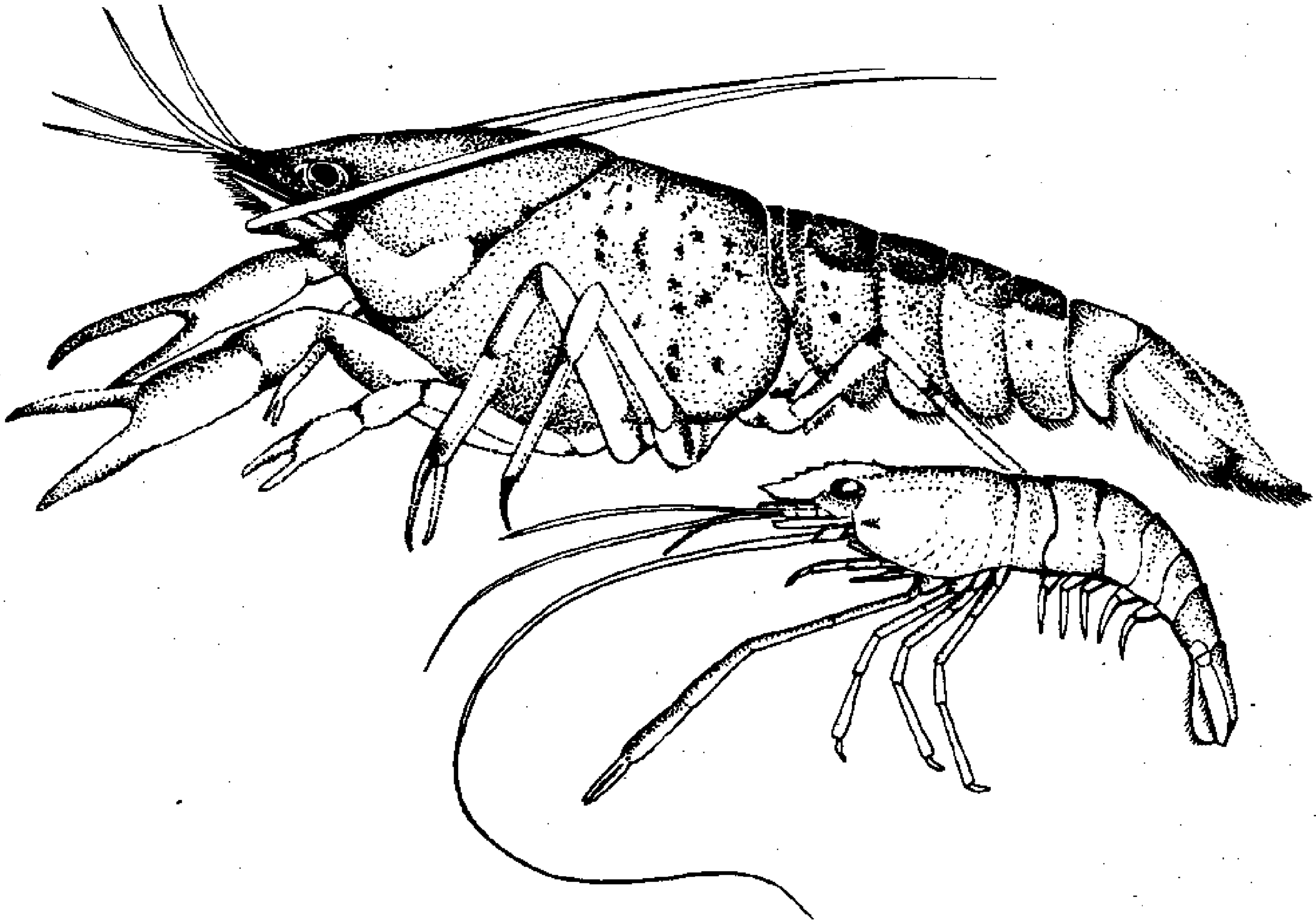

Crawfish and Freshwater Shrimp Diseases

S. K. Johnson

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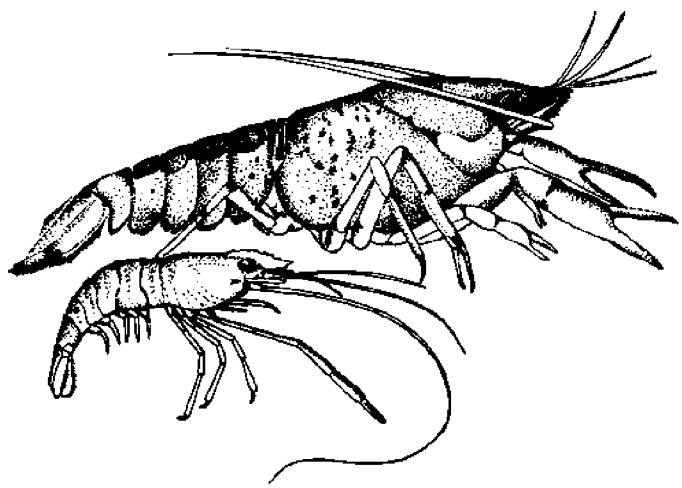

Handbook of Crawfish and Freshwater Shrimp Diseases

S. K. Johnson
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Department of Wildlife and Fisheries

This handbook is designed as an information source and field guide for crustacean culturists, commercial fishermen and others interested in parasites or abnormal conditions of freshwater crustaceans. In addition to detailed descriptions and illustrations of the common parasites and commensals, the publication includes information on the life cycles and general biological characteristics of disease producing organisms which spend all or part of their life cycles with crawfish and freshwater shrimp. Several conditions of unknown cause are also described.

Crawfish and freshwater shrimp collectively are only part of a variety of freshwater animals known as crustaceans. Their larger size and other features make them important. Crawfish culture is a multimillion dollar industry in the southern United States. Larger kinds of freshwater shrimp (*Macrobrachium* spp.) are used for food throughout the world and are now the subject of widespread aquaculture research. Smaller kinds of freshwater shrimp (*Palaemonetes* spp.) are used as food in some parts of the world but their main importance is as a forage species for many fish. Crawfish and freshwater shrimp comprise the majority of the freshwater representatives of a crustacean group known as decapods. Marine decapods include the familiar crabs, lobsters and marine shrimp.

As man begins to culture freshwater crustaceans at higher densities, unnatural conditions will be created and diseases will become more prominent obstacles to successful production. New methods will be required to control diseases and identify basic factors causing them Fortunately, many tested methods of allied aquacultures can be adapted to meet the needs in the culture of freshwater crustaceans.

Disease may be caused by living or non-living agents. Non-living causes include lack of oxygen, poisons, low temperatures, water hardness extremes, etc. This guide concentrates on living agents and on illustrations and photographs of the structure and effects of such agents.

DEFINITIONS

Bacteria — one-celled organisms that can be seen only with a microscope. Compared to protozoans they are of less complex organization and normally less than 1/5,000 inch in size.

Chitinoverous — deriving nutrition from chitin, the support substance of the exoskeleton.

Commensal — a plant or animal that lives in association with a host organism but is not injurious to it.

Crustacean — an animal with a hard exoskeleton of chitin and with jointed appendages. Larger crustaceans usually have gills for breathing. Most are marine, many are freshwater and some live on land.

Decapods — a crustacean group that includes shrimp, crabs, crawfish and lobsters. Common decapods have five pairs of legs with the first or second pair enlarged and adapted for pinching.

Ectocommensal — a commensal that lives on the surface of the host's body.

Fungus — in shrimp, a microscopic plant that reproduces by spores and develops interconnecting tubular structures.

Genus — (plural: genera) a classification of plants or animals with common, distinguishing characterisitcs. A genus may include one or several species. A species name consists of the genus name plus a second word called the **specific epithet** (example: *Procambarus clarkii,* the scientific name for the red crawfish, and *Procambarus acutus* for the white crawfish — both belong to the genus *Procambarus*).

Gregarine — name for a group of parasitic protozoa that live in insects, crustaceans, earthworms and several other types of invertebrate animals.

Hemocoel — the enclosed space around organs of a shrimp which contains the animal's blood.

Host — one that has a parasite or commensal living on or in it.

Invertebrate — animal without a backbone.

Microbe — a very minute living organism, especially bacteria, viruses and fungi.

Microscopic — small enough to be invisible or obscure except when observed through a microscope.

Microsporidian — a name for a group of parasitic protozoa that lives in insects, crustaceans, fish and many other types of animals.

Molting — for shrimp, shedding of the exoskeleton. Molting occurs at intervals during a shrimp's life and allows for expansion in size.

Parasite — a plant or animal that lives in or on a host to the detriment of the host.

Protozoan — a microscopic, usually one-celled animal that belongs to the lowest division of the animal kingdom. Normally, they are many times larger than bacteria.

sp. and spp. — singular and plural abbreviations for species, respectively. The singular abbreviation is often used when the genus of the organism is known but the exact species is not known.

Spore — a small cell that can develop into a new individual.

Virus — ultramicroscopic infective agent that is capable of multiplying in connection with living cells. Normally, viruses are many times smaller than bacteria.

Anatomy

A crustacean is covered with a protective exoskeleton and has jointed appendages. Most organs are located in the head end (cephalothorax) with muscles concentrated in the tail end (abdomen). The following parts are apparent upon outside examination of crawfish (Fig. 1) and freshwater shrimp (Fig. 2).

1. Cephalothorax
2. Abdomen
3. Antennules
4. Antenna
5. Antennal scale
6. Rostrum (horn)
7. Eye
8. Mouthparts (several appendages for holding and tearing food)
9. Carapace
10. Areola
11. Walking legs (periopods, one of which is enlarged and called the chela)
12. Abdominal segment (one of which overlaps the others in freshwater shrimp)
13. Swimmerets (pleopods, the first of which is modified in crawfish males)
14. Telson
15. Uropod
16. Gills (under carapace)
17. Gill bailer (under carapace)

Inside structures (Fig. 3) include:

1. Antennary gland
2. Esophagus
3. Stomach
4. Hemocoel
5. Digestive gland (hepatopancreas)
6. Heart
7. Reproductive organs
8. Intestine
9. Abdominal muscles

The reproductive organs lie to the side of and below the heart, sometimes extending backward beside the intestine. The "skin" or hypodermis of a crustacean lies just beneath the exoskeleton. It is functional in secreting the new exoskeleton that replaces the old at shedding.

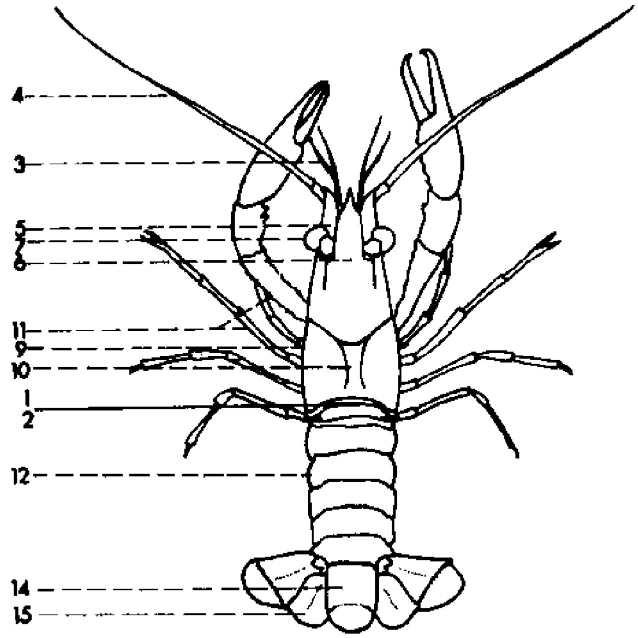


Fig. 1. External anatomy of crawfish. Numbers conform to list.

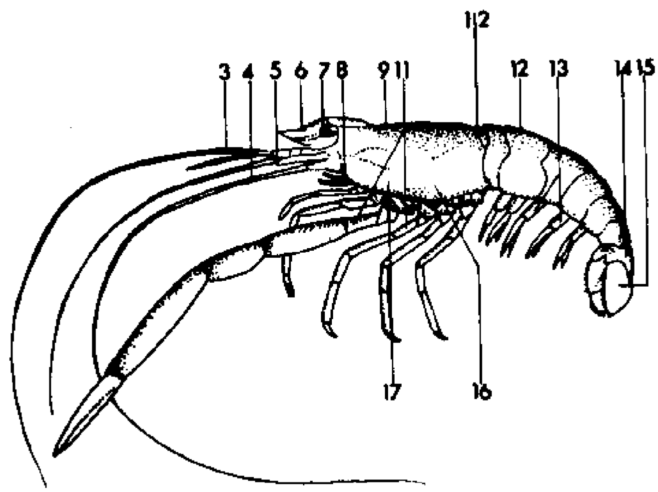


Fig. 2 External anatomy of *Macrobrachium*. Numbers conform to list.

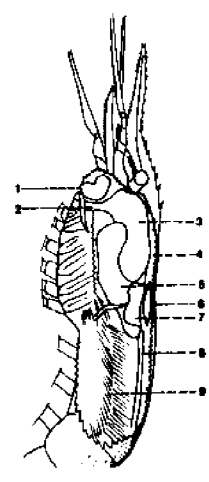


Fig. 3. Internal anatomy of *Macrobrachium*. Numbers conform to list.

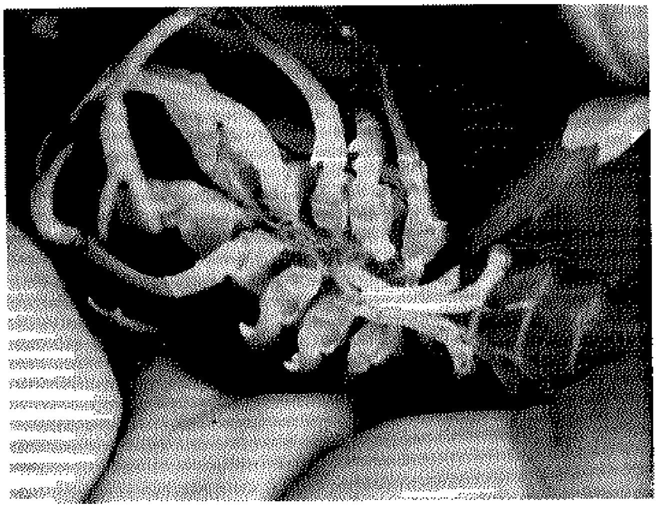


Fig. 4. Prominent secondary sex characteristics of crawfish: modified swimmeret of male. An amber colored tip indicates a fully mature individual. The structure of this modified appendage is the principal character used for species indentification.

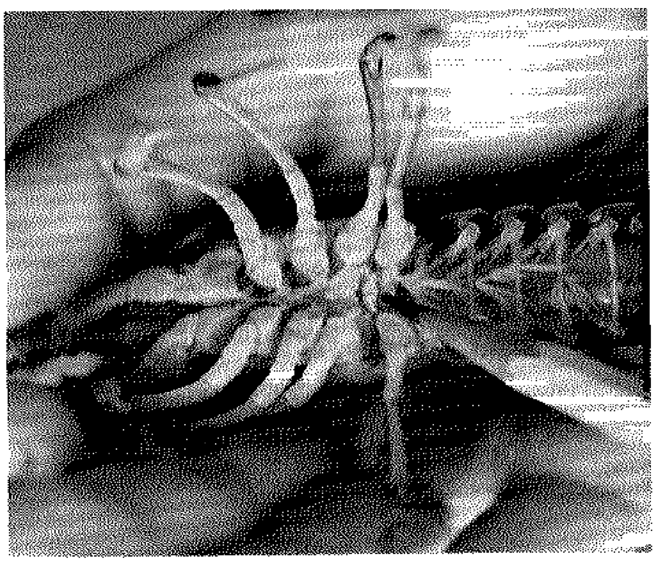


Fig. 5. Prominent secondary sex characteristic of crawfish: annulis ventralis of female.

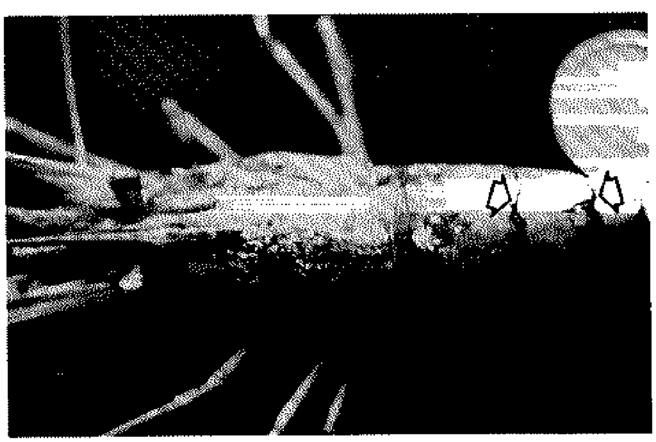


Fig. 6. Bacterial erosion of exoskeleton of *Macrobrachium rosenbergii.*

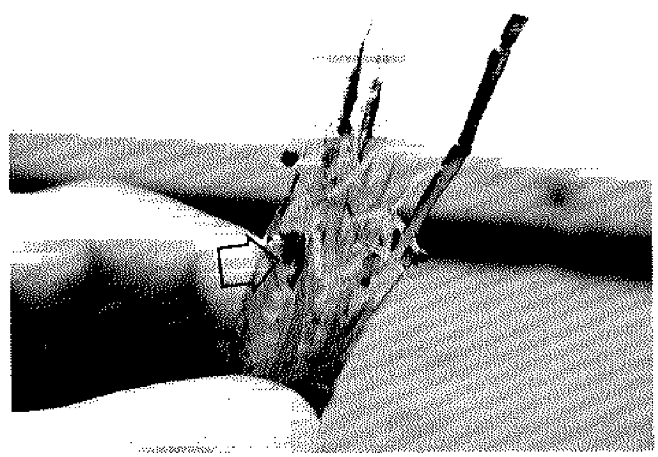


Fig. 8. Bacterial erosion of limbs of *Macrobrachium rosenbergii.* Note also darkening due to bacterial action around gill bailers (arrow), a favorite site of microbial attack.

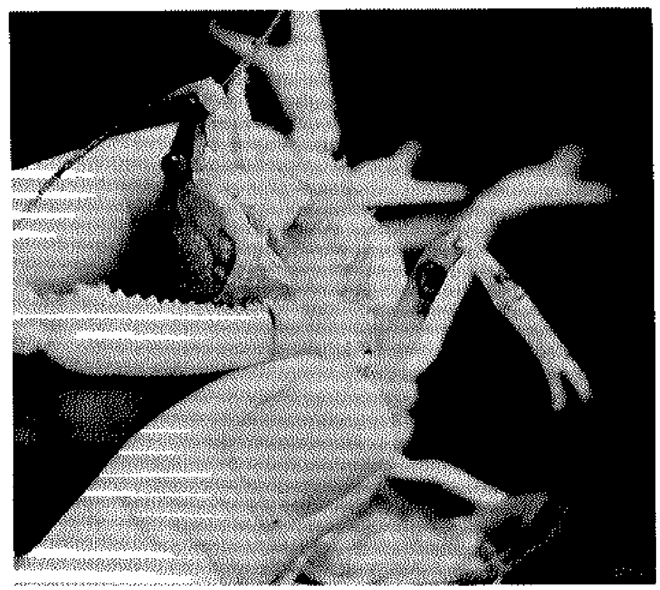


Fig. 9. Bacterial lesion on limbs of crawfish.

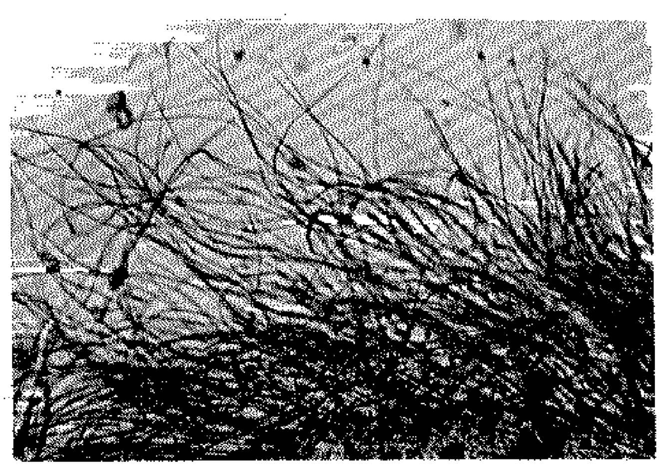


Fig. 11. Filamentous bacteria on body surface.

Differences in structure between sexes are apparent in both crawfish and freshwater shrimp (Fig. 4, 5). Females may get larger than males and vice versa depending on the species. In crawfish, males have modified swimmerets that act as a copulatory organ. Male freshwater shrimp can be recognized by a modified segment on the last walking leg. Claws of males and females are strikingly different in the larger freshwater shrimp and to a somewhat lesser degree in crawfish species. Accurate identification of crawfish species is particularly dependent on the modified swimmerets of larger mature males.

Kinds of Crawfish and Freshwater Shrimp

Freshwater shrimp occur worldwide. In North America they are represented by two main groups. The genus *Macrobrachium* is composed of four native species and an introduced species. The other group is composed of small species called grass shrimp, most of which belong to the genus *Palaemonetes*. Some *Palaemonetes* and *Macrobrachium* species have a coastal distribution. Consequently, several conditions described here are peculiar to shrimp of the brackish water environment.

Crawfish occur naturally worldwide with the exception of Africa. In North and Middle American approximately 300 species have been described. The genera *Cambarus, Orconectes* and *Procambarus* comprise over two-thirds of the American species with *Procambarus* accounting for over one-third and including the commercially important red crawfish *Procambarus clarkii* and the white crawfish *Procambarus acutus*. Crawfish are distinctly freshwater animals.

Microbes

BACTERIA

Bacterial infections of crawfish and freshwater shrimp are similar in characteristic and effect to those seen in marine shrimp.

Chitinoverous bacteria utilize the exoskeleton as a source of food and points of attack appear as erosive areas. Cracks in the exoskeleton provide a point of entry for this type of bacterium (Figs. 6, 7C, 8, 9, 10C*).

Filamentous bacteria (Fig. 11) are frequently found on body surfaces and gills. Heavy infestations may interfere with respiration when gills become sufficiently clogged. Filamentous bacteria are often a problem in larval rearing tanks of aquaculture enterprises.

*The letter "C" denotes color plate which may be found on pages 10 and 11.

Systemic infections, or those that invade body fluids, are rare when compared to bacterial problems that occur in localized areas at the body surface. Softer parts of the cuticle, joints, and pores that open into setae are common places where bacteria enter and establish infections.

Species of *Pseudomonas*, *Aeromonas*, *Acinetobacter* and *Vibrio* (brackish water) are bacteria generally expected when examining infected crawfish and freshwater shrimp.

FUNGI

Fungi became notorious as disease agents of the larger freshwater crustaceans in European stocks. Crawfish were almost totally eliminated in several European countries during the latter 19th Century and the early 20th Century because of infestation by the fungus *Aphanomyces astaci*. Other fungi known to invade flesh of crawfish include species of *Fusarium* and *Ramularia*. *Fusarium* spp. (Fig. 12) are particularly prevalent in freshwater and

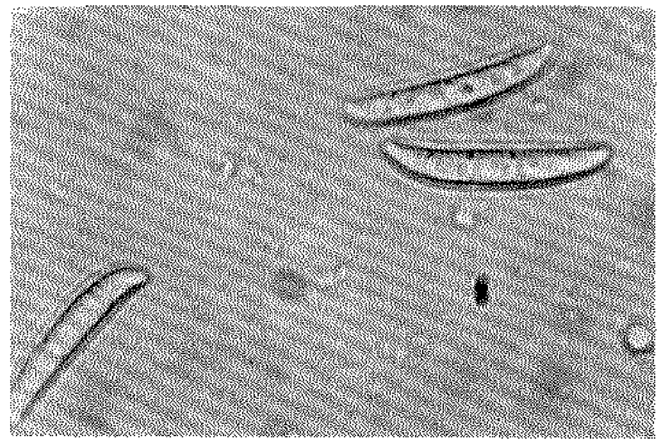


Fig. 12. Fungus (*Fusarium* sp.) macroconidia.

marine environments and have recently been shown to be a problem in aquaculture of marine shrimp and lobsters. *Fusarium* spp. have the ability to cause problems in their freshwater relatives as well.

A fungal group known as Trichomycetes contains species that live in the intestine of freshwater and marine crustaceans (Figs. 13, 14). Crawfish in Texas

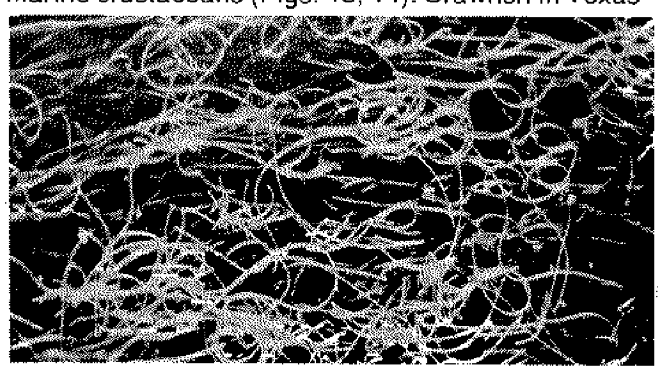


Fig. 13. Fungus (Trichomycetes) on inside of intestinal wall (molt of crawfish).

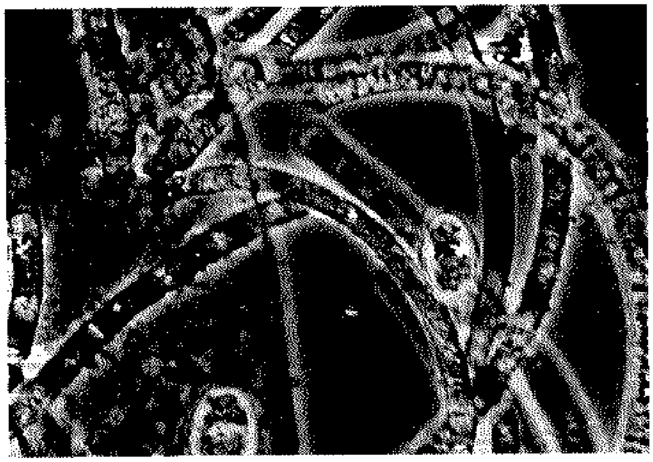


Fig. 14. Fungus (Trichomycetes) in crawfish intestine.

are common hosts for these fungi. Adverse effects to infested crustaceans are not known.

Fungi cause problems to eggs and early larval stages of crustaceans because of the ease with which they may enter the more fragile stages. Once established, fungi will spread rapidly to other eggs or larvae because of their close proximity on the mother or in the hatchery rearing tank. Development of three common fungi is depicted in Fig. 15.

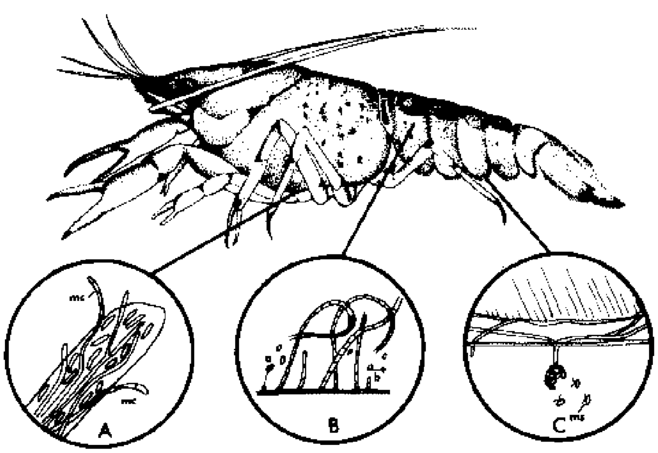


Fig. 15. Life cycles of three types of crustacean fungi: A. *Fusarium*. Fungus develops in gill or other infected part. Spores (macroconidia, mc) bud off and are released. Spores make contact with another crawfish and gain entry through breaks in exoskeleton. B. Trichomycetes (*Arundinula*). Fungus develops in gut of crawfish and releases two types of spores. One type (a) reinfects the gut; the other type (b) passes out later to be ingested by and to establish in another crawfish. The second type of spore apparently has features that make it resistant to environmental abuse. C. *Aphanomyces*. Typically found in poorly protected tissues on the underside of tail and joints. This fungus sends protrusions outward through the soft cuticle. Motile spores (ms) develop on the ends of the protrusions. These released spores settle on a new crawfish and penetrate inward. The fungus then developes in nearby tissues (especially nerve tissue).

VIRAL AND RICKETTSIAL INFECTIONS

Viruses and rickettsia have not been shown to be infective agents in crawfish and freshwater shrimp. Marine shrimp and crabs have documented viral infections, and insects are infected by both viruses and rickettsia. As knowledge advances about diseases of freshwater decapods, similar infections may be discovered.

Protozoa

Protozoa associate with crawfish and freshwater shrimp as true parasites and as commensals that live on the exterior surface of the body. The main protozoan associates are the microsporidians, the apostome ciliates and the ectocommensals. Gregarines, a protozoan group found in marine decapods and other animals, are apparently absent from freshwater decapods.

MICROSPORIDIA

Microsporidia parasitize most major animal groups — notably insects, fish and crustaceans. In the United States microsporidia have been reported in grass shrimp but rarely in crawfish. *Macrobrachium* spp. have not been found to be affected.

Microsporidian infections of crawfish have found more notice in European countries where the common name "porcelain disease" has been used. In the United States, shrimp infected with microsporidia are commonly called "milk" or "cotton" shrimp.

Microsporidia infect the muscular tissue in freshwater shrimp and crawfish (Figs. 16C-18C, 19, 20C, 21, 22) giving a whitish coloration to the affected animal. As the disease progresses the hosts become whiter.

Microsporidia are present in the diseased animal in the form of spores (Figs. 19, 22). The spores are present in lightly infected animals in isolated bundles within the muscles. In heavily infected animals they spread throughout the muscular tissue. Spores are microscopic and those of *Thelohania* and *Inodosporus* species are present in groups of eight and enclosed in a membrane. Spores of *Thelohania* spp.

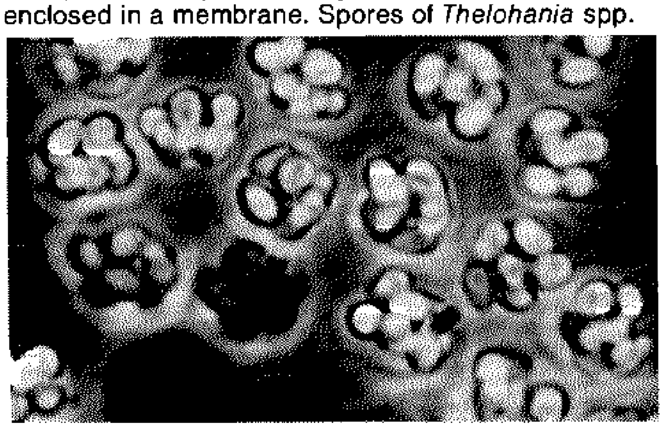


Fig. 19. Microscopic view of parasite (*Thelohania* sp.).

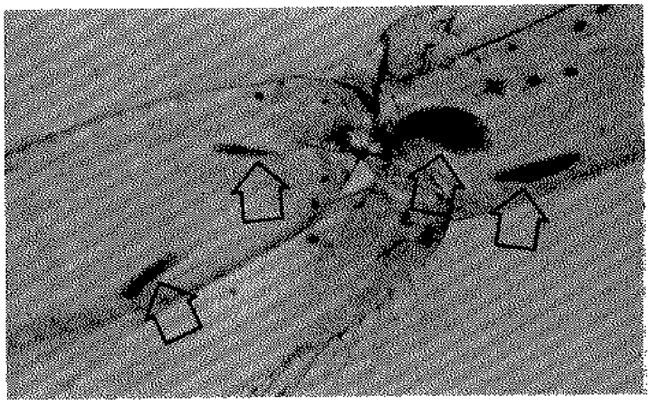


Fig. 21. Microscopic view of tail of lightly infested grass shrimp showing bundles of microsporidia.

Fig. 22. Microscopic view of spores of *Inodosporus* from *Palaemonetes*. Note characteristic tail-like extensions.

are egg-shaped and those of *Inodosporus* spp. are egg-shaped with tails. *Pleistophora* spp. and *Nosema* spp. also have egg-shaped spores but *Pleistophora* spp. are found in groups of 16 or more within a membrane and *Nosema* spp. are distributed individually throughout the tissues.

Infected crawfish and shrimp are agile and feed normally. The author has observed a heavily infected crawfish regenerate missing legs while kept in the laboratory.

The life cycles of microsporidia of crawfish and shrimp have not been satisfactorily worked out. However, by examining the cycles of related species and miscellaneous facts from the literature, the cycle presented in Fig. 23 may be considered a good representation of a microsporidian life cycle.

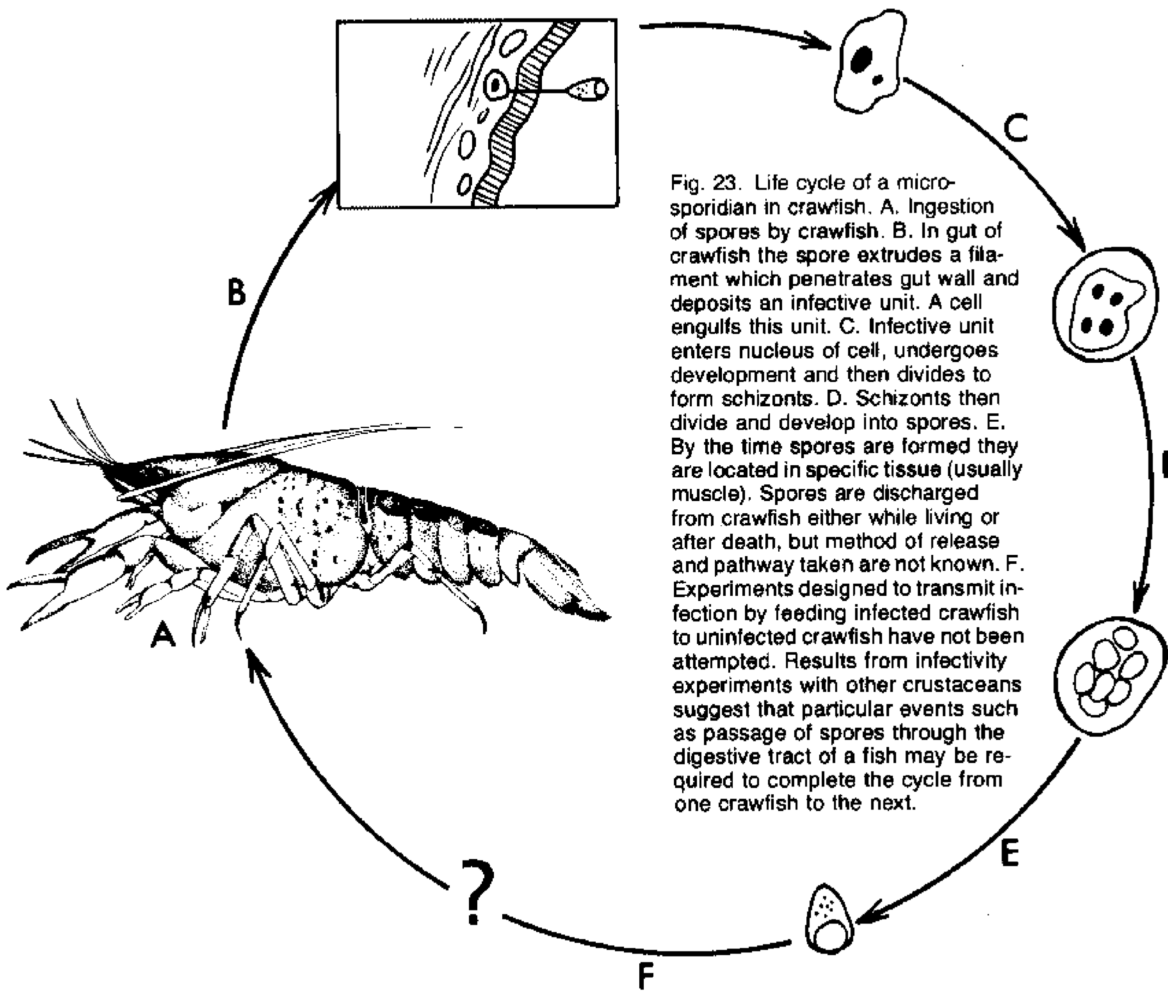


Fig. 23. Life cycle of a microsporidian in crawfish. A. Ingestion of spores by crawfish. B. In gut of crawfish the spore extrudes a filament which penetrates gut wall and deposits an infective unit. A cell engulfs this unit. C. Infective unit enters nucleus of cell, undergoes development and then divides to form schizonts. D. Schizonts then divide and develop into spores. E. By the time spores are formed they are located in specific tissue (usually muscle). Spores are discharged from crawfish either while living or after death, but method of release and pathway taken are not known. F. Experiments designed to transmit infection by feeding infected crawfish to uninfected crawfish have not been attempted. Results from infectivity experiments with other crustaceans suggest that particular events such as passage of spores through the digestive tract of a fish may be required to complete the cycle from one crawfish to the next.

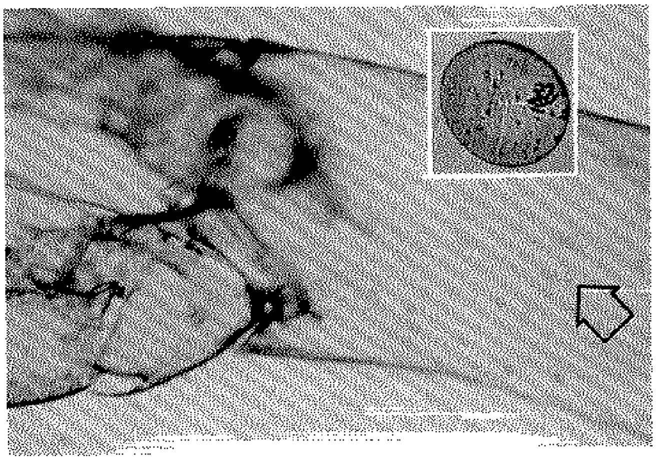


Fig. 24. Microscopic view of several apostome ciliates inside grass shrimp molt. Microscopic view of apostome ciliate (inset). Proper identification of genus cannot be determined from living animal. Staining with technique called silver impregnation is required.

APOSTOMES

These protozoa (Figs. 24, 25) occur on crustaceans as encysted stages on the exoskeleton, but when the crustacean molts the protozoa hatch out and feed on the rich fluid trapped within the shed exoskeleton. They become bloated with food and appear as tiny transparent bubbles within the cast exoskeleton. After reproduction, the apostomes search out a new crustacean and encyst.

Apostomes occur on several crustacean groups and are common in crawfish and freshwater shrimp. Cast exoskeletons from nearly every molt will support the development of many individuals. Common apostome genera in North American fresh and brackish waters are *Hyalophysa*, *Gymnodinioides* and *Terebrospira*, the former being found more often in truly fresh water.

Damaging effects to freshwater crustaceans by apostomes have not been noted.

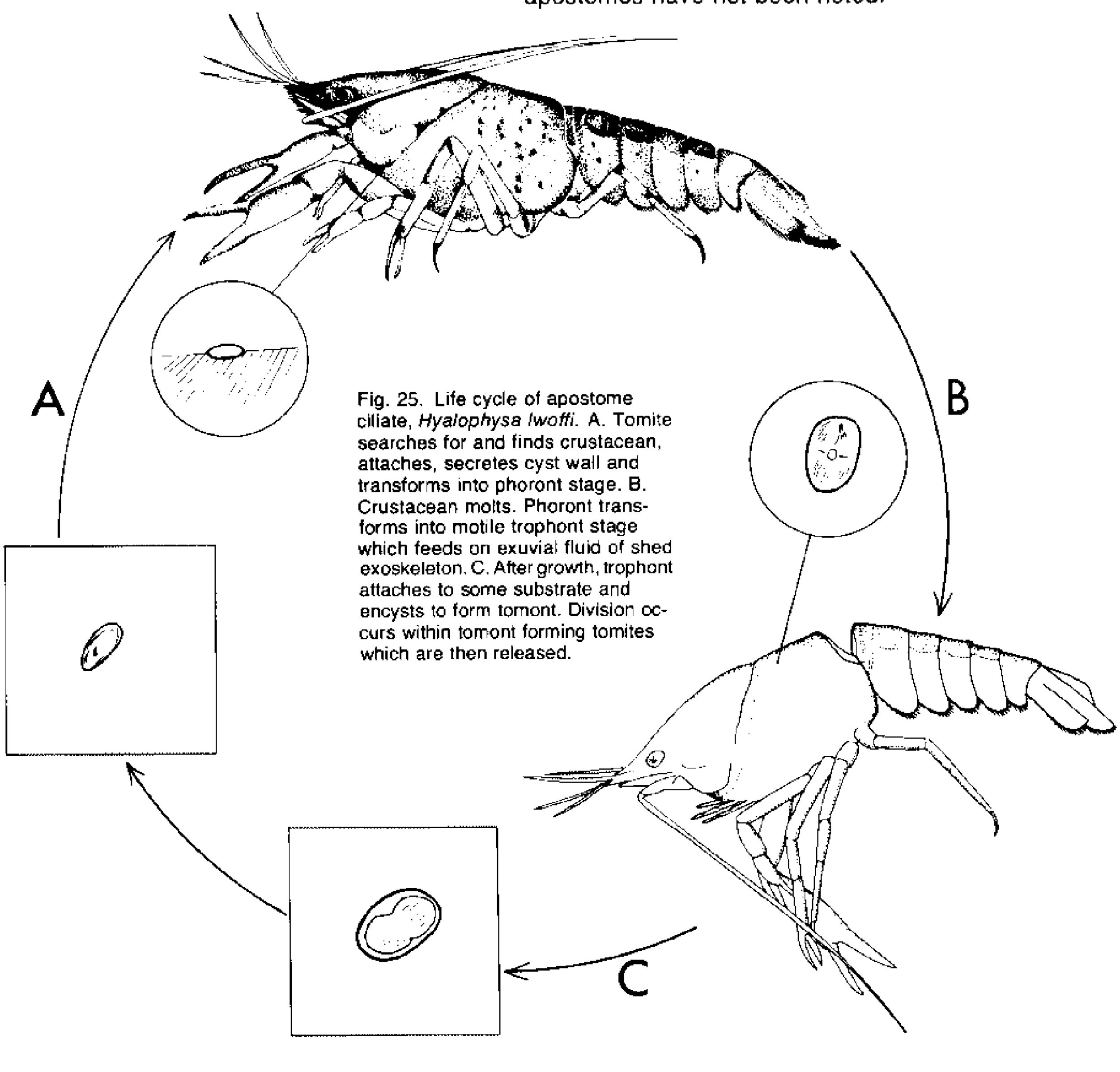


Fig. 25. Life cycle of apostome ciliate, *Hyalophysa lwoffi*. A. Tomite searches for and finds crustacean, attaches, secretes cyst wall and transforms into phoront stage. B. Crustacean molts. Phoront transforms into motile trophont stage which feeds on exuvial fluid of shed exoskeleton. C. After growth, trophont attaches to some substrate and encysts to form tomont. Division occurs within tomont forming tomites which are then released.

ECTOCOMMENSAL PROTOZOA

A variety of protozoa move about or attach to the body surface and gills of crawfish and freshwater shrimp. Common genera associated with crawfish and freshwater shrimp include *Epistylis, Zoothamnium, Lagenophrys, Corthunia* and *Acineta* (Figs. 26-30). Less common genera include *Vorticella, Vaginicola* and *Opercularia.*

Acineta sp. is common in brackish water on grass shrimp and *Macrobrachium* spp. *Corthunia* sp. is found commonly on crawfish and occasionally on *Macrobrachium* spp. in fresh water. *Epistylis, Zoothamnium* and *Lagenophrys* spp. are found on both crawfish and shrimp in both fresh and brackish waters.

Lagenophrys sp. is more commonly found on freshwater shrimp than on crawfish. When found on crawfish they tend to be concentrated on the gills.

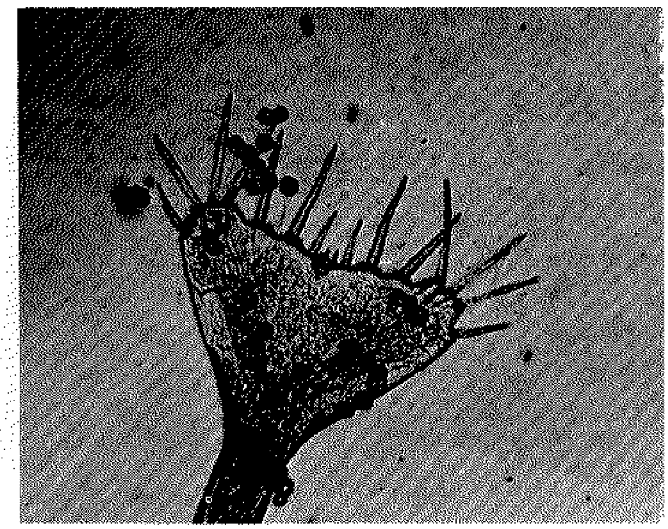


Fig. 26. Microscopic view of *Zoothamnium* sp. on *Macrobrachium* larva.

Fig. 27. Microscopic view of *Epistylis* sp. on *Macrobrachium. Epistylis* is distinguished from *Zoothamnium* by the absence of a retractile fiber in the stalk.

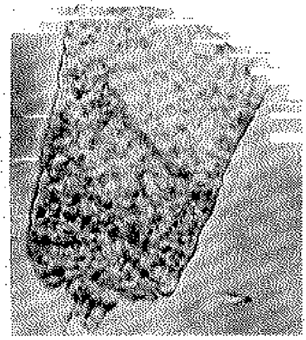


Fig. 28. Microscopic view of *Acineta.*

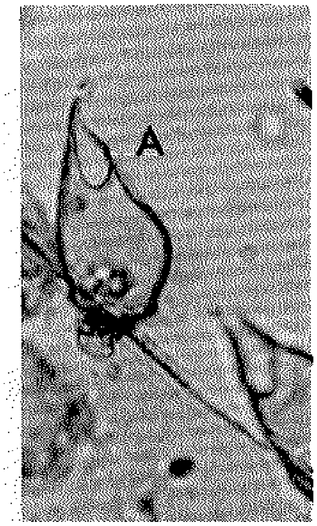


Fig. 29. Microscopic views of *Corthunia,* a common crawfish ectoprotozoan. A. Typical outer covering. B. Living organism, typical outer covering. C. Living organism, outer covering less common.

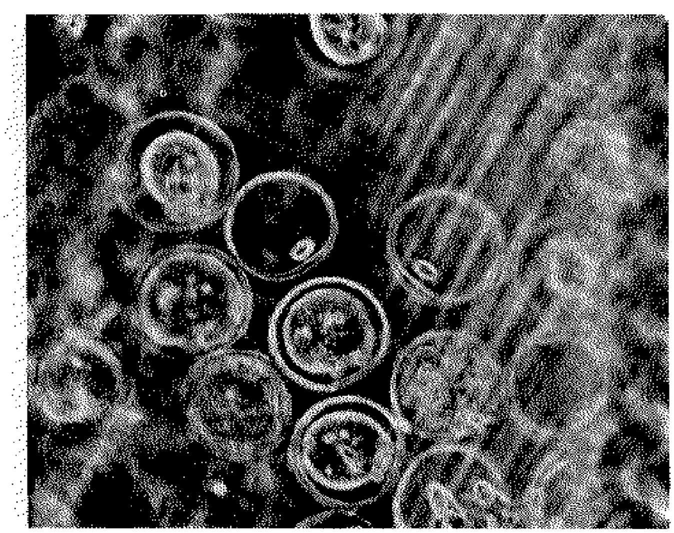


Fig. 30. Microscopic view of *Lagenophrys.*

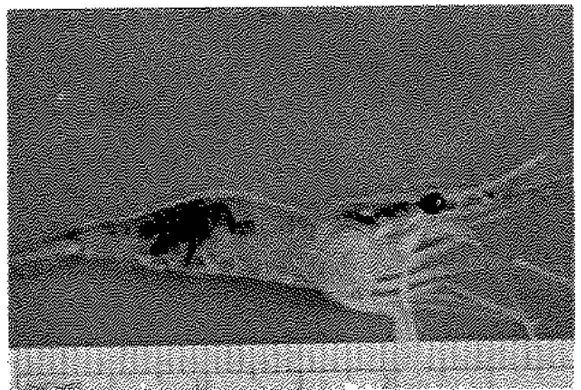


Fig. 7C. Bacterial erosion of exoskeleton of *Macrobrachium amazonicum.*


Fig. 10C. Bacterial lesion on abdominal segment of crawfish.

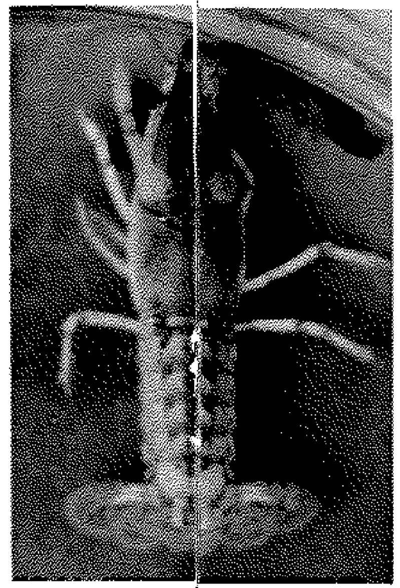


Fig. 16C. Crawfish with microsporidian infection. Note whitish tail and muscle attachment sites on carapace (arrow). The species shown is *Procambarus simulans* but *P. acutus* has also been found with microsporidian infection in Texas.

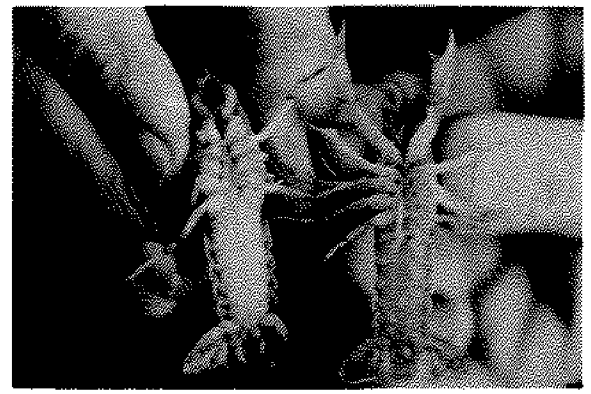


Fig. 17C. Crawfish with microsporidian infection (arrow) compared to normal individual. Infected crawfish is more whitish.


Fig. 18C. Crawfish tails showing microsporidian infection. Whitened tail is infected.

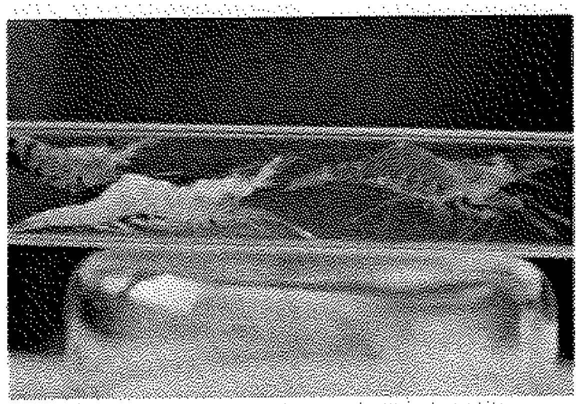


Fig. 20C. Grass shrimp (*Palaemonetes kadiakensis*) heavily infested with microsporidia. Normal individual is transparent.


Fig. 32C. Encysted flukes (*Carnaeophallus choanophallus)* in tail of grass shrimp. Removed and stained individual (inset).

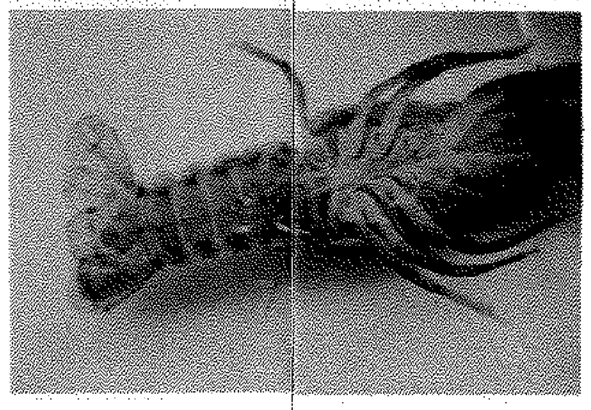


Fig. 36C. Branchiobdellids on underside of crawfish tail. These worms often congregate here when exposed to daylight.


Fig. 38C. Branchiobdellid eggs on rostrum of crawfish.

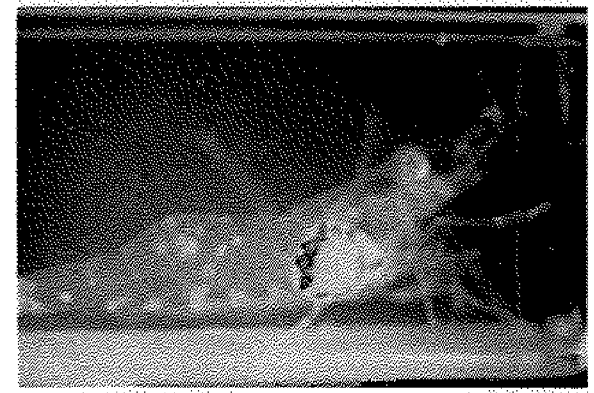


Fig. 39C. Isopod inside carapace of grass shrimp.

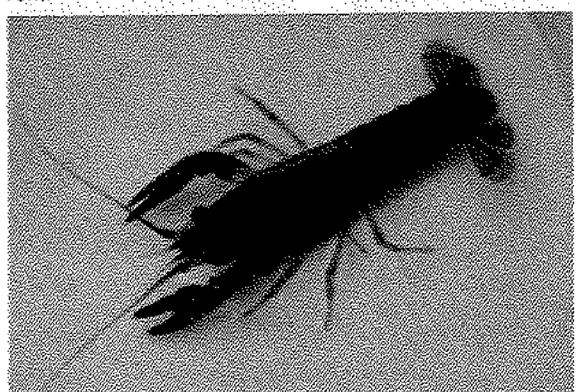


Fig. 46C. Blue color anomaly in *Orconectes deanae.*

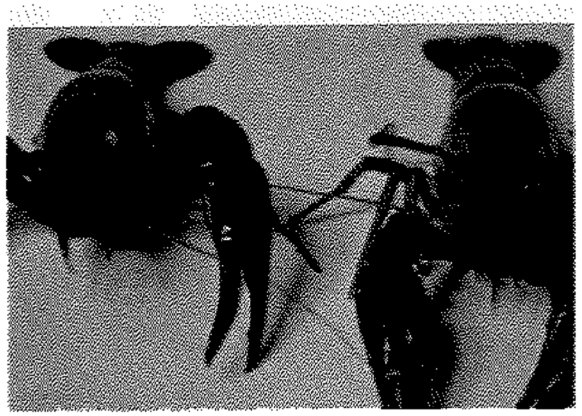


Fig. 49C. Crawfish with yellow eyes next to normal individual. (Photo courtesy of Louisiana State University Sea Grant Program.)

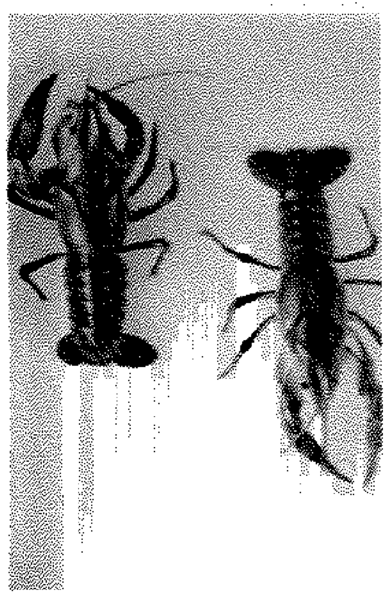


Fig. 47C. Blue color anomaly in crawfish with normal individual shown for comparison.

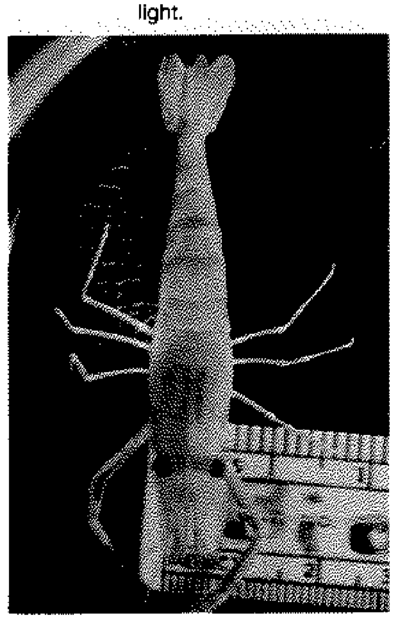


Fig. 48C. *Macrobrachium* with yellowish coloration. It is uncertain as to whether this represents a color extreme or a true anomaly. Color is dispersed in muscle tissue.

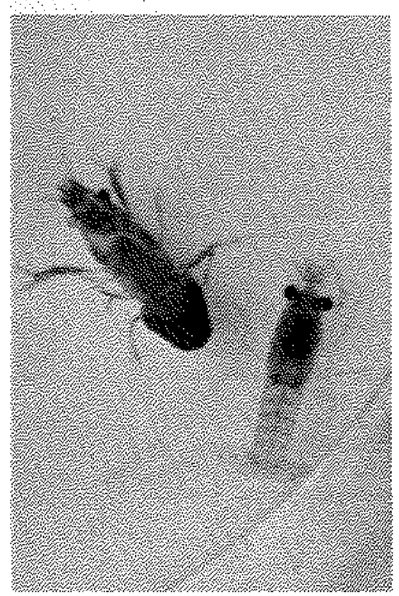


Fig. 50C. Rusty condition of crawfish. Rusty (on back) and normal individual.


Fig. 52C. Exoskeleton spotting in *Macrobrachium* shown in dissected carapace.

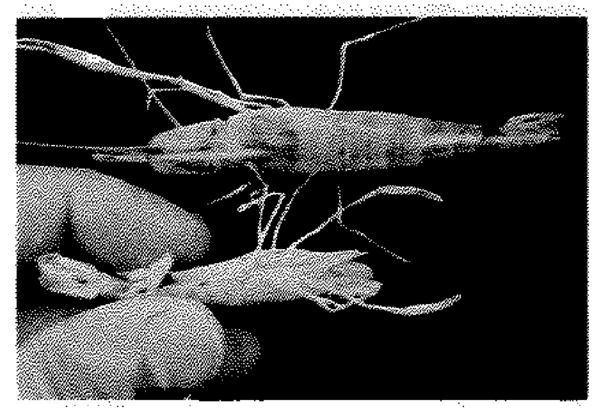


Fig. 53C. Discoloration of *Macrobrachium* following handling. Sub-cuticle tissues are a milky color and pigmentation is reddish.

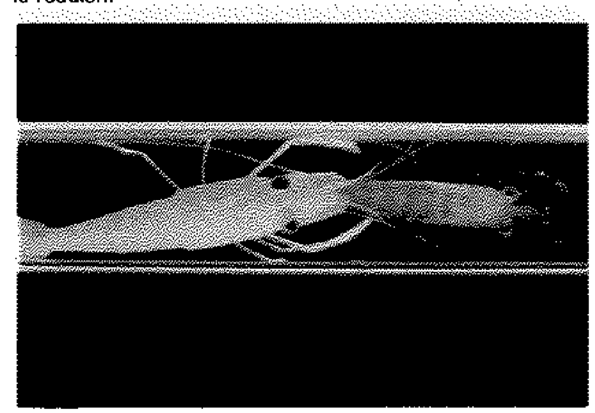


Fig. 54C. Advanced stage of discoloration in *Macrobrachium* compared to normal individual.

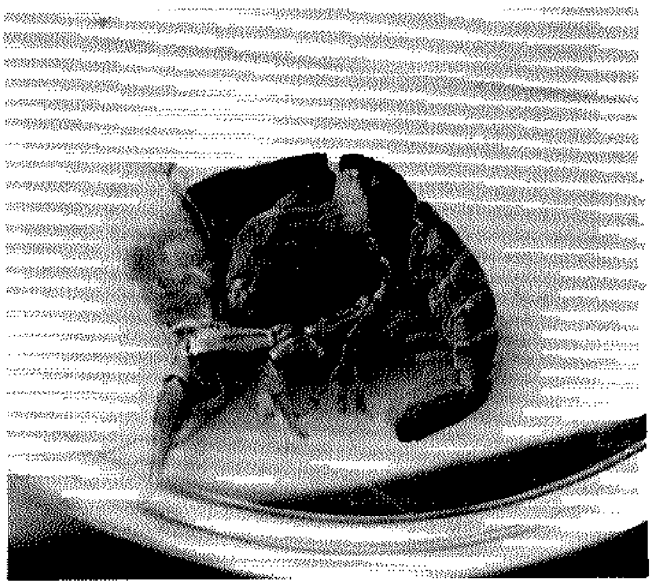


Fig. 31. Molting crawfish. Molting provides periodic relief from buildup of ectocommensals.

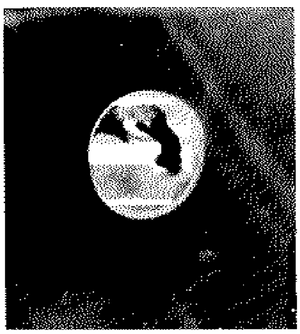


Fig. 33. Microscopic view of encysted immature stage (metacercaria) of a fluke from a crawfish, left. Microscopic view of excysted immature fluke, right.

Other investigators have noted a similar association on marine crabs. *Corthunia* sp. characteristically locates on the gills of crawfish. (Older literature relates cases where deaths occurred from massive infestation.) *Zoothamnium* sp. has been found to cause problems for marine shrimps in pond culture situations when large numbers of the protozoa were present on the gills and lower than normal oxygen levels existed in the water. A similar situation is found with *Macrobrachium* in larval rearing facilities.

Rearing ponds often acquire rich loads of organic material when food is added and water replacement is not practiced. In such conditions ectocommensal protozoa flourish. Overburdening by ectocommensals is particularly apparent in older individuals that molt infrequently (Fig. 31). Some *Macrobrachium* adults in culture ponds occasionally become so massively beset with ectocommensals that culturists refer to them as "moss backs". It is yet to be determined why some individuals become so affected and others do not.

Worms

Immature stages of flukes are the more prevalent worm parasites of crawfish and freshwater shrimp in North America. The presence of an immature stage of other types of worms parasitizing these crustaceans would be considered rare. Parasitism by immature spiny-headed worms (Acanthocephala) has been reported occasionally in Louisiana. Spiny-headed worms are found encysted on the outside of the intestine at a point just before the intestine enters the abdomen. Adult stages of parasitic worms do not occur.

FLUKES

Flukes (trematodes) are relatively common in wild stocks of crawfish and freshwater shrimp. They occur as immature stages, encysted within a membrane that produces a spherical enclosure (Figs. 32C, 33). They are found in various parts of the body such as the antennary gland, abdominal muscles and heart cavity — the location reflecting the preference of the particular fluke species. The presence of immature flukes is not considered critical to the crustacean's health.

Although some flukes begin to produce eggs while encysted within the crustacean, most become adults after they enter the digestive tract of an appropriate crustacean-eating host (Fig. 34). Fluke eggs that are released from this larger host animal (final host) typically infest snails or clams (first host) before being acquired by the crustacean (second host).

Carneophallus choanophallus is a common fluke of freshwater shrimp in the Gulf Coast area. This fluke is very common in brackish water (Figs. 32C, 34, 35).

Fig. 34. Life cycle of *Crepidostomum cornutum*, a parasitic fluke common in crawfishes (above). A. Egg hatches and miracidium (penetration stage) enters first host, a small clam. B. The redia stage develops within clam and produces 30-40 new individuals of cercaria stage. C. Free swimming cercaria leave clam in search of second host, a crawfish. D. Cercaria penetrates crawfish and migrates to area around heart. E. Metacercaria, the next stage, develops within a cyst. F. Second host is eaten by final host, either a fish or amphibian. G. Fluke breaks out of excreted cyst and soon begins to produce eggs. H. When eggs are released and reach a host clam, cycle is complete.

Life cycle of *Carneophallus choanophallus*, a parasitic fluke of *Macrobrachium* and *Palaemonetes* (below). A. Snail eats egg, egg hatches and miracidium (penetration stage) migrates into snail tissue. B. Next stage, the sporocyst, develops and releases a number of cercariae. C. Cercariae leave snail and swim continuously in search of second host, a shrimp. D. When shrimp is contacted, cercaria penetrates and migrates into muscle tissue to begin metacercaria stage. E. When the proper site is reached, metacercaria develops within a cyst. F. The cyst is eaten by final host such as a racoon, rat or other suitable mammal. G. The fluke is released and develops into an adult. H. Eggs are released by adult, passed into the water and eaten by a snail to complete the cycle. (Modified from Bridgeman 1969).

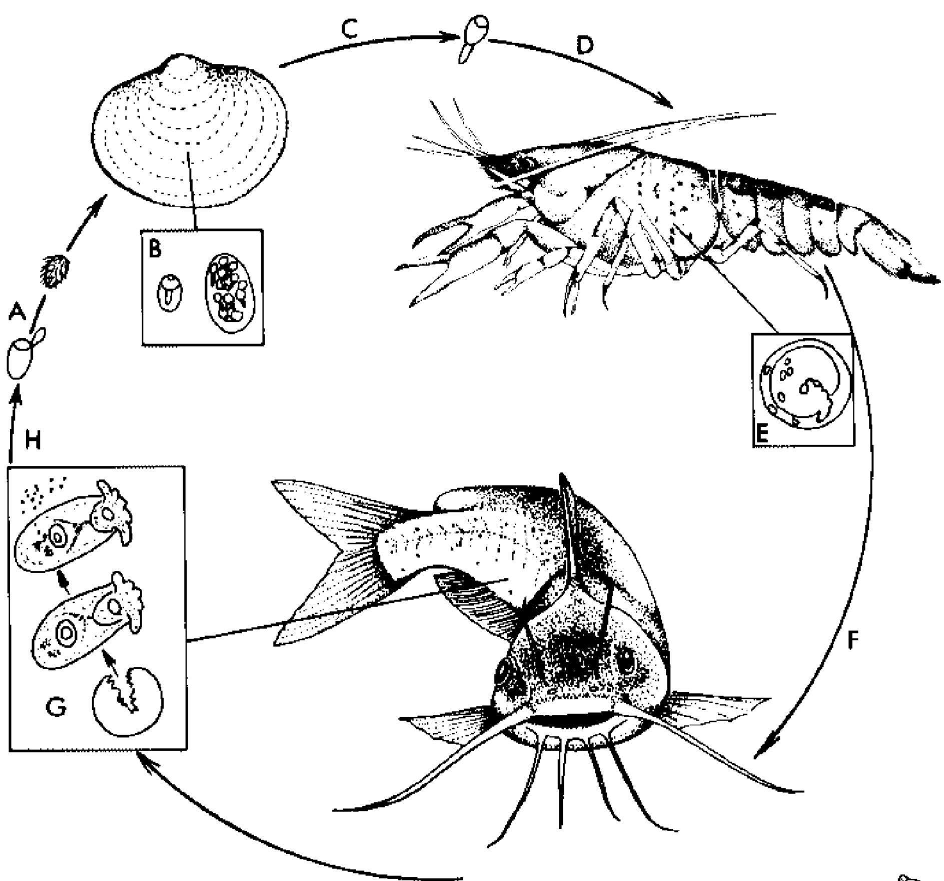
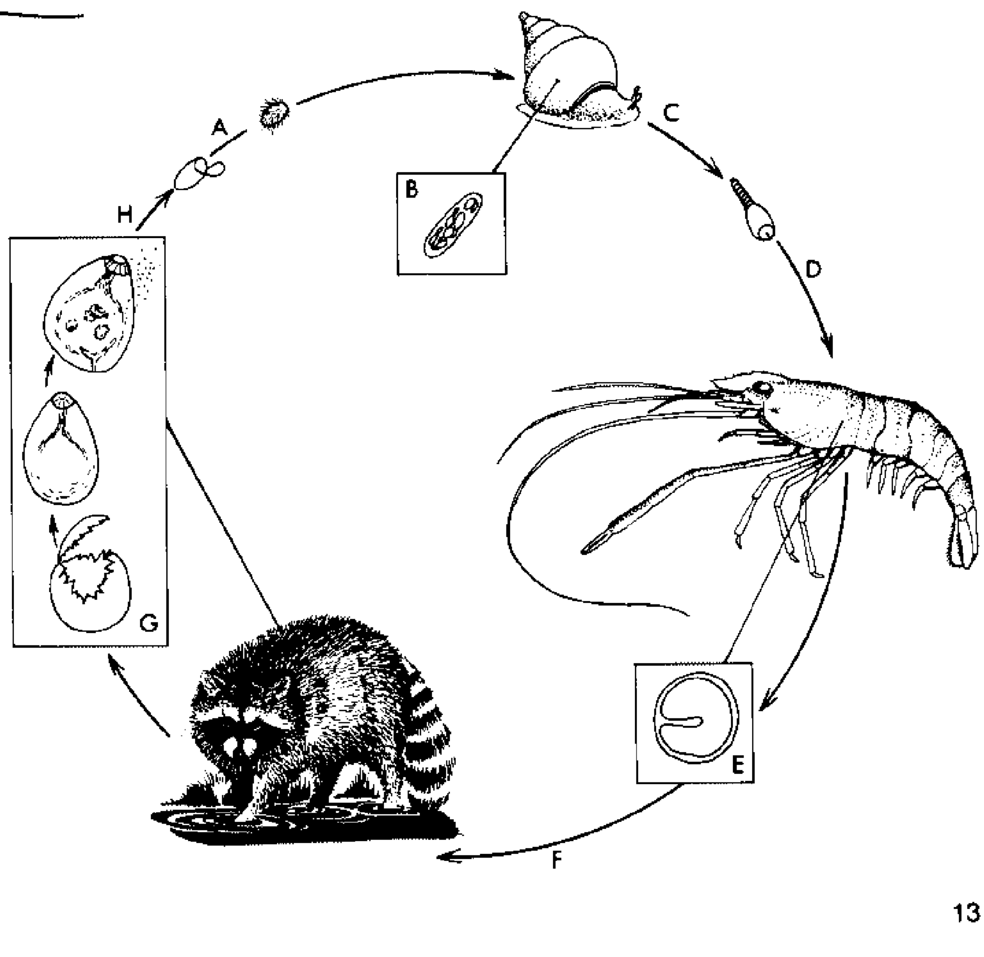


Fig. 34



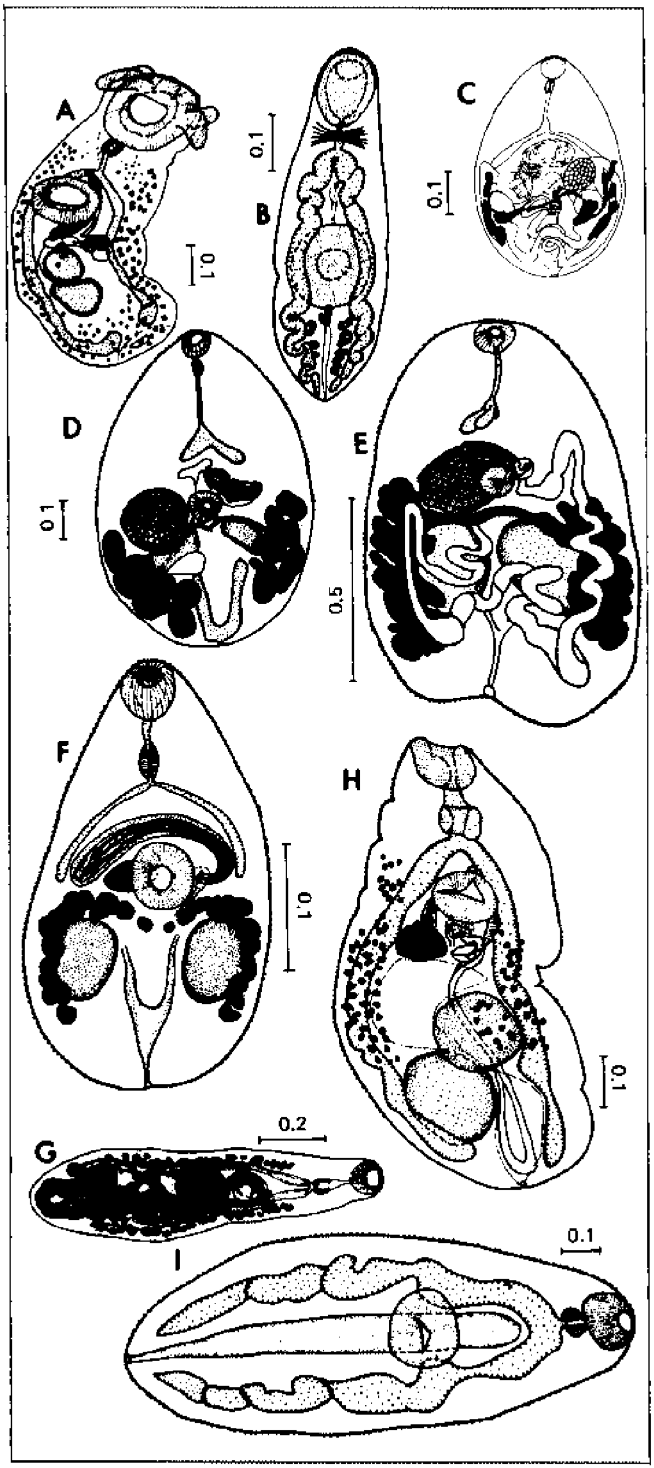


Fig. 35. Metacercariae from larger freshwater crustaceans. A. *Crepidostomum cornutum*, crawfish cephalothorax, near heart. B. *Gorgodera amplicava*, crawfish stomach wall. C. *Carneophallus choanophallus*, body musculature of freshwater shrimp. D. *Microphallus opacus*, crawfish digestive gland. E. *Microphallus progeneticus*, crawfish cephalothorax. F. *Maritrema obstipum*, crawfish central shaft of gill filaments and hepatopancreas. G. *Macroderoides progeneticus*, crawfish antennary gland. H. *Macroderoides typicus*, crawfish cephalothoraxic and antennal musculature. I. *Paragonimus kellicotti*, crawfish heart and surrounding membrane. Scale is in millimeters.

A variety of flukes infest crawfish (Fig. 35). *Crepidostomum cornutum* and *Macroderoides* spp. are most common.

PUBLIC HEALTH SIGNIFICANCE OF WORMS

Certain flukes described in this publication can infest mammals. Flukes belonging to the microphallid group have been known to infest crustacean-eating mammals but no human infestations have been noted in North America. *Paragonimus kellicotti*, a lung fluke of various mammals including man, is an uncommon parasite of crawfish in North America. A similar fluke, *Paragonimus westermani*, is an important parasite of humans and crustacean-eating animals in Asia where it is transmitted by consumption of raw freshwater crabs and crawfish. Customary cooking practices eliminate the possibility of fluke infestations.

Angiostrongylus catnonensis, a nematode (roundworm) which parasitizes the lungs of rats in Asia and the Pacific areas, is contracted as rats eat infected snails. If man eats raw snails he may also be infected as an abnormal host with the worms causing meningocephalitis. It has been shown that a species of *Macrobrachium* could serve as transport for the parasite if the shrimp fed on infected snails and were subsequently eaten raw before the parasites were eliminated from the digestive tract. Cooking practices eliminate the possibility of accidental infection.

External Associates

BRANCHIOBDELLIDS

Branchiobdellids are small worm-like animals that are similar to leeches and aquatic earthworms (Figs. 36C, 37). They occur primarily on crawfish but have been found on freshwater crabs and brackish water crabs that have moved into fresh water. They also have been reported to occur on freshwater shrimp in China and elsewhere on small crustaceans

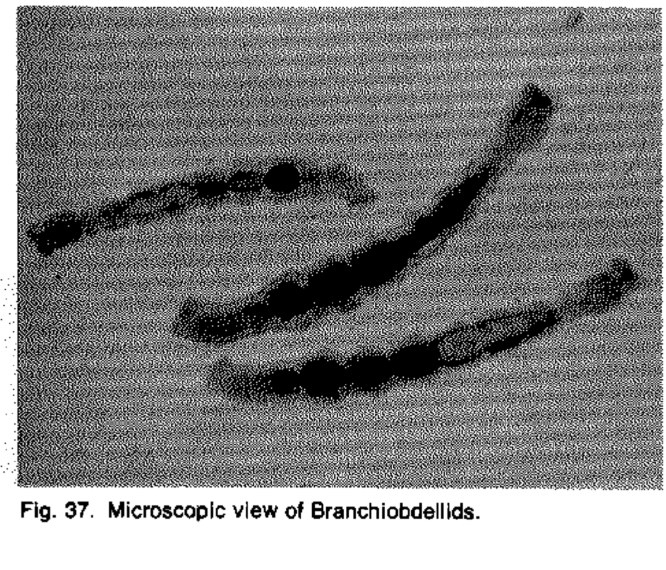


Fig. 37. Microscopic view of Branchiobdellids.

called isopods. They are distributed throughout the northern hemisphere.

Cocoons are deposited on larger crawfish, usually on the underside of the tail or top of the rostrum (Fig. 38C). Transfer from crawfish to crawfish occurs when the crustaceans make body contact. Population density is greatest in late spring and least in winter. Branchiobdellids are considered commensals but it is uncertain whether those that live on the gills of their hosts will be found to be parasites. Although branchiobdellids are removed by dipping crawfish into salt water at the time of processing or by boiling when prepared for the table, they present no danger as parasites even if accidentally consumed.

ISOPODS

The isopods that infest freshwater shrimp belong to the family Bopyridae and the genus *Probopyrus*. These parasites are found within the gill cavity of their hosts and give the cephalothorax a distinctive bulge (Figs. 39C, 40). The females are much larger than the males that often share the space within the shrimp's gill cavity. The female supports young within a brood pouch on the underside of her body. After release, the young parasitize smaller crustaceans for a while before seeking a shrimp. On shrimp they develop into adults.

Both grass shrimp and *Macrobrachium* spp. are common hosts for isopods in brackish water along the Texas coast. Isopods are absent from shrimp that do not frequent the brackish water environment. The adverse effect of isopods on shrimp has not been determined.

OSTRACODS

Ostracods, like the decapods, are a subordinate group of the animal class Crustacea. There are many free living species, but a few live in an environment restricted to the surface of crawfish (Fig. 41). Almost every sizable crawfish in the southern United States supports a few ostracods. They inhabit crawfish body surfaces but apparently cause no damage.

TEMNOCEPHALID FLATWORMS

These freshwater worms (Fig. 42) are akin to the planaria that students examine in high school biology classes. The worms occur on the exterior of freshwater animals, usually on crustaceans but occasionally on turtles and aquatic snails. Nearly all species occur in the southern hemisphere. They are found on the gills and body surfaces of *Macrobrachium* spp., grass shrimp and crawfish.

Food for most species consists of the variety of ectocommensal associates that frequent their vicinity on the host. One species, however, has been found to withdraw blood from the gills. Cocoons deposited on the body surface hatch to produce miniature adults.

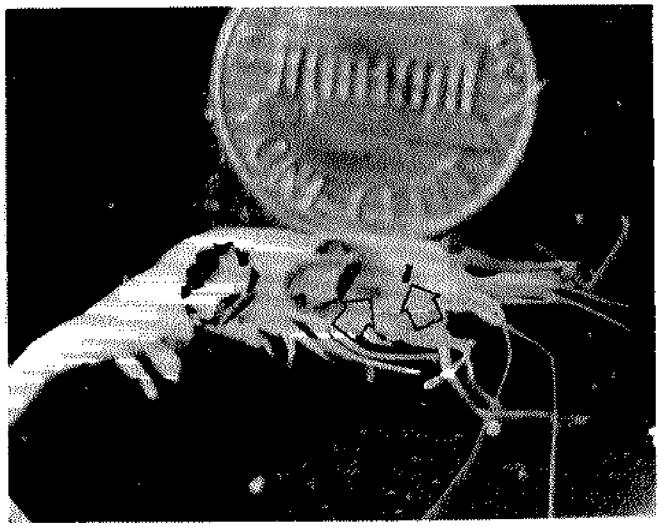


Fig. 40. Isopods inside carapace (normal situation) and also placed on body surface for comparison. Males (indicated by arrows) are much smaller than females.

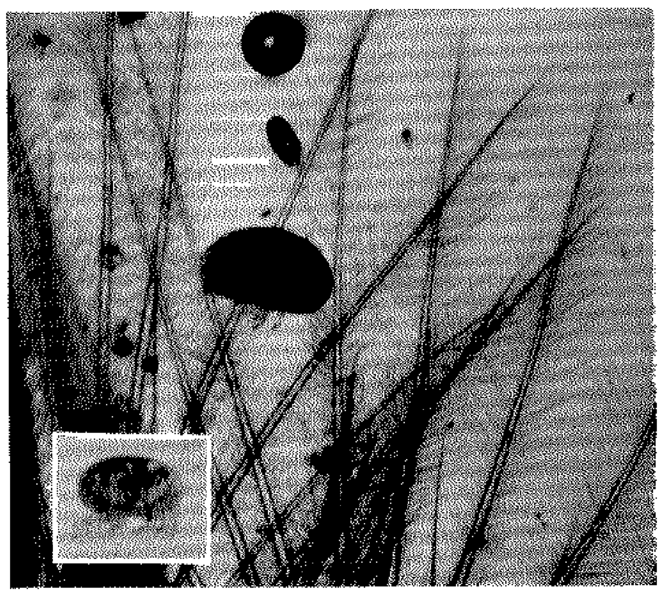


Fig. 41. Microscopic views of ostracods on crawfish. Side view of individual (inset).

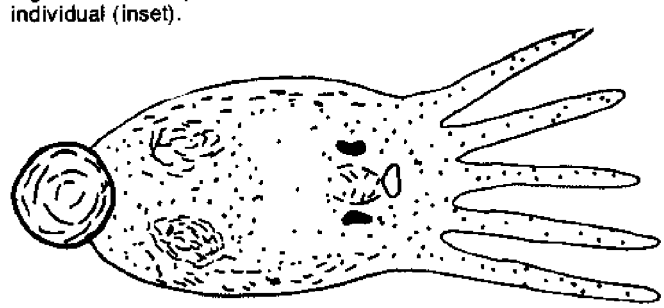


Fig. 42. Line drawing of microscopic view of temnocephalid flatworm.

BARNACLES

Infestations with barnacles are rare and are restricted to those freshwater species that occasionally migrate into brackish water. It takes time for barna-

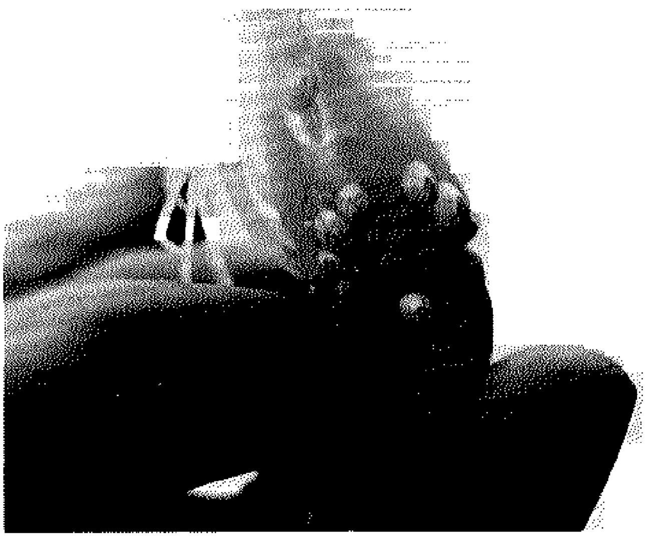


Fig. 43. Barnacles attached to a *Macrobrachium* collected in brackish water.

Fig. 44. Grass shrimp with leech attached.

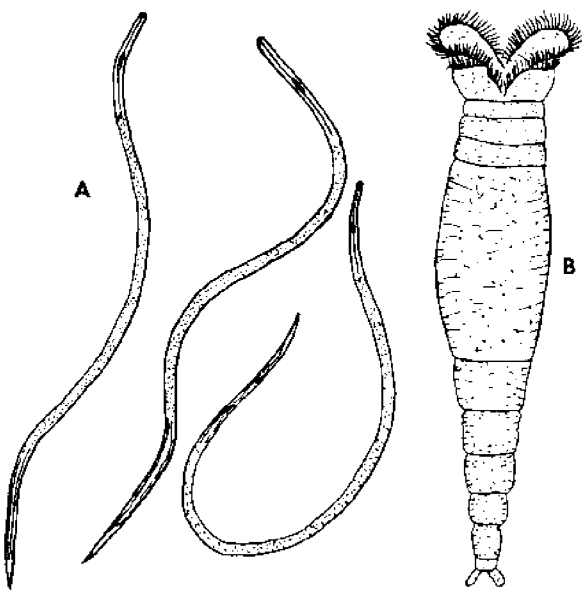


Fig. 45. Microscopic views of nematodes (a) and rotifer (b) from gill cavity of crawfish.

cles to establish and grow, therefore the hosts beset with barnacles are older individuals that molt infrequently (Fig. 43).

LEECHES

Leeches are often found on grass shrimp that live in brackish water. The most common leech is *Mazobdella* sp. (Fig. 44). Aside from being extra weight to carry, leeches are not considered a danger to the shrimp's health.

NEMATODES, ROTIFERS, INSECTS, ALGAE

Nematodes and rotifers are commonly observed within the gill cavity of crawfish and freshwater shrimp (Fig. 45). These animals are not considered to be parasites. Eggs of nematodes and insects will be found occasionally on the body surfaces of crawfish and shrimp. Many kinds of algae (particularly desmids) are found on body surfaces that are exposed to sunlight.

Miscellaneous Conditions

COLOR ANOMALIES

Freshwater crustaceans have a long record of discoveries describing individuals that differ markedly in color from the normal range of color for the species (Figs. 46C-48C). Recent work has established that these colors are due to genetic mutation. The most common type is usually referred to as the blue anomaly. Pigmentation that is usually brownish is blue instead. Another unusual case is that of a silver or yellow-eyed crawfish found in Louisiana (Fig. 49C).

RUSTY CONDITION

Occasionally freshwater crustaceans are seen to possess a brownish or rust-like coloration (Figs. 50C, 51). This condition appears to be more superficial than the browning that follows bacterial attack on the exoskeleton. Attempts at isolation of bacteria and reestablishment of the condition have so far been negative in the author's laboratory. The cause of the condition remains unknown.

EXOSKELETON SPOTTING

Spotting of the exoskeleton has been observed occasionally in larger individuals of *Macrobrachium rosenbergii* from culture situations (Fig. 52C). The brownish patches that are produced differ from the brownish lesions of chitinoverous bacteria in that the affected area is the inside layer of the exoskeleton that lies adjacent to the hypodermis. The cause of this condition is not known and attempts to observe or isolate living disease agents in or from affected tissues have been negative.

WHITE MACROBRACHIUM

For unknown reasons a portion of the *Macrobrachium ohioni* adults collected from the wild in Texas soon become whitish in color. This condition progressively worsens while they are maintained in captivity (Figs. 53C, 54C). Tissues beneath the exoskeleton assume a milky appearance but muscular tissues appear normal. Examinations have not demonstrated microbial pathogens.

SPONTANEOUS NECROSIS

Opaque muscles are characteristic of this condition. When crustaceans are exposed to stressful conditions muscles lose their normal transparency. If this process becomes too advanced the whitish condition is retained as tissues degenerate, causing death. A common result of handling and close confinement in marine shrimp, this condition is much less prevalent in freshwater crustaceans. Occasionally the condition has been noted by culturists of *Macrobrachium.*

TUMORS

Tumors are not common on crustaceans but occasionally they can be spotted as bulges of the exoskeleton when hypodermal tissue is involved (Fig. 55). The cause of such tumors is unknown.

OTHER CONDITIONS

There are documented reports of female crawfish that have male secondary sex characteristics. The most noticeable secondary sex characteristics are modifications of the first and second swimmerets.

Injury is common to many crawfish species and missing body parts are often observed. Certain species tend to have individuals with bad dispositions, and incomplete bodies are the rule rather than the exception.

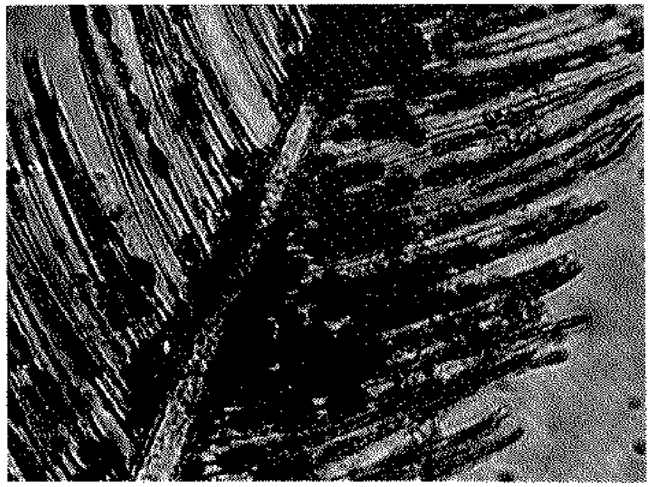


Fig. 51. Microscopic view of rusty material on exoskeleton surface.

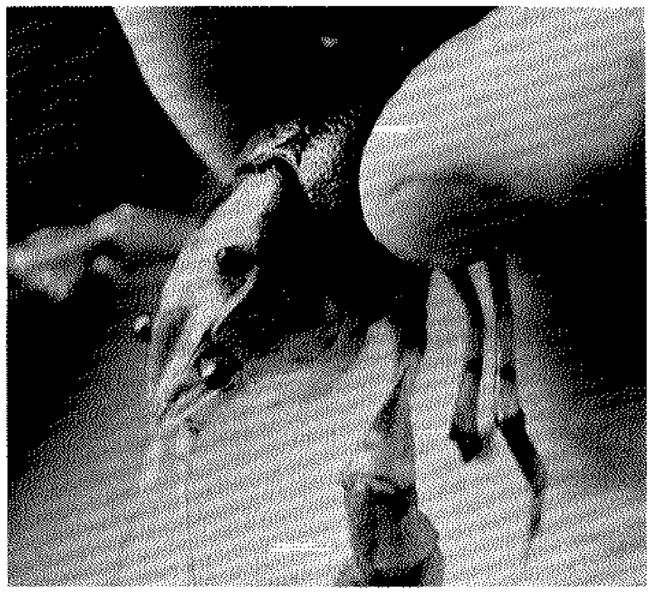


Fig. 55. Tumor on cephalothorax of crawfish.

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AND E, previous page.

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