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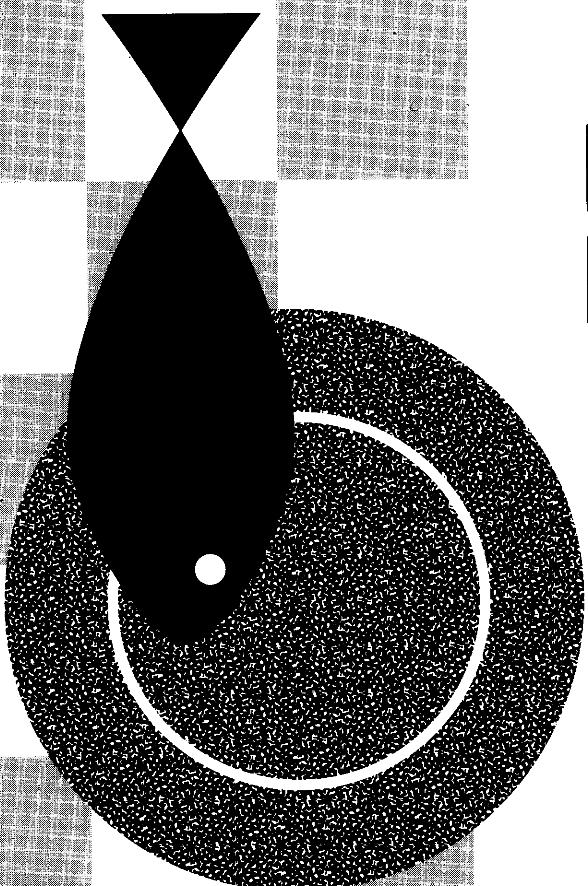

Fish Parasites and Human Health

Epidemiology of Human Helminthic Infections

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Fish Parasites and Human Health

Epidemiology of Human Helminthic Infections

Judy A. Sakanari, Mike Moser, and Thomas L. Deardorff

1995

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California Sea Grant College
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DEDICATION

This publication is dedicated to the memory of our friend and colleague, Dr. Gerald D. Schmidt.

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SUMMARY

Like all living things, fish and other aquatic animals can carry parasites. This is entirely a natural occurrence. Most pose little public health concern. Some parasitic worms, or helminths, can, however, be transmitted to people who eat infected fish or fish by-products.

Worldwide, over 50 species of parasitic helminths–commonly known as roundworms, tapeworms, flukes, and thorny-headed worms–are known to cause human infections. They are found in fishes, crabs, crayfishes, snails, and bivalves, such as clams and oysters. Most of these parasitic infections are rare and cause only slight to moderate illness. Some infections are more prevalent, however, and may pose serious potential health hazards.

At one time, the majority of marine fish-borne infections occurred primarily in coastal regions, where seafood products were most likely to be consumed. However, continuing improvements in transportation, technology, and food handling now allow fresh fish to be shipped throughout the world.

Although the overall risk of human infection remains slight in developed countries like the United States, increased exploitation of marine resources, changes in dietary habits (especially the growing consumption of raw fish dishes like sushi and sashimi), and the tendency to reduce cooking times when preparing fish products, all increase our chances of becoming infected with these parasites.

Nonetheless, with the exercise of common sense and proper precautions, fish dishes will continue to be a safe and wholesome component of our diet.

INTRODUCTION

Fish is correctly regarded as a healthy component of the diet; it is an excellent source of protein and is low in saturated fats. In addition, most fish and seafood products are safe to eat. Just as there are risks to eating raw or undercooked meat, however, there are risks associated with eating raw, undercooked, pickled, and lightly or cold-smoked fish dishes.

Compared to the large-scale and indisputable public health hazards associated with natural toxins, bacteria, and viruses found in seafood, human infections by parasitic worms in edible fishes are comparatively rare. Risks do exist, however, and the consumer should be aware of them and know how to evaluate their potential consequences.

Acceptance of certain risks should be voluntary, as is true with other foods. For example, most consumers are aware that raw beef (steak tartare) may be the vector for the beef tapeworm or cause toxoplasmosis, just as they know that undercooked pork may transmit the pork tapeworm or cause trichinosis. When consumers choose to eat uncooked or undercooked beef or pork, they accept the risks. Similarly, there exist possible hazards to eating raw or undercooked seafood.

The parasitic worms we will describe use the aquatic food chain to complete their life cycles. Each link of this chain is host to a different stage of the parasite's life history.

We can become infected when we consume freshwater or marine fish or seafood containing an infective stage of the parasite. The infective stage is usually, but not always, a larval stage.

Over 50 species of parasitic worms are known to be transmitted to humans by aquatic animals such as fishes, crabs, crayfishes, snails, and bivalves (Sprent 1969; Williams and Jones 1976). The most commonly observed parasites in marine food fishes are roundworms called nematodes. Another common parasite of fishes, especially freshwater fish like trout and anadromous fish like salmon, are tapeworm larvae.

Thorough cooking and adequate freezing of seafoods are good preventive measures, but these practices are not always followed and are difficult to enforce. Further, interrupting the parasite's life cycle is difficult, and it may not be possible to improve sanitary conditions in some regions. Prevention and control of these parasitic diseases are probably best accomplished by educating consumers, health care workers, and those in seafood industries and government agencies as to the risks of eating raw and undercooked seafoods.

In this brief review, we will discuss how food habits and geographic location make certain groups of people more susceptible to worm infections. We also describe how improved methods of transportation, and even political decisions, have increased the chances of becoming infected with certain parasites. Most importantly, we will provide information on how to prevent infection.

LIFE CYCLES OF AQUATIC HELMINTHS

It is surprisingly difficult to define "parasite" precisely. In general, however, parasites are organisms that live in, or on, other organisms for much of their life cycle, deriving food from their host (or hosts).

The helminthic parasites we will be considering have evolved very complicated and fascinating life cycles. We will give specific, though simplified, examples throughout the text. In general, their life histories involve a common pattern in which an aquatic embryonic or larval stage is followed by one or more larval stages spent in intermediate hosts. Finally, the adult stage of the parasite is found in the definitive host, which is usually a different species from the intermediate hosts.

In this publication, we have illustrated the major hosts of the intermediate and adult stages of a number of common parasites in freshwater and marine fishes. We have described which life-history stages are potentially dangerous, the factors affecting transmission, and ways in which consumers can avoid becoming infected. We have also provided a table organized by the following taxonomic groups: Cestodes (tapeworms), Trematodes (flukes), Acanthocephalans (thorny-headed worms), and Nematodes (roundworms). This table summarizes information on the epidemiology, disease, diagnosis, and treatment of the infection.

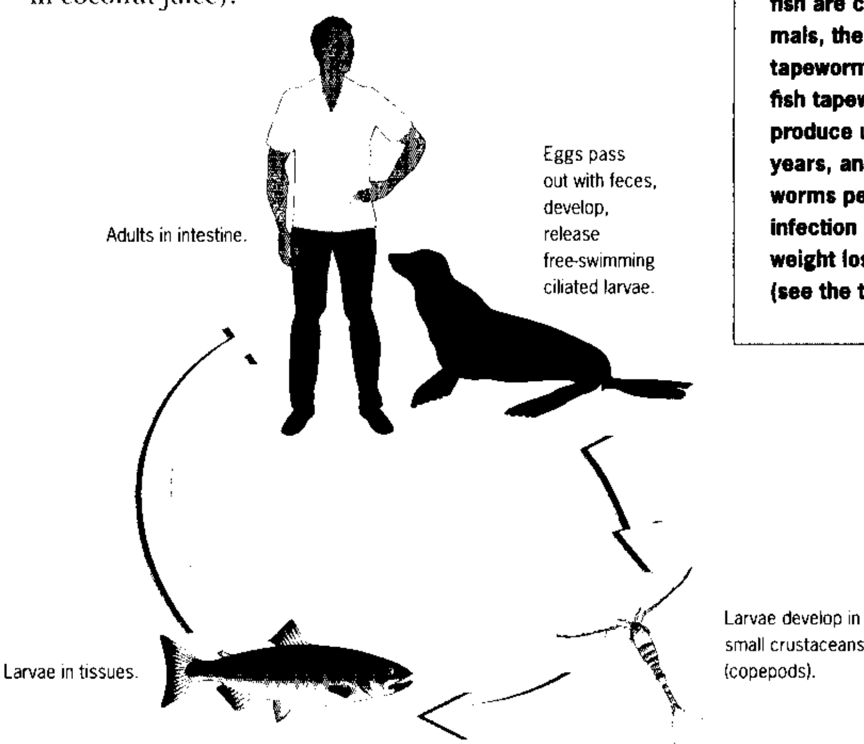
FACTORS AFFECTING TRANSMISSION

A number of very different factors affect the transmission of parasites. These include human eating habits and behaviors, particularly consumption of raw or "lightly cooked" seafood; the geographic distribution of host species; the possibility of incidental infection; and importation of seafood from around the world.

Uncooked Fish Dishes

Examples of raw fish dishes known to transmit parasitic helminths include the following:

- Japanese sushi (may have raw seafood with rice and seaweed)
- Japanese sashimi (thinly sliced raw fish)
- Japanese "salad" (raw fish, fresh lettuce, and soy sauce)
- Hawaiian *lomi lomi* (chopped salmon, bell peppers, and tomatoes)
- *Tako poki* (Japanese and Hawaiian squid or octopus dish)
- *Palu* (fish head and visceral organs ripened in a closed container)
- Dutch green herring (pickled herring)
- Scandinavian *gravlax* (cold-smoked salmon)
- Latin American *ceviche* (raw fish marinated in lime juice)
- Philippine *bagoong* (uncooked whole fish)
- Cantonese *yue-shan chuk* (sliced raw carp in soup)
- Pacific Island *poisson cru* (fish fillets marinated in coconut juice).



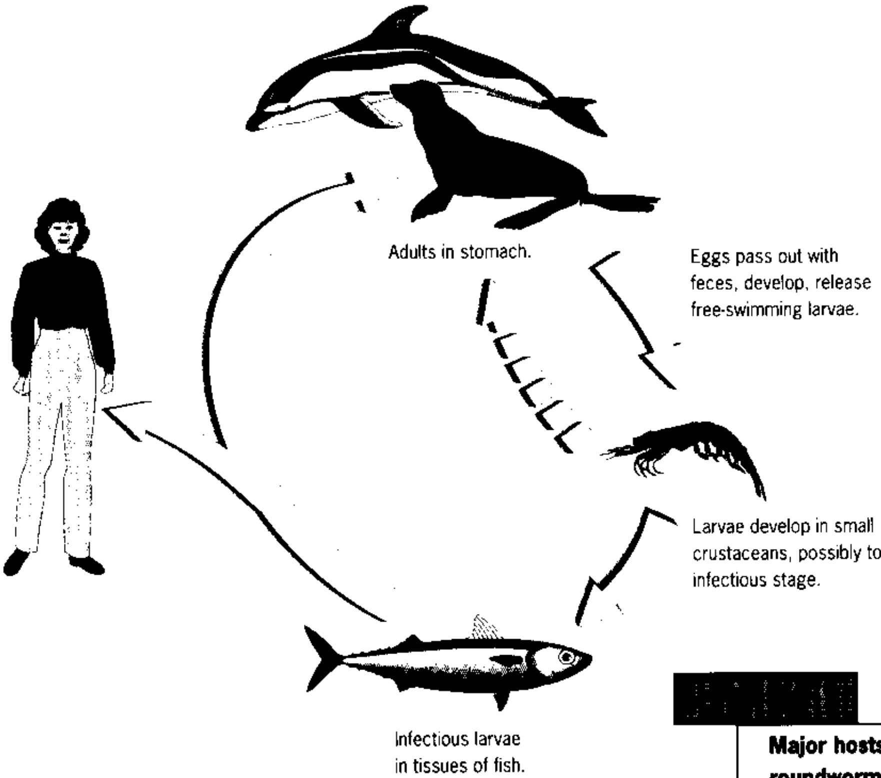
Eating Habits and Human Behavior

Social and behavioral patterns often play a significant role in the transmission of parasitic diseases. For example, in the United States, Jewish women once had a higher rate of infection of the broad fish tapeworm, *Diphyllobothrium latum*, than did people from other cultures (Desowitz 1981). This was because housewives unknowingly ingested the infective stage of the tapeworm while sampling the raw minced-fish in preparation for gefilte fish (Fig. 1).

Major hosts of the genus *Diphyllobothrium*. The life cycle of the broad fish tapeworm involves fish-eating mammals (such as humans, dogs, bears, or sea lions) as definitive hosts, and crustaceans and fishes as intermediate hosts.

Eggs are excreted by the mammal in its feces and enter the water. An embryo hatches from the egg, develops into a free-swimming ciliated larva, and is consumed by a minute crustacean called a copepod. The infected copepod is then eaten by a fish, and the larval parasite develops in the muscle or viscera of the fish. This is the infective stage to mammals.

When a suitable predatory fish consumes an infected fish, it will become infected. If infected fish are consumed by humans or other mammals, the larval parasite matures into an adult tapeworm in the host's intestine. An adult broad fish tapeworm may grow to 10 meters in length, produce up to a million eggs a day, live 25 years, and reach infection intensities of 200 worms per person. A human with a moderate infection might experience nausea, vomiting, weight loss, and a number of other symptoms (see the table).



Major hosts of *Anisakis simplex*.* These roundworms, sometimes called "herring worms" or "seal worms," are stomach parasites of marine mammals such as dolphins and sea lions. The intensity of infection may be enormous, and stomach lesions filled with worms have been reported. One scientist reported more than 10,000 adult roundworms in the stomach of the gray seal (Brattey 1989).

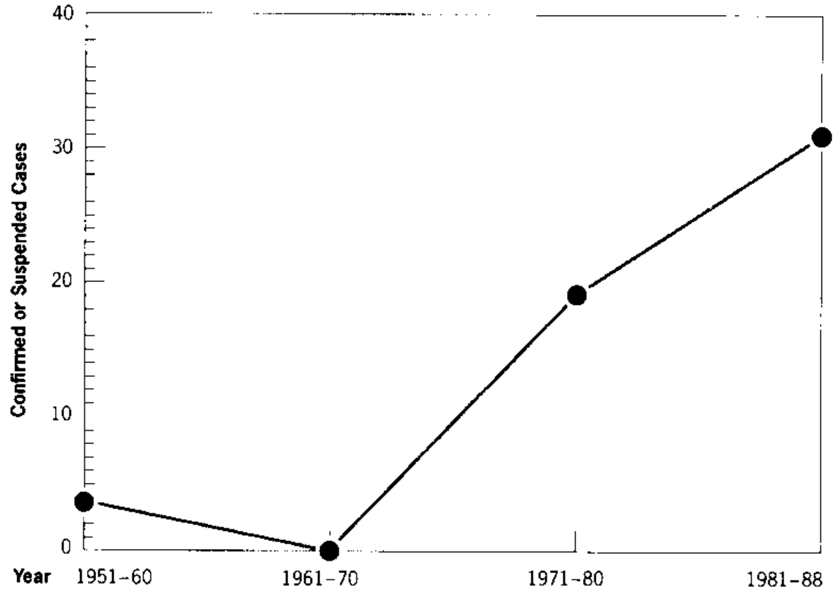
Eggs pass into the seawater with the mammal's feces and develop into first- and second-stage larvae within the shell. Free-swimming larvae emerge from the egg to infect small crustaceans such as krill and certain amphipods or juvenile mysids, which thus serve as intermediate hosts. If the infected crustacean is eaten by a suitable fish or squid, the larvae will molt into a third stage, which is the infective stage to marine mammals and humans.

When a predatory fish consumes an infected fish or squid, the third-stage larvae become established in that host. Serial infections (that is, infections that occur when one fish eats another and acquires its parasites) can lead to high intensities of infection in older or strictly fish-eating fish. The life cycle is completed when these intermediate hosts are consumed, and the fourth-stage matures into an adult in the stomach of a marine mammal. Humans represent a dead-end in the life cycle of these nematodes (see the table, and Oshima 1987; Sakanari and McKerrow 1989.)

*The closely related nematode *Pseudoterranova decipiens* (=*Ascaris d.*, *Porrocaecum d.*, *Terranova d.*, *Phocanema d.*) has a similar life cycle.

Another example of how social and cultural habits can contribute to the transmission of aquatic parasitic infections is the current trend of eating raw or "lightly cooked" seafoods. This trend has created a notable increase in the incidence of a parasitic disease known as anisakiasis, which is caused by larval anisakid nematodes, sometimes called "herring worms" or "seal worms" (Fig. 2). In the United States, for example, the number of cases of anisakiasis (suspected and confirmed) rose from 4 between 1951 and 1960 to 31 between 1981 and 1988 (Fig. 3). In Japan, where raw fish and squid are an integral part of the diet, the number of cases exceeds 1,000 per year (Oshima and Kliks 1986).

The recent increase in reported cases of anisakiasis worldwide may well reflect advances in diagnostic technology (for example, endoscopy, radiology, and immunology), as well as increased physician awareness. Explosive growth in marine mammal populations in recent years may also be a contributing factor. Still another explanation for the increase may be that we are now consuming many different kinds of fishes than we did.



Suspected and confirmed cases of anisakiasis in the United States from 1951 to 1988 (from Deardorff and Overstreet 1990). These data are based primarily on reports in scientific literature or personal knowledge; the actual number of occurrences may well have been higher.

An uncommon example of the link between human behavior and parasitic infection was provided by the case of a 17-year-old male who was stricken with severe abdominal pain (Eberhard et al. 1989). During surgery, two red nematodes of the genus *Eustrongylides* (Fig. 4) were removed from his body cavity. The larvae of this worm are found in fresh- and brackish-water fishes, and it was later discovered that the patient had a history of swallowing minnows and other live bait while fishing.

Similarly, three cases of peritonitis in Maryland were traced to the peculiar habits of two tavern patrons, who gulped live bait while drinking beer, and a bored fisherman who swallowed live minnows. Two of these patients required immediate abdominal surgery: a pair of worms was recovered from each.

In another case, a New York City resident who had eaten sashimi earlier in the day was admitted to the hospital with a preoperative diagnosis of appendicitis (Wittner et al. 1989). During surgery, it was observed that the patient's appendix was normal, but a 42-mm worm (identified as a larval *Eustrongylides*) migrated out of his abdomen.

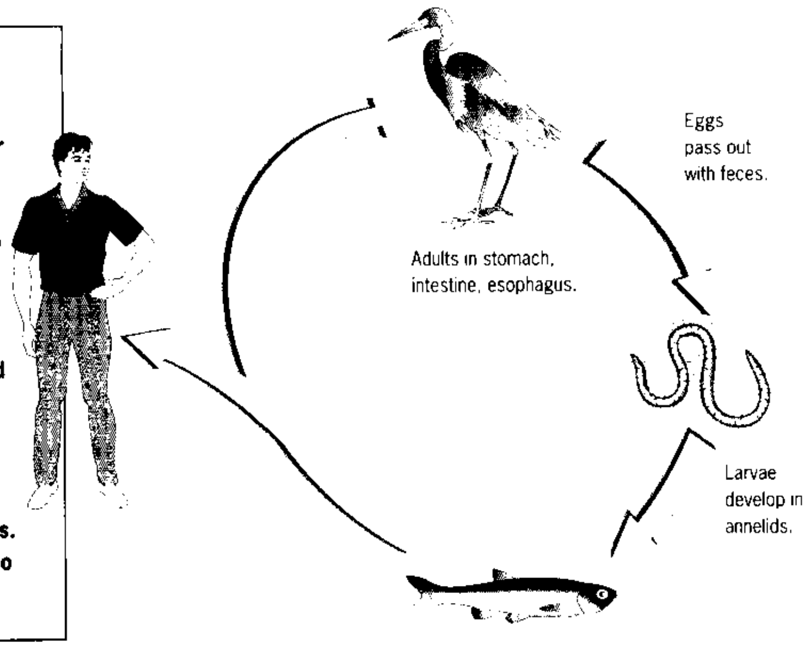
Note that all the above cases occurred in the Northeast. It has been suggested that the high prevalence of the nematode *Eustrongylides* in northeastern fishes may account for these human infections (Eberhard et al. 1989). One study found *Eustrongylides* in 48% of minnows near Baltimore, Maryland.

A closely related species of roundworm, *Dioctophyma renale*, is also known to infect humans; its life cycle is similar to that depicted in Figure 4, except that its definitive hosts are fish-eating mammals, such as minks and raccoons. Males may grow to 200-mm long and 6-mm wide and females to 1000 mm by 12 mm. Eggs pass out in the urine of the definitive mammalian hosts and develop into infectious larvae in the oligochaete worm and encyst in fish, crustaceans, or amphibian hosts. When fourth-stage larvae are consumed by a mammal, they migrate from the intestine to the kidney.

There have been three reported human cases of *D. renale* infections, two in the United States and one in Thailand (Gutierrez, Cohen, and Machicao 1989). (In each case, the infections were subcutaneous.) The large, red larvae are easily detected in the flesh of fishes. Infected fishes may appear lumpy, have flesh lesions resulting from migrating worms, or have encysted larvae in the body cavity–factors that can lessen the aesthetic value of the catch. Cooling the fish, however, may prevent larvae from migrating into the fillets (Deardorff and Overstreet 1990).

FIGURE 4

Major hosts of the genus *Eustrongylides*. The adult worm of the genus *Eustrongylides* infects the intestinal tract of shorebirds like herons and mergansers. Eggs pass into water with the bird's feces, and first-stage larvae develop in the eggs. The eggs are eaten by worms (oligochaete annelids) and continue to develop inside the oligochaete. For at least one species of this parasite, *Eustrongylides tubifex*, fishes are necessary intermediate hosts, and development continues to the third and fourth stage. Larval worms may also encyst in reptiles and amphibians. Adult worms mature and embed in the stomach, intestine, and esophagus of fish-eating shorebirds, and have caused mass mortalities. Infected fish, reptiles, or amphibians may also pass the parasites to humans.



Recent cases of human infection in Mexico have underscored the need for caution when one species of fish is substituted for another in raw fish dishes. A case of gnathostomiasis, caused by the larval stage of the spirurid nematode *Gnathostoma spinigerum* (Fig. 5), was reported when marinated tilapia, a freshwater fish, was substituted for a more expensive marine fish normally used in *ceviche*. Although marinating fish fillets in lemon juice changes their texture and appearance, it has little affect on many parasites.

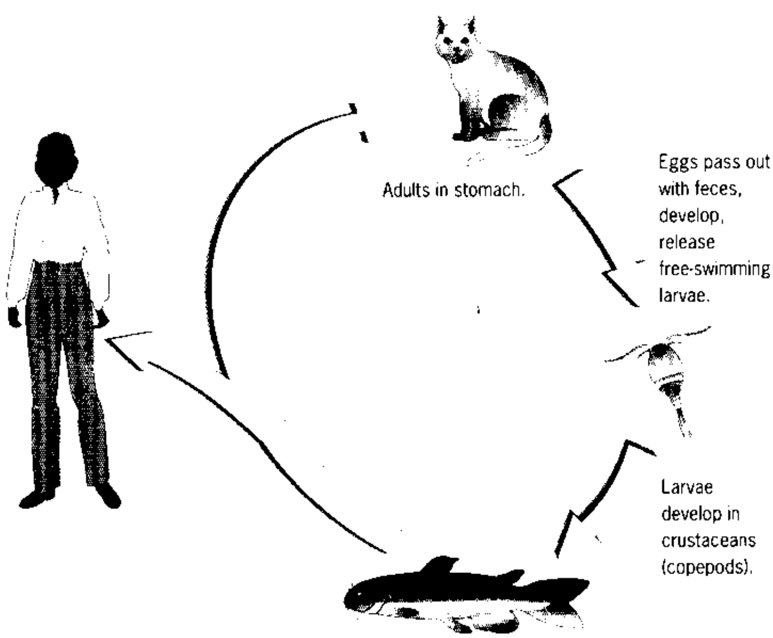


FIGURE 5

Major hosts of *Gnathostoma spinigerum*. The third-stage larvae of this roundworm can cause gnathostomiasis, or "creeping eruption," as well as various neurological disorders in humans. Adult worms, which range from 30 to 50 mm in length, are found embedded in the stomach of numerous domestic and wild carnivores such as cats, tigers, and dogs. Eggs pass into the water with feces, and first-stage, free-swimming larvae are released. When consumed by minute crustaceans called copepods, the larva molts and becomes a second-stage larva. If an infected copepod is eaten by a suitable vertebrate, the infective third-stage larva develops. Acceptable intermediate hosts include fishes, amphibians, birds (including ducks and chickens), and reptiles. The life cycle is completed when the infected intermediate host is eaten by the wild carnivore. In humans, the migrations of the infective third-stage larvae can cause both visceral and cutaneous *larva migrans*. In addition to other tissue and organ damage, the brain and eye can be affected. The larvae, up to 10 mm in length, can live for many years in humans (Harinasuta and Bunnag 1989).

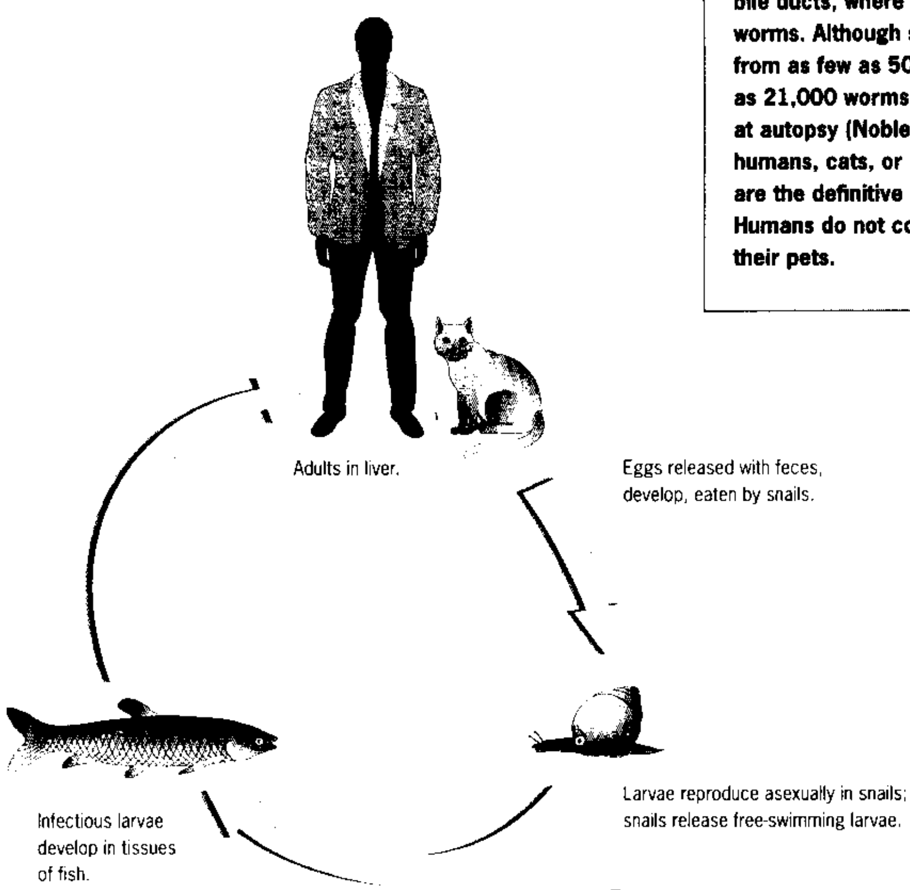
In developing countries where human feces are used to fertilize freshwater fish farms and where fishes are not sufficiently salted, cooked, dried, smoked, or pickled, parasitic infections are common. In mainland China, for example, it is estimated that there are 20 million people infected by the liver fluke *Opisthorchis sinensis*, and there may be 4.5 million cases in Korea (Bunnag and Harinasuta 1989; see Fig. 6). The prevalence of infection in Hong Kong is estimated to be 14%, and may reach 80% in rural areas (Bogitsh and Cheng 1990). Definitive hosts of *O. sinensis* include camels, tigers, cats, dogs and other canines, and minks; in some areas, 100% of these animals are infected. Humans may also be definitive hosts.

Flukes similar to *O. sinensis* are *O. felineus*, *O. viverrini*, and *Amphimerus pseudofelineus*. All differ from *O. sinensis* in the species of snail used as first intermediate host. In Europe, where *O. felineus* is primarily a cat parasite and more prevalent than *O. sinensis*, several million human cases are estimated to occur. Hosts of *O. viverrini* include domestic and wild carnivores. Thailand is estimated to have 7 million human cases, and some villages have a 90% infection rate (Bunnag and Harinasuta, 1989). In addition to humans, *A. pseudofelineus* infects North American cats and wild carnivores (Schmidt and Roberts 1985).

FIGURE 6

Major hosts of *Opisthorchis (=Clonorchis) sinensis*. This parasite is also called the Chinese liver fluke. Adult worms reside in the liver of definitive hosts such as humans and release their eggs, via the bile ducts, into the host's intestine. An adult worm can produce up to 4,000 eggs per day (Schmidt and Roberts 1985) and may live over 30 years (Bunnag and Harinasuta 1989). Eggs passed out with feces reach freshwater ponds, where they are consumed by a suitable aquatic snail. After several generations of asexual reproduction in the snail, larvae are released (Schmidt and Roberts 1985).

Upon contacting a fish, a larva embeds itself under the scales or in the tissue of the fish and encysts. An infected fish may have up to 1,000 encysted larvae. When infected fish are consumed by a human or other appropriate host, these larval flukes are released in the small intestine and migrate to the liver via the bile ducts, where they develop into adult worms. Although severe symptoms can result from as few as 500 to 1,000 worms, as many as 21,000 worms were seen in one individual at autopsy (Noble et al. 1989). Note that humans, cats, or other fish-eating mammals are the definitive hosts of this parasite. Humans do not contract the infection from their pets.



Geographic Distribution of Hosts

In nature, parasites are restricted to certain geographic areas by the availability of specific intermediate and definitive hosts. Hence, particular parasitic infections only occur in certain geographic locations. For example, sea lions, which are the definitive hosts for the broad fish tapeworm (*Diphyllobothrium pacificum*, see Fig. 1), inhabit areas along the Pacific coast of Peru, but not the Gulf of Mexico. The life cycle of this parasite is therefore maintained along the coast of Peru, not Panama. This is the reason why Peruvians become infected with the broad fish tapeworm but Panamanians do not, even though both cultures eat the same raw fish dish (Deardorff and Overstreet 1990).

Tourists and immigrants represent one potential vehicle for introducing a parasite into a new area, but only if there are appropriate hosts. For example, the broad fish tapeworm (*D. latum*) was introduced into the United States by European immigrants in the middle of the 19th century (Deardorff and Overstreet 1990). It became established because proper conditions and suitable intermediate hosts (copepods and freshwater fishes) and definitive hosts (bears) existed in the lake regions of the central United States.

The present-day incidence of the broad fish tapeworm in the United States is uncertain. However, based on indirect evidence, the Centers for Disease Control has reported an upward trend (Deardorff and Overstreet 1990). In some North American lakes, 50% to 70% of the northern and wall-eyed pike are hosts of the infective stage of this parasite (Bogitsch and Cheng 1990).

The British Isles, Argentina, Australia, Venezuela, and The Federal Republic of Madagascar also have reported cases of tapeworm infection as a result of importation of parasites by travelers (von Bonsdorff and Bylund 1982).

As we have seen, marine mammals are common hosts to parasitic worms. If a parasite is capable of infecting a marine mammal, it may also infect humans. Some marine mammal parasites known to infect humans include the genera *Diphyllobothrium* (Fig. 1), *Diplogonoporus* (see table), and *Anisakis*, as well as the species *Pseudoterranova decipiens* (Fig. 2), *Corynosoma strumosum*, *Acanthocephalus rauschi*, and *Bolbosoma* species (Fig. 7).

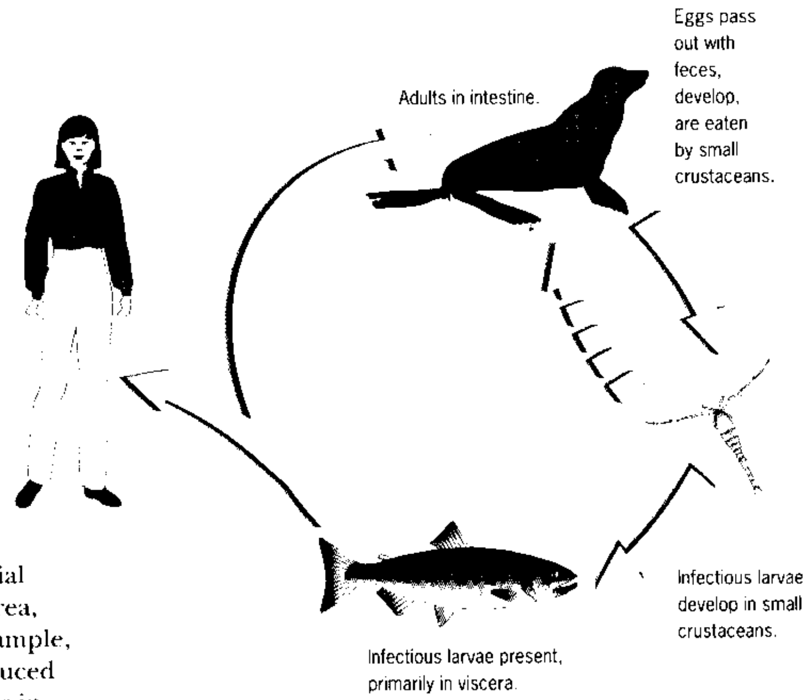


FIGURE 7

Major hosts of *Corynosoma strumosum*. Adult acanthocephalans (or "thorny-headed" worms) infect the intestines of pinnipeds, such as sea lions. Eggs are released with feces into seawater and eaten by minute crustaceans. The infected crustacean may be eaten by a pinniped; if so, the parasite develops into an adult. If the crustacean is consumed by a host such as a fish, larvae will become established in the fish, mostly in its internal organs. Other hosts include dogs, otters, and birds.

***C. strumosum* and *Acanthocephalus rauschi* have been reported from Alaskan Eskimos who ate infected salmon. Larvae in fish are found primarily in the internal organs rather than the flesh and because few individuals eat raw fish viscera, the number of infections is low (Schmidt and Roberts 1985; Deardorff and Overstreet 1990). Another example of thorny-headed worms infecting humans is *Bolbosoma* sp., a closely related species, which caused serious intestinal problems in two Japanese patients. This worm parasitizes aquatic animals found in American waters (Deardorff and Overstreet 1990).**

Because the life cycle of these parasites begins and ends in marine mammals, it is logical that fishes would have a greater opportunity of becoming infected and possess increased worm burdens in areas where marine mammals are abundant. Surveys conducted for ascaridoid nematodes along the Atlantic coast (Cheng 1976; Jackson et al. 1978), the Gulf of Mexico coast (Norris and Overstreet 1976; Deardorff and Overstreet 1981), the coastline of the Pacific Northwest (Myers 1979), and the waters near the Hawaiian Islands (Deardorff et al. 1982) confirmed this association. The fishes of the U.S. Pacific coast had a greater prevalence (percentage of population infected) and intensity (number of parasites per infected host) of potentially infective worms than did fishes from the other areas. As might be expected, fish along the southeastern coast of the United States did not show heavy infections with marine mammal parasites. However, both the prevalence and intensity of infection increase along the northeastern coastline of the United States and Canada, where there are large populations of harbor and gray seals.

Preliminary findings of a survey of Pacific herring (*Clupea pallasi*) from the waters along the Pacific Northwest of the United States showed that all of the herring caught in Puget Sound, Washington, and 99% of those from Prince William Sound, Alaska, were infected with juvenile anisakid nematodes (Adams et al. 1990). The average number of worms

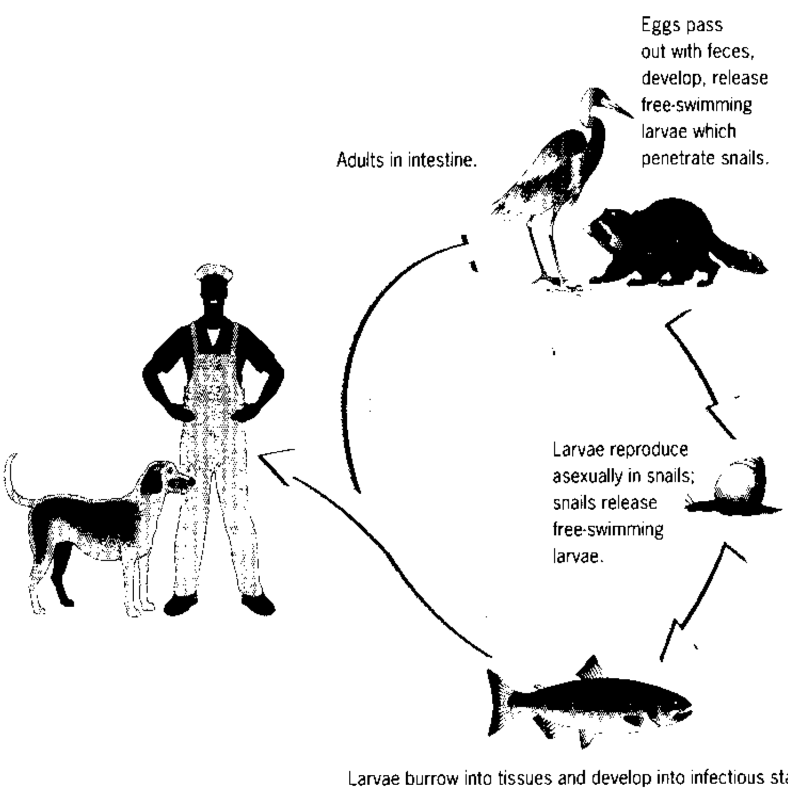


FIGURE 8

Major hosts of the species *Nanophyetus salmincola*. This small fluke and its symbiotic rickettsia, *Neorickettsiae helminthoeca*, are the cause of "salmon poisoning" in dogs and other canines. If untreated, the rickettsia (not the parasite alone) will kill up to 90% of infected canines. In humans, this infection probably does not involve the rickettsia or cause fatalities.

Eggs containing the flukes (which are, in turn, infected with the rickettsia) are released into the water with feces of fish-eating birds and mammals. Eggs develop and hatch, and the free-swimming larvae penetrate a freshwater snail, *Juga plicifera*, whose distribution limits the area of infection. In the northwestern United States, seasonal prevalence of infection in snails can reach 50% (Eastburn, Fritsche, and Terhune 1987). After asexual reproduction in the snail, free-swimming larvae are released. This stage of the parasite can penetrate numerous species of fishes, notably juvenile (i.e., freshwater) salmonids and the Pacific salamander.

The parasite then encysts in most tissues, but predominantly in the fins, muscles, and kidneys of the fish. Heavy infections can be fatal to young fish. Salmonids retain their infections during their oceanic phase and are infective upon returning to fresh water. If canines eat infected fish, the symbiotic rickettsia will cause "salmon poisoning." Adult flukes that are not infected with the rickettsia cause little disease in canines. Birds, raccoons, and spotted skunks serve as the main natural definitive hosts (Eastburn, Fritsche, and Terhune 1987).

In human infections, the flukes cause irritation of the mucosa of the intestine. In eastern Siberia, 98% of humans may be infected. It is believed that the onset of clinical symptoms of infection requires at least 500 adult flukes. The increase in reported cases of *N. salmincola* in the western coastal states of the United States is most likely the result of the recent popularity of consuming incompletely cooked or smoked salmonids, or fresh fish eggs (Deardorff and Overstreet 1990).

per fish was 27 and 20, respectively. These results correlate with the geographic distribution, as well as the increase in population of marine mammals (especially sea lions) in the Pacific Northwest (McKerrow et al. 1988). Correspondingly, approximately 90% of all U.S. cases of human anisakiasis have occurred along the West Coast, Alaska, and Hawaii.

Incidental Infections

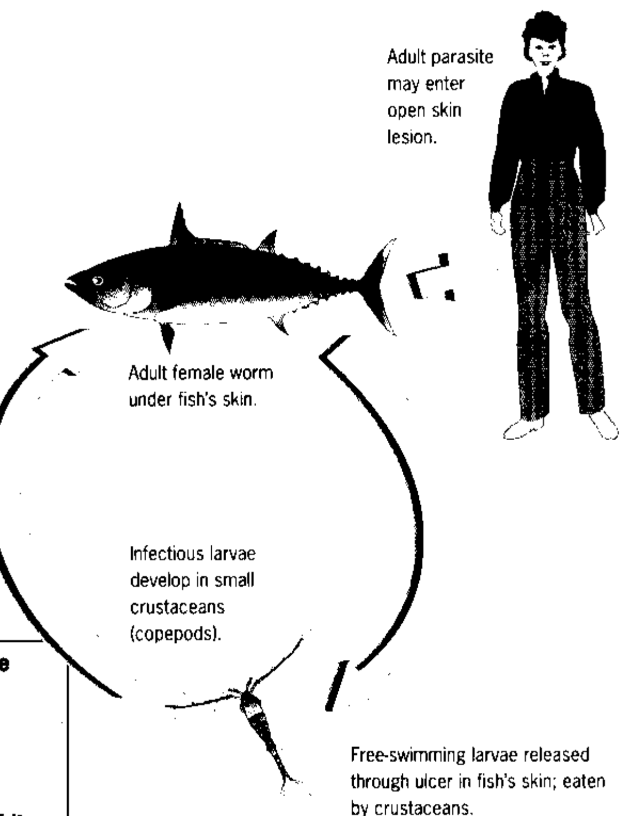
Occasionally parasites infect humans in rather unusual ways. In one case (Kikuchi et al. 1981), a 40-year-old Japanese patient complained of pharyngeal pain, which began about 3 hours after he had eaten raw squid (*Ommastrephes solani pacificus*). During examination, a larval tapeworm (*Nybelinia surmenicola*) was found firmly anchored by its tentacles to one of his tonsils. This was a highly unusual infection since the hooked tentacles of this parasite are not normally extruded in the larval stage.

There have also been reports of cases which resulted from handling infected seafood. In one, involving the fluke *Nanophyetus salmincola* (Fig. 8), human transmission occurred during the handling of freshly killed coho salmon (*Oncorhynchus kisutch*). It is likely that the patient ingested the larval parasite when he simultaneously cleaned fish and smoked cigarettes (Harrell and Deardorff 1990). The second incident of contact transmission by a marine parasite involved an adult worm (Deardorff et al. 1986) and represented the first known case of an adult parasitic nematode entering the human body through an open lesion. The worm, *Philometra* sp. (Fig. 9), invaded a puncture wound in a fisherman's hand while he was filleting an infected fish (*Caranx melampygus*) from Hawaii. This accidental infection represents a previously unrecognized risk in handling uncooked infected fish.

Importation

Today, improved modes of transportation, advanced technology, and refined methods of food handling allow fresh fishes to be shipped throughout the world. In 1987, for example, 65% of the seafood consumed in the United States was imported from 141 countries. Canada supplies approximately 20% of U.S. demand for seafood, Europe about 12%, and Thailand 8%.

Some seafoods imported into the United States harbor parasites that are infectious to humans. For example, scallops may be infected with larvae of the gnathostome roundworm *Echinocephalus sinensis*, and live freshwater crabs with encysted larvae of the Oriental lung fluke *Paragonimus westermani* (Deardorff and Overstreet 1990). The broad fish tapeworm was introduced into several countries of South America during artificial stocking of fishes into lakes (Williams and Ballard 1982).



Major hosts of *Philometra* sp. Adult worms of this nematode are found in fish. The adult female parasites release free-swimming, first-stage larvae into the water through ulcers in the fish's skin. In the case of the parasitic species *P. oncorhynchi*, the female worms themselves are released with the host's eggs and burst, releasing their larvae (Schmidt and Roberts 1985). The larvae are eaten by copepods and develop to infective third-stage larvae. When the copepods are consumed by a suitable fish, the larvae molt, mature into adults, and mate; the male dies and the female migrates to the definitive site. Humans are accidentally infected when the adult worms move into an open wound.

PREVENTION

Understanding the Degree of Risk

Admittedly, the risk of becoming infected with a marine fish parasite is extremely low, and most parasites cause only slight to moderate illness.

It is difficult to *quantify* the degree of risk, however, primarily because most cases go unreported. There is no national database for incidences of illness caused by fish parasites. In addition, few cases are documented in the literature or correctly diagnosed. In one study of 92 cases of anisakiasis in Japan, for example, over 60% were misdiagnosed preoperatively as appendicitis, acute abdomen, gastric tumor or cancer, ileitis, cholecystitis, diverticulitis, tuberculous peritonitis, or cancer of the pancreas. For these reasons, although approximately 50 cases of anisakiasis were reported in the United States between 1958 and 1988 (Sakanari and McKerrow 1989), we believe this is only the tip of the iceberg. Fish species implicated include Pacific salmon, rockfish, herring, cod, halibut, mackerel, and squid (Deardorff and Throm 1988; Hauck 1977; Oshima 1987).

Though the risk of becoming infected with helminthic parasites is low, it can be completely eliminated by using commercially frozen or canned fish products or by cooking fish thoroughly.

Those who choose to accept the risks associated with consuming raw fish should at a minimum ask whether or not the product has been commercially frozen and, perhaps, what kind of fish they are consuming.

Cooking

Parasites do not present a health concern when fish is thoroughly cooked. Fish should be cooked so that the *internal* temperature of all parts of the meat is at least 63°C (145°F) for at least 15 seconds. Normal cooking procedures generally exceed this temperature. If a fish thermometer is not available, the fish should be cooked until it loses its translucency and flakes easily with a fork.

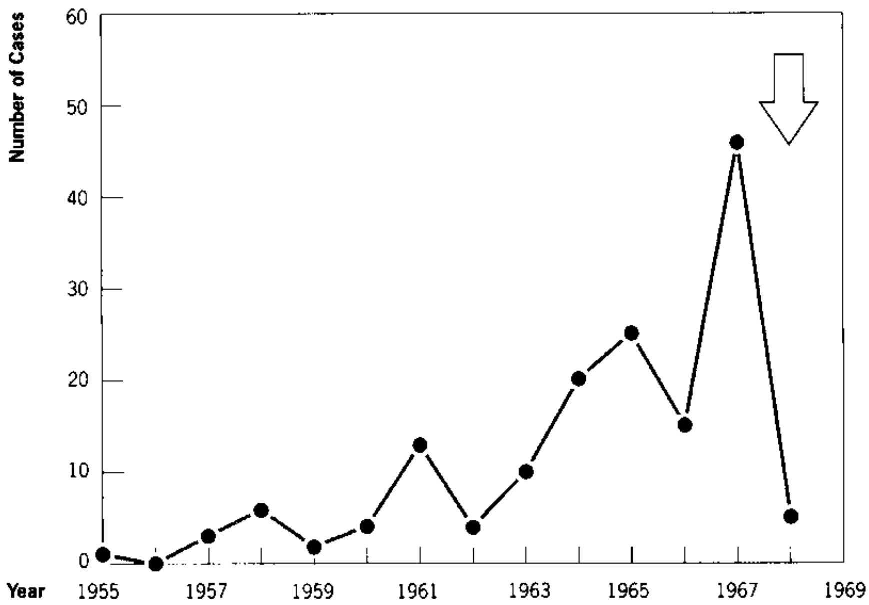
Additional precautions are necessary if fish is cooked in the microwave because of the uneven distribution of heat. The U.S. Public Health Service recommends that raw animal foods (including fish) cooked in a microwave oven should be:

- rotated or stirred throughout or midway during cooking to compensate for uneven distribution of heat;
- covered to retain surface moisture;
- heated an additional 14°C (25°F)–that is, to 77°C (170°F)–for at least 15 seconds to compensate for shorter cooking times; and
- allowed to stand covered for 2 minutes after cooking to obtain temperature equilibrium.

Freezing

Commercial freezing is also a good way to kill parasites in fish. (Home freezers vary in holding temperature and may not achieve necessary temperatures to kill parasites.)

Some countries have regulations related to commercial freezing of fish products. In the Netherlands, for example, there are restrictions on the consumption of raw herring, and fresh herring must be frozen to a temperature of at least -20°C (-4°F) for 24 hours. The effectiveness of the Netherlands' "Green Herring Laws" is clear from Figure 10, which illustrates the number of confirmed cases of anisakiasis in that country from 1955 to 1968. Note the trend after 1967, the year in which legislation was enacted. The World Health Organization credits these laws for the disappearance of human anisakiasis from a country that formerly had approximately 300 cases per year (World Health Organization 1988). The European Economic Community subsequently followed the freezing regulations of the Netherlands (Eurofish Report 1987).



Number of confirmed cases of anisakiasis in the Netherlands from 1955 through 1968. Arrow indicates the year legislative action against this infection was instituted. The regulations, known as "The Green Herring Laws," require fresh herring to be frozen prior to release to the public (modified from Ruitenberg 1970).

On the other hand, there are no regulations regarding freezing of fish products in Japan, though it is common practice to use frozen fish in Japan and other countries where raw fish dishes are traditional. Japan's National Health Institute recommends freezing fish to -20°C (-4°F) for several hours when preparing raw fish, or avoiding fish that are susceptible to parasites (Price and Tom 1990). The enormous diversity of fishes and invertebrates known to harbor potentially infective parasites does make control difficult, however (Oshima 1972). Japanese chefs, familiar with the risks of parasites in fish, freeze Pacific salmonids to kill potentially invasive helminths before serving raw dishes (Deardorff and Overstreet 1990). Preparation and consumption of raw fish dishes in the home environment most likely account for the approximately 1,000 episodes of anisakiasis reported every year in Japan (Oshima and Kliks 1986; Oshima 1987).

In the United States, commercial freezing has been recommended by the U.S. Food and Drug Administration (FDA) to state and local regulatory agencies with primary responsibility for inspecting retail food establishments. The FDA recommends that before service or sale in ready-to-eat form, raw, marinated, or partially cooked fish, other than molluscan shellfish, should be frozen throughout to a temperature of:

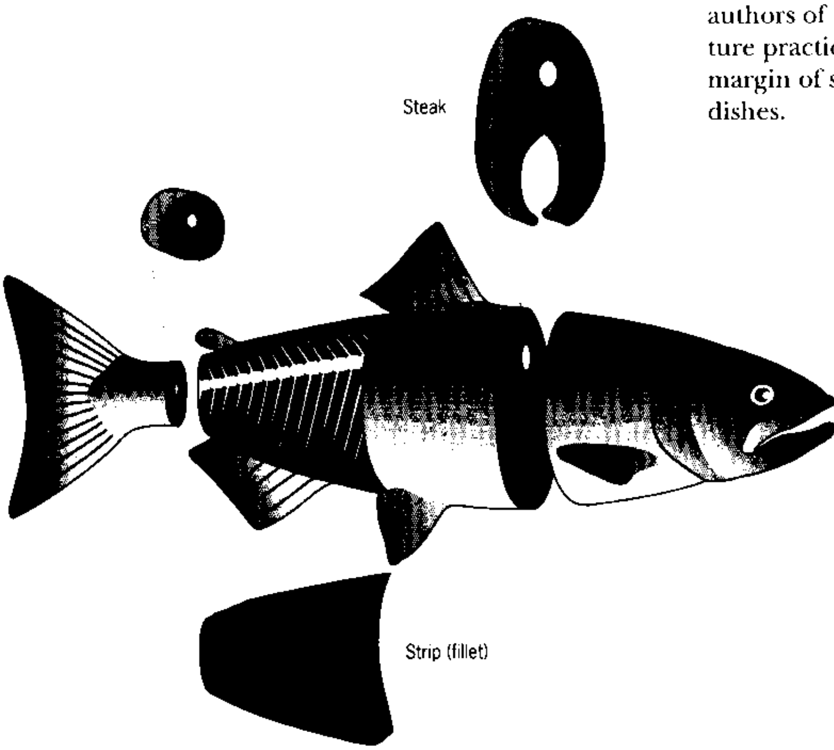
- -20°C (-4°F) or below for 7 days in a freezer; or
- -35°C (-31°F) or below for 15 hours in a blast freezer.

The Hawaiian tuna industry has requested an exemption for yellowfin tuna (ahi) from pending FDA regulations. The industry claims that freezing will diminish the quality of the product, and hence depress this market. It also claims that the sections of tuna used for sashimi are worm-free (Kaneko 1990; Deardorff, Fukumura, and Kayes 1991).

Removing Worms

Some portions of the edible musculature of some fishes harbor more worms than do others. One comparison of salmon steaks with strips (fillets) determined that steaks contained more of the infective stage larvae of *Anisakis simplex* (Deardorff and Throm 1988). This is probably because salmon steaks are cut from the region of the fish that includes the "belly-flap," the area associated with the abdominal cavity (Fig. 11).

Diagram of salmon showing location and shape of a standard steak and strip (or fillet). The horseshoe-shaped steak harbors more larval *Anisakis simplex* than the strip. It is even less common for a circular-shaped steak to contain worms (adapted from Deardorff and Throm 1988).



The second-stage larval anisakid worm is released from its crustacean host during digestion in the stomach of a salmon, penetrates the salmon's gut wall, and migrates to the muscle. It is possible that because the larval worms encounter abdominal muscle first, they encapsulate there in greater numbers. Thus, salmon fillets likely have fewer worms because most of the tissue in a fillet is not associated with the abdominal cavity, and the commercial filleting process generally leaves the rib bones and associated tissues on the carcass of the fish.

Consumers should be made aware that if they find a parasite in a fish they should remove it, examine the fish for others, and cook the fish thoroughly. They may also wish to notify the store where they bought the fish so that remaining fish may be carefully inspected. Some stores may also allow consumers to return or exchange unused portions (Price and Tom 1990).

Interrupting the Parasite's Life Cycle

Salmon aquaculture in Puget Sound, Washington, provides an example of suppressing a parasite's life cycle. One study found that salmon held in net-pens and fed commercially prepared salmon diets had no parasites of public health importance (Deardorff and Kent 1989). In contrast, over 90% of the native salmon, which fed on naturally available foods such as herring, were infected with *Diphyllobothrium sp.*, *Nanophyetus salmincola*, and *Anisakis simplex*. The authors of the study concluded that these aquaculture practices offer an increased, but not certain, margin of safety for those who prefer raw salmon dishes.

POLITICS AND PARASITISM

The relationship between the growing populations of marine mammals and human parasitic infections is becoming more apparent. Since the establishment of the Marine Mammal Protection Act in 1972, the numbers of some marine mammals have rapidly increased worldwide. Marine mammal populations along the West Coast of the United States, for example, are reported to be increasing at a rate of 18,000 animals per year (Save Our Seafood 1987).

Norwegian hooded and harp seal stocks have also increased by at least 300,000, following a ban on killing these animals. In order to protect the Norwegian cod fishery (Seal Bite 1987), Norway now manages the marine mammals along its shoreline as it does any other resource.

Canadian fishermen have expressed concern over the population explosion of harbor and gray seals along the northeastern coastline of North America and the increased prevalence and intensity of the larval anisakid nematode *Pseudoterranova decipiens* (commonly called the "cod worm") in Atlantic cod and in other commercially important fishes (Chandra and Khan 1988). Canadian researchers report approximately two worms per kilo of cod. The increase in parasite burden has cost Canada's cod industry and consumers substantial sums of money (because of the costs associated with removing worms from fillets by candling and lost sales to consumers). The industry estimates that about $50 million is spent each year to reduce the numbers of cod worms in commercially important fish fillets. (On the other hand, worm removal has become an important source of employment in eastern Canada.) The cod worm also has been found in other ground fish, such as sole (Family: Soleidae), haddock (*Melanogrammus aeglefinus*), and American plaice (*Hippoglossoides platessoides*).

Because gray seals serve as a definitive host for the parasites, fishes in areas closest to large populations of these mammals have the highest infections. For example, Sable Island, Nova Scotia, is the breeding area for approximately 70,000 gray seals. As expected, fishes offshore this island have high worm burdens. Canadian fishermen, the east coast fishing industry, and the Royal Commission on Sealing, all favor a "cull" (random killing) to decrease the total population of seals, thus reducing the numbers of parasite eggs released into the environment.

It has been suggested that the time has come to manage certain marine mammal populations just as we control several other species of wildlife. This, obviously, is not a popular platform. Several groups in Canada, for example, disagreed with the proposed cull program because they did not believe that killing gray seals would reduce the worm problem. A single infected seal, they noted, could spew thousands of fertilized nematode eggs into the marine environment daily. As a result, Canada extended its ban on the killing of gray seals off its eastern coast, a decision not embraced by Canadian fishing fleets. There is a moratorium presently in effect while new ideas for worm reduction are considered; these include deworming or vaccinating gray seals.

Clearly, the presence or absence of large marine mammal populations serves as a barometer by which to predict the presence or absence of some worms that are of potential human health significance.

PUBLIC EDUCATION

Educating consumers, physicians, and seafood industry and government personnel about the hazards of aquatic parasites appears to be an excellent safeguard against infections. Consumers have the right to know both the benefits and the potential risks of handling and eating seafoods.

But consumers cannot assume total responsibility for the quality and safety of seafoods, nor be aware of changes that affect processing in other countries. The seafood industry, too, must be aware of potential problems and employ appropriate methods for removing or killing parasites. In addition, we believe that governmental regulatory agencies should inform consumers of the risks, or discourage the consumption of such raw dishes as sushi, sashimi, *ceviche,* and *lomi lomi* unless appropriate commercial freezing techniques have been applied.

The medical community also needs to become more aware of human infections by parasites acquired from improperly prepared seafood dishes. Fortunately, most parasitic infections are treatable. The table that follows lists drugs and appropriate regimens for the treatment of various fish-borne infections. Not all diseases, however, are treatable with antihelmintics, and not all antiparasitic drugs are available.

In addition, many species of parasites known by specialists to be potential health risks are unknown to the medical community and public. For example, the intestinal fluke *Phagicola* sp., widespread in freshwater fishes in the southeastern United States, is a potential pathogen, though it has not been reported in humans to date. This may be the result of the lack of *bona fide* infections or the result of misdiagnoses.

Parasitic infections can easily evoke unwarranted fears in consumers. When vivid pictures of herring parasites were shown on German TV, seafood sales there suffered an immediate 70% decline from which they took months to rebound. In contrast, a similar program aired in France with no impact to the seafood industry. The lack of consumer backlash was attributed to the fact that French seafood dealers take the time to properly educate their customers. The United States and Canada have also seen few negative results following media reports on marine food-borne infections.

Educational efforts must be made on a continuing basis. Constant reminders of potential hazards are necessary to reinforce proper seafood-handling practices, especially since consumers continue to be introduced to new seafood products. In addition, as we continue to exploit the resources of the marine environment, new parasites will be encountered, some of which may be capable of infecting humans. We must keep pace with the changing types of foods we eat and the various cultural and social habits that may play a role in the transmission of parasitic infections.

The challenge is to achieve the delicate balance between educating the public and creating unnecessary alarm. Because the news media may choose to focus on the sensational aspects of eating seafood, knowledgeable people in the seafood industry, the medical community, and regulatory agencies should step forward to explain the important points of the epidemiology of helminthic infections and preventative measures, while placing the risks of infections into perspective. Education clearly represents the best long-term solution for protecting the consumer.

TABLE LISTING PARASITES TRANSMITTED TO HUMANS BY FISHES, AND ASSOCIATED BIOLOGICAL AND MEDICAL PARAMETERS

Parasite	Principal Vectors	Geographic Distribution	Signs and Symptoms of Disease	Prepatant Period[1]	Infective Form	Method of Diagnosis	Treatment Regime[2]
CESTODES							
Diphyllobothrium latum	salmon, pike, perch, burbot	Europe, Japan, Hawaii, North America, Russia, Africa, Australia, South America, New Guinea, Taiwan	May involve nausea, vomiting, colicky pain, bouts of diarrhea and constipation, dizziness, fatigue, back pain, weight loss, pernicious anemia; mild cases may be asymptomatic.	16–42 days	pleroceroid in fish	eggs or proglottids in stool	niclosamide: adults 2 g/single dose; children 34–57 kg 1.5 g; <34 kg 1 g; biothional 30 mg/kg/1 or 2 days; praziquantel 5–10 mg/kg/1 day; paramomycin sulphate 50 mg/kg/1 day; vitamin B_{12} and folic acid.
D. pacificum	marine fishes	Peru, Chile, Japan, British Columbia (?)	*	*	*	*	**
D. ursi	salmon	Alaska, Canada	*	*	*	*	**
D. chordatum	**	Greenland	*	*	*	*	**
D. dendriticum	†	North America, Siberia, Ireland	*	*	*	*	**
D. lanceolatum	**	Alaska	*	*	*	*	**
D. cameroni	salmon	Japan	*	*	*	*	**
D. yonagoensis	†	Japan	*	*	*	*	**
D. nihonkaiense	salmon	Japan	*	*	*	*	**
D. scoticum	marine fish	Japan	*	*	*	*	**
D. alascense	**	Alaska	*	*	*	*	**
D. hians	†	Japan	*	*	*	*	**
Diplogonoporus balaenopterae	sardine, scad, bonito	Japan	abdominal pain	**	*	*	**
Nybelinia surmenicola	squid	Japan	pharyngeal pain	3 hours	pleroceroid	visual	mechanical removal
Hepatoxylon sp.	fish	South America(?)	**	**	*	*	**
TREMATODES							
Nanophyetus salminicola	usually salmonids	USA, Siberian Russia	abdominal discomfort, episodic diarrhea, nausea, vomiting, fatigability, weight loss, eosinophilia.	6–10 days	metacercaria	eggs in stool	niclosamide 2 g × alt. days/3 days; biothional 50 mg/kg × alt. days/2 days; praziquantel 20–60 mg/kg × tid × 1 day.
N. schikhobalowi	*	*	*	*	*	*	**

Parasite	Principal Vectors	Geographic Distribution	Signs and Symptoms of Disease	Prepatant Period[1]	Infective Form	Method of Diagnosis	Treatment Regime[2]
Heterophyes heterophyes	mullet, tilapia, mosquito fish	southeast Europe, Egypt, Orient, USA, Africa, Turkey, India, Philippines, Israel	abdominal discomfort, mucoid diarrhea, with possible heart and central nervous system (CNS) involvement.	several weeks	*	*	tetrachloroethylene, niclosamide (no details); praziquantel 75/mg/kg tid × 1 day.
H. katsuradai	mullet	Japan	*, no CNS involvement	*	*	*	**
H. nocens	mullet	Middle East, Asia	*, no CNS involvement	*	*	*	**
H. brevicaeca	*	Philippines	*, no CNS involvement	**	*	*	**
Haplorchis yokogawai	mullet	Philippines, southeast Asia, Far East, south China, Australia, India, Egypt	abdominal discomfort	**	*	*	**
H. taichui	mullet	Philippines, southeast Asia, Far East, south China, Australia, India, Egypt	*	**	*	* and serological	**
Stellanthchasmus falcatus	mullet	Philippines, Far East, Hawaii	abdominal discomfort	**	*	*	**
Metagonimus yokogawai	salmon, mullet, carp, cyprinoids	Asian countries, Siberia, Spain, Balkan region	abdominal discomfort	several weeks	*	*	**
Diorchitrema pseudocirratum	mullet	Hawaii	abdominal discomfort	**	*	*	**
Centrocestus formosanus	mullet	Philippines, Far East, Hawaii	abdominal discomfort	**	*	*	**
Stictodora sp.	mullet	Korea	abdominal discomfort	**	*	*	praziquantel 15 mg/kg/1 day
Microphallus (as *Spelotrema*)	*	Philippines	abdominal discomfort	**	*	*	**
Metorchis sp.	†	Alaska, Canada	abdominal discomfort	**	*	*	**
Cryptocotyle lingua	†	Alaska, Canada, Greenland, Europe	abdominal discomfort	**	*	*	**
Opisthorchis sinensis	various freshwater fish	Asia, including China, Taiwan, Japan, Korea, Vietnam, Hong Kong	low-grade fever, abdominal discomfort, diarrhea, liver enlargement, fibrosis, bile duct thickening, anorexia.	1 month	*	serological and stool	praziquantel 25–75 mg/kg × tid after meals/1–2 days; chloroquine; dichlorophen; tetrachloroethylene (no details).

Parasite	Principal Vectors	Geographic Distribution	Signs and Symptoms of Disease	Prepatant Period[1]	Infective Form	Method of Diagnosis	Treatment Regime[2]
O. viverrini	*	Europe, Turkey, Caribbean Islands, southern Russia, southeast Asia, India, Japan, also Asia (China excepted), Philippines	*	*	*	*	praziquantel as above and 40–50 mg/kg single dose; mebendazole 30 mg/kg daily 3–4 weeks.
O. felineus	*	*	*	*	*	eggs in stool	**
Amphimerus pseudofelineus	various freshwater fish	North America	abdominal discomfort	**	*	eggs in stool	**
			ACANTHOCEPHALANS				
Corynosoma strumosum	salmon(?)	Alaska	**	**	acanthella	eggs in stool	atabrine (no details)
Acanthocephalus rauschi	salmon(?)	Alaska	abdominal pain	**	*	**	surgical removal from peritoneal cavity
Bolbosoma sp.	*	Japan, Americas	abdominal pain, eosinophilic granulomatous, purulent masses.	**	*	**	surgical removal
			NEMATODES				
Anisakis simplex	numerous fish, including salmon, tuna, herring, mackerel, squid, anchovies	global	sporadic stomach distress, may involve nausea and vomiting, if gastric; severe lower abdominal pain, occult blood in stool, if intestinal.	1–12 hr (if gastric); 2–5 days (if intestinal)	third-stage larval	endoscopy, radiology, surgery, regurgitation.	endoscopical or surgical removal; conservative treatment of fluid therapy and antibiotics recommended for intestinal cases.
A. typica	*	Japan	*	*	*	*	*
Pseudoterranova decipiens	cod, pollock, haddock	USA	"tickling throat syndrome," or similar to gastric anisakiasis.	up to 2 weeks	*	coughing and regurgitation of worm, or as above.	*
Eustrongylides spp.	killifish, estuarine spp.	USA	acute abdominal pain	**	fourth-stage larval	abdominal surgery	surgical removal
Dioctophyma renale	freshwater, estuarine fish	USA, Thailand	acute abdominal pain	**	fourth-stage larval	abdominal surgery	surgical removal
Philometra sp.	crevalle jack	Hawaii	itching, slight discomfort at point of invasion.	**	adult female	visual	surgical removal

Parasite	Principal Vectors	Geographic Distribution	Signs and Symptoms of Disease	Prepatant Period[1]	Infective Form	Method of Diagnosis	Treatment Regime[2]
Dracunculus insignis	freshwater, estuarine fish	USA	cutaneous ulcers, abscesses, chronic arthritic condition, diarrhea, asthma.	10–14 months in *D. medinensis*	third-stage larval	eosino-philia, cutaneous ulcer or blister, female or larvae in ulcer, or x-ray showing calcified worms.	mechanical or surgical removal, niridazole 25–35 mg/kg daily/5–7 days; metronidazole 250 mg tid × 10d; thiabendazole 50–75 mg/kg daily in 2 doses × 3d.
Capillaria philippinensis	freshwater, estuarine fish	Taiwan, Philippines, Thailand, Japan, Iran, Egypt	abdominal discomfort and distention, diarrhea, degeneration of small intestinal mucosa, emaciation.	2–4 weeks	third-stage larval	eggs, larvae, and adults in stool.	mebendazole 200 mg/bid/20 days; albendazole 200 mg bid × 10d.
Trichinella spiralis or *Nativa*	arctic marine fish	Arctic	most cases asymptomatic. Phase 1 (lasts 1 week): nausea, fever, sweats, diarrhea, edema. Phase 2 (lasts 3 weeks): pneumonia, heart and CNS damage, peritonitis, resembles rheumatism. Phase 3: CNS and heart damage, muscular pain, breathing difficulty.	2–7 days	first-stage larval	serological tests, muscle biopsy, x-ray for calcified worms.	bed rest and supportive treatment such as corticosteroids, mebendazole 1000 mg/daily/10–14 days; albendazole promising; thiabendazole 25 mg/kg bid/7–10 days, but side effects, steroids for severe symptoms plus mebendazole 200–400 mg tid/3 days, then 400–500 mg tid/10 days.
Angiostrongylus cantonensis	freshwater fish	Pacific Islands, between Tropics of Cancer and Capricorn, southeast Asia, Taiwan, Japan, Hawaii, Thailand, Australia, Egypt, Indian Ocean islands, Puerto Rico	headache, nausea, low-grade fever, neck stiffness, CNS and ocular damage.	2 weeks	third-stage larval	exposure in endemic area, eosinophils in spinal fluid.	supportive; levamisole; albendazole (no details), mebendazole 100 mg bid/5 days (adults, children).

Parasite	Principal Vectors	Geographic Distribution	Signs and Symptoms of Disease	Prepatant Period[1]	Infective Form	Method of Diagnosis	Treatment Regime[2]
Gnathostoma spinigerum	freshwater fish	Korea, Taiwan, the Americas, China, Japan, Indonesia, Thailand, Philippines, southeast Asia, Israel	ocular damage, edema, "creeping eruption," possible CNS damage, nausea, fever, urticaria.	24–48 hours	third-stage larval	visual, intradermal test, serological.	surgical removal; albendazole 400–800 mg/d × 21d.
G. hispidum	*	Asia	*	*	*	*	surgical removal
G. nipponicum	*	*	*	*	*	*	surgical removal
G. doloresi	*	*	*	*	*	*	surgical removal

[1]Period between time of acquiring infection and finding parasite (e.g., eggs in stool specimen)
[2]The "Treatment Regimes" listed in text and in this table are drawn from scientific literature and do not necessarily constitute the recommended treatment by authors
*Data suspected to be similar for closely related species
closely related species
**Insufficient data
†Suggestion in literature that marine vertebrates or invertebrates may be involved

ADDITIONAL INFORMATION

For supplemental information on these helminths and the diseases they cause, the following publications are recommended:

General publications
(Hildebrand et al. 1993; King and Peters 1991; Price and Tom 1990);

***Diphyllobothrium* spp. and tapeworm infections**
(Ward 1930; Baer et al. 1967; Baer 1969; de Carneri and Vita 1973; Bylund 1976; von Bonsdorff and Bylund 1982; Ruttenber et al. 1984; Yamane et al. 1986; Kamo et al. 1971);

Acanthocephalans
(Golvan 1969; Schmidt 1971);

Digeneans
(Africa et al. 1936; Ching 1961; Yokogawa and Yoshimura 1967; Paperna and Overstreet 1981; Eastburn, Fritsche, and Terhune 1987);

Nematodes
(Yokogawa and Yoshimura 1967; Ruitenberg 1970; Oshima 1972, 1987; Smith and Wootten 1978; Matsui et al. 1985; Bier et al. 1987; Halsteinsson and Rizvi 1987; Eberhard et al. 1989; Sakanari and McKerrow 1989; Wittner et al. 1989);

Overview of infections transmitted by aquatic animals
(Williams and Jones 1976; Rohde 1982; Beaver, Jung, and Cupp 1984; Higashi 1985; Schantz 1989; Deardorff and Overstreet 1990).

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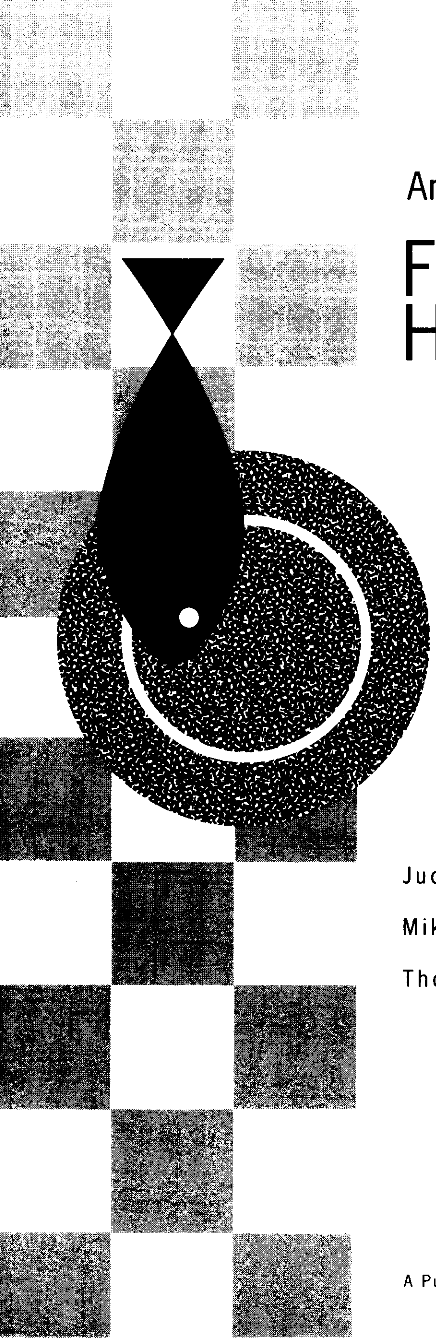

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