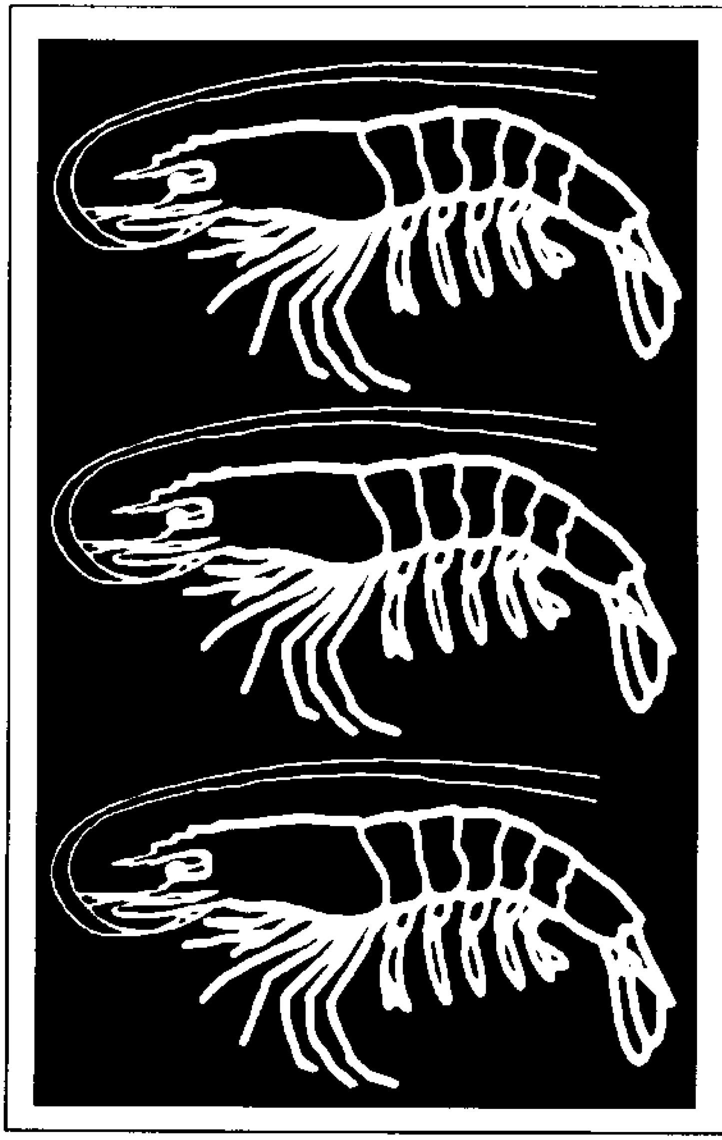
Handbook of Shrimp Diseases



Aquaculture

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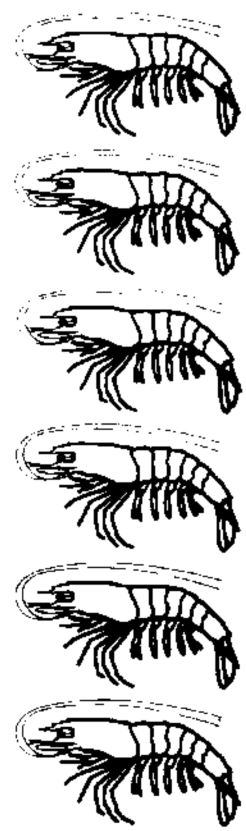

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Handbook of Shrimp Diseases

S. K. Johnson
Extension Fish Disease Specialist

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

Disease is an important factor in reducing shrimp numbers in natural populations. Natural mortality or death from old age is the potential fate of all shrimp, but the toll taken by predation (man being one of the major predators), starvation, infestation, infection and adverse environmental conditions is highly significant. Therefore, conditions described in the following pages exert considerable influence on shrimp numbers in natural stocks.

Disease problems are considered important to successful production in shrimp aquaculture. Because high-density, confined rearing is unnatural and produces stress, some shrimp-associated organisms will become prominent. Special measures are required to offset their detrimental effects.

Disease may be caused by living or non-living agents, as well as by physical or chemical factors. Non-living causes include lack of oxygen, poisons, low temperatures, salinity extremes, etc. This guide concentrates on the living agents and on visual presentation of the structure and effects of such agents.

Shrimp Species

There are many shrimp species distributed worldwide. Important shrimp of the Gulf of Mexico catch are the brown shrimp, *Penaeus aztecus;* the white shrimp, *Penaeus setiferus;* and the pink shrimp, *Penaeus duorarum.*

Two exotic shrimp have gained importance in Gulf Coast aquaculture operations. These are the Pacific white shrimp, *Penaeus vannamei*, and the Pacific blue shrimp, *Penaeus stylirostris*. These two species are used likewise throughout the Americas on both east and west coasts.

In Asia, the Pacific, and to some extent the Mediterranean, the following species are used: *Penaeus monodon, Penaeus merguiensis, Penaeus chinensis, Penaeus japonicus, Penaeus semisulcatus* and *Metapenaeus ensis.*

Shrimp Anatomy

A shrimp is covered with a protective cuticle (exoskeleton, shell) and has jointed appendages. Most organs are located in the head end (cephalothorax) with muscles concentrated in the tail end (abdomen). The parts listed below are apparent upon outside examination (Fig.1):

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 (covering of cephalothorax)
10. Walking Legs (pereiopods)
11. Abdominal Segment
12. Swimmeretes (pleopods)
13. Sixth Abdominal Segment
14. Telson
15. Uropod
16. Gills (under carapace)

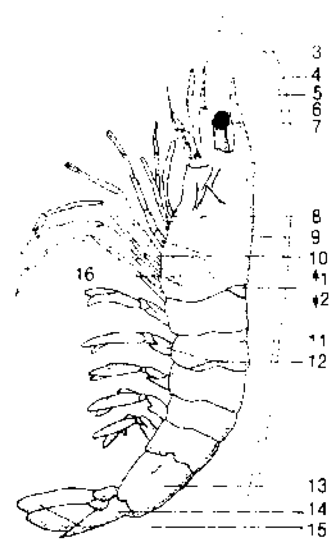


Fig. 1. External anatomy of shrimp. (Numbers conform to list.)

Inside structures include (Fig. 2):

1. Esophagus
2. Stomach
3. Hemocoel (blood space)
4. Digestive Gland (hepatopancreas)
5. Heart
6. Intestine
7. Abdominal Muscles

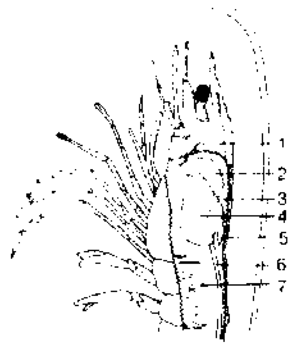


Fig. 2 Internal anatomy of shrimp. (Numbers conform to list.) Jagged line represents cut-away of cuticle to expose internal organs.

The "skin" or hypodermis of a shrimp lies just beneath the cuticle. It is functional in secreting the new exoskeleton that develops to replace the old at shedding. Shedding of the cuticle (also known as molting or ecdysis) occurs at intervals during a shrimp's life and allows for expansion of size.

The reproductive organs of adults are particularly noticeable. When ripe, the ovaries of females may be seen through the cuticle to begin in the cephalothorax and extend dorsally into the abdomen.

Microbes

VIRUSES

Viruses cause disease as they replicate within a suitable host cell type and thereby cause destruction or improper cell function. The damage varies according to host species and is usually confined to a single species or closely related group of hosts.

Much knowledge is needed about shrimp viruses. Exposure to particular environmental conditions may predispose shrimp to disease by viruses that act only as opportunists. Cause and effect for all shrimp virus disease needs careful attention. Another problem worth considering is that known viruses may be more diverse than currently recognized. This is because presumptive identifications are often made merely on the basis of size and shape. In the case of some detected viruses, are they replicating in the shrimp, or are they merely accumulated transient lodgers? Little is known also of how shrimp viruses are transmitted from one shrimp to another.

Viruses of shrimp have been assigned explicitly or tentatively to four viral groups (Fig. 3).

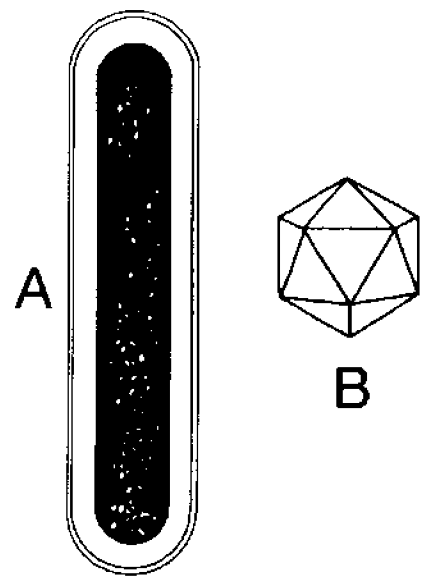


Fig. 3. Structure of viral groups reported from shrimp. A. Baculoviridae (four representative in penaid shrimp.) Size range is about 300 to 400 nanometers in length. B. Basic structure of other known shrimp viruses (four). A Picornavirudae-like virus is 20 nm in diameter and contains DNA. A Parvoviridae-like virus is 22 to 24 nm in diameter and contains RNA. Two Reoviridae-like viruses are 55 to 61 and 60 to 70 nm in diameter and contain DNA.

Microbes

Microbes are minute, living organisms, especially viruses, bacteria, rickettsia and fungi. Sometimes protozoa are considered microbes.

Protozoa are microscopic, usually one-celled, animals that belong to the lowest division of the animal kingdom. Normally, they are many times larger than bacteria.

Bacteria are 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.

Viruses are ultramicroscopic, infective agents capable of multiplying in connection with living cells. Normally, viruses are many times smaller than bacteria but may be made clearly visible at high magnification provided by an electron microscope.

Rickettsia are microbes with similarity to both viruses and bacteria and have a size that is normally somewhat in-between.

Fungi associated with shrimp are microscopic plants that develop interconnecting tubular structures. They reproduce by forming small cells known as spores or fruiting bodies that are capable of developing into a new individual.

The microbial world is vast in number and kind and has both beneficial and harmful members. Those that live in association with shrimp are normally either parasitic and capable of causing disease when present in sufficient numbers, or commensal and capable of living in association without causing injury.

Shrimp Viruses

Baculovirus

Baculovirus penaei — a virus common to Gulf of Mexico shrimp. This virus damages tissue by entering a cell nucleus and subsequently destroying the cell as the virus develops (Fig. 4). It has become a constant problem for many shrimp hatcheries where it damages the young larval animals. *Baculovirus penaei* has a characteristic that distinguishes it from some of the other shrimp viruses; some of the small infective virus particles form within a pyramid-shaped mass called an occlusion. The occlusion is large enough to be seen easily with a light microscope (Fig. 5).

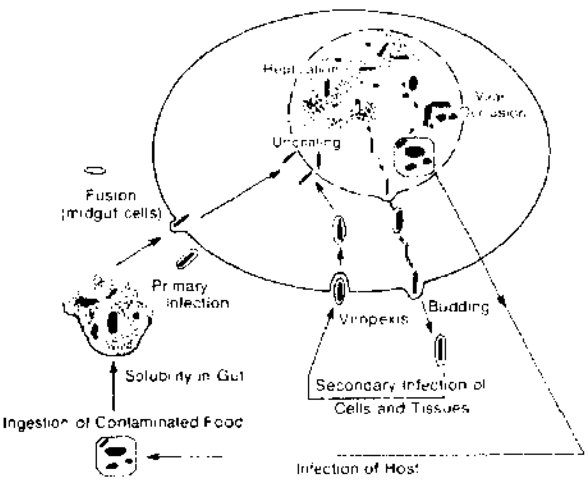


Fig. 4 Baculorvirus life cycle. Transmission of the virus is thought to be initiated as a susceptible shrimp ingests a viral occlusion. Virus initially enters cell cytoplasm either by viroplexis (cell engulfs particle with surrounding fluid) or by fusion where viral and cell membranes fuse and viral core passes into cell. Secondary infection occurs as extracellular virus continues to infect. (Redrawn from Summers and Smith, 1987. Used with permission of author and Texas Agricultural Experiment Station, Texas A&M University System.)

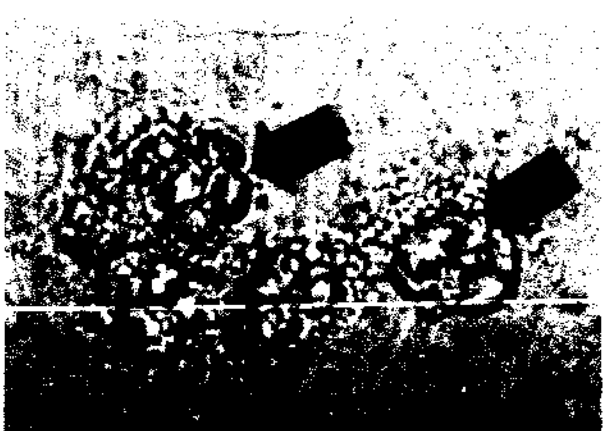


Fig. 6. Monodon baculovirus in a tissue squash showing groups of spherical occlusions.

Monodon-type baculovirus — one that forms spherical occlusions (Fig. 6) and whose effects are seen mostly in the culture of the Asian giant tiger prawn, *Penaeus monodon*. A recent report of transmission to *Penaeus vannamei* did not involve causation of disease.

Plebejus baculovirus — A spherical occlusion-forming virus of the Australian shrimp *Penaeus plebejus*.

Midgut gland necrosis virus — a virus harmful to the Kuruma prawn, *Penaeus japonicus*, in Japan.

Picornavirus

Infectious hypodermal and hematopoietic necrosis virus — a virus affecting several commercially important shrimp and, particularly, the Pacific blue shrimp, *Penaeus stylirostris*.

Parvovirus

Hepatopancreatic parvo-like virus — a virus causing disease in several Asian shrimp. A recently noted transmission to *Penaeus vannamei* did not result in disease of that species.

Reovirus

Reo-like virus of Kuruma prawn — a newly recognized virus of *Penaeus japonicus*.

Reo-like virus of Tiger prawn — a newly recognized virus of *Penaeus monodon*.

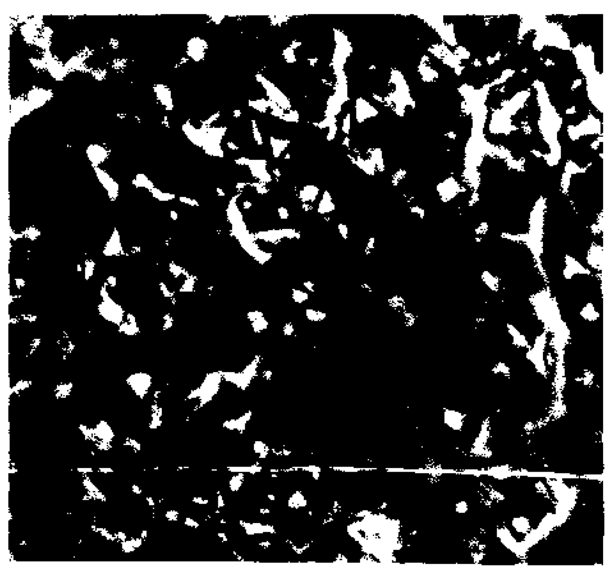


Fig. 5. Occlusion bodies of *Baculovirus penaei*. These bodies, visible to low power of light microscope, are characteristic of this virus. The occlusions and those of other baculoviruses are found mainly in the digestive gland and digestive tract.

RICKETTSIA

Rickettsial infections have recently been documented as cause of shrimp disease. Cells of the digestive gland and other tissues are damaged (Fig 7). No infections have been documented from shrimp of North American shores

BACTERIA

Bacterial infections of shrimp have been observed for many years. Scientists have noticed that bacterial infection in the blood or digestive gland usually occurs when shrimp are weakened. Otherwise, normal shrimp also may become infected if conditions favor presence of a particularly harmful bacterium

Shrimp body fluids are most often infected by the bacterial group named *Vibrio*. Shrimp infected with bacteria show discoloration of the body tissues in some instances, but not in others. The clotting function of the blood, critical in wound repair, is slowed or lost during some infections. Occasionally parts of the body are lost (Fig. 8).

If infected by bacteria capable of using shell for nutrition, the exoskeleton will demonstrate erosive and blackened areas (Figs. 9 and 10). These bacteria typically attack edges or tips of exoskeleton parts, but if breaks occur in the exoskeleton the bacteria are quick to enter and cause damage.

Filamentous bacteria are commonly found attached to the cuticle, particularly fringe areas beset with setae (Fig. 11). When infestation is heavy, filamentous bacteria may also be present in large quantity on the gill filaments. Smaller, less obvious bacteria also settle on cuticular surfaces but are not considered as threatening as the filamentous type.

FUNGI

Several fungi are known as shrimp pathogens. Three groups commonly infect larval shrimp, whereas another attacks the juvenile or larger shrimp. The

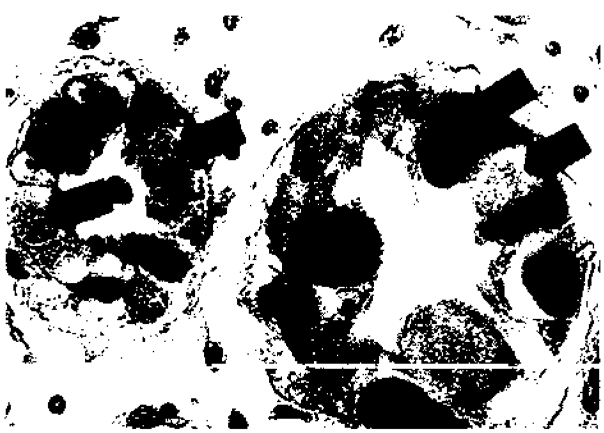


Fig. 7. Histological cross section of a digestive gland tubule. Rickettsial microcolonies are shown at arrow. Rickettsia will exhibit constant brownian motion and color red with Giemsa stain, but electron microscopy is needed for definte diagnosis. (Specimen courtesy of J. Brock.)

Fig. 8. Damage to abdomen of a shrimp as a result of *Vibrio* infection.

Fig. 9. Shrimp with numerous black erosive areas considered a result of action by bacteria. The darkening itself is considered a host response.

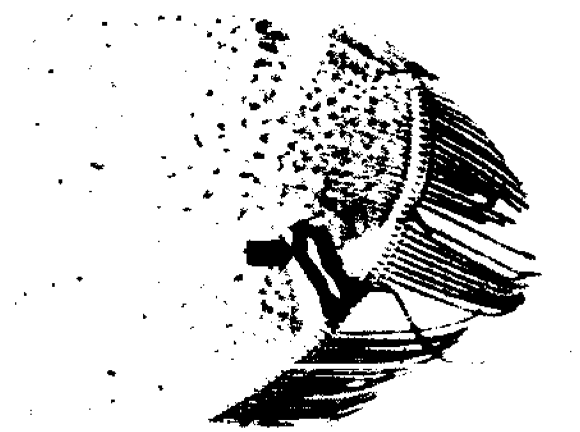


Fig. 10. Microscopic view of a lesion on a uropod (tail part.)

Fig. 11. Microscopic view of filamentous bacteria on a shrimp pleopod.

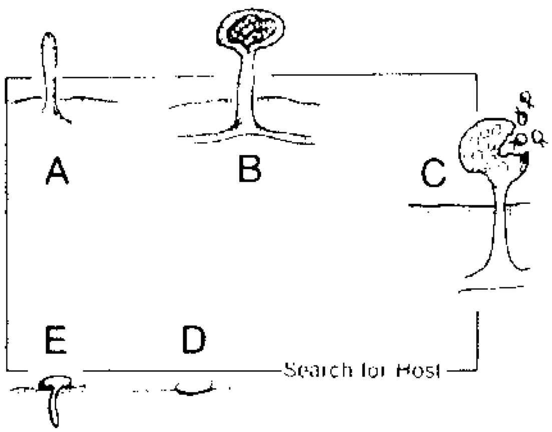


Fig. 12. Transmission of *Lagenidium*. A. Fungus sends out discharge tube out of shrimp body. B. Vesicle form. C. Vesicle produces motile spores that are released. D. Motile spores contact shrimp and undergo encystment. e. Germ tube is sent into the body of the shrimp and fungus then spreads throughout.

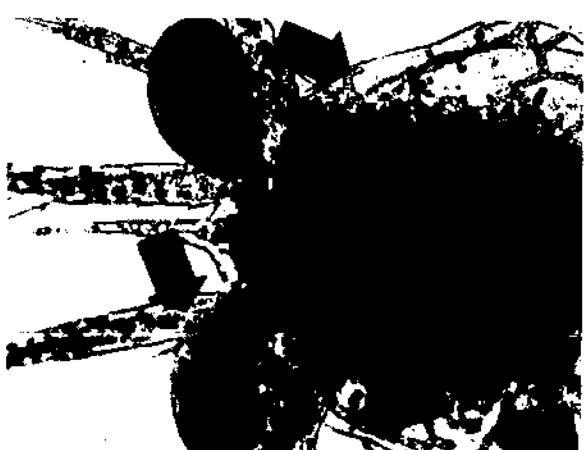


Fig. 13. *Lagenidium* infection in larval shrimp. Note extensive development of branchings of fungus throughout the body. (Photo courtesy of Dr. Don Lightner, University of Arizona.)

most common genus affecting larval shrimp is *Lagenidium*. Less common but important are *Sirolpidium* and *Haliphthoros*. The method of infection requires a thin cuticle such as that characteristic of larval shrimp (Fig. 12).

The most common genus affecting larger shrimp is *Fusarium*. It is thought that this fungus gains entry into the body through cracks or eroded areas on the cuticle. *Fusarium* may be identified by the presence of canoe-shaped macroconidia that the fungus produces. Macroconidia and examples of fungal infections are shown in Figures 13-16.

Fig. 14. Canoe-shaped macroconidia of *Fusarium*. These structures bud off of branches of the fungus and serve to transmit fungus to shrimp.

Fig. 15. Microscopic view of fungus in gill filament.

Fig. 16. Microscopic view of fungus at tip of antenna.

PROTOZOA

Protozoan parasites and commensals of shrimp will occur on the inside or outside of the body. Those on the outside are considered harmless unless present in massive or burdensome numbers. Those on the inside can cause disease and are representative of several groups of protozoan parasites: Microsporidia, Haplosporidia and Gregarina. Members of these groups are known or believed to require that some animal besides shrimp be present in order to facilitate completion of their life cycles. A few protozoa are known to invade weakened larval animals directly and contribute to disease.

Microsporidians

Microsporidians parasitize most major animal groups, notably insects, fish and crustaceans. In shrimp, microsporidian infections are best known locally as cause of a condition known as "milk" or "cotton" shrimp (Figs. 17-19). Microsporidians become remarkably abundant in the infected shrimp and cause the white appearance of muscle tissues. A

Fig. 17. Infected or "milk" shrimp (upper) in comparison to normal shrimp (lower.) (Photo courtesty of Dr. R. Nickelson.)

Fig. 18. Two brown shrimp cut across tail. Note infected area (arrow).

Fig. 19. Grass shrimp with "milk" shrimp condition. The normal shrimp in the figure is transparent.

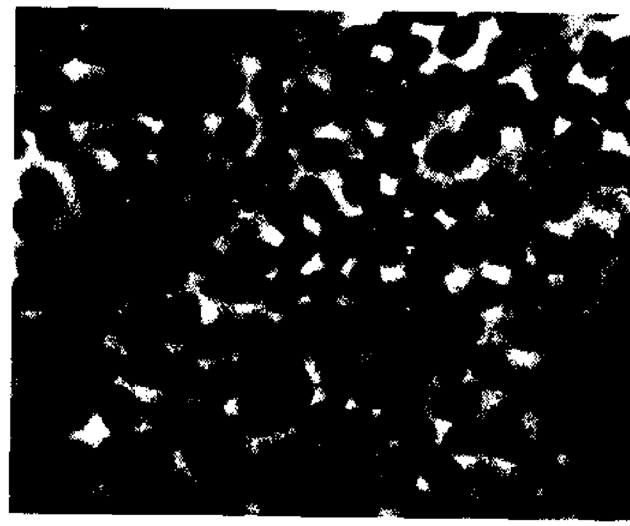


Fig. 20. Microscopic view of many spores of *Ameson (=Nosema)* sp. The spores are free or unenveloped. Parasitic microsporidians of commercially important shrimp with enclosing envelopes are assigned to genera *Pleistophora, Thelohania* and *Agmasoma*. The latter two differ from *Pleistophora* in that their members retain a constant spore number of eight per envelope. *Pleistophora* sp. have more than eight spores per envelope.

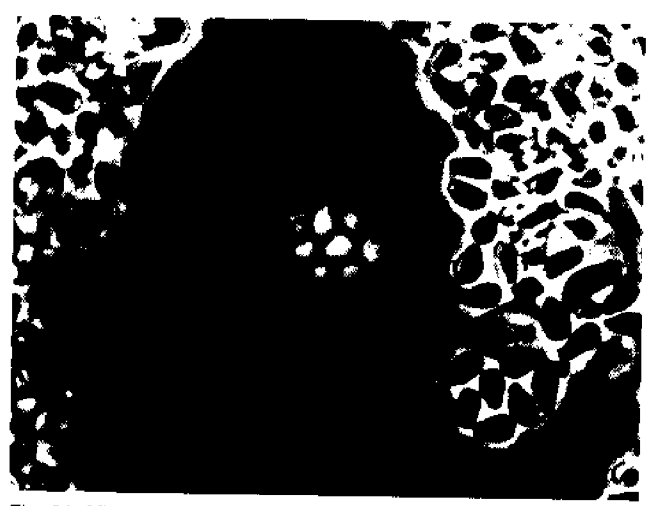


Fig. 21. Microscopic view of many spores of *Thelohania* sp. Note envelope (arrow).

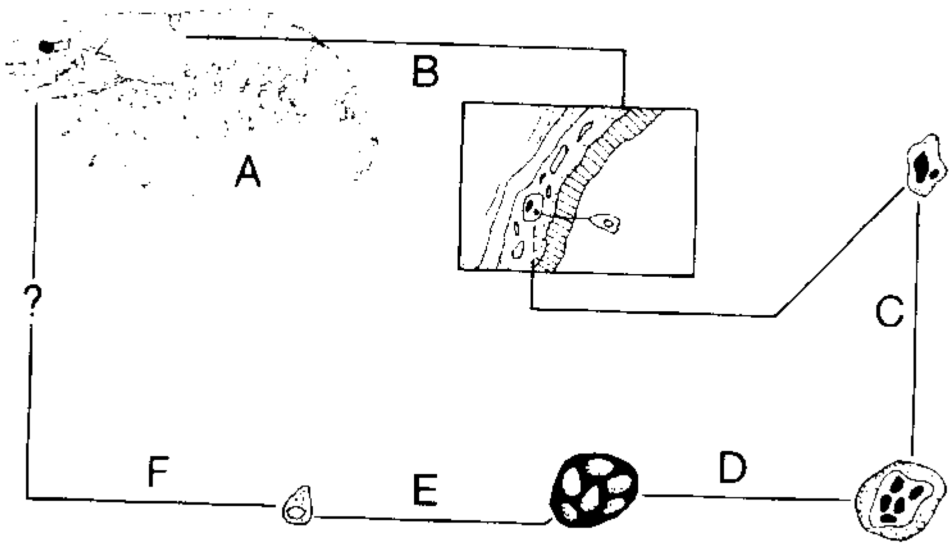


Fig. 23. Life cycle of microsporidian of shrimp. A. Ingestion of spores by shrimp. B. In gut of shrimp, the spore extrudes a filament that penetrates gut wall and deposits an infective unit. A cell engulfs this unit. C. Infective unit enters the nucleus of the cell, undergoes development and then divides to form schizonts. D. Schizonts then divide and develop into spores. E. By the time spores are formed, they are located in a specific tissue (muscle, tissues around intestine, etc.). The spores are either discharged from the shrimp while living or after death, but the method of release and the pathway taken is not known. F. Experiments designed to transmit infection by feeding infected shrimp to uninfected have been unsuccessful. It is assumed particular events such as involvement of another host may be required to complete passage from one shrimp to the next. Successful transmission has been reported when infected shrimp were fed to fish (speckled trout) and fish fecal material was then fed to shrimp.

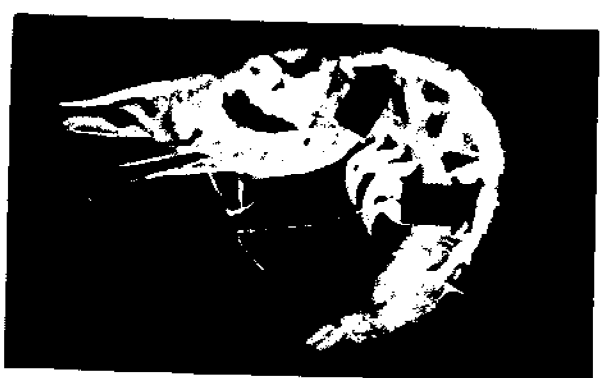


Fig. 22. *Agmasoma penaei* in white shrimp. This parasite is always located along the dorsal midline (arrows). Advanced infections can be seen through the cuticle with the unaided eye.

typical catch of wild shrimp will contain a few individuals with this condition. These shrimp are usually discarded before processing. Depending on the type of microsporidian, the site of infection will be throughout the musculature of the shrimp or, in particular, organs and tissues.

Microsporidians are present in the affected shrimp in the form of spores. Spores are small cells that can develop into a new individual. They are very minute and detection requires examination with a microscope (Figs. 20-21).

Infected shrimp are noted to be agile and apparently feed as normal shrimp. However, tissue damage occurs and no doubt affects many life functions. No eggs have been found in "milk" shrimp and it is suspected that all types of microsporidian infections can render shrimp incapable of reproduction (Fig. 22).

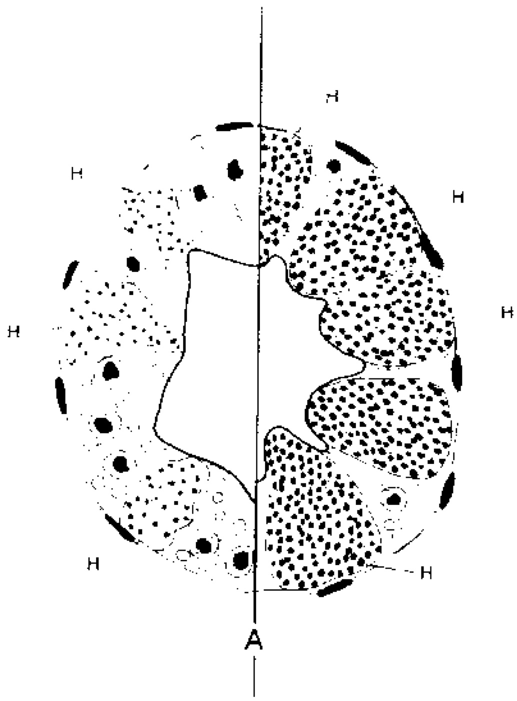
The life cycles of shrimp microsporidians have not been satisfactorily worked out. However, examination of the cycles of related species and the miscellaneous facts contained in literature indicate that the cycle presented in Figure 23 is representative of microsporidians.

Haplosporidia

A member of the Haplosporidia, another spore-forming protozoan group, was recently recognized as important to shrimp health when researchers found infected animals in an experimental population that had been imported into Cuba from the Pacific Coast of Central America. The parasites invaded and destroyed tissues of the digestive gland (Fig. 24).

Gregarines

Gregarines are protozoa that occur within the digestive tract and tissues of various invertebrate animals. They occur in the digestive tract of shrimp and are observed most often in the form of a tropho-



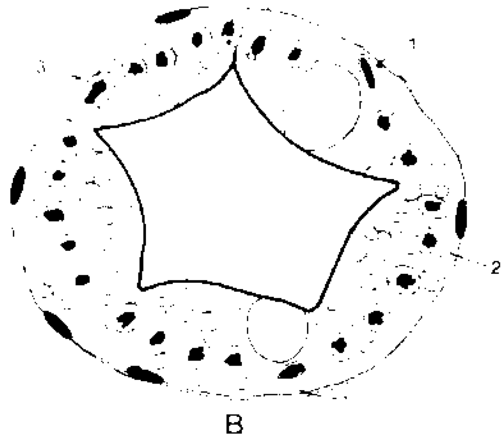


Fig. 24. A. Drawing of transverse section of digestive gland tubule containing haplosporidian parasites. Straight line separates appearance of a tubule into early (reader's left) and late stages of infection. (Drawn from Dykova et al., 1988.) A recent report from Malaysian *Penaeus monodon* figures a quite similar manifestation by an assumed microsporidian infection. B. For comparison a section of a normal tubule. Toward the digestive tract secretory cells (1) predominate and fibrous cells (3) become more numerous. Absorptive cells (2) contain varying amounts of vacuoles according to nutritional status.

Fig. 25. Microscopic view of trophozoite of *Nematopsis* sp.

Fig. 29. Microscopic view of gametocyst of *Nematopsis* sp.

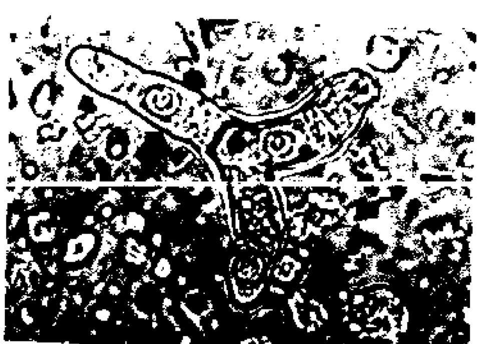


Fig. 26. Microscopic view of trophozoite of *Nematopsis* sp.

Fig. 27. (Left.) Microscopic view of trophozoites of *Nematopsis* sp.
Fig. 28 (Above.) Trophozoites of *Cephalobus*, a gregarine that attaches to the base of the terminal lappets of the shrimp stomach rather than the intestinal wall. (Photo courtesy of Dr. C. Corkern.)

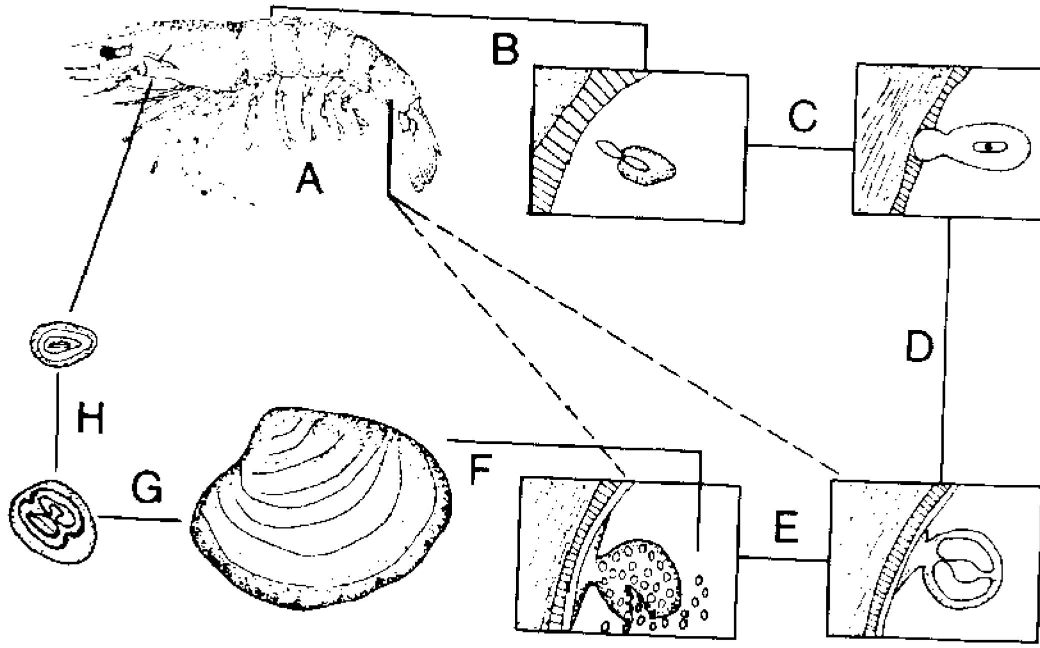


Fig. 30. Life cycle of a gregarine of shrimp. A. Shrimp ingests spores with bottom debris. B. Sporozoite emerges in the gut of the shrimp. C. Sporozoite attaches to the intestinal wall and grows into a delicate trophozoite; other trophozoites do not atach to the wall but onto each other and form unusual shapes (See Figs. 26, 27.) D. The unusual forms develop and attach to the end of the intestine (rectum) to form gametocysts. E. Gametocyst undergoes multiple divisions to produce "gymnospores" that are set free with rupture of the gametocyst. F. Gymnospores are engulfed by cells at the surface of the flesh of clams. G. They develop to form spores in the clam. H. Then the spores (with sporozoite inside) are liberated from the clam in mucous strings (slime).

zoite (Fig. 25 - 28) or a gametocyst (Fig. 29). The life cycle involves marine snails or clams as diagrammed in Figure 30.

Minor damage to the host shrimp results from attachment of the trophozoites to the lining of the intestine. Absorption of food or intestinal blockage by the protozoa is perhaps detrimental. It is the consensus of most parasitologists that these effects are relatively unimportant and, consequently, they consider gregarines of little pathological importance.

Body Invaders

Several protozoa have been noted to invade a shrimp body and feed on tissues as they wander throughout. Tentative identifications name *Parauronema*, *Leptomonas*, *Paranophrys* and an amoeba. Adverse effects of these protozoa are not fully understood, but they are usually found associated with shrimp that have become weakened or diseased (Fig. 31).

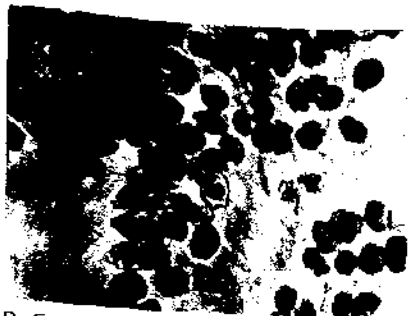
Fig. 31. Weakened larval shrimp invaded by ciliated protozoans (arrows).

Ectocommensal Protozoa

Several kinds of protozoa are regularly found on surfaces, including gills, of shrimp. Apparently, shrimp surfaces are a favored place to live within the water environment. Common on the surfaces of shrimp are species of *Zoothamnium*, *Epistylis*, *Acineta*, *Ephelota*, and *Lagenophrys* (Fig 32).

Zoothamnium is a frequent inhabitant of the gill surfaces of shrimp, and in ponds with low oxygen content, heavily infested shrimp can suffocate. Surface-settling protozoa occasionally cause problems in shrimp hatcheries when larval shrimp become

A. *Zoothamnium.*



B. *Epistylis.*

C. *Lagenophrys*

D. *Acineta.*

Fig. 32. Common surface dwelling protozoa

E. *Ephelota*

overburdened and are unable to swim normally. As protozoa continuously multiply in numbers, shrimp acquire an increasing burden until shedding of the cuticle provides relief.

Members of one unique group of protozoa, the apostome ciliates, have a resting stage that will settle on shrimp surfaces. When the crustacean molts, the protozoan releases and completes the life cycle within the shed cuticle before entering a resting stage on a new crustacean (Fig. 33).

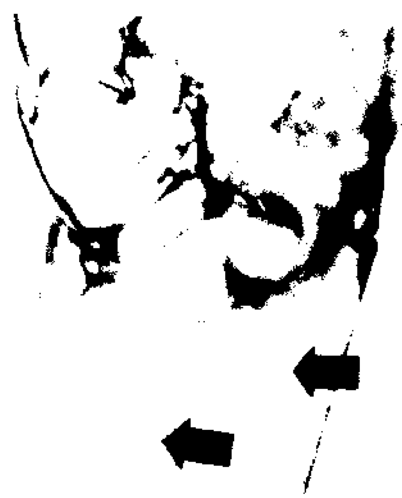


Fig. 33. Microscopic view of several apostome ciliates inside grass shrimp molt. Proper identification of genus cannot be determined from living animal. Staining with a technique called silver impregnation is requried.

Other Infestations

A variety of other organisms attach to shrimp surfaces. Their abundant presence on gills and limbs can interfere with breathing and mobility. Small, single-cell plants called diatoms are often found attached to larval shrimp in hatcheries. (Fig. 34). Shrimp from aquaculture facilities that are exposed to an unusual amount of sunlight often will have overgrowths of algae of mixed variety (Fig. 35).

Fig. 34. Diatoms attached to gill surfaces of larval shrimp.

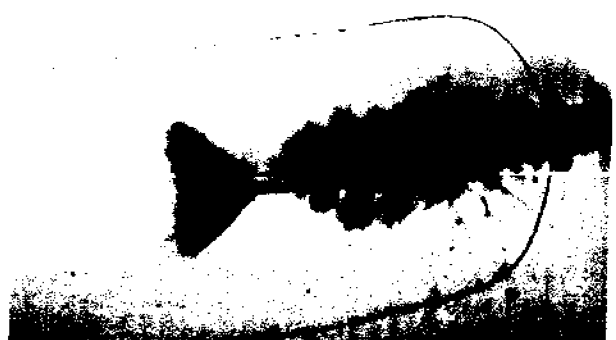


Fig. 35. Algal overgrowth on shrimp exposed to abundant light. (Photo courtesy of Steve Robertson.)

Occasionally, one will find barnacles, leeches and the colonial hydroid *Obelia bicuspidata* affixed to body surfaces. These organisms are probably quite common in the vicinity of the shrimp and select surfaces of infrequently molting, older shrimp as spots to take up residence. Insects will sometimes lay eggs on shrimp and a strange group of animals called ellobiopsids settle on the carapace and provide the shrimp with a feathered-cap appearance (Figs. 36-38).

Some members of the crustacean group called isopods are parasitic on shrimp of commercial importance. Commercially important shrimp of the Gulf of Mexico are apparently not parasitized. However, smaller shrimp of the family Palaemonidae are often seen infested along our coastline. Commercial shrimp of the family Penaeidae are parasitized in Pacific areas (Fig. 39).

Fig. 38. Ellobiopsids attached to shrimp cuticle

Fig. 36. Grass shrimp with leech attached. (Photo courtesy of Kenneth R.H. Read.)

Fig. 39A. Asian shrimp infested with parasitic isopods (gill cover flared open to expose parasites).

Fig. 37. Shrimp with insect eggs attached to cuticular surface.

Fig. 39B. Parasites removed from shrimp.

Worms

Worms that have been found in shrimp are trematodes (flukes), cestodes (tapeworms), and nematodes (roundworms). Some species are more common than others and, as yet, none have been known to cause widespread shrimp mortality. Worms may be found in various parts of the body (Fig. 40).

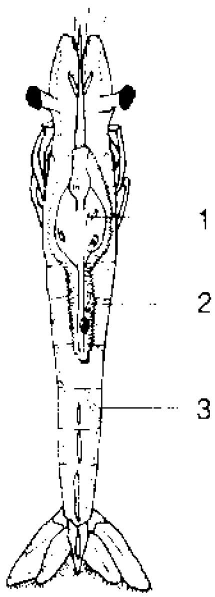


Fig. 40. Common sites of infestation by worms. 1 Tapeworms: usually associated with tissues covering digestive gland. 2 Roundworms; in and outside of organs in cephalothorax, but also in and along outside of intestine. 3 Flukes; commonly encysted in tissues adjacent to organs in cephalothorax, but also in abdominal musculature and under cuticle.

TREMATODES

Trematodes (flukes) are present in shrimp as immature forms (metacercariae) encysted in various body tissues. Metacercariae of trematodes of the families Opecoelidae, Microphallidae and Echinostomatidae have been reported from commercial species of penaeid shrimp (Fig. 41). One species, *Opecoeloides fimbriatus*, has been noted to be more common than others, and the hypothetical life cycle of this species is illustrated in Figure 42.

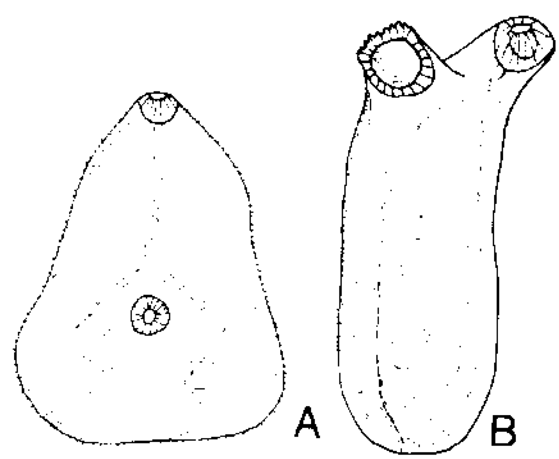


Fig. 41. Drawing of microscopic view of common flukes of shrimp (excysted). A. *Microphallus* sp. B. *Opecoeloides fimbriatus*.

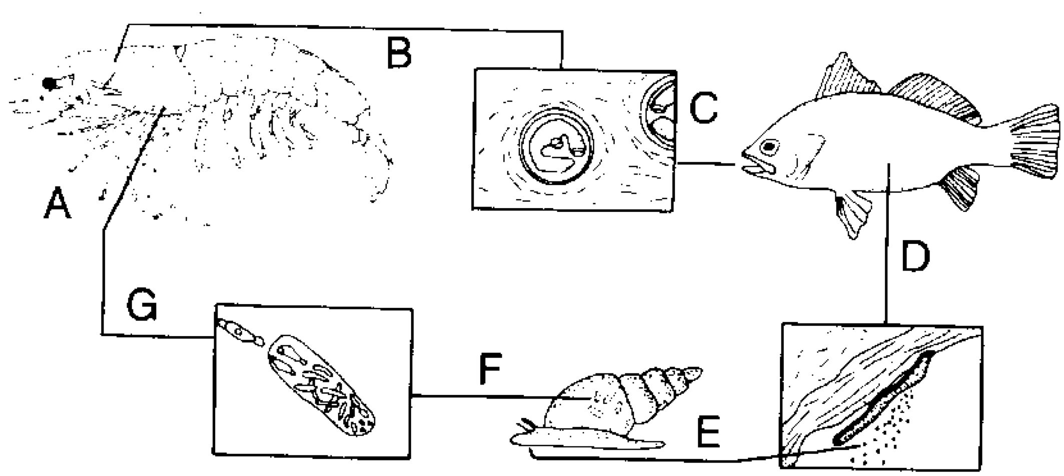


Fig. 42. Hypothetical life cycle of a shrimp fluke, *Opecoeloides fimbriatus*. A. Infective stage or cercaria penetrates shrimp. B. Cercaria migrates to the appropriate tissue and encysts forming a stage called metacercaria. C. Shrimp infected with metacercaria is eaten by fish (silver perch, red drum, sheepshead, several others.) D. Shrimp is digested. This releases metacercaria. Metacercaria stage undergoes development until it forms an adult. E. Eggs laid by adult fluke pass out of fish with wastes. Egg hatches and an infective stage known as a miracidium is released. The miracidium penetrates a snail and multiplies in number within sporocysts. F. Cercariae develop within sporocysts. When fully developed, cercaria leaves the sporocyst and snail and swims in search of a shrimp. If contact is made with a shrimp within a short period, the cycle is completed.

CESTODES

Tapeworms in shrimp are associated typically with the digestive gland. They are usually found imbedded in the gland, or next to it, in the covering tissue. In shrimp, tapeworms are present as immature forms (Fig. 43), while adult forms are found in rays. Species of the genera *Prochristianella*, *Parachristianella* and *Renibulbus* are common. Other tapeworms from wild shrimp include a relatively common pear-shaped worm of the intestine and a less common worm of the cyclophyllidean group. Tapeworms are most often encountered in wild shrimp.

Differentiation between the tapeworm groups is made in general body form and tentacular armature. A hypothetical life cycle for *Prochristianella penaei* is presented in Figure 44.

NEMATODES

Nematodes occur more commonly in wild shrimp than in cultured shrimp. The degree of infection is probably related to the absence of appropriate alternate hosts in culture systems. Nematodes will occur within and around most body organs, as well as in the musculature. Nematodes of shrimp include *Spirocamallanus pereirai* (Fig. 45A), *Leptolaimus* sp. and *Ascaropsis* sp. The most common nematode in Gulf shrimp is *Hysterothylacium reliquens* (Fig. 45B).

It is the juvenile state of nematodes that infects shrimp with the adult occurring in fish. An illustrated life cycle thought to represent *Hysterothylacium reliquens* is depicted in Figure 46.

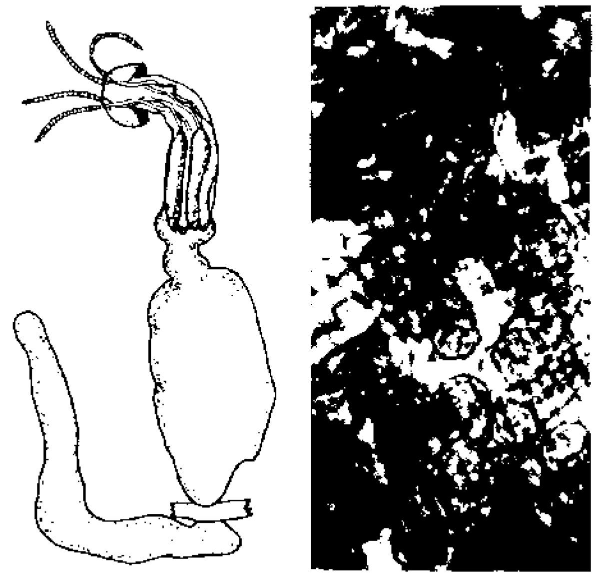


Fig. 43 A. A drawing of the shrimp tapeworm, *Prochristianella penaei* as it would appear in a microscopic view after removal from its cyst. B. Unnamed pear-shaped tapeworm larvae in gut. (Photo courtesy of C. Corkern.)

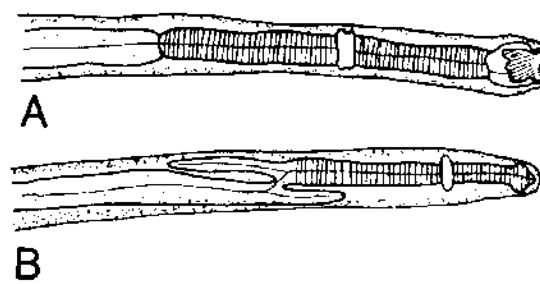


Fig. 45. Drawing of microscopic view of head end of (A) *Spirocamallanus pereirai* and (B) *Hysterothylacium* sp. common round worms found in penaid shrimp.

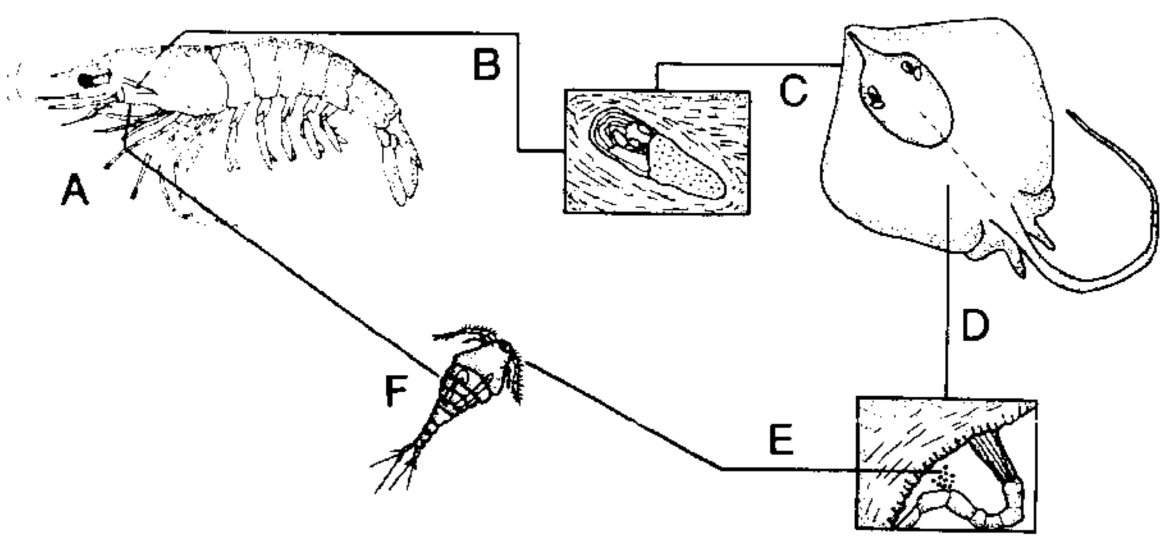


Fig. 44. Hypothetical life cycle of the tapeworm, *Prochristianella penaei* Kruse. A. Shrimp eats a copepod or other small crustacean infested with larval tapeworm. B. Tapeworm develops into advanced larval stage in tissues of shrimp. C. Stingray ingests infested shrimp. D. Tapeworm develops into adult in gut (spiral valve) of ray and begins to release eggs. E. Eggs pass out of the fish with feces and are eaten by copepod. Eggs hatch and larval worm develops inside copepod.

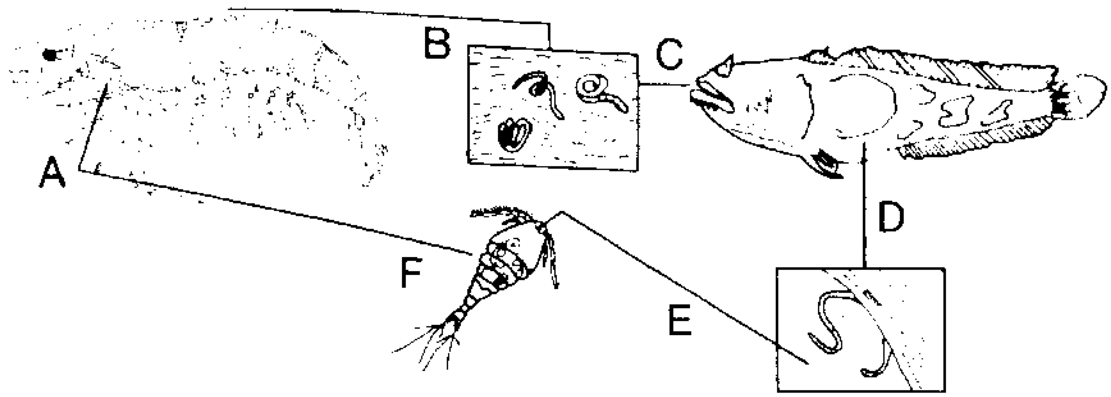


Fig. 46. Hypothetical life cycle of *Hysterothylacium reliquens*, a roundworm of shrimp. A. Shrimp eats a copepod or other small crustacean infested with larval roundworm. B. Roundworm develops into advanced larval stage in tissues of shrimp. C Toadfish ingests infested shrimp D Roundworm develops into adult in gut of fish and begins to release eggs E Eggs pass out of the fish with feces and are eaten by copepod

Fig. 47. Eyes of shrimp are normally black, but rubbing of a tank wall has caused this eye to appear whitish because of a prominent lesion

Fig. 48. Cannibalism usually begins as other shrimp devour the appendages.

Miscellaneous Conditions

INJURY

Shrimp cuticle is easily damaged in aquaculture situations when hard structures are impacted or rubbed. (Fig. 47). Shell damage may also be inflicted by the pinching or biting of other shrimp in crowded conditions. Cannibalism has an important influence on survival in some phases of shrimp culture where stronger individuals devour weak ones (Fig. 48).

DEVELOPMENTAL PROBLEMS

Deformaties are quite prevalent in some populations. They arise from complex interactions that involve environment, diet and gene expression. Bodies may be twisted or appendages misshaped or missing. Deformaties are less prevalent in wild caught larvae than hatchery populations probably because wild shrimp have more opportunity for natural selection and exposure to normal developmental conditions (Fig. 49).

Fig. 49. Deformed larval shrimp. Arrow points to deformed appendage.

Molt arrest occurs in affected animals of some populations. Animals begin but are unable to complete the molting process. In some cases, there is abnormal adherence to underlying skin, but most animals appear to lack the necessary stamina. Nutritional inadequacies and water quality factors have been identified as causes.

The shell or cuticle may become fragile during development. The reasons for soft shells remain a mystery, but many think the condition results primarily from inadequate nutrition (starvation). Shells are normally soft for a couple of days after molting, but shells of those suffering from soft-shell condition remain both soft and thin and have a tendency to crack under the slightest pressure.

COLOR ANOMALIES

Shrimp of unusual color are occasionally found among wild and farm stocks. The striking coloration, which may be gold, blue or pink, appears throughout the tissue and is not confined to the cuticle or underlying skin. A genetic cause is suspected. Transformation to blue coloration from a natural brown is known for some captive crustaceans and has been linked to nutrition. Pond-cultured Pacific tiger shrimp sometimes develop a condition where digestive gland degeneration contributes to a reddish coloration.

DIGESTIVE GLAND MANIFESTATIONS

Pond-reared shrimp occasionally die in large numbers because of diseased digestive glands. Shrimp digestive gland tissues are organized as numerous tubular structures that ultimately feed into the digestive tract. The specialized cells that line the inside of the tubules are particularly fragile and may become damaged by a variety of causes. Once damage is initiated, the shrimp will begin to respond in a predictable manner that progresses toward the formation of granulomas (Figs. 50, 51). Many shrimp that exibited this manifestation were lost during 1985-1988 on Texas shrimp farms.

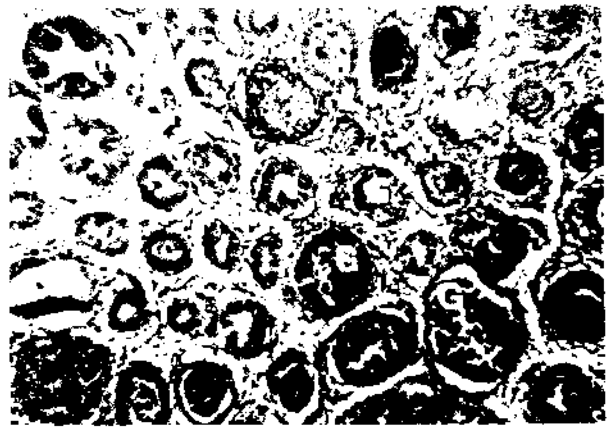


Fig. 50. Transverse section of digestive gland tubules showing progression of granuloma formation. Normal tubules are to the left (N) and affected tubules are to the right (G).

Fig. 51. Tissue squash of hepatopancreas with advanced granuloma formation. Note dark necrotized tissue of tubules (arrows).

Fig. 52. A shrimp photographed (A-left) near time of back injury and (B-right) hours later. Injury by a toxin or disease agent will usually trigger a similar response of inflammation and melanization.

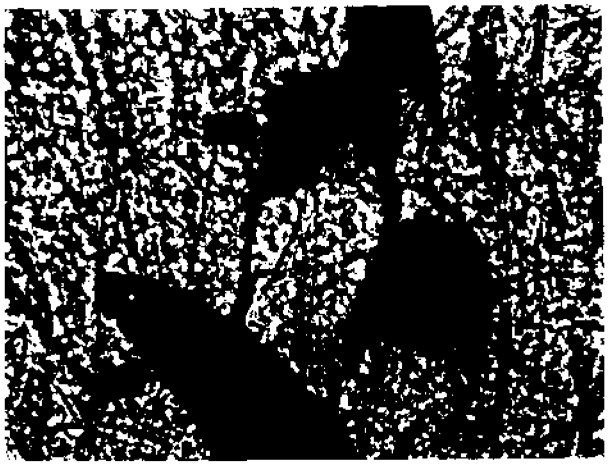


Fig. 53 State of gills during initial stages of darkening condition.

Fig. 54. Emaciated shrimp. Gills and body fringes have become obviously darkened and the soft tail is covered with a thin and fragile cuticle.

Fig. 55. Lipoid (fat) spheres in microscopic view of digestive gland tubule.

INFLAMMATION AND MELANIZATION

Conditions of tissue darkening is a frequent occurrence with shrimp and other crustaceans. In the usual case, blood cells gradually congregate in particular tissue areas (inflammation) where damage has occurred and this is followed by pigment (melanin) deposition. An infective agent, injury or a toxin may cause damage and stimulate the process (Fig. 52). Gills are particularly prone to darkening due to their fragile nature and their function as a collecting site for elimination of the body's waste products (Fig. 53). Gills readily darken upon exposure to toxic metals or chemicals and as a result of infection by certain fungi (*Fusarium* sp.).

EMACIATION AND NUTRITIONAL DEFICIENCY

Unfed shrimp lose their normal full and robust appearance. The shell becomes thin and flexible as it covers underlying tissue such as tail meat that becomes greatly resorbed for lack of nutrients. Molting is curtailed and shell and gills may darken in time. Emaciation may result from unavailable nutrients or loss of feeding behavior after exposure to unfavorable environmental conditions (Fig. 54).

Prepared diets deficient in necessary constituents may predispose or cause disease. Vitamin C deficiency, for example, will initiate darkening of gills or certain tissues associated with the cuticle and eventually result in deaths.

Digestive glands sometimes will become reduced in size. Among other things, this is an indication of poor nutrition. Well-fed shrimp will have an abundance of fat globules within storage cells of the digestive gland tubules that provide bulk to the gland (Fig. 55).

CRAMPED SHRIMP

This is a condition described for shrimp kept in a variety of culture situations. The tail is drawn under the body and becomes rigid to the point that it cannot be straightened (Fig. 56). The cause of cramping is unknown.

Fig. 56. Cramped shrimp condition. Full flexure (A-left.) Flexure maintained when pressure applied (B-right.)

MUSCLE NECROSIS

Opaque muscles are characteristic of this condition. When shrimp are exposed to stressful conditions, such as low oxygen or crowding, the muscles lose their normal transparency and become blotched with whitish areas throughout. This may progress until the entire tail area takes on a whitish appearance (Fig. 57).

If shrimp are withdrawn from the adverse environment before prolonged stress exposure, they may return to normal. Extremely affected shrimp do not recover, however, and die within a few minutes. In moderately affected shrimp, only parts of the body return to normal; other parts, typically the last segments of the tail, are unable to recover (Fig. 58). These shrimp die within one or two days. Shrimp muscles with this condition are known to undergo necrosis (death or decay of tissue). The whitish condition can be confused with milk shrimp (microsporidian infection), but examination of the figures should aid in distinguishing the two diseases.

TUMORS AND OTHER TISSUE PROBLEMS

Conspicuous body swellings or enlargements of tissues have been reported in shrimp. In most cases, affected individuals were captured from polluted waters. Occurrence of shrimp with evident tumors is rare in commercial catches. Miscellaneous irritations experienced by captive shrimp in tank systems will sometimes result in focal areas of tissue overgrowth (Fig. 59).

A hemolymphoma or fluid-filled blister may form on the inner surface of the portion of carapace that covers the gills (Fig. 60). The cause of this rare condition is not known. Another rare condition is necrosis and subsequent melanization of tissue within the musculature. Like hemolymphoma, the cause is unknown and marketability of the product is greatly influenced (Fig. 61).

A degeneration of male reproductive tracts occasionally occurs in captive adults of certain penaeid species. A swelling and darkening of the tubule leading from the testes to the spermatophore is readily apparent when viewed through the translucent body (Fig. 62).

A condition where the the basement layer of tissue lining the intestine thickens and results in loss of food absorption and some nerve dysfunction is known from *Penaeus japonicus* and *Penaeus merguiensis*. A cause has not been established.

ENVIRONMENTAL EXTREMES

Temperature, irradiation, gas saturation, hydrogen ion content (pH), oxygen content and salinity all have appropriate tolerable ranges for sustaining life of various shrimp species and life stages. If these ranges are exceeded or extremes combine for an

Fig. 57. Shrimp with necrotic muscle tissue following stress. Affected tissue at arrow.

Fig. 58. Shrimp with advanced muscle necrosis (arrow) shown beside normal shrimp.

Fig. 59. Tumorous growths on an adult shrimp from a tank system.

Fig. 60. Blister condition. Inset shows blister removed. The blister will darken upon death of shrimp.

Fig. 61. Areas of melanized necrotic tissue in tail musculature.

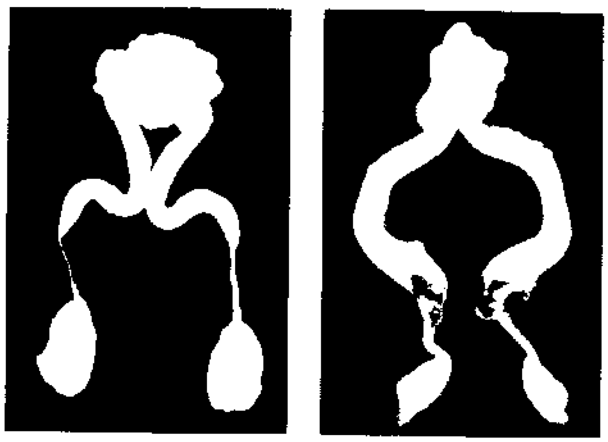


Fig. 62. Darkening of male reproductive tract of *Penaeus stylirostris*. A. Normal tract. B. Initial darkening. Darkening will advance until spermatophores and testes become affected. (Photos courtesy of George Chamberlain.)

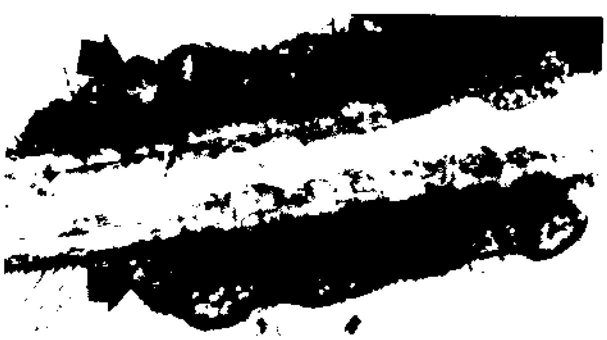


Fig. 63. Precipitant of iron salt on a shrimp's fringe hair (setule).

interactive effect, shrimp will become diseased. Besides the direct effect from these noninfectious agents, exposure may result in predisposal to effects of opportunistic infective agents.

Gas bubbles will form in the blood of shrimp if exposed to waters with large differences in gas saturations. If a large amount of bubbling occurs in the blood, death will result.

In the presence of acidic water, minerals will often precipitate on cuticular surfaces. Usually the precipitant is iron salt (Fig. 63).

TOXICITY

Poisoning can result from toxic substances absorbed from the water or consumed food. Water may accumulate excessive concentrations of ammonia, nitrite, hydrogen sulfide or carbon dioxide, all of which can have a toxic effect on shrimp. Some metals also may cause a toxic effect when present in excess. Both presence and toxicity of these chemicals are influenced by the changeable environmental conditions mentioned above. They may act singularly or have combined effects.

Certain microbes and algae will excrete poisonous materials. Examples of algal release are the occasional red tides that occur along our coast. Aside from survival loss, affected animals behave in a disorientated manner. Microbes become concentrated in high density rearing systems and such systems are known to develop species that can cause damage by toxic release.

Pesticides can be harmful if they occur seasonally in surface water supplies affected by agricultural practice. Because of migrations into estuaries or near effluent disposal sites, wild shrimp populations are more susceptible than cultured stocks to the variety of pollutants released.

There are reports of toxicity caused by the food shrimp consume. Toxins from microbes are known to build up in feeds stored in unfavorable conditions. Some foodstuffs and live larval food, such as brine shrimp, can contain pesticides. Perhaps more common are undesirable effects of feeds that have aged and become rancid.

Breakdown of lining tissues (necrosis) of the intestine have been associated with consumption of certain algae. Because cultured shrimp feed both on prepared feeds and bottom materials, it is suspected that the occasional occurrence of detrimental irritants and toxins contained within bottom surfaces could cause tissue breakdown when such sediments are consumed. ■

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