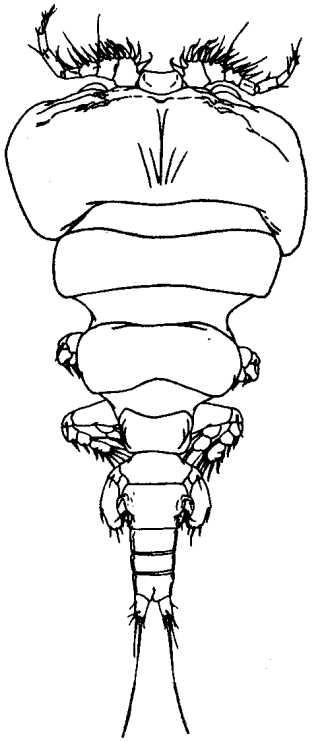
Damage to Host - Unknown, but probably slight. This copepod has never been known to cause epizootics.

Detection - Almost microscopic, they can barely be seen with the naked eye. They may be found in scrapings of the inside of the opercular flap

and linings of the gill chamber observed with a dissection microscope.

Significance to Sportfishing - These copepods are so small and occur in such low numbers that they probably do little damage to hosts.

Treatment - This parasite is supposed to be exclusively marine. It is reported to drop off the host when it enters fresh water. This may explain the low numbers in our records.



Bomolochus nitidus

Ergasilids

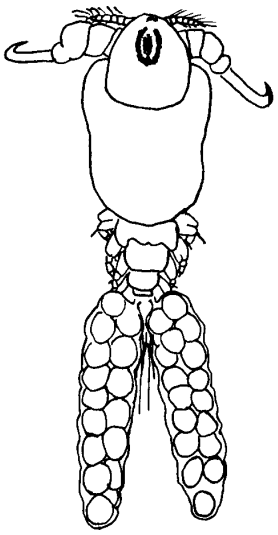
Members of the genus *Ergasilus* have extremely enlarged second antennae that look like long arms when viewed with a compound microscope. The terminal segment of this arm is a single spine. Eggs, laid in egg sacs, hatch as free swimming nauplii with oval bodies and six legs. In the plankton, molting occurs between multiple naupliar stages, and several copepodid development stages. Males mate with free-swimming females, then die. Females find a fish host, attach to the gills, mature and begin producing eggs. Ergasilids are little modified from free-living copepods. One species in the genus remains free-living. Females on the gills of fishes can still swim.

To find these parasites on the gill filaments, the gill arches are removed from the host and examined with a dissection microscope. *Ergasilus labracis* Krøyer has been reported from striped bass in the West Indies, but this host and parasite are actually limited to North America. Prieto (1991) found *Neoergasilus japonicus* (Harada) on the skin and gills of carp, tilapia and other fishes in Cuba.

***Ergasilus caeruleus* Wilson**

This copepod was introduced to Puerto Rico on sunfishes. We found it in Cidra and La Plata, but it probably occurs in other lakes and reservoirs. Puerto Rico may be the only exotic location known for this freshwater parasite.

Diagnostic Characters - The body of this species is translucent with bluish lines on the back. The second antennae have a knob on the inner, distal margin of the third (next to last) segment.



Ergasilus caeruleus

Records in Puerto Rico - One to 3 copepods occurred on 6 redbreast sunfish, and 15 on a bluegill in Cidra and one on a redbreast sunfish in La Plata. More examinations of sunfishes are necessary to determine the exact distribution and abundance of this parasite.

Geographic Range - Known throughout the eastern USA and Canada, this copepod may eventually be found wherever the sunfish hosts occur. Sunfishes, other than largemouth bass, have not been widely introduced. This may be the first introduction of this parasite.

Location in Host - Gill filaments.

Size - Female 0.7-0.9 mm long (excluding egg strings).

Host Specificity - It is known mostly from *Lepomis* spp., but it also occurs on a few other fishes in the USA. Records from largemouth, smallmouth and spotted basses were probably erroneous. This copepod occurred more commonly on the redbreast sunfish in Puerto Rico, but was found in higher numbers on the bluegill. It will probably be found on the redear sunfish.

Damage to Host - Large numbers of this parasite can irritate the gills. It has caused fish kills in reservoirs.

Significance to Sportfishing - These copepods, although small, could become a problem in crowded conditions. They are able to reproduce quickly and could heavily infect fishes kept in marginal and crowded conditions. Outbreaks are more likely in hatchery or culture conditions, but epizootics have occurred in lakes and reservoirs.

***Ergasilus lizae* Krøyer**

This native and cosmopolitan parasite has caused kills of wild freshwater fishes and large aquaculture losses. It is one of two species of ergasilids always found on the gills of mullets in Puerto Rico, but can occasionally occur on any fish. This rather damaging copepod is one of the very few able to tolerate salinities ranging from full strength salt water to totally fresh water.

Diagnostic Characters - This species is white to light beige. The body is narrow. The terminal spine of the second antennae is approximately half the length of the next segment.

Records in Puerto Rico - Twelve to 80 copepods occurred on every white mullet, fantail mullet and liza we examined from the Bucaná

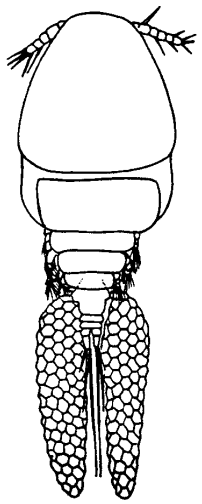
River, Guanajibo River mouth and Joyuda Lagoon. It probably occurs in every mullet found in river mouths and coastal fresh waters on the island. Rarely, 1-4 copepods occurred on timucu, ladyfish, tarpon and a redbreast tilapia in the Loiza River and the Santa Teresa Lagoon.

Geographic Range - Occurs worldwide.

Location in Host - Usually on the gill filaments. Three copepods occurred in the nares of a timucu. This odd shift in attachment site might be worthy of additional study.

Size - Female 0.7-0.8 mm long (excluding egg strings).

Host Specificity - A consistent parasite of mullets, it can also occur in a great variety of marine and freshwater fishes around the world, including largemouth bass, bluegill, blue tilapia, fantail mullet, redbreast sunfish, redear sunfish, striped and white mullet. The liza, ladyfish, tarpon and timucu are new host records for this parasite.



Ergasilus lizae

Damage to Host - Large numbers of this parasite irritate the gills. Fish become emaciated and finally die. It caused fish kills of largemouth bass, bluegill and redbreast sunfish in southeastern USA fresh waters. This copepod has also produced heavy losses of striped mullet in culture ponds in Israel and Louisiana (USA), and of blue tilapia in Israel.

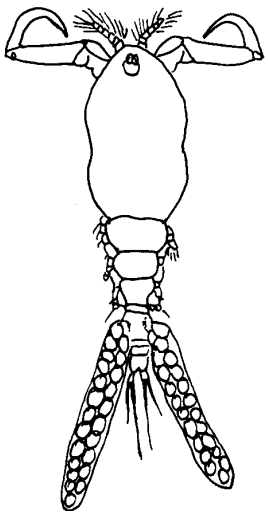
Significance to Sportfishing - This copepod has a broad salinity tolerance. It has been shown to cause problems when in contact with largemouth bass and bluegill. Caution should be taken not to transport this parasite to fresh water. Mullets should not be cleaned or discarded in freshwater lakes.

Comments - A great deal of confusion exists about the exact number of ergasilid species on mullets. At least one other species very similar to the *Ergasilus lizae* (*Ergasilus* sp. cf *lizae*) occurs on the gills of island mullets. Since these species are all but indistinguishable, and copepod experts cannot decide what to do about them, it is probably best, for the purposes of this book, to simply acknowledge the possibility of unnamed species of ergasilids on local mullets. The names *Ergasilus mugilis* Vogt and *Ergasilus nanus* van Beneden have been reported from Western North Atlantic mullets, but the taxonomic status of these parasites is uncertain.

Ergasilus spatulus Cressey was reported from a timucu in Costa Rica. Copepod experts later decided that this copepod was actually *Ergasilus arthrosis* Roberts, but Cressey's original figure looks more like the *Ergasilus lizae* that we found on this host in Puerto Rico.

***Ergasilus versicolor* Wilson**

This copepod was probably introduced to Puerto Rico with catfishes. It is quite rare here. Puerto Rico may be the only exotic location known for this brackish and freshwater parasite.



Ergasilus versicolor

Diagnostic Characters - This species is white to beige with black lines. The body is broad, almost square. The terminal spine is long, approximately 70% as long as the next segment.

Records in Puerto Rico - One copepod occurred on a redear sunfish in the Santa Teresa Lagoon (USNM).

Geographic Range - Known throughout the eastern USA and eastern Canada. This record may be the first known introduction of this parasite. It may have been introduced on catfishes or bluegill, but we have not found it on any we examined. It could also be a native parasite that occurs on mullet, but we have never found it on them.

Location in Host - Gill filaments.

Size - Female 1.1-1.5 mm long (excluding egg strings).

Host Specificity - It occurs on a variety of fishes including bluegill, brown bullhead, channel catfish and striped mullet in the USA. Some authors suggest that it does not occur on sunfishes in North America. The redear sunfish from Puerto Rico is a new host record. This may be an example of unusual combinations of parasites and hosts that can occur in a new environment.

Damage to Host - Unknown, but any ergasilid can cause injury.

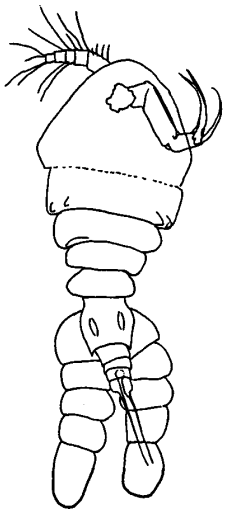
Significance to Sportfishing - Unimportant unless it begins to appear in high numbers.

***Paraergasilus* sp.**

The appearance of one of these odd, little-known, and largely old-world copepods in the Caribbean is quite surprising. This is, apparently, a new species.

Diagnostic Characters - It is a white to beige copepod similar to the other ergasilids by having an extremely enlarged second antennae that look like long arms. However, the last segment of its arm is split into three long, slim "fingers", instead of just one spine.

Records in Puerto Rico - Common snook and bigmouth sleeper from fresh water and striped mojarra from brackish water in the Guanajibo River mouth were parasitized by 1-2 copepods each.

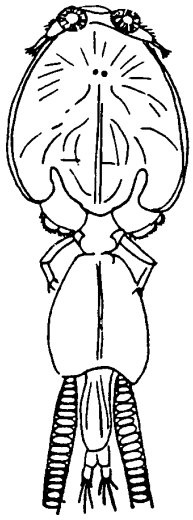


Paraergasilus sp.

Geographic Range - The range for this species is not known. Other members of this genus have been reported from Asia, east Africa and the Gulf of Mexico. This is the first record of *Paraergasilus* in the West Indies. This parasite could be endemic to Puerto Rico.
Location in Host - Gills. Most species in this genus have been found in the nares of fishes.
Size - Female 0.4-0.5 mm long (excluding egg strings).
Host Specificity - Since we found it in three species in three different families of fishes, we assume that it can infect a wide range of fishes. Probably any fish in brackish water or coastal fresh waters is a potential host.
Damage to Host - *Paraergasilus* spp. have not been implicated in fish kills or epizootics, but they have received very little study or attention.
Detection - Gill arches must be removed from the fish and examined with a dissection microscope.
Significance to Sportfishing - These copepods are so small and occur in such low numbers that they probably do little harm to hosts.

***Caligus irritans* Heller**

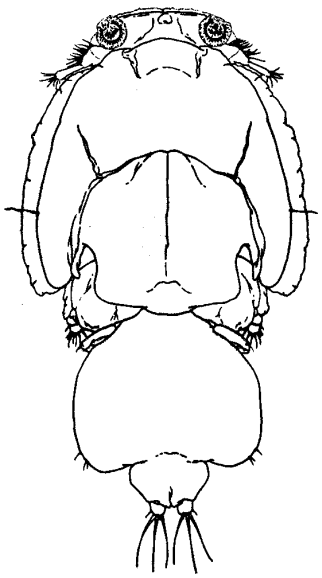
This relatively large, obvious copepod occurs throughout the new world tropics. It is easily seen by fishermen, but does little damage to sport fishes. How long it may survive in fresh water is uncertain.
Diagnostic Characters - This copepod is saucer-shaped, grasping the host with suction made by the body shape and by two special sucking disks (lunules) located on the anterior end of the head. This species is beige in color. The second body segment (abdomen) is longer than wide. The lunules are separated by less than one of their widths.
Records in Puerto Rico - One to two copepods occurred on gray snapper in the Joyuda Lagoon. It can probably be found in low numbers on gray snappers of coastal fresh waters around the island. This marine parasite may not survive for long periods of time in fresh water.



Caligus irritans

Geographic Range - It is known from Brazil, south Florida, Jamaica and the Galapagos Islands in the Eastern

Pacific. Puerto Rico is a new locality record, but it probably occurs throughout the Caribbean.
Location in Host - Mouth or skin.
Size - Female 4.16 mm long (excluding egg strings).
Host Specificity - It is reported from snappers, groupers, jacks and mullet, including gray snapper and striped mullet. Apparently, this parasite is not very selective.
Damage to Host - It can cause considerable irritation and minor tissue injury.
Detection - It is easily seen on the skin or in the mouth.
Significance to Sportfishing - These copepods occur in such low numbers that they probably do little damage to hosts.

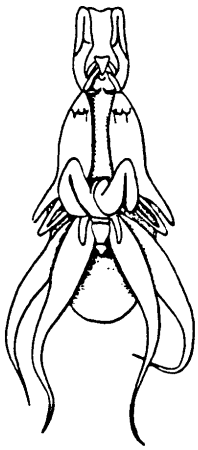


Caligus pomacentrus

***Caligus pomacentrus* Cressey**

This parasitic copepod probably occurs throughout the Caribbean. Its importance and ability to survive in fresh water has not been determined.
Diagnostic Characters - This copepod is saucer-shaped, holding on to the host with suction made by the body shape and by two special sucking disks (lunules) located on the anterior end of the head. This species is golden in color. The second body segment (abdomen) is wider than long. The lunules are separated by approximately two of their widths.
Records in Puerto Rico - Three of 28 white mullet examined from the Bucaná River were parasitized by one copepod each. It may also occur on mullets and other euryhaline fishes in coastal fresh waters. This marine parasite may not survive for long periods of time in fresh water.
Geographic Range - This copepod was recently described from Belize. Puerto Rico is a new locality record, but it probably occurs throughout the Caribbean.
Location in Host - Skin.
Size - Female 2.0 mm (excluding egg strings).
Host Specificity - It was found on a variety of coral reef fishes. The white mullet is a new host record. This parasite appears to have little host preference.
Detection - Easily seen on the skin.
Significance to Sportfishing - These copepods occur in such low numbers that they probably do little damage to the host.

***Lernanthropus giganteus* Krøyer**



Lernanthropus giganteus

This relatively large, obvious copepod occurs on jacks around the world in the tropics. It causes some gill damage to sport fishes. How long it may survive in fresh water is uncertain.

Diagnostic Characters - Species in this genus of copepod are generally cylindrical in shape and have distinctive elongate projections from the second thoracic segment on the ventral side. The body of this species is beige in color. The first thoracic segment is as wide as the rest of the body. The tail (caudal rami) does not extend to the end of the second thoracic segment.

Records in Puerto Rico - It was found in about 15% of horse-eye and crevalle jacks examined from the Joyuda Lagoon, river mouths and coastal fresh waters. One copepod was in each host.

Geographic Range - This parasite is found around the world in the tropics (circumtropical). Puerto Rico is a new locality record, but it has been reported in Jamaica, and probably occurs throughout the Caribbean.

Location in Host - Gills.

Size - Female 8-9 mm (excluding egg strings), male 2.8-4.0 mm long.

Host Specificity - It parasitizes many species of jacks (genus *Caranx*), including the crevalle and horse-eye jack.

Damage to Host - Gill filaments surrounding this copepod have thickened epithelium.

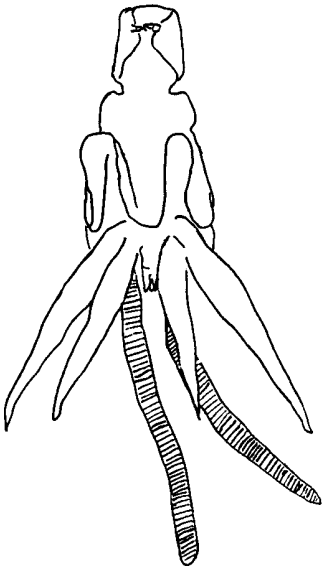
Detection - It can easily be seen on the gills of the host.

Significance to Sportfishing - These copepods occur in such low numbers that they probably do little damage to hosts.

***Lernanthropus rathbuni* Wilson**

This is another primarily saltwater copepod found occasionally in fresh water. The ladyfish host enjoys foraging in brackish and fresh water, but lives much of its life in saltwater.

Diagnostic Characters - Species of this genus of copepod are generally cylindrical in shape and have distinctive elongate projections from the second thoracic segment on the ventral side. This species has a beige colored body with the first thoracic segment as wide as rest of body. The tail (caudal rami) extends beyond the end of the second thoracic segment.



Lernanthropus rathbuni

Records in Puerto Rico - A female and male copepod were found on a ladyfish from the Bucaná River. It probably occurs on all populations of ladyfish.
Geographic Range - This copepod has been reported from North Carolina on the Atlantic coast to the Gulf of Mexico in the USA. Puerto Rico is a new locality record for this copepod, but it probably occurs throughout the Caribbean.
Location in Host - Gills.
Size - Female 4.0-4.9 mm (excluding egg strings), male 3.1 mm long.
Host Specificity - It has been reported from a great variety of marine bony fishes and sharks, including ladyfish.
Damage to Host - Gill filaments surrounding the copepod have thickened epithelium.
Detection - Easily seen on the gills.
Significance to Sportfishing - These copepods occur in such low numbers that they probably do little damage.

***Lernaea cyprinacea* Linnaeus**

This highly destructive parasite has been spread throughout the world on aquarium and aquaculture fishes, especially goldfish and carp. It has caused kills of wild and cultured fishes. We found it on goldfish in Puerto Rico, but not in the wild. This copepod is very non-specific, infecting any freshwater fish. It reproduces quickly, is difficult to control, and is very damaging to fishes. Every effort should be made to keep this parasite out of Puerto Rico.
Diagnostic Characters - These copepods are embedded in the flesh of the fishes with part of the body (thorax and abdomen) trailing out of the flesh like a string. They look like implanted tags sometimes placed in fish. The body is beige to brown in color. The head has horns that branch and form an anchor in the flesh of the fish. The neck is approximately as long as the body. The egg strings are shorter than the body.
Records in Puerto Rico - Three to 6 were found on goldfish from aquaria and ponds in San Juan and Mayaguez (USNM).
Geographic Range - This parasite occurs worldwide on aquarium fishes, aquaculture fishes and in the wild, except in the coldest areas.
Life History - Eggs hatch in water and several larval stages (multiple naupliar and copepodid) take place in the plankton of the pond or lake. Immature copepods attach to a fish. The females begin to grow and are fertilized by males which then die. After mating, the female

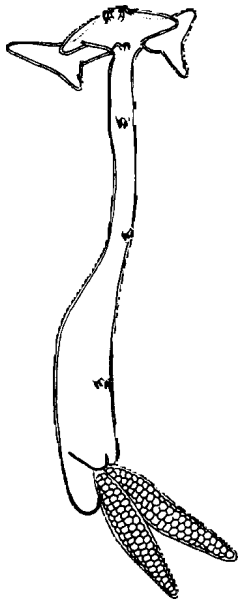
copepod grows longer and begins to burrow its head into the flesh of the fish. The head grows horns that branch into the flesh anchoring the parasite firmly. Finally the female produces egg strings that appear on the posterior end of the thorax. Eggs are laid in egg sacks that break off as the eggs mature. The eggs break out of the sack and hatch in the water.

Location in Host - Skin anywhere on the body of the fish and penetrating into the muscle. It can also perforate the eyes or gills.

Size - Female 5-12 mm, rarely up to 15.9 (excluding egg strings), males up to 0.8 mm long.

Host Specificity - Any freshwater fish may be parasitized. Almost every freshwater fish in Puerto Rico has been reported as a host for this parasite elsewhere. It can even infect tadpoles and salamanders. Prieto (1991) found this parasite on carp, channel catfish, tilapia and other fishes in Cuba.

Damage to Host - Immature stages irritate skin and cause excess mucus to be produced. Adults produce hemorrhagic lesions in the flesh. They can kill fishes if vital organs are penetrated. Large numbers of parasites on a single individual can cause death and even a few may be fatal to small fishes. Epizootics sometimes occur among wild fishes. Cultured mullet and tilapia in Israel, Nigeria and Malawi have been made unmarketable or were killed by this parasite. Just one parasite per fish causes fishes to feed poorly.



Lernaea cyprinacea

Detection - Female copepods are large and obvious. Larval stages can be seen in scrapings viewed with a compound microscope.

Significance to Sportfishing - This parasite has the potential to infect every species of sport fish in Puerto Rico, causing reduced growth and fecundity and possibly killing large numbers of fishes. Anyone seeing a parasite resembling this copepod should report it to this project or the Fisheries division of the DNER immediately.

Preparation for Study - Adults must be carefully teased out of the flesh of the host. The undamaged head is necessary for the proper identification of this parasite.

Treatment - Since these copepods are embedded they are difficult to remove. Almost anything used to treat them will also harm the host. Larval stages in the water have to be killed or reinfection will occur. Green sunfish are apparently not harmed by this parasite because they eat this copepod and act as a cleaner fish. Unfortunately, the green sunfish is otherwise an undesirable reservoir fish.

Comments - The importation of goldfish into Puerto Rico poses a

potential source for introduction of this copepod and also *Argulus japonicus*, both highly dangerous parasites. These pests have already been brought into Puerto Rico, but have fortunately not become established, or at least not widespread. Inspection and treatment of fishes and the water in which these fishes are imported would help prevent the introduction of these parasites. Puerto Rico's freshwater resources remain vulnerable to these highly damaging parasites.

***Lernaeenicus longiventris* Wilson**

Lernaeenicus longiventris

This is another primarily saltwater copepod found occasionally in fresh water. It is similar in appearance to *Lernaea cyprinacea.*

Diagnostic Characters - This parasite, like *Lernaea cyprinacea*, is embedded in the flesh of fishes with part of the body (thorax and abdomen) trailing out like a string. The body of this species is beige in color with horns on the head that are not branched. The neck is approximately four times as long as the body. Egg strings are approximately twice as long as the body.

Records in Puerto Rico - It was found on 27 of 133 white mullet, 1 of 2 liza, and 3 of 7 horse-eye jacks from the Joyuda Lagoon. Usually 1-2 copepods occurred per host. Nine were found in a liza.

Geographic Range - It is known from the east coast of the USA, Gulf of Mexico, Brazil and the west coast of Africa. Puerto Rico is a new Caribbean record, but it probably occurs throughout the region.

Location in Host - Skin.

Size - Female 25.0 mm (excluding egg strings).

Host Specificity - It has been reported from a great variety of fishes, including horse-eye jack and striped mullet. The liza and white mullet are new host records for this parasite.

Damage to Host - Severe, but local injury occurs around the copepod. Young fishes or adults with heavy infections may be stunted or killed.

Detection - Female copepods must be carefully teased out of the flesh of the host. The undamaged head is necessary for the proper identification of this parasite.

Significance to Sportfishing - These copepods occur in such low numbers that they probably do little damage to hosts.

BRANCHIURA (FISH LICE)

The fish lice, argulids or branchiurans form a small class of crustaceans. They can be very harmful to fishes, especially those in hatchery or culture facilities. Fish lice have only been reported to infect humans once, but may bite careless handlers of live fishes. Approximately 130 species have been described, about 100 in the genus *Argulus*. They are relatively large parasites varying from a few to 13 mm long. The body is flattened (strongly depressed) and has a large, expanded head, fused with the first and sometimes second thoracic segments (cephalothorax), thorax and an abdomen. The thorax has three segments (four and five are fused with the abdomen) and the abdomen is completely fused. One pair of thoracic appendages is modified into mouthparts, and four pairs are unmodified. The abdomen has no appendages, and terminates in a bifurcate tail (caudal rami). Females leave the host to deposit eggs. Juveniles hatch from eggs in 15-55 days and develop directly into adults. Swimming juveniles must find a host in 2-3 days and, once attached, develop into adults in 30-35 days. Sexes are separate. They attach on the body, fins, gills and mouths of fishes and sometimes on frogs and tadpoles. They are obligate parasites and feed on blood, but adults are capable of changing hosts. Fish lice are not known to directly transmit microbial disease, but the wounds they cause may provide entry points for infection.

Class Branchiura Taxonomy an Contents . . . . . **Page**

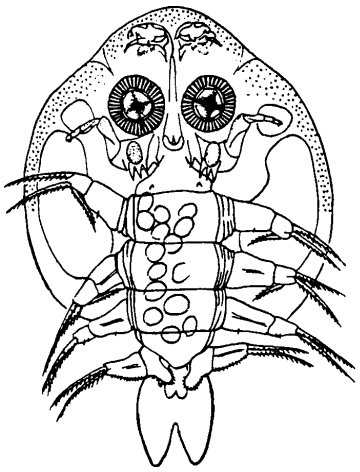
***Argulus japonicus* Thiele**

This extremely dangerous and damaging parasite has been repeatedly introduced to Puerto Rico on goldfish. It has an international reputation for invading new hosts and habitats. If this parasite becomes established here it could cause extensive damage to island sport fishes.

Diagnostic Characters - This brown to golden colored parasite is thumbtack sized, shield-shaped, and has a short tail.

Records in Puerto Rico - It is a common parasite of goldfish imported into Puerto Rico as aquarium fish and for ornamental ponds (USNM). Goldfish cases referred to us have been heavily infected. This parasite has killed local goldfish in aquaria. We received one case

from oscars in aquaria. We have not found it in streams or reservoirs.



Argulus japonicus

Geographic Range - It occurs worldwide (cosmopolitan). The exact origin has been obscured by the early spread of this parasite around the world. It probably came from Asia with the goldfish, but this may never be determined. This is an international parasite which has become established in Cuba and could easily cause problems in Puerto Rico.

Location in Host - Body, fins or gills.

Size - up to 8.5 mm long.

Host Specificity - They are most commonly found on goldfish and common carp around the world, but are also reported from channel catfish, various species of tilapia and barbs, and many other fishes. It is probably capable of infecting almost any freshwater fish. Prieto (1991) found *Argulus* sp. on Cuban grass carp and cultured tilapia, and other fishes in reservoirs.

Damage to Host - Large numbers debilitate fishes and cause fish kills. The wounds are often infected with fish pathogenic bacteria. It is a dangerous parasite in hatchery and fish culture facilities. Other fish lice have caused fish kills in wild populations. Some of these kills were associated with deteriorated environmental conditions.

Detection - This large and obvious parasite is easily found. In heavy infections, they can be seen scurrying about on the body of the host.

Harm to Humans - Careless handling of fish lice or infected fishes could result in a bite. Fish lice do not naturally attack humans.

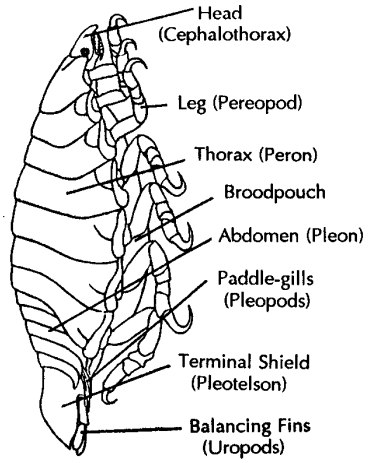
Significance to Sportfishing - This is a highly damaging and dangerous parasite. If it becomes established, it could kill sport fishes; reduce their size and health; make hatchery production more difficult; and cause widespread fish kills during times of poor environmental conditions.

Preparation for Study - Argulids can be preserved and stored in 70% ethanol or 40% isopropanol (rubbing alcohol). No special treatments or stains are necessary.

Treatment - Fish lice on aquarium fishes can be removed with tweezers (forceps). These cleaned fishes should be dipped in a salt

solution to kill any developing parasites, and placed in clean (uncontaminated) water. The aquarium, water, substrate, nets, etc. contaminated by argulids must be sterilized with a chlorine solution. Do not discard untreated contaminated water or fishes into a stream, lake, or sewage system with less than secondary treatment. Careless handling of this pest by only a few people could spread this parasite and contaminate all of Puerto Rico.

ISOPODA (ISOPODS)



Lironeca symmetrica
Lateral (side) view

Isopods form an order in the crustaceans. The common name refers to all legs being similar in size and shape. Isopods are extremely significant because they kill, stunt and damage commercially important fishes. A few fish-parasitic isopods actively swim after and bite humans, sometimes alarmingly in mass attacks, but we are more likely to be bitten when carelessly handling fishes parasitized by isopods. Free-living isopods are reported to clean *Saprolegnia* spp. from fishes. Isopods serve as important food items for a variety of animals. Fish-parasitic isopods are alleged to indicate tropical fishes which are free of ciguatera (fish poisoning toxins). This is not proven.

Approximately 4000 species have been described, and more than 450 species are known to parasitize fishes. They vary from 0.5-440 mm in length. The largest species on earth occurs off Puerto Rico. Their body is usually dorso-ventrally flattened (depressed) with a head, fused with the first thoracic segment (cephalothorax), thorax and abdomen. The thorax has seven segments and abdomen six (often fused into two to five). One pair of thoracic appendages is modified into mouthparts, and seven pairs are unmodified. The abdomen has six pairs of appendages, and ends in a terminal shield (pleotelson). Eggs, larval forms and juveniles develop in a brood pouch beneath or in the female. Free-swimming juveniles develop into adults. Sexes are separate in some isopods, while others begin life as males and turn into females (protandrous hermaphrodites). They are common in most environments, including dry land. They parasitize fishes, crabs, shrimp and other isopods. Fish-parasitic isopods vary from accidental, or temporary, to permanent parasites. A broad range of food habits occur.

The fish-parasitic forms feed on blood or ooze from wounds. Isopods have been accused of directly transmitting lymphocystis disease, but this is unlikely considering their feeding habits and behavior. The wounds they cause may provide entry points for microbial diseases. Isopods can be mechanically removed from aquarium fishes and preserved in 10% formalin or 70% ethanol and stored in 70% ethanol (151 proof rum will do) or 40% isopropanol (rubbing alcohol). Isopods from aquarium fishes could be harmful to the environment. Please send them to us, we would like to examine any of these isopods.

References - Williams and Bunkley-Williams (in press), Kensley and Schotte (1989) and Schultz (1969).

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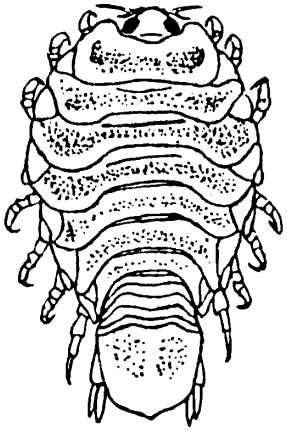
Artystone trysibia Schioedte



Artystone trysibia

This parasite forms large cavities in the body muscles of fishes. It has been brought to Puerto Rico in South American aquarium fishes, but fortunately has not become established in the wild.

Diagnostic Characters - The last (seventh) pair of legs ends in a straight spine rather than a recurved hook. The body is widest in the anterior portion.

Records in Puerto Rico - It was found in aquarium fishes imported from South America. It has not become established in island fresh waters. Local conditions and fishes should allow this pest to cause persistent problems if it ever escapes from aquaria.

Geographic Range - Found in streams throughout South America, this parasite was inadvertently shipped to Puerto Rico and the USA in wild-caught aquarium fishes.

Life History - Young isopods develop to juveniles in a brood pouch under the body of the female. Free-swimming juveniles leave the fish through the opening in the side of the host and search for a new host. Juveniles attach to the skin and slowly force an invagination into the musculature. As the isopod penetrates and grows, the host forms a connective tissue pouch around the parasite. The isopod seems to cause almost no other inflammation, immune reaction or tissue

response. The movement of the paddle-gills (pleopods) and balancing fins (uropods) on the posterior of the isopod keep the entrance hole from closing. This opening is necessary for respiration, to allow the small male to come courting, and to allow the infective juveniles to leave. This impressive cavity is "excavated" mostly by displacement, not by eating the tissue. This parasite feeds on body fluids.

Location in Host - Muscle.

Size - Female 1.7-2.4 cm long.

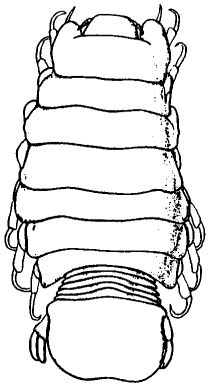
Host Specificity - It occurs mostly in South American cichlids. In tropical fish aquaria or tropical fish production ponds, they seem to be able to infect any fish.

Damage to Host - It forms a large cavity in the muscle of its host. Young fishes are quickly killed. Hosts too small to support the isopod, or apparently inappropriate host species are killed. Infection makes fishes useless as human food even if they survive.

Detection - A distinct bulge with a small opening on the body of the host can be seen. Juvenile isopods are difficult to detect and are the form transported with tropical fishes.

Significance to Sportfishing - This isopod could be very damaging to sport fishes.

Treatment - Chemical treatments kill the isopods in the pouches, but the decomposition of the parasites would kill the host. Infected fishes should be removed and either sent to us or destroyed without contaminating other fishes or natural waters.



Cymothoa oestrum

***Cymothoa oestrum* (Linnaeus)**

This large isopod does little damage to adult jacks. It is very injurious to young jacks, and kills other aquarium fishes. Caribbean folklore suggests that jacks with this isopod do not have ciguatera fish poison. This fable requires testing.

Diagnostic Characters - It is the only large, white isopod on the tongue of jacks.

Records in Puerto Rico - It occurs in 5-20% of horse-eye and crevalle jacks in coastal fresh waters.

Geographic Range - It is found throughout the West Indies, Gulf of Mexico, Atlantic coast of USA and South America.

Life History - Juveniles escape from the brood pouch of the female; swim in the plankton; feed off a variety of small fishes as transfer hosts; enter the mouth of the final host; and grow into an adult.

Ecology - There are no reports of this isopod in coastal fresh waters of North America (Williams and Bunkley-Williams in press). In Puerto Rico, it seems to be able to survive at least for short periods in fresh

water. The salinity tolerances of this isopod should be studied to see if long-term survival in fresh water is possible.

Location in Host - The adult female attaches on the top of the tongue, facing out. The male attaches behind and beneath the female and lying across the gill rakers of one gill chamber.

Size - Female 2.3-3.8 cm, juveniles 6.5-9.7 mm long. The first four juvenile stages are 6.5, 7.2, 8.1 and 9.0 mm long (Williams and Bunkley-Williams in press).

Host Specificity - Generally a parasite of crevalle and horse-eye jacks, it occasionally occurs in other jacks, the great barracuda *Sphyraena barracuda*, and other hosts. In marine aquaria, juvenile isopods will infect almost any fish.

Damage to Host - Little damage to the host is apparent. There may be some general stunting. Jacks with isopods eat different food items, presumably because the isopod takes up so much room in the mouth of the host. Large numbers of juvenile isopods can kill fishes of any size. Juvenile jacks can be killed by a few isopods.

Significance to Sportfishing - This parasite may kill a few jacks, so slightly fewer are available for sportfishing. Infected jacks are smaller than uninfected ones of the same age. Jacks with isopods do not fight as well or as long on hook-and-line. Large isopods in the mouth may alarm some sport fishermen, but they have no effect on the quality of the fish as food.

Larger jacks and barracuda in Puerto Rico are notorious for carrying harmful amounts of ciguatera fish poisoning toxins. The sale of these fishes is banned on the island. Caribbean folklore sug-gests that fishes with isopods are free from ciguatera. In some fish markets in the Lesser Antilles, isopods are illicitly added to fishes to make them sell. This legend has not been proven and should not be taken as fact. Research must confirm or deny this intriguing idea.

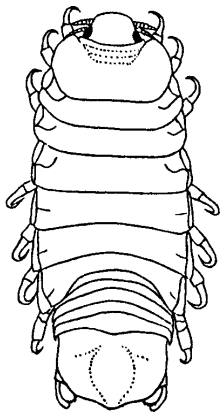
Lironeca symmetrica Van Name

This parasite is often shipped in South America tropical fishes. It was even accidentally raised in tropical fish farms in Florida and unwittingly shipped to pet stores across the USA. It has been brought to Puerto Rico, but fortunately has not become established.

Diagnostic Characters - The body is rectangular and there are no large shoulders beside the head.

Records in Puerto Rico - Found in aquarium fishes imported from South America; it has not become established in local fresh waters.

Geographic Range - It is found in streams in South America from Colombia to Brazil. This parasite has been inadvertently shipped directly from South America to Puerto Rico, the USA and Germany with field-collected aquarium fishes. This isopod was accidentally reared on a tropical fish farm and may be established in the wild in south Florida. Infected fishes from this farm were shipped all over the USA and to Puerto Rico. This parasite could easily become established in Puerto Rico.



Lironeca symmetrica

Location in Host - Gill chamber.

Size - Female 17.0-20.6 mm, juveniles 3.6 mm long.

Host Specificity - It occurs in a variety of tropical aquarium fishes including green sword-tail and southern platyfish.

Damage to Host - Adult isopods damage gill chambers and erode gill filaments. Juvenile isopods may kill small fishes.

Detection - An adult female is easy to see in the gill chamber. Juvenile isopods are smaller, more difficult to detect, and are the form transported with tropical fishes.

Significance to Sportfishing - This isopod could cause serious problems with sport fishes. The growth of infected fishes would be stunted and juvenile isopods could kill young fishes.

ACARI (MITES)

"Mite" means a coin of slight value (originally a Flemish copper; see Bible [Mark 7:43]). They form a loosely related assemblage in the phylum of eight-legged organisms with thin external coverings (Arachnida) that includes the spiders, scorpions and ticks. Mites are the smallest and least known group (despite the poems by Robert Frost and Jonathan Swift) in the arachnids. They cause severe dermatitis, mange, scabies and other diseases in humans and their domestic animals and plants. Mites produce the itchy and irritating "chiggers" welts, and house dust mite allergies (Moser 1986). They are vectors of some of the most devastating and lethal microbial diseases (viruses, rickettsia, protozoans), and serve as intermediate hosts for tapeworms in monkeys, rabbits, cattle and sheep. Approximately 30,000 species are known, and one-half to one million remain undescribed. The abundance and diversity of mites is only exceeded by insects and possibly round worms in the Animal Kingdom. Several million may occur in a few square centimeters of substrate. Adults are 0.1 mm (microscopic) to 3 cm, but most are 0.25-0.75 mm long. Mites are the

smallest of the arthropods (whether a subkingdom or a phylum). The head, abdomen and thorax are fused into a globular body covered by a shell of chitin. An anterior jaw-unit (gnathosoma or capitulum) has two pairs of mouthparts and is separate from the body (idiosoma) which usually has four pairs of legs. A great variety of reproductive strategies exist which are related to various hosts and habitats. All involve a direct develop-ment through egg, several larval molts, two nymphs (one may be a resting or transport stage), and adult. Sexes are separate. Mites are predators, scavengers, commensals, permanent parasites or parasitic for part of their life cycles. There may be more parasitic than free-living species, but in total numbers of individuals, the free-living greatly outnumber the parasitic. Mites parasitize plants, mush-rooms, sponges, nemerteans, crabs, barnacles, mollusks, their fellow arachnids (spiders and scorpions), millipedes, insects, amphibians, reptiles, birds and mammals. Some species associate with a great variety of hosts, while others are specific to a single species. Mites are potential biological controls of cockroaches, fire ants, houseflies, mosquitoes, termites and other species humans consider pests (even fellow mites). Parasitic forms occur on and in the skin, circulatory system, cocoon, ear, feathers, gills, hair follicles, intes-tine, lungs, mantle chamber, nasal passages and urinary tract of hosts; and feed on blood or other fluids. Mites can withstand extremes of water temperature (50EC) and alkalinity (pH 9.6), and live within the vacuum of an electron microscope. They appear in Devonian fossil sandstones (285-320 million years ago) and in more recent amber.

Reference - "How to Know the Mites and Ticks" (McDaniel 1979).

Phylum Arachnida Taxonomy and Contents . . . . . **Page**

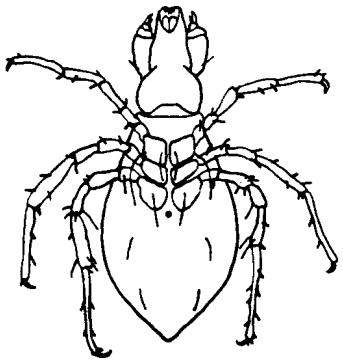
***Hydrachna* sp. (larval form)**

The red water mite parasitizes aquatic insects but may feed off fishes during its search for an appropriate host. This association is rare, transient and probably insignificant to the health of fishes. Identification of larval forms to species may require the deter-mination of the entire life cycle. This species may be undescribed.

Diagnostic Characters - This small parasite has a fused globular body, three pairs of legs and two pairs of mouthparts. Red adults and

nymphs have four pairs of legs, but clear larval forms found on fishes have only three pairs.

Records in Puerto Rico - This mite was found once each on a largemouth bass and a redbreast tilapia in La Plata. It probably occurs occasionally on a variety of hosts. Since it spends so little time on the fish, the association is seldom documented.



Hydrachna sp. (larval form)

Geographic Range - This genus occurs worldwide in most freshwater habitats.

Life History - Members of this genus lay eggs in the intercellular air spaces of higher aquatic plants. Larvae are parasitic on aquatic insects (Hemiptera and Coleoptera), and occasionally are found on fishes. Larvae pass through a series of molts and remain with the insect host for long periods of time (up to 10 months). The nymphochrysalis stage passes on the host and the mite leaves as a newly metamorphosed nymph. The adult is free-living.

We suspect that these larvae only use fishes temporarily to rest and possibly feed, but soon leave to find an appropriate aquatic insect host. They are not known to metamorphose on fishes. This may explain the rarity of records from fishes.

Location in Host - Body or gills.

Size - 0.18 mm long.

Host Specificity - It has little or no preference in aquatic insect or fish hosts.

Damage to Host - Slight.

Harm to Humans - Any mite should be handled with care.

Preparation for Study - Preserve in Koenike's fluid (approximately 10 parts acetic acid, 45 parts glycerine and 45 parts water). Alcohol and formalin make mites brittle and fix the muscles and other tissues, making clearing more difficult. Permanent mounts may be made with glycerine jelly.

Marine mite

One specimen was seen on the gills of a white mullet collected in the Bucaná River, east of Ponce. It was lost before it could be identified. Probably, this was a marine mite carried into fresh water by this euryhaline host.

PENTASTOMIDA (TONGUEWORMS)

Tongueworms or pentastomes form a small phylum of strange animals. They were dinosaur parasites and most perished with these spectacular hosts. "Tongueworm" refers to their shape. "Pentastome" means "five mouths" and refers to the finger-like projections supporting the four legs and a mouth in some species. They can infect humans. About 95 species are known. Adults are a few mm to 15 cm long. They are flat, elongate, and their soft body is reduced and worm-like. Two pairs of legs occur under the anterior end and may be reduced to only single or double hooks or claws. The body covering is chitinous, highly porous, and marked with striations, rings (annuli) or segments. Molts occur between growth stages. Sexes are separate with males smaller than females. Females hold up to several million small, thick-shelled eggs, that pass up the trachea or down the nasal passages of the host, are swallowed, and pass out the intestine. Eggs on vegetation or bottom mud are inadvertently eaten by a vertebrate, three larval (nymphal) stages develop, and infective stages either break out or are digested out when an appropriate predator eats the intermediate host. Fishes may suffer massive infections. Adult parasites occur in the lungs, nostrils and nasal sinuses of reptiles, primarily, but may occur in some mammals and birds. Larval forms infect fishes, amphibians, reptiles and a few mammals. In humans, they can become encysted in calcareous capsules, soon die, and usually do little damage. Many of these people do not even realize that they have been parasitized. However, some species can develop in nasal passages or throat of humans, can damage eyes and other vital organs and cause severe irritation or even death. Tongueworms are permanent parasites that feed on mucus, tissue fluids and blood of their host.

Popular Reference - "Foundations of Parasitology" (Schmidt and Roberts 1989).

Phylum Pentastomida Taxonomy and Contents . . . . . **Page**

Caiman tongueworm

This unknown species of tongueworm appears to be a possible threat to sport fishes. The damage caused must be carefully evaluated to determine if eradication would be worth the costs involved. Exotic caimans hardly seem a desirable addition to the fauna of Puerto Rico, and reducing their numbers might eliminate this parasite.

Diagnostic Characters - These elongate larvae have rounded ends and are encased in heavy host cysts. The seventh stage larvae

(nymphs) have an expanded head containing four pairs of large hooks, and the body is striated. The fifth stage is smaller and more compact, armed only with a lateral mouth hook. The third stage is even smaller and lacks a mouth hook.

Records in Puerto Rico - This parasite was recently found in low numbers on a largemouth bass and in high numbers in 12 peacock bass from Guajataca. It did not occur in previous examinations of fishes from this lake. Caimans *Caiman crocodilus* recently entered this lake and they may be the final host. Caimans also occur in the Tortuguero Lagoon and Toa Vaca and possibly other places.

Caiman tongueworm

Geographic Range - Caimans occur naturally in South and Central America. Another exotic caiman is established in Jamaica.

Life History - Eggs are swallowed by fishes with food items. If the larvae has developed into the seventh or infective stage when a fish is eaten by a caiman, then it develops into an adult.

Location in Host - We have found this parasite in the mesenteries and gills, but it can probably occur in any fish tissue.

Size - Third stage larvae 0.7 mm, fifth stage 2 mm, seventh stage 7 mm long.

Host Specificity - Another tongueworm has been reported from bluegill, fathead minnow, green swordtail, largemouth bass, western mosquitofish and other fishes in the USA. Adults are probably limited to caimans, but larvae can be in any vertebrate.

Damage to Host - Massive infections can kill and heavy ones can stunt fishes. Widespread infections reduce the productivity of the entire system. Other tongueworms encourage or intensify bacterial diseases in fishes. This threat needs to be monitored to discover the amount of damage and determine if action against caimans is justified.

Harm to Humans - Infections could be caused by eggs from bottom mud; by rubbing the eyes, nose or mouth with hands contaminated with larval stages released when handling or cleaning infected fishes; or by eating raw or undercooked infected fishes. These parasites are killed by cooking.

Significance to Sportfishing - If allowed to spread across the island, it could reduce the quality and quantity of sportfishing.

Preparation for Study - These parasites can be teased out of their cysts and identified as tongueworms in wet mounts. They can be preserved in 5% formalin, and mounted in glycerine jelly. Study of the entire life cycle of a tongueworm may be necessary to identify a larval

form because very few life cycle stages are described.
Treatment - Larval tongueworms in fish tissues cannot be killed. The simplest method to stop these worms is to harvest the caimans.
Comments - Caimans do not seem a highly desirable addition to the freshwater fauna of Puerto Rico. They are quite efficient in eliminating fishes, birds and other small animals, may bite humans, and seem to have brought a highly damaging new parasite for local sport fishes. Eradication of caimans would appear to be a valid management option.

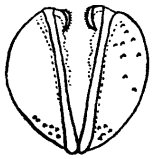
MOLLUSCA (GLOCHIDIA)

Sea shells or mollusks form a phylum in the Animal Kingdom. "Shell" refers to their hard calcium-carbonate coverings. "Mollusk" means soft (referring to the soft body). These include the familiar oysters *Crassostrea rhizophorae*, queen conch *Strombus gigas*, octopus *Octopus briareus* and top shells *Cittarium pica* which are important Caribbean food items. More than 50,000 living species are described. They range from sand-grain-size to the 1.3 meter giant clams *Tridacna gigas* and 20 meter giant squid *Architeuthis sanctipauli*. The shell can be external, internal, or absent; and is produced by a fold in the body wall (mantle). Usually, sexes are separate and fertilization occurs in the water. Eggs are normally encased in various kinds of coverings. Typically, free-swimming larvae (trochophore) hatch and develop into veliger larvae in the plankton, but many other methods occur. The larvae of most freshwater clams and mussels develop as parasites in fishes. Many mollusks are predators, grazers or filter-feeders. Only a few associate with or parasitize other organisms. We described the only adult mollusk known to associate with a fish (Williams and Williams 1986). Mollusks inhabit marine and fresh waters and moist areas on the land. They serve as intermediate hosts for many parasites.

Local snails are intermediate hosts for a variety of flukes that parasitize fishes, birds and humans. The larvae of local clams do not seem to infect fishes. New exotic mollusks should not be allowed to become established in Puerto Rico as they may allow more parasites to invade the island.

Phylum Mollusca Taxonomy and Contents . . . . . **Page**

***Anodonta grandis* Say**


Glochidium of mussel

Larvae of this large, edible mussel would parasitize local fishes. It was introduced into the Dominican Republic by larval clams parasitizing the common carp. This mollusk has been studied in Puerto Rico. Potential damage by this parasite should be investigated before any introduction is contemplated. The parasitic larvae of this mussel are called "glochidia". The adult mollusk is called the "giant floater".

Diagnostic Characters - Very small, golden brown clam shells are found in cysts in the gills or fins.

Records in Puerto Rico - This mussel and possibly others have been brought into Puerto Rico on at least three occasions. We believe that all of these stocks have been destroyed. We have not found these mussels in local streams or lakes, or glochidia in fishes.

Geographic Range - It is known from the eastern USA. Common carp introduced from the USA into the Dominican Republic were already infected with glochidia. These parasitic stages developed into adults and the mussel was inadvertently introduced.

Life History - Mussels cannot reproduce without passing through a parasitic stage in fishes. Larvae (glochidia) develop inside the adult mussel, pass into the environment, find a fish, and attach. Some mussels form a lure out of their mantle to attract fish close enough to spray them with glochidia. Once attached, glochidia are surrounded by host tissue within a few hours and remain encysted for days to a year (usually 10-30 days). Here they develop into small mussels. When the cysts rupture, they fall to the substrate and grow to adults.

Location in Host - Encysted in gill filaments and fins.

Size - Larvae 0.05 to 0.5 mm, mussels up to 13 cm.

Host Specificity - It may only occur on carps. Preliminary experiments in Puerto Rico were unable to infect any of the species of local tilapia. The species of fishes it can infect must be determined.

Other species of mussels have been reported from a great variety of freshwater fishes and amphibians. They are probably capable of infecting almost any freshwater fish. Many local freshwater fishes, American eel, bluegill, channel catfish, goldfish, guppy, largemouth bass, redbreast sunfish, redeye bass and western mosquitofish are known to be attacked by these parasites in the USA.

Damage to Host - When these tiny clams are abundant, they can cause severe damage and have caused fish kills. Their exit wounds may be infected with fish pathogenic bacteria. Glochidia may be particularly damaging to many of our freshwater fishes which have had no exposure (and no resistance) to this parasite.

Detection - When cysts occur in high numbers, they are easily seen in fins and less easily in gill filaments. Gill arches should be removed and examined in fresh water with a dissection microscope.
Significance to Sportfishing - If these mussels establish here, their larval stages may infect many freshwater fishes causing a slight, but widespread loss of productivity. A few young fishes will be killed, and heavy infections will sometimes kill adults.

The giant floater is an edible mussel. Its foot has been suggested as a possible substitute for queen conch meat. It produces pearls which have commercial value, and its shell can be sold for seed-pearl nuclei for the cultured pearl industry in Japan.
Preparation for Study - Gill filaments or pieces of fins with encysted glochidia can be preserved in 10% formalin. Adult mussels should be preserved in 70% ethanol. Identification to species may be possible in more mature cysts. They should be cleared in glycerine, lactophenol, or other clearing agents, before examination. The easiest, if not the fastest, method is to let the larvae mature on live fishes, drop off, and grow into mussels or clams. Any suspected glochidia can be sent to us for examination.
Treatment - Chemicals that kill mussel larvae (molluscacides) in fishes also tend to kill the host. Hatcheries and culture facilities can only remove mussels from their facilities, screen or filter incoming stream water, or switch to a spring or well as a water source. No treatment is practical in streams and lakes. Once mussels are established, some level of parasitism by their larvae is inevitable.
Comment - The unregulated importation of mussels into the island may establish exotic mussels and their parasitic larval stages. We do not pretend to judge if edible mussels may be more important than real but unpredictable losses to sportfish production. We do suggest that the possibility of exotic parasites and diseases be considered in any introduction. The effect of glochidia on local fishes should be evaluated before any mussel or clam is introduced.
Reference - Williams, J. et al. (1993).

Sphaeriid clams

Sphaeriid clams (fingernail and peaclams) in North America have been found attached to the mouths of small fishes. Our local representatives in this family, Puerto Rican fingernail clam *Eupera portoricensis* Prime and ubiquitous peaclam *Pisidium casertanum* Poli, can be found in stomachs of local freshwater fishes. This may explain why other species have been found on the lips. We have not seen it on local fishes. Its larvae are not reported to encyst in fishes.

OTHER DISEASES AND CONDITIONS

In addition to parasites, we found viral and bacterial diseases, tumors, diseases of unknown cause and damage caused by physical conditions in local freshwater fishes. Efforts should be made to bar other, very contagious and destructive diseases from Puerto Rico.

VIRUSES

An extremely damaging and highly contagious virus, channel catfish virus disease (CCVD), has not been brought to Puerto Rico. We were lucky to avoid this disease that can kill almost 100% of a reproductive year class of channel catfish. Fry and fingerlings are affected but adults can carry this virus and pass it to their offspring. Once infected, our channel catfish might be eliminated from Puerto Rico. Many channel catfish in the USA carry this disease. Actually, local aquaculturalists might benefit by selling fingerlings of CCVD-free stock to production facilities in other uncontaminated regions or uncontaminated hosts for research on this disease.

Lymphocystis disease, a common viral disease of the skin and fins of almost any species of fish, has been found here in aquarium fishes, but not in the wild (Williams, Grizzle and Bunkley-Williams in review). Although seldom lethal, infection of sport fishes could cause angler rejection of heavily infected individuals. Efforts should be made to keep this deforming virus out of our natural fresh waters.

BACTERIA

Most isolates from our freshwater fishes were ubiquitous gram negative water bacteria (*Aeromonas hydrophila* complex). This group of pathogens has caused numerous mortalities of fishes, has been involved in fish kills, and helps cause red sore disease of largemouth bass. Many fishes were infected with *Flexibacter columnaris*, including three cases of trophy-sized 3-4 kg largemouth bass found struggling at the surface at Lucchetti in 1994. The skin of these fish was heavily infected with *Flexibacter columnaris*. Two others cases with skin lesions infected with *Aeromonas hydrophila* complex were examined in 1992 and 1993. All these cases occurred in the spring of the year and affected gravid females. The cause of mortality of these prize fish needs to be investigated further.

Edwardsiella ictaluri is a common pathogen of channel catfish and can be found in other ictalurids. It causes a virulent, contagious septicemia and often death. This bacteria was not found in Puerto

Rico. Fishes larger than 15 cm are susceptible. Our catfishes have no immunity to this bacteria and introductions of ictalurids carrying this disease could infect our populations of catfishes and cause devastating losses. Extreme caution should be used if ictalurids must be brought to Puerto Rico. This includes channel catfish often used in the aquarium trade. Because of this disease and CCVD, Puerto Rico should consider banning the import of all ictalurid catfishes.

Gram positive cocci were less common. Two cases of largemouth bass with extreme spinal curvature were seen. Research in progress in the southeastern USA suggests that a bacteria similar to *Renibacterium salmonarum* might be the cause. This bacteria was not isolated in Puerto Rico but reportedly caused a mass mortality of cultured tilapia in Cuba (Prieto 1991).

TUMORS

These growths seemed to occur with unusual rarity in Puerto Rico, although our fresh waters are far from pristine (Tetra Tech 1992). Lipomas were found twice in spleens of largemouth bass (RTLA 5701) and once in a white catfish (RTLA 5222) but may occur more frequently. A kidney tumor, renal adenocarcinoma (RTLA 5910), occurred in a Mozambique tilapia, the first record in tilapias. Numerous nerve-sheath tumors (neurofibroma) (RTLA 5452) were found in a population of semi-captive goldfish over an eight year period. An undifferentiated sarcoma (RTLA 5862) was found in a channel catfish (Bunkley-Williams and Grizzle in review). None of these tumors have been reported in Caribbean freshwater fishes.

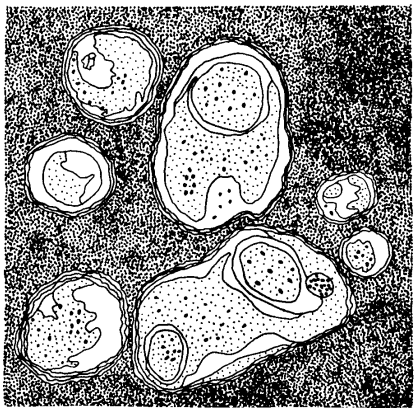
TILAPIA WASTING DISEASE

Mass mortalities of Mozambique tilapia have occurred chronically in the Mandri and Santa Teresa Lagoons near Humacao since at least 1990. Some of the larger kills coincided with times of poor water conditions, but the tilapia were weakened before the water quality declined. These mortalities were caused by an unknown, possibly fungal, agent which produced a persistent, debilitating condition. Understanding this condition may allow control of this disease or this fish in Puerto Rico and in other warm-water regions.

Fish with this condition were very emaciated, had relatively large heads and sunken eyes. Fins were frayed and skin was hemorrhaged. Internal organs appeared pale and rough on the surface, and mesenteries contained small spherical golden to reddish-brown cysts, 0.3-1.3 mm in diameter. Histologically, tissues were filled with spherical cysts. Most cysts were empty, but some contained cell debris. The cyst wall was thickened. Hyphae or germinating spores, which would indicate a fungus, were not seen in tissue sections of diseased

fish. Larger fish seemed to be more affected than smaller ones. The damage caused by this disease could be cumulative.

A similar condition was recorded by the Southeastern Cooperative Fish Disease Project at Auburn University, Alabama from tilapia raised in hydroponic polyculture in Missouri. A comparison of tissue sections from this outbreak suggest that it was identical to the condition found here.



Histological section of spleen with cysts seen in tilapia wasting disease.

This condition seems to be more debilitating than the two species of larval cestodes infecting Mozambique tilapia in the reservoirs. It has severely affected these fish in these coastal lagoons.

The over-population of Mozambique tilapia in local lagoons has reduced the sizes available for sportfishing. The elimination of many of these fishes by tilapia wasting disease may, ironically, provide more tilapia which are large enough for sport fishing. The exact effect can only be determined with more study. Also, the disease might be used as a biological control for Mozambique tilapia in areas where this fish is not desired.

Our attempts to isolate or identify this pathogen from Mozambique tilapia have failed. Possibly, examining less advanced cases in younger fish may provide more clues. Also, use of additional types of culture media and differential histological stains or aquarium studies of lagoon mud and fish may also help solve the mystery. It is important to identify the cause of this debilitating condition in these fish so that either a remedy can be found or its usefulness as a controller of these tilapia could be developed.

Extreme caution should be exercised when handling highly virulent, highly destructive, incompletely known diseases. Fish with tilapia wasting disease should not be transported around the island or placed in other water systems where this disease could spread.

GAS BUBBLE DISEASE

This is a condition caused by exposing fishes to water supersaturated with air. The gas passes into the fish via the gills and coalesces, forming bubbles that appear in the gills and, more obviously, in the eye membranes. It causes distress in fishes, may upset their buoyancy, can be lethal, but usually disappears when the water returns to normal gas levels. This condition has occasionally been seen in Lucchetti where water from a higher elevation reservoir passes down a large pipe and exits at Lucchetti. This water becomes supersaturated with air as it passes through the pipe and fishes living near the lower opening occasionally suffer from gas bubble disease. Threadfin shad have also been noted with this condition at the Lajas Agricultural Experiment Station.

SENDING SPECIMENS OR INFORMATION

We are pleased to receive fishes or parasites for examination; information concerning parasites; and to answer questions, discuss techniques, and encourage everyone to take a closer look at some of the fascinating parasites on our local fishes. We are authorized to examine fish kill specimens for parasites, but we are **not** the proper agency to call when a fish kill is first discovered. **Please call the DNER (724-8648 or in an emergency 375-7660) or the Environmental Quality Board (721-5317, 722-1710 or in an emergency 766-2823) to report a fish kill.** These are the proper authorities to investigate a fish kill. You could also call the Civil Defense or your regional office of the Vigilantes.

CHOOSING SAMPLES

FISHES

Choose fishes which have obvious signs of disease or parasites, but **are still alive**. If no live fishes are available, then **very freshly** dead fishes (no more than one hour after death) may be used. Dead fishes must be placed immediately in a plastic bag without water, and the bag refrigerated or placed in a cooler with ice below and on top of the sample. **DO NOT FREEZE**. Some parasites quickly leave dead fishes in water while others soon die and decompose. Freezing destroys almost all parasites.

PARASITES

Sometimes large parasites are found on fishes that cannot be sent for examination, or on dead fishes too decomposed to examine. In some cases identification of these parasites is still desired. Most parasites will stay alive for many hours in small containers of water, or they can be preserved before sending. When in doubt, preserve them. Methods of parasite preservation are explained in each section of this book. If you cannot identify the parasites, preserve them in either 10% formalin or 70% ethanol (151 proof rum will do).

TRANSPORTING SPECIMENS

Please call or FAX before sending or bringing specimens. **Telephone:** (809) 899-2048; **FAX:** 899-5500. The best way is to personally deliver or have someone deliver them to us, especially with live fishes or parasites. Freshly dead and properly iced specimens can be sent by **next-day** service of the U.S. Postal Service or by a parcel service. Preserved materials can be sent by slower methods. Fishes or parasites can be sent to the Sportfish Disease Project at: **Mail:** Department of Marine Sciences, University of Puerto Rico, P.O. Box 908, Lajas, PR 00667-0908; or **Parcel Service:** Ciencias Marinas, Road 304, Isla Magueyes, La Parguera, Lajas, PR 00667.

Transport live fishes in the water from which they were collected (not tap water - it may contain chlorine which will kill fishes and some parasites). A few small fishes can live in a bucket for a few hours. Battery-powered aerators can keep more fish-per-bucket alive. A few live fishes can be transported for hours in a sealed bag half filled with water and half filled with oxygen (not air). Place the bag in a styrofoam container with a little ice around it. Do not place ice in the water (most ice contains some chlorine).

PLEASE include a copy of the following form filled out along with your specimens [or that found in Anonymous (1989)].

SEND FISHES OR PARASITES FOR EXAMINATION TO:
The Sportfish Disease Project
Telephone: (787) 899-2048ext 264 or 221; **FAX:** (787) 899-5500
Please call or FAX before sending

Mail: Dept. Marine Sciences
Univ. Puerto Rico, P.O.Box 908
Lajas, PR 00667-0908

Parcel Service: Ciencias Marinas,
Road 304, Isla Magueyes
La Parguera, Lajas, PR 00667

COLLECTOR/SENDER

Name: _____ **Phone No.:**_____

Address: _____

_____

Circle Category: Fisher Student DNER UPR Environmentalist

COLLECTION
Date Collected: _____ **Collection Method:** _____

Location (Lake, river, distance from road etc.): _____

_____

Species of Fishes: _____

_____

Reason for Exam: Disease Small-scale mortality Fish Kill
Obvious Parasites Sores Abnormality Tumor Biological Study

Other: _____

If Parasites are Sent Without Fishes, Please Also Include:

Size of Fishes: _____

Location of Parasites on Fishes: _____

_____

Comments:

_____

Please copy this form, complete and send it with the samples.

DISCUSSION

FRESHWATER FISH PARASITES

The sport fishes of Puerto Rico have few parasites. This desirable situation can only be maintained by understanding the importance of healthy fishes and striving to preserve this status.

NUMBER AND VARIETY

We found approximately 100 species of parasites in the freshwater fishes of Puerto Rico. We cannot be certain of the exact number because some of the protozoans and larval worms, which we have not identified to species, may be multiple species. These require more study. The overall diversity of parasites is quite high. Sixteen of the 18 phyla with fish parasitic members are represented. The number of species in each phylum, the number of parasite species on each host species, and the numbers of parasite specimens per host are generally quite low. Fish imports are evaluated by DNER and restrictions are imposed but the relatively low numbers of parasites is largely due to a quirk of parasite ecology rather than conscious human management.

ORIGIN AND EVOLUTION

The freshwater fauna of Puerto Rico originally contained few native fishes. Exotic fishes, and inadvertently their parasites, have been imported from the southeastern USA (1915-1958), Africa via Auburn University (1958) and South America (1967) to create sportfishing for recreation and food; from the USA (1923) for mosquito control; from the southeastern USA (1957-1963) to provide baitfishes for largemouth bass; from Africa via Auburn University (1963-1990) for commercial tilapia production; from China via the USA (1972-1990) for weed control; and from Central America, China, India, and South America (1940-1990) via pet stores as aquarium pets. Most of the introduced species were imported only once, but largemouth bass have been imported at least five times, tilapias many times, and aquarium fishes almost every day. Each reintro-duction may bring new, potentially dangerous, parasites into Puerto Rico. Many of these intentional and accidental introductions became established because available habitats were virtually empty. These exotic species were also favored by modern habitat modifications, especially the construction of ponds and reservoirs. Most parasites of Puerto Rican freshwater sport fishes are either introduced (53%) or marine parasites which are able to survive, but do not reproduce in fresh water (33%). Only a few are

native (10%) or of unknown origin (4%) and two are endemic. These exotic parasites are faced with a great diversity of available but unfamiliar hosts in an alien environment. The few native parasites now have new hosts available. Some parasites have already slightly modified their behavior and host choices, but greater modifications may occur to allow highly adaptive parasites to take advantage of additional hosts and attachment sites. Introductions into Puerto Rico have unintentionally created a large scale experiment in the adaptive ability of parasite species. We have documented much of the existing parasite fauna, but the eventual modification or evolution of this fauna should be the most interesting story, worthy of future study.

FISH KILLS

Sudden kills of large numbers of fishes in a short time are not usually caused by parasites. Parasites typically kill a few fishes at a time, over a period of weeks. Commonly, parasites act in combination with other environmental shocks to cause fish kills. They may kill weakened fishes left over from fish kills caused by other insults (Williams 1982; Williams et al. 1982). In Puerto Rico, parasites have killed fishes in combination with poor water quality or pesticide and herbicide contamination. Meyer and Barclay (1990) and Anonymous (1992a) are useful guides for examining fish kills.

SIGNIFICANCE TO SPORTFISHING

Most parasites infecting sport fishes in Puerto Rico cause relatively minor damage to their hosts, reducing their growth and productivity. However, *Epistylis colisarum*, *Gyrodactylus cichli-darum*, *Lernaea cyprinacea*, *Argulus japonicus* and caiman tongue-worms are damaging or are clear threats to sport fishes. *Ophio-taenia* sp., *Ophiovalipora minuta* and tilapia wasting disease appear to be potential biological controls for Mozambique tilapia, which may be a serious competitor among local sport fishes. *Piscinoodinium pillulare*, *Trypanoplasma* sp., *Ichthyophthirius multifiliis*, *Tricho-dina* spp., *Chlorella* sp., *Saprolegnia* spp., *Posthodiplostomum mini-mum*, *Uvulifer ambloplitis*, *Proteocephalus ambloplitis*, *Eustrongylides ingotus*, *Myzobdella lugubris* and *Ergasilus lizae* are all potentially serious threats to our sport fishes. Further study is required to determine the extent of these problems.

EXOTIC PARASITE ECOLOGY HYPOTHESES

The fresh waters of Puerto Rico were once a simplified environment with almost no native fishes or parasites. Since the early 1900s, there has been a steady stream of introductions of fishes and their parasites

from around the world and a virtual flood of importations since the advent of air transportation of aquarium fishes. Although the fish fauna is totally dominated by exotic species, amazingly few parasites have survived these transfers. No better "laboratory" could be imagined for studying the ecological development of a complex mix of exotic fishes and exotic parasites.

Why then, with so many species of introduced fishes and their associated parasites, has Puerto Rico escaped so relatively undamaged and so lightly parasitized? From our 20 years of working with these introductions, we have formulated a few hypotheses concerning the ecology of these exotic parasites.

1. Almost no parasites with complex life cycles will be introduced, and not all parasites with direct life cycles will be initially introduced. Most exotic parasites with complex life cycles require specific intermediate hosts that probably do not exist in the new environment. Even those with direct life cycles may not be favored by all the conditions in the new environment. Thus, once introduced fishes are established, their parasite fauna typically becomes greatly diminished, as we see in Puerto Rico.

2. Reintroductions of hosts add additional parasites to the host-parasite mix. Numerous reintroductions may eventually establish most of the host's native parasites. A dangerous misconception about exotic fishes is that once an introduction has been made, all possible damage to the new environment has occurred, and reintroductions make little difference. This is a false notion which is particularly hazardous when parasites and other pathogens are concerned. Not all pathogens occur in each batch of exotic fishes, due to differences in geographic distribution, life cycle stage, and treatment before shipping. The more reintroductions that occur, the greater are the odds of bringing in more pathogens. Decades of tilapia introductions occurred before *Cichlidogyrus tilapiae* became established in Puerto Rico. The highly dangerous *Gyrodactylus cichlidarum* was established even later. Grass carp have been brought in repeatedly since 1972 to control aquatic weeds. This fish carries a highly dangerous tapeworm *Bothriocephalus acheilognathi*, that probably did not become established until the 1990s.

3. Repeated introductions of fishes from a native region predisposes the new environment to support parasites with complex life cycles. Most parasites with complex life cycles require specific intermediate hosts that initially do not occur in the new environment. Some fishes and invertebrates that serve as intermediate hosts may be deliberately or accidentally introduced with repeated shipments from the same native region. Three southeastern USA freshwater fish parasites with complex life cycles have become established in Puerto Rico. Many shipments of fishes have been sent from this region, and consequently our island may now be able to support parasites with complex life cycles. We should be wary of introducing new parasites from the USA, such as the dangerous

Proteocephalus ambloplitis that was recently brought back into Puerto Rico. Those introduced in 1946 did not become established, but the island now may have the correct copepods and young fishes to complete its life cycle. Hopefully, eradication efforts prevented this from happening. This process was called "predisposition of the environment" by Williams and Sindermann (1992).

4. Complex life cycles may be completed by introducing a single key species. One subspecies of grub, *Posthodiplostomum minimum centrarchi*, only occurs in sunfishes. Before exotic sunfishes were brought into Puerto Rico, this life cycle could not be completed. Migratory fish-eating birds brought in the adult fluke for thousands of years, and appropriate snail first intermediate hosts were present, but the fish second intermediate host only became available after 1915. Most of the adult flukes, tapeworms and roundworms that occur in fish-eating birds could rarely, if ever, have completed their life cycles in Puerto Rico prior to 1915 due to the virtual absence of freshwater fishes.

5. Even unsuccessful attempts to introduce fishes may succeed in introducing their parasites. Although the Florida largemouth bass brought into Puerto Rico in 1992 were never released, the gillworm *Onchocleidus principalis* from these fish became established on local largemouth bass. Grass carp have not become established, but their highly dangerous parasite, *Bothriocephalus acheilognathi*, is now established. Despite repeated introductions and releases, goldfish have not become established, but we fear that two of the most dangerous parasites they carry, *Lernaea cyprinacea* and *Argulus japonicus*, could become established as they have around the world.

6. Exotic parasites often change their behaviors and host preferences immediately in new environmental conditions. *Trichodina pediculus* only occurs on largemouth bass in the USA, but they infect a variety of host species in Puerto Rico. *Apiosoma piscicolum* has similarly spread to several new hosts in Puerto Rico. *Trichodina discoidea* is restricted to channel catfish in Puerto Rico, but also infects various sunfishes in the USA. *Trichodina fultoni* is also much more restrictive in its host choices in Puerto Rico. *Gyrodactylus cichlidarum* does not occur on the gills, as in its native habitat, *Actinocleidus gracilis* has spread to two new *Lepomis* spp., *Clavunculus bursatus* does not occur on bluegill, *Cichlidogyrus tilapiae* occurs on far more host species and *Onchocleidus ferox* occurs on redbreast sunfish in Puerto Rico. All exotic gillworms in wild fishes in Puerto Rico occur in lower numbers per host than they do in their native ranges. Similarly, all grubs occur in lower numbers per host and much more rarely in Puerto Rico. *Bothriocephalus acheilognathi* spread to tilapia in Cuba and this host shift may eventually occur locally.

7. Exotic parasites often cause serious disease in native

fishes or fishes with no prior exposure and defenses against them. Conversely, native parasites can cause serious diseases in exotic fishes. The exotic leech *Myzobdella lugubris* may injure all freshwater fishes including native ones. Since few native freshwater fishes exist in Puerto Rico, new exotic parasites are more likely to affect "old" exotic fishes. The caiman tongueworm seems to be destructive to the peacock bass. *Bothriocephalus acheilognathi* has a worldwide reputation for causing severe disease problems when introduced to new hosts. *Proteocephalus ambloplitis* was quite destructive to new salmonid hosts in the state of Washington (USA) when first introduced. If it ever becomes established locally, it could produce severe problems. Local parasites have also taken a toll on exotic fishes. Tilapia have the reputation of being extremely hardy and having no parasite problems. *Neobenedenia melleni* attacked tilapia reared in saltwater in the Caribbean. Tilapia wasting disease and local immature tapeworms have either caused mass mortalities or have reduced the numbers and condition factor of tilapia from some reservoirs and lagoons.

8. Established exotic parasites that maintain strict host specificity can be eradicated by eliminating their host. More generalized parasites can only be eradicated in the early stages of introductions. *Dactylogyrus bifurcatus* survived in Puerto Rico for 20 years, but was lost when its host, the fathead minnow, perished. If adult caiman tongueworms occur only in this exotic reptile, then they may be destroyed by reducing the caiman population. Hopefully, all *Proteocephalus ambloplitis* brought into Puerto Rico in 1992 were destroyed as well as several batches of the highly dangerous *Lernaea cyprinacea* and *Argulus japonicus* on aquarium and pond fishes. Unfortunately, we do not learn of all local outbreaks of these pests. All clams that produce glochidia have apparently been eliminated from Puerto Rico. Quick reaction to new exotic disease problems offers the best hope of control.

9. Aquaculture management practices and treatments for disease problems actually select for the most hardy and adaptive parasite species. Often fishes with these parasites are then sent into new areas for aquacultural purposes. Puerto Rico miraculously has few of these pests, but the list includes *Trypanoplasma* sp., *Ichthyophthirius multifiliis*, *Gyrodactylus cichlidarum*, *Cichlidogyrus tilapiae*, *Bothriocephalus acheilognathi* and *Camallanus cotti*. We are also vulnerable to *Lernaea cyprinacea*, *Argulus japonicus*, *Lironeca symmetrica* and a variety of other commercially encouraged pests.

10. Exotic parasites that become established among fishes having few parasites will eventually change their host and attachment-site preferences to take advantage of these new niches. Ultimately, the new environmental system will drive

the speciation of parasites. The normal checks and balances of competition among parasites, parasites cleaners, or simple space on hosts do not exist in this new man-made environment. Highly adaptive parasites should evolve to fill open niches. Parasitologists will have the opportunity to follow species changes in this "natural" experiment. We can only document the beginning, the results will only be apparent long after we are forgotten.

PARASITE CONTROLS

Usually "parasite control" takes the form of treatment, management or eradication methods used against parasites, but some parasites may be developed as specific biological controls against undesirable fishes.

TREATMENT

Treatments for parasites are used primarily by aquarium hobbyists, aquaculturalists and hatchery managers. We have not given many details about treatments in this book because (1) fishermen seldom need this information, (2) some chemical agents are not approved by the USFDA for use on food fishes or are hazardous to humans and (3) books explaining treatments are available. Most books about fish diseases include information about treatments (Hoffman and Meyer 1974; Jimenez-Guzman et al. 1986; Martty 1986; Paperna 1980; Plumb 1985, 1994; Post 1987; Prieto 1991; Reichenbach-Klinke 1980; Schäperclaus 1986; Warren 1991).

The U.S. Food and Drug Administration has approved several treatments at specific levels for certain fishes or fish eggs (Anonymous 1994). Because the approval of treatments by the USFDA can change, published summaries become rapidly out-of-date. It is the responsibility of the person treating fishes to know what is approved. Most treatments should only be conducted by professional biologists who have knowledge about the biology of the fishes, the water in which they live and the USFDA recommendations.

ERADICATION

Parasites, like some exotic fishes, are nearly impossible to eliminate once they become established. They are actually more insidious because they often spread to new host species in the new environment. Many have resistant, off-host stages which are difficult to destroy.

Any attempt at eradication of exotic parasites must be made as soon as possible after the initial introduction. The original host must be eliminated. The spread to other hosts may not have occurred, and the original host remains the greatest source of new infective units. If

possible, the area contaminated by the parasite should be calculated (considering dispersion rates for the host and parasite), a safety factor of 20% added, and the original, potential, transfer, and possible intermediate hosts and parasites in this area exterminated. A quarantine period of 2-3 weeks should be maintained. Parasites with resistant stages may require 2-3 additional treatments.

Even though the ideal reaction described above is difficult to achieve, as much as is practical should be done. This might sufficiently lower the reproduction of the parasite to make its introduction fail. Well established parasites are simply part of the new environment that we have made for ourselves.

BIOLOGICAL CONTROL

Biological control is seen as a new and environmentally friendly way to limit pests. Such attempts are not new to Puerto Rico. Redear sunfish were brought onto the island in 1957 to eat the freshwater snail *Biomphalaria glabrata* that carry the bilharzia disease of humans caused by the fluke *Schistosoma mansoni*, cane toads *Bufo marinas* in 1919 to eat cane beetles, and guppies were reputed to control swimming bilharzia cercaria (Oliver-Gonzalez 1946).

Larval cestodes inland and tilapia wasting disease in coastal areas stunt and kill Mozambique tilapia in Puerto Rico. These parasites have reduced the population and condition of this fish in some reservoirs and lagoons. They seem good prospects, if biological control for this fish is needed, and could also be useful in other warm-water regions where this fish is considered a problem. Careful study will be required to understand and evaluate these parasites as potential biological controls.

Before we can attempt to biologically control the more damaging of our local fish parasites, we must thoroughly understand all aspects of their biology. A "weak link" in their life cycle, a close environmental tolerance, or other peculiarities in their physiology, that we can manipulate to their disadvantage, must be discovered. These fascinating puzzles may produce great benefits both locally and nationally, but require extensive efforts.

PREVENTION

Treatments and eradication of parasites may seem to be effective controls, but they are essentially the admission of failure. Prevention of parasite introduction (whether it is a pond, reservoir or island) is the only effective method of dealing with parasites. It is also the best way to protect the relatively parasite-free environment of our freshwater sport fishes. Introductions or reintroductions of fishes should be managed to minimize the importation of parasites (see Avoiding New

Parasites below). Transfers to a reservoir, pond or system should be screened for parasites that do not exist in the new system. When possible, a sample of fish should be held in quarantine prior to transfer to test for the appearance of density-dependent parasite problems. Water, nets or other gear should not be used in more than one pond, reservoir or drainage without cleaning or sterilizing. The public should be informed about their role in preventing introductions or transfers of parasites.

AVOIDING NEW PARASITES

Fishes carry parasites. It is almost impossible to rid a fish of all its parasites. Treatments can only lower the number of parasites on the surface or even in the gut but those in other internal organs and mesenteries are not affected by treatments. Therefore, we must assume that any fish being imported to Puerto Rico has parasites. How then can we reduce the chances of new parasites entering Puerto Rico? The following is a list of management suggestions that might help to reduce the probability of new parasites becoming established in Puerto Rico.

PARASITE EXCLUSION PRACTICES

Importation procedures should minimize the number of parasites introduced. Most protocols only try to exclude known pathogens. Since ordinarily harmless parasites may become problems in new environments, it is best to attempt complete exclusion.

Know the native and exotic parasites of the host. Study the literature about the biology and parasites found on a potential fish introduction; contact experts on this species; consult biologists in the source facility about parasites that may be present at the facility and in the species; and seek advise from biologists where this host has been previously introduced. The less that is known about a host, the higher the potential danger.

Choose a source with as "disease-free" a history as possible. Do not use wild fishes or poorly known stocks. A facility that is the source of fish importation should have been without major disease problems for at least two years.

Use as early a host life cycle stage as possible. Eggs can be more thoroughly treated and carry few parasites. They should be used if they can be raised locally. Fry or young fishes usually support fewer parasites than adults.

Inspect an adequate sub-sample of stock for parasites. Adequate percentages depend on the number of separately raised lots that make up the shipment and the parasites known from the host. Worlund and Taylor (1983) discuss sample-size estimates. Detailed examinations are necessary. If dangerous parasites (with potential to

damage sport fishes) are found, the shipment should be cancelled. The necessity of sub-sample sacrifices must be calculated into the size of the original shipment.

Treat for parasites. Parasites can be hard to find. Treat for them even if the sub-sample appeared to be clean (parasite free). Use as strong and as prolonged a treatment as possible without injuring the shipment.

Re-inspect a sub-sample of stock for parasites. Treatments do not always work. Check to see if existing parasites were eliminated.

Transport by secure means. The shipment must not be lost, damaged, leak or become contaminated. It should be clearly labeled as exotic fish and accompanied by any necessary inspection and importation forms or certificates.

Destroy containers and sterilize containment water. Transfer shipment to new water in a quarantine facility. Sterilize the water in which the fish were shipped. Destroy the containers that held the shipment.

Re-inspect a sub-sample of stock for parasites. This insures lack of contamination and the thoroughness of the overseas examination. If dangerous parasites are found, the shipment must be destroyed. If parasites unlikely to damage sport fishes are found, the fish must be re-treated.

Rear in quarantine. When eggs are introduced, these may be raised to a suitable stocking size. If no parasite problems have occurred, they may be used as releasable stock. When fry or larger fishes are imported, they should be raised to adults, reproduced, destroyed, and their offspring raised for release.

Challenge local fishes with the exotic fish. Samples of local sport fishes should be held from 1-6 months with a sample of the new exotic species in quarantine. Detailed examinations should detect any new exotic parasites on local fishes or any local parasites infecting the new exotic fishes.

Inspect a sub-sample before stocking or releasing. If a detailed examination reveals a dangerous parasite, delay release until eradication of the parasite from all stocks can be assured. If parasites unlikely to be damaging are found treat all stocks and re-inspect.

Collect and re-inspect after six months and a year. The appearance of exotic parasites or infection by local parasites should be a part of the evaluation of introduced species. This may be of value when the original stocking is limited or on a test basis. It should be a part of the biological studies monitoring the host in its new environment.

Maintain a local brood stock. These should be used for additional stocking to avoid dangerous and complicated reintroductions.

FISH INTRODUCTIONS

A complete consideration of introductions is beyond the scope of this book. The United Nations (Turner 1988), U.S. Fish and Wildlife Service (Anonymous 1992b), American Fisheries Society (Kohler and Courtenay 1986a,b) and others have published proposed regulations for introducing new fishes (Courtenay and Stauffer 1984, Welcomme 1986, 1988).

Private individuals or organizations should never consider making introductions or transfers of fishes. They lack the expertise, equipment and personnel to properly evaluate the consequences of their actions. The small numbers of fishes that private organizations move are usually too few to allow a fish species to establish, but may allow its associated parasites to contaminate local fishes.

Importing fishes for aquaculture purposes is the same as making a deliberate introduction. Fishes always escape. Water flowing from ponds and facilities will carry parasites out to the environment even if the fishes do not escape. Each re-stocking from overseas brings in new parasites and other pathogens. It would be wiser to establish brood stock at local facilities.

AQUARIUM FISHES

Keeping aquarium fishes is a fascinating hobby that is not intended to injure our natural resources. Taking a few simple precautions will insure that no harm is done to the natural aquatic environment.

Never release live aquarium fishes, invertebrates or plants into natural waterways. Most tropical fishes can survive in Puerto Rico. You may be introducing these new fishes, invertebrates or plants as well as their parasites into the natural environment. These exotic species could harm native fishes and the sport fishes that Puerto Rico has worked so hard to develop. An exotic species could be established with only a few releases of the same species of pets at the same time. Instead of releasing these pets, you could: (1) give them to a friend; (2) call your local pet store and see if they will take the fishes; (3) contact any local aquarium hobbyist organization for help; or (4) take the fishes to any DNER office or agent or to the authors.

A new exotic fish had not been established in Puerto Rico since the early 1970s until populations of the South American sailfin armored catfish from Venezuela became established about 1990. It was probably introduced by aquarium hobbyists and has been found in at least eight rivers and three reservoirs in Puerto Rico. This exotic species has some economic value. Its flesh is edible, eggs are valued as caviar, and young may be sold as aquarium fish. Unfortunately, its burrowing behavior and capacity for overpopulation are detrimental to

local reservoir sport fishes. Locally endangered brown pelicans have choked to death attempting to swallow this fish. Increased availability of this aquarium fish and habitat modifications may have facilitated the invasion into Puerto Rico. The spread of this alien species should be monitored closely, and introductions of other aquarium catfishes must be avoided (Bunkley-Williams et al. 1994).

Never dispose of dead aquarium animals or plants in natural waterways or where such material may be washed into waterways. Many parasites have resistant spores or stages that can survive the death of their host and drying. Some sewage treatment processes are too incomplete to kill these parasites. Dead plants and animals can be more safely eliminated by deep burying where they will not be dug up by animals or washed away by run-off to contaminate local waterways. They may also be sealed in plastic bags and disposed of as garbage that will be placed in landfills.

Refuse to buy fishes which you believe could be dangerous to the Puerto Rican natural waters. Pet stores are a business. They respond more readily to the wishes of their customers than to government regulations. The DNER is forming a list of dangerous fishes. Aquarium hobbyist organizations have made up their own list of dangerous or undesirable aquarium fishes.

Report any large or destructive fish parasites to the authors or to agents of the DNER. We need to stay aware of what parasites are coming into Puerto Rico. Live, parasitized fishes make the best samples (see Sending Specimens or Information). We will send you a report concerning the parasites we find.

FISH PARASITES IN HUMANS

Many parasites in fishes can affect humans. The recent popularity of the Japanese "sushi" and "sashimi" raw fish dishes has caused a surge in human-parasite afflictions around the world. Locally, "escabeche" or "seviche", popular fish dishes, are sometimes prepared with raw fish.

EXISTING AND POTENTIAL THREAT

Many larval parasites in fishes can develop into adults in humans. *Clinostomum complanatum* and caiman tongueworm nymphs will mature in humans, and some of our larval roundworms and tapeworms might be able to parasitize humans. Larval roundworms that cannot mature in humans can cause severe gastric distress and may burrow randomly through the tissues of humans. Adult roundworms can cause severe gastric distress or even perforate the intestine, requiring surgical removal of worms. Eggs of the caiman tongueworm from fishes or bottom mud can directly infect humans and practically any

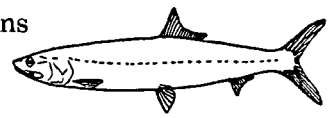
vertebrate. The nymphs may penetrate almost any organ. They are usually encapsulated and killed by the human body, appearing as calcifications in X-rays. These nymphs can cause sight impairment if they attack the eyes, or other serious damage if they attack vital organs. Some algal parasites of fishes and the local fish bacteria *Aeromonas hydrophila* complex can infect humans.

PREVENTION

Proper cooking kills all of the parasites that occur in fishes. Freezing for two days will also kill parasites. Modern sanitation systems and proper handling of fishery products in Puerto Rico protects the public from most parasites and fish-related diseases. Freshwater fishes should not be used in raw-fish dishes because they contain parasites that can injure humans. Most people think that only fresh fish can be used in raw-fish dishes. Actually, Japanese and Europeans freeze most fishes that they use in raw-fish preparations for several days to kill parasites. Cleaning fishes may contaminate hands, utensils and clothing with immature parasite stages that can infect humans. Utensils, pans, and cutting boards used to prepare raw fish for cooking, should be washed before being used for vegetables, salads or other foods that will not be thoroughly cooked. Do not return cooked fish to platters or plates that held uncooked fish. In areas where caimans are found, eggs of tongueworms may contaminate fishes or pond mud. Frequent washing of hands may prevent hand-to-mouth contamination and infection. Far more horrible parasites that affect humans are found in fishes overseas. We should take particular care that these pests are not allowed to immigrate. We would appreciate receiving reports from physicians who treat local human diseases caused by fish parasites.

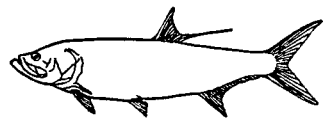
HOST-DISEASE CHECKLIST

Order Elopiformes, Family Elopidae - tarpons



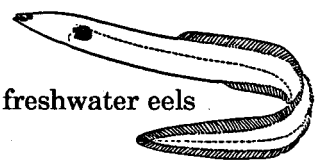
***Elops saurus* Linnaeus - ladyfish**

Protozoa	*Ambiphrya ameiuri.*
Digenea	*Brachyphallus parvus*
Copepoda	*Ergasilus lizae*
	Lernanthropus rathbuni



***Megalops atlanticus* Valenciennes - tarpon**

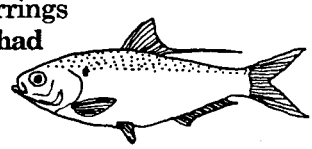
Protozoa	*Ambiphrya ameiuri*
	Trichodina sp.
Monogenea	*Diplectanocotyla gracilis*
Digenea	*Bivesicula tarponis*
	Brachyphallus parvus
Hirudinida	*Myzobdella lugubris*
Copepoda	*Ergasilus lizae*



Order Anguilliformes, Family Anguillidae - freshwater eels

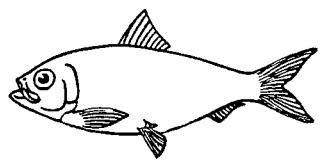
***Anguilla rostrata* (Linnaeus) - American eel**

Order Clupeiformes, Family Clupeidae - herrings



***Dorosoma petenense* (Günther) - threadfin shad**

Bacteria	*Flexibacter columnaris*
Protozoa	*Epistylis colisarum*
	Trichodina microdenticula
Chlorophyta	*Chlorella* sp.
Condition	gas bubble disease

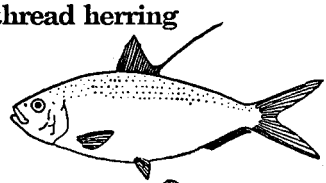


***Harengula jaguana* Poey - scaled sardine**

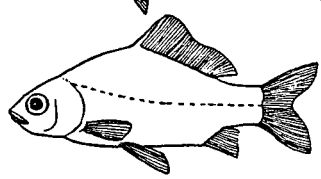
Nematoda *Contracaecum spiculigerum**

***Opisthonema oglinum* (Lesueur) - Atlantic thread herring**

Nematoda *Contracaecum spiculigerum**



Order Cypriniformes, Family Cyprinidae - carps and minnows

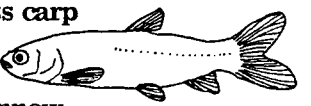


***Carassius auratus* (Linnaeus) - goldfish**

Protozoa	*Trichodina reticulata*
Monogenea	*Dactylogyrus anchoratus*
Copepoda	*Lernaea cyprinacea*
Branchiura	*Argulus japonicus*
Neoplasm	neurofibroma

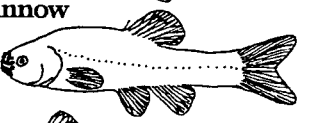
* Larval forms

***Ctenopharyngodon idella* (Valenciennes) - grass carp**



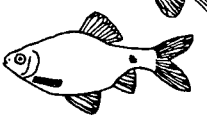
Cestoidea *Bothriocephalus acheilognathi*

***Pimephales promelas* Rafinesque - fathead minnow**



Monogenea *Dactylogyrus bifurcatus*
Cestoidea *Bothriocephalus acheilognathi*

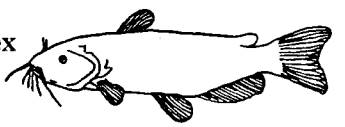
***Puntius conchonius* (Hamilton) - rosy barb**



Monogenea *Dactylogyrus* sp.

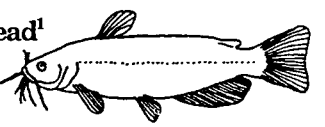
Order Siluriformes, Family Ictaluridae - bullhead catfishes

***Ameiurus catus* (Linnaeus) - white catfish**



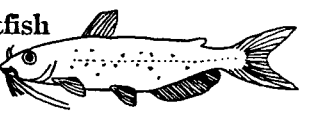
Bacteria *Aeromonas hydrophila* complex
Micrococcus sp.
Staphylococcus sp.
Protozoa *Epistylis colisarum*
Trichodina pediculus
Monogenea *Cleidodiscus pricei*
Nematoda skin blister roundworm
Neoplasm spleen lipoma

***Ameiurus nebulosus* (Lesueur) - brown bullhead[1]**



Bacteria *Aeromonas* sp.
Aeromonas hydrophila complex
Protozoa *Epistylis colisarum*
Trichodina pediculus
Chlorophyta *Chlorella* sp.
Monogenea *Cleidodiscus pricei*

***Ictalurus punctatus* (Rafinesque) - channel catfish**



Bacteria *Aeromonas hydrophila* complex
Micrococcus sp.
Staphylococcus sp.
Protozoa *Epistylis colisarum*
Trichodina discoidea
Trichodina vallata
Trichodina sp.
Monogenea *Cleidodiscus pricei*
Digenea *Clinostomum complanatum**
Neoplasm undifferentiated sarcoma
Condition epithelial hyperplasia

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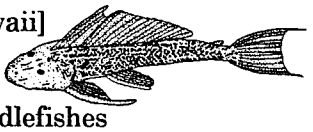
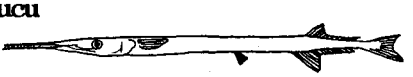
[1]Two subspecies of the brown bullhead have been noted locally, *Ameiurus nebulosus nebulosus* and *Ameiurus nebulosus marmoratus*. We combine them in the checklist because their parasites are the same.

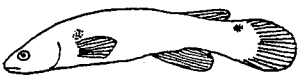
Family Loricariidae - suckermouth armored catfish
***Liposarcus multiradiatus* (Hancock), sailfin armored catfish**
Protozoa *Ichthyophthirius multifiliis* [Hawaii]



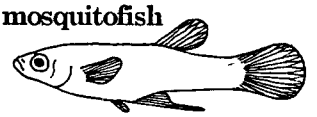
Order Atheriniformes, Family Belonidae - needlefishes
***Strongylura timucu* (Walbaum) - timucu**
Monogenea *Murraytrematoides* sp.
Copepoda *Ergasilus lizae*



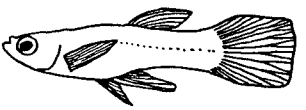
Family Aplocheilidae - rivulins
***Rivulus marmoratus* Poey - mangrove rivulus**

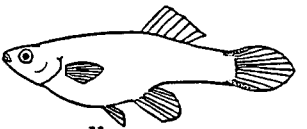


Family Poeciliidae - livebearers
***Gambusia affinis* (Baird & Girard) - western mosquitofish**
Digenea *Echinochasmus donaldsoni**



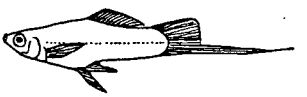
***Poecilia reticulata* Peters - guppy**
Protozoa *Trichodina* sp.
Digenea *Neogogatea pandionis**
*Posthodiplostomum minimum**
Cestoidea *Bothriocephalus acheilognathi*
*Ophiovalipora minuta**
Nematoda *Camallanus cotti*
*Eustrongylides ingotus**



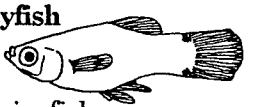


***Poecilia vivipara* (Bloch & Schneider) - mangrove molly**

***Xiphophorus helleri* Heckel - green swordtail**
Bacteria *Flexibacter columnaris*
Isopoda *Lironeca symmetrica*

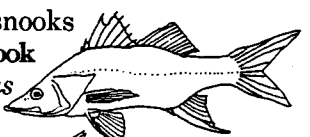


***Xiphophorus maculatus* (Günther) - southern platyfish**

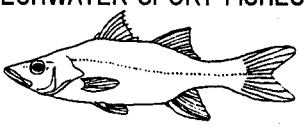


Order Gasterosteiformes, Family Syngnathidae - pipefishes
***Microphis brachyurus* (Bleeker) - opossum pipefish**

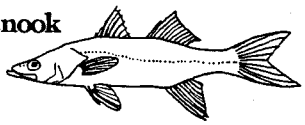
Order Perciformes, Family Centropomidae - snooks
***Centropomus ensiferus* Poey - swordspine snook**
Monogenea *Rhabdosynochus rhabdosynochus*
Hirudinida *Myzobdella lugubris*



***Centropomus parallelus* Poey - fat snook**



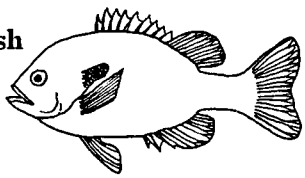
***Centropomus pectinatus* Poey - tarpon snook**



***Centropomus undecimalis* (Bloch) - common snook**

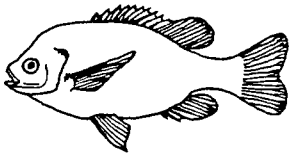
Bacteria	*Vibrio* sp.
Protozoa	*Trichodina* sp. a
	Trichodina sp. b
Monogenea	*Rhabdosynochus rhabdosynochus*
Digenea	*Paracryptogonimus centropomi*
Copepoda	*Paraergasilus* sp.

Family Centrarchidae - sunfishes



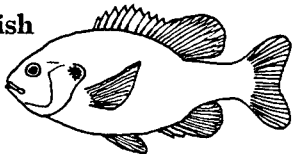
***Lepomis auritus* (Linnaeus) - redbreast sunfish**

Bacteria	*Flexibacter columnaris*
Protozoa	*Epistylis colisarum*
Monogenea	*Actinocleidus gracilis*
	Haplocleidus furcatus
	Onchocleidus ferox
Digenea	*Posthodiplostomum minimum**
Copepoda	*Ergasilus caeruleus*



***Lepomis macrochirus* Rafinesque - bluegill**

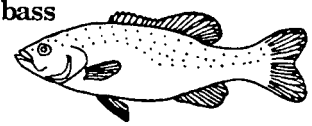
Bacteria	*Flexibacter columnaris*
Protozoan	*Epistylis colisarum*
	Trichodina pediculus
Oomycota	*Saprolegnia* spp.
Monogenea	*Actinocleidus gracilis*
	Haplocleidus furcatus
	Onchocleidus ferox
Digenea	*Echinochasmus donaldsoni**
	*Posthodiplostomum minimum**
Nematoda	*Philometroides* sp.
Copepoda	*Ergasilus caeruleus*



***Lepomis microlophus* (Günther) - redear sunfish**

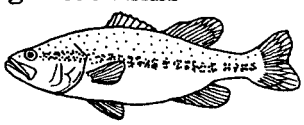
Bacteria	*Flexibacter columnaris*
Protozoa	*Ambiphrya ameiuri*
	Trichodina pediculus
Monogenea	*Actinocleidus gracilis*
	Haplocleidus furcatus
	Onchocleidus ferox
Digenea	*Echinochasmus donaldsoni**
	*Posthodiplostomum minimum**
Copepoda	*Ergasilus versicolor*

***Micropterus coosae* Hubbs & Bailey - redeye bass**



Protozoa	*Apiosoma piscicolum*
Monogenea	*Acolpenteron ureteroecetes*
	Clavunculus bursatus
	Haplocleïdus furcatus
Digenea	*Uvulifer ambloplitis**
	*Echinochasmus donaldsoni**
Nematoda	*Contracaecum spiculigerum**
Acanthocephala	*Acanthocephalus alabamaensis*

***Micropterus salmoides floridanus* - Florida largemouth bass**

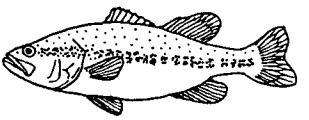


Bacteria	*Aeromonas* sp.
	Aeromonas hydrophila complex
	Flexibacter columnaris
Protozoa	*Epistylis colisarum*
	Trichodina fultoni
	Trichodina pediculus
Oomycota	*Saprolegnia* spp.
Monogenea	*Acolpenteron ureteroecetes*
	Actinocleidus fusiformis
	Clavunculus bursatus
	Haplocleidus furcatus
	Onchocleidus principalis
Digenea	*Echinochasmus donaldsoni**
	*Posthodiplostomum minimum**
Cestoidea	*Proteocephalus ambloplitis**
Nematoda	*Contracaecum spiculigerum**
Pentastomida	caiman tongueworm*
Condition	kidney stone
	spring mortality

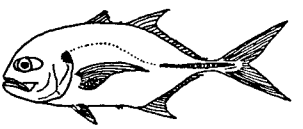
***Micropterus s. f.* X *M. s. salmoides* hybrid - largemouth bass[2]**

Bacteria	*Aeromonas* sp.
	Aeromonas hydrophila complex
	Flexibacter columnaris
	possible *Renibacterium salmoninarum*-type
Protozoa	*Apiosoma piscicolum*
	Epistylis colisarum
	Ichthyophthirius multifiliis
	Myxobilatus mictosporus
	Trichodina fultoni
	Trichodina pediculus

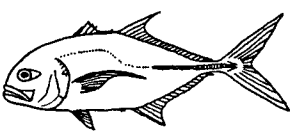
[2]This hybrid bass is the most common form of largemouth bass found in Puerto Rico. For convenience we call it "largemouth bass". Traditionally, *Micropterus salmoides* (Lacepède) or *M. s. salmoides* is called largemouth bass.



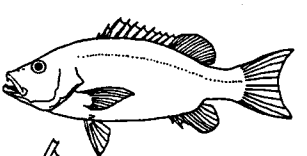
Oomycota *Saprolegnia parasitica*
Monogenea *Acolpenteron ureteroecetes*
Actinocleidus fusiformis
Clavunculus bursatus
Haplocleidus furcatus
Onchocleidus principalis
Acari *Hydrachna* sp.*
Neoplasm spleen lipoma
Condition gas bubble disease
spinal curvature
spring mortality



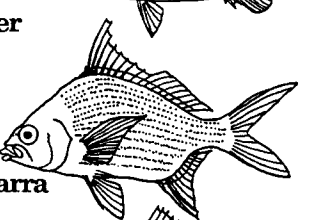
Family Carangidae - jacks
***Caranx hippos* (Linnaeus) - crevalle jack**
Monogenea *Allopyragraphorus hippos*
Cemocotyle noveboracensis
Protomicrocotyle mirabilis
Digenea *Stephanostomum ditrematis*
Copepoda *Lernanthropus giganteus*
Isopoda *Cymothoa oestrum*



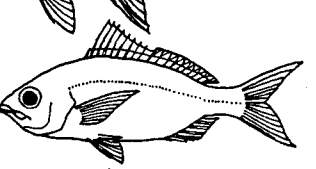
***Caranx latus* Agassiz - horse-eye jack**
Monogenea *Allopyragraphorus hippos*
Cemocotyle noveboracensis
Protomicrocotyle mirabilis
Copepoda *Lernaeenicus longiventris*
Lernanthropus giganteus
Isopoda *Cymothoa oestrum*



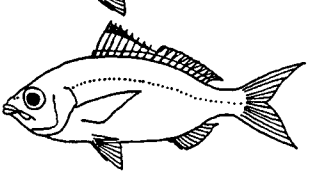
Family Lutjanidae - snappers
***Lutjanus griseus* (Linnaeus) - gray snapper**
Bacteria *Vibrio* sp.
Copepoda *Caligus irritans*



Family Gerreidae - mojarras
***Diapterus plumieri* (Cuvier) - striped mojarra**
Monogenea *Diplectanum collinsi*
Copepoda *Paraergasilus* sp.



Eucinostomus argenteus Baird & Girard
- spotfin mojarra

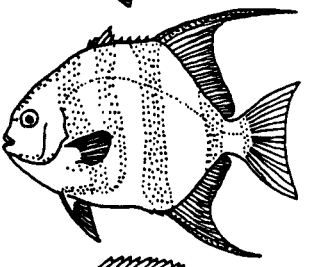


Eucinostomus melanopterus (Bleeker)
- flagfin mojarra

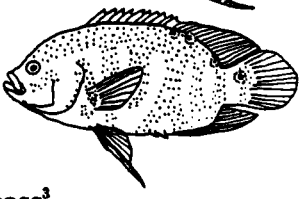
***Gerres cinereus* (Walbaum) - yellowfin mojarra**
Monogenea *Diplectanum collinsi*

Family Haemulidae - grunts
***Pomadasys crocro* (Cuvier) - burro grunt**
Digenea *Stephanostomum* sp.*

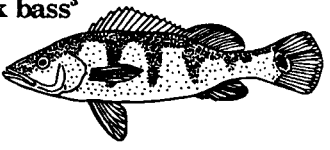
Family Ephippidae - spadefishes
***Chaetodipterus faber* (Broussonet)**
- Atlantic spadefish



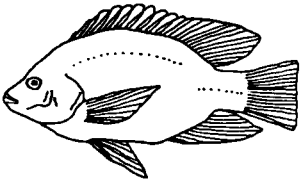
Family Cichlidae - cichlids
***Astronotus ocellatus* (Agassiz) - oscar**
Protozoa *Ichthyophthirius multifiliis*
Trichodinella sp.
Oomycota *Saprolegnia* spp.
Monogenea *Ancyrocephalus* sp.
Branchiura *Argulus japonicus*



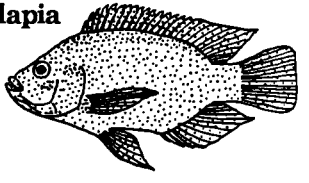
***Cichla ocellaris* Bloch & Schneider - peacock bass[3]**
Protozoa *Epistylis colisarum*
Pentastomida caiman tongueworm*



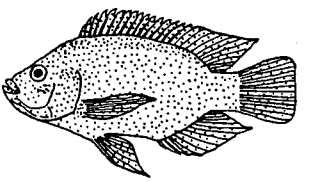
***Tilapia aurea* (Steindachner) - blue tilapia**
Bacteria *Flexibacter columnaris*
Protozoa *Apiosoma piscicolum*
Epistylis colisarum
Trichodina sp.
Trypanoplasma sp.
Monogenea *Cichlidogyrus tilapiae*
Gyrodactylus cichlidarum
Neobenedenia melleni



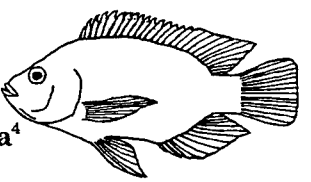
***Tilapia mossambica* (Peters) - Mozambique tilapia**
Bacteria *Aeromonas hydrophila* complex
Flexibacter columnaris
Micrococcus sp.
Stapholococcus faecalis
Staphylococcus sp.
Vibrio alginolyticus
Vibrio vulnificus
Vibrio sp.



[3]Called "peacock cichlid" by Robins et al. (1991), but "peacock bass" is used locally. The taxonomic status of the stock originally sent to Puerto Rico from Colombia is uncertain, but is under investigation.

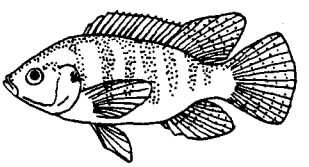


Protozoa	*Ambiphrya ameiuri*
	Apiosoma piscicolum
	Epistylis colisarum
	Ichthyophthirius multifiliis
	Piscinoodinium pillulare
	Trichodina fultoni
	Trichodina pediculus
Chlorophyta	*Chlorella* sp.
Oomycota	*Saprolegnia* spp.
Monogenea	*Cichlidogyrus tilapiae*
	Gyrodactylus cichlidarum
	Neobenedenia melleni
Cestoidea	*Ophiotaenia* sp.*
	*Ophiovalipora minuta**
Neoplasm	nephroblastoma
Condition	tilapia wasting disease



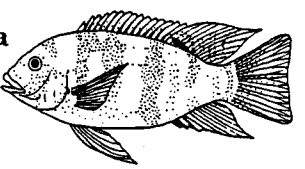
***Tilapia mossambica* X *T. urolepis* - red tilapia**[4]

Bacteria	*Vibrio* sp.
Protozoa	*Epistylis colisarum*
	Trichodina sp.
Monogenea	*Cichlidogyrus tilapiae*
	Neobenedenia melleni



***Tilapia nilotica* (Linnaeus) - Nile tilapia**

Bacteria	*Vibrio* sp.
Protozoa	*Trichodina* sp.
	Epistylis colisarum
Monogenea	*Cichlidogyrus tilapiae*

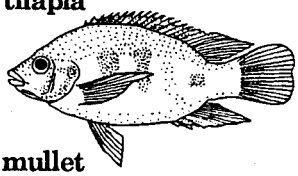


***Tilapia rendalli* (Boulenger) - redbreast tilapia**

Bacteria	*Aeromonas hydrophila* complex
Protozoa	*Epistylis colisarum*
	Trichodina pediculus
Chlorophyta	*Chlorella* sp.
Oomycota	*Saprolegnia* spp.
Monogenea	*Cichlidogyrus tilapiae*
Cestoidea	*Ophiovalipora minuta**
Hirudinida	*Myzobdella lugubris*
Copepoda	*Ergasilus lizae*
Acari	*Hydrachna* sp.*

[4]Also called *Tilapia* sp. by some authors.

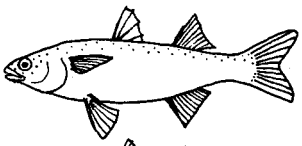
***Tilapia urolepis hornorum* (Trewavas) - Wami tilapia**[5]



Oomycota *Saprolegnia* spp.

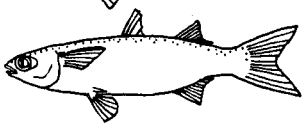
Family Mugilidae - mullets

***Agonostomus monticola* (Bancroft) - mountain mullet**



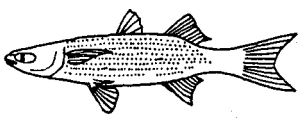
Protozoa *Trichodina* sp.
Monogenea *Ancyrocephalus* sp. a
Digenea *Echinochasmus donaldsoni**
Nematoda *Spinitectus carolini*

***Mugil curema* Valenciennes - white mullet**



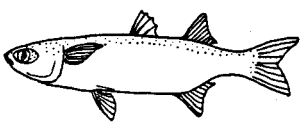
Bacteria *Vibrio* sp.
Protozoa *Tricodina* sp.
Monogenea *Metamicrocotyla macracantha*
Pseudohaliotrema mugilinus
Neobenedenia pacifica
Digenea *Haplosplanchus mugilis*
Hymenocotta manteri
Cestoidea tetraphyllidean larvae*
Acanthocephala *Floridosentis mugilis*
Hirudinida *Myzobdella lugubris*
Copepoda *Bomolochus nitidus*
Caligus pomacentrus
Ergasilus lizae
Ergasilus sp.
Lernaeenicus longiventris
Acari marine mite*

***Mugil liza* Valenciennes - liza**



Copepoda *Bomolochus nitidus*
Ergasilus lizae
Lernaeenicus longiventris
Digenea *Lecithochirium monticellii*
Nematoda *Contracaecum spiculigerum**

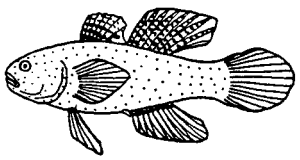
***Mugil trichodon* Poey - fantail mullet**



Copepoda *Ergasilus lizae*

Family Eleotridae - sleepers

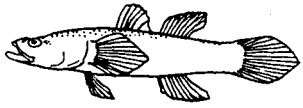
***Dormitator maculatus* (Bloch) - fat sleeper**



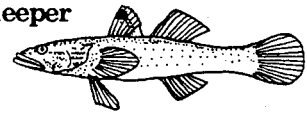
Digenea *Clinostomum complanatum**
Cestoidea *Ophiovalipora minuta**

[5]The species is *Tilapia urolepis* Norman, but this subspecies apparently occurs locally.

Eleotris pisonis **(Gmelin) - spinycheek sleeper**

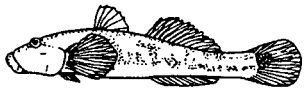


Gobiomorus dormitor **Lacepede - bigmouth sleeper**



Digenea *Clinostomum complanatum**
*Echinochasmus donaldsoni**
Nematoda *Tetrameres fissispina**
Copepoda *Paraergasilus* sp.

Family Gobiidae - gobies



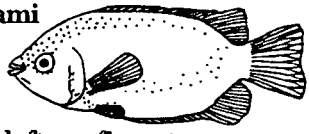
Awaous tajasica **(Lichtenstein) - river goby**
Protozoa unidentified
Digenea *Uvulifer ambloplitis**

Gobioides broussoneti **Lacepède - violet goby**

Gobionellus boleosoma **(Jordan & Gilbert) - darter goby**

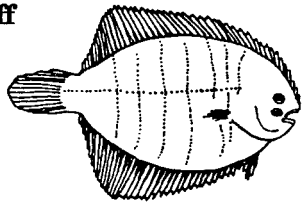
Sicydium plumieri **(Bloch) - sirajo goby**
Digenea *Uvulifer ambloplitis**

Family Anabantidae - gouramies



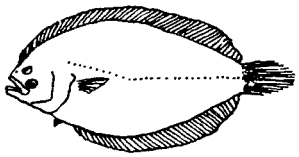
Helostoma temmincki **Cuvier - kissing gourami**
Oomycota *Saprolegnia* spp.

Order Pleuronectiformes, Family Bothidae - lefteye flounders



Citharichthys spilopterus **Günther - bay whiff**

Family Soleidae - soles



Achirus lineatus **(Linnaeus) - lined sole**
Digenea Lecithochirium monticellii

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*Larval forms

ACKNOWLEDGMENTS

The research detailed in this book was supported by the Puerto Rico Department of Natural and Environmental Resources (DNER) with Sportfish Restoration Funds (Puerto Rico Federal Aid Projects F-28 and F-35) and the University of Puerto Rico, Mayaguez Campus (UPRM). The Caribbean Aquatic Animal Health Project, Marine Ecological Disturbance Information Center, Caribbean Stranding Network and the Caribbean Aquaculture Association also provided information and/or support.

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ILLUSTRATION SOURCES

Illustrations of the following species were redrawn or modified from illustrations in the sources cited: *Piscinoodinium pillulare*, *Ichthyophthirius multifiliis*, *Apiosoma piscicolum*, *Ambiphrya ameiuri*, *Epistylus colisarum*, *Posthodiplostomum minimum*, *Clinostomum complanatum*, glochidia (Hoffman 1967); *Saprolegnia* spp. (Anonymous 1967); *Rhabdosynochus rhabdosynochus* (Yamaguti 1963); *Uvulifer ambloplitis*, *Neogogatea pandionis* (Hoffman 1959); *Bivesicula tarponis* (Sogandares-Bernal and Hutton 1959); *Haplosplanchus mugilis* (Nahhas and Cable 1964); *Hymenocotta manteri* (Overstreet 1969); *Stephanostomum ditrematis* (Yamaguti 1971); *Paracryptogonimus centropomi*, *Brachyphallus parvus*, *Lecithochirium monticellii* (Siddiqi and Cable 1960); *Bomolochus nitidus* (Cressey 1983); *Caligus pomacentrus* (Cressey 1991); *Ergasilus caeruleus*, *Ergasilus versicolor* (Wilson 1911); *Ergasilus lizae*, *Caligus irritans*, *Lernanthropus giganteus*, *Lernanthropus rathbuni*, *Lernaea cyprinacea*, *Lernaeenicus longiventris*, *Argulus japonicus* (Yamaguti 1963); *Artystone trysibia*, *Lironeca symmetrica* (Van Name 1936); *Cymothoa oestrum* (Kensley and Schotte 1989).

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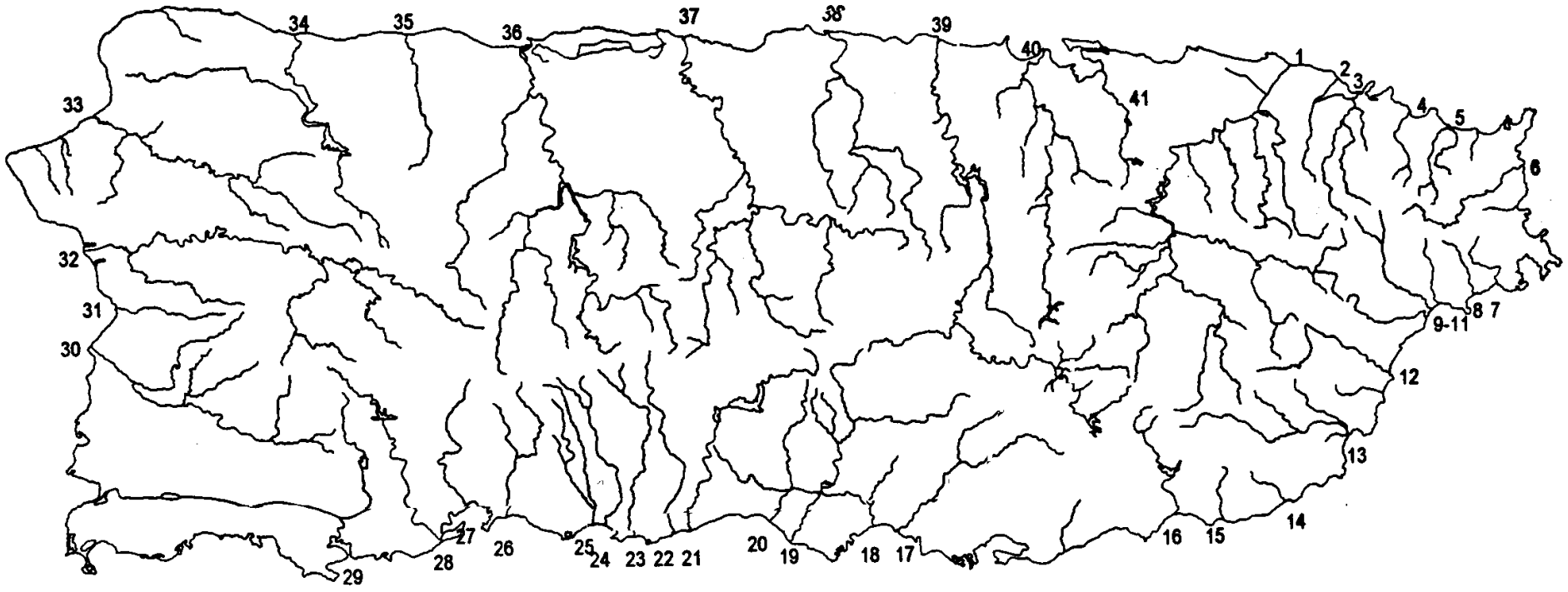
Lakes and Lagoons of Puerto Rico

Lagoons are denoted with an asterisk (*) after their name. The Maricao Fish Hatchery (west central) and the Lajas Agricultural Experiment Station (southwest) are also noted. The scale bar equals 10 km and the cross indicates the position 18°N, 65°40'W (both in the lower right of the figure).

Major Rivers of Puerto Rico

1 -Loíza
2 -Herrera
3 -Espiritu Santo
4 -Mameyes
5 -Sabana
6 -Fajardo
7- Dagüao
8 -Palma
9 -Santiago
10 -Blanco
11 -Antón Ruiz
12 -Humacao
13 -Guayanés
14 -Maunabo
15- Jaraboa
16 -Patillas
17 -Salinas
18- Jueyes
19 -Coamo
20 -Descalabrado
21 -Jacaguas
22 -Inabón
23- Bucaná
24 -Portugés
25 -Matilde
26- Tallaboa
27 -Guayanilla
28 -Yauco
29- Loco
30 -Guanajibo
31- Yagüez
32 -Añasco
33 -Culebrinas
34 -Guajataca
35 -Camuy
36 -Arecibo
37 -Manatí
38 -Cibuco
39 -La Plata
40 -Bayamón
41 -Piedras



INDEX

Numbers in emphasis indicate the location of the general description of parasites or diseases, and the location of the classification for fishes and other hosts. Local fish hosts are not indexed from the parasite descriptions because these can be more easily found in the Checklist. Only diseases not specifically named in the text are indexed from the Host-Disease Checklist.