National Wildlife Health Center

Anisakiosis and Pseudoterranovosis

Circular 1393

U.S. Department of the Interior
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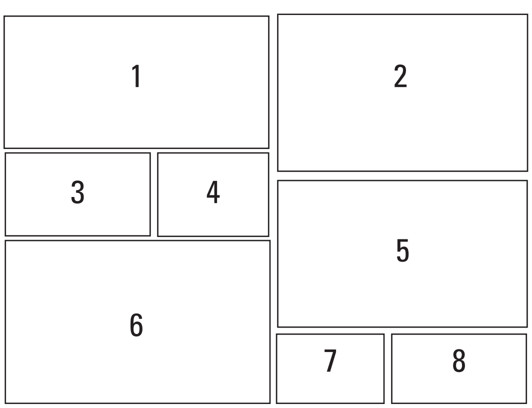

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Anisakiosis and Pseudoterranovosis

By Lena N. Measures

Edited by Rachel C. Abbott and Charles van Riper, III

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Foreword

C. van Riper, III, R. C. Abbott, C. Bunck, and M. Friend

> *"Make no mistake, they are connected, these disease outbreaks coming one after another. And they are not simply happening to us; they represent the unintended results of things we are doing. They reflect the convergence of two forms of crisis on our planet. The first crisis is ecological, the second is medical."*
>
> *David Quammen, Spillover*

The emergence of many new (and older) zoonotic diseases in humans in recent years is largely a result of our densely populated, highly mobilized, and environmentally disrupted world that is experiencing rapid climatic changes. The number of zoonotic diseases detected has been of unprecedented scope relative to geographic areas of occurrence, wildlife species affected, and the variety of pathogens involved (Daszak and others, 2000; Friend, 2006). As towns and cities expand, the wildland-urban interface broadens and human associations with wildlife become increasingly frequent. With geographic distance and isolation no longer serving as meaningful barriers, opportunities for once isolated diseases to spread have never been greater. Consequently, and especially as a result of rapid warming in the polar region due to climate change, zoonotic diseases such as anisakiosis and pseudoterranovosis will begin to appear more frequently in northern latitude animal and human populations.

Human infections with "whale worm" or "seal worm" are becoming more common with the popularity of eating raw fish. People are accidentally infected by larval stages of the nematodes in marine fish or squid that are raw, poorly cooked, cold-smoked, lightly salted, or marinated. It is safe to assume that both these parasites can be found wherever suitable hosts occur and favorable environmental conditions permit. Thus, humans consuming improperly prepared infected wild fish or squid are at risk, especially those with cultural culinary practices that do not kill larvae. And as gastronomic trends spread around the globe, foodborne zoonoses, such as anisakiosis and pseudoterranovosis, will occur in new locations.

Dealing with emerging zoonotic diseases requires the ability to recognize pathogens when they first appear and to act quickly and appropriately. Because outbreaks often are evident in nonhuman components of the environment before humans are affected, understanding our environment and associated 'sentinel' wildlife is a prerequisite to protecting human health. Through understanding infection levels in wildlife populations, we will be better able to predict future human infection levels. This report, seventh in the series of U.S. Geological Survey Circulars on zoonotic diseases, will help us to better understand the routes of anisakiosis and pseudoterranovosis infections and how best to adequately monitor these zoonotic diseases.

Daszak, P., Cunningham, A.A., and Hyatt, A.D., 2000, Emerging infectious diseases of wildlife—Threats to biodiversity and human health: Science, v. 287, p. 443–449.

Friend, M., 2006, Disease emergence and reemergence: The wildlife-human connection: Reston, Va., U.S. Geological Survey Circular 1285, 388 p.

Quammen, D., 2012, Spillover: animal infections and the next human pandemic: New York, N.Y., W.W. Norton and Co., Inc., p. 39.

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Conversion Factors and Abbreviations

International System of Units to Inch/pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Words shown in **bold** are defined in the glossary.

Anisakiosis and Pseudoterranovosis

By Lena N. Measures[1]

Synonyms

Anisakiasis, whaleworm and herringworm infection, pseudoterranovosis, sealworm, and codworm infection

Overview

Anisakiosis is a **parasitic** disease caused by infection with **larval nematodes** or **roundworms** of the **taxonomic genus** *Anisakis,* which belong to the family, Anisakidae, subfamily Anisakinae. Anisakiosis is a **zoonotic** disease, meaning it is transmissible between animals and humans and vice versa. Other related roundworms, such as *Pseudoterranova* and *Contracaecum*, may cause similar, but less frequently reported, diseases (pseudoterranovosis, contracaecosis). The terms anisakidosis (anisakidiasis), referring to disease caused by members of the family, and anisakinosis (anisakiniasis), referring to disease caused by members of the subfamily, may be encountered in technical literature (Kassai and others, 1988) when specimens cannot be identified to genus. Because most cases of anisakidosis in humans are due to larval *Anisakis* spp. and, to a lesser extent, larval *Pseudoterranova* spp., further discussion will be limited to these **anisakids** (table 1).

The life cycles of *Anisakis* spp., commonly called whaleworm (previously known as herringworm), and *Pseudoterranova* spp., commonly called sealworm (previously known as codworm), are complex and involve three marine **hosts** (**invertebrates**, **fish**, and marine mammals). Whales, dolphins, or porpoises (collectively known as **cetaceans**) are the **definitive host**s in which *Anisakis* spp. become sexually mature, and seals, sea lions, or walrus (collectively known as **pinnipeds**) are the definitive hosts of *Pseudoterranova* spp. These zoonotic parasites have medical and economic importance and can result in considerable costs to the fishing industry. Humans are accidentally infected by consuming raw, poorly cooked, cold smoked, lightly salted, or marinated marine fish or squid, the **intermediate host**s infected with **larval** stages. Human infections are becoming more common with the popularity of eating raw fish as well as improved medical diagnostics. Infections are rarely diagnosed correctly in North America, which often leads to surgical intervention. Symptoms in humans may involve nausea, vomiting, and severe stomach (**gastric**) or abdominal pain.

[1] Maurice Lamontagne Institute, Fisheries and Oceans Canada.

Table 1. Taxonomic classification of the parasites causing anisakiosis and pseudoterranovosis.

Classification	Designation	
Kingdom	Animalia	
Phylum	Nematoda	
Class	Secernentea	
Order	Ascardida	
Family	Anisakidae	
Subfamily	Anisakinae	
Genus	*Anisakis*	*Pseudoterranova*
Species	*simplex* **sensu stricto**	*decipiens* sensu stricto
	berlandi	*krabbei*
	pegreffi	*bulbosa*
	typica	*azarasi*
	physeteris	*cattani*
	ziphidarum	*decipiens E*
	paggiae	*kogiae*
	brevispiculata	*ceticola*
	nascettii	
	schupakovi	

Background

Although the genus of *Anisakis* was established in 1845 by Félix Dujardin to group some parasitic nematodes known from the stomach and intestine of marine mammals, it took more than 100 years until the first human infections were described in Holland and Japan (table 2). Since then, thousands of people in Japan have contracted anisakiosis.

In the Western hemisphere, infections caused by larvae of the Anisakidae family or similar larvae were reported from **Inuit** in Greenland as early as 1867 (Martin, 1921 cited in Jackson, 1975) and Alaska (Hitchcock, 1950). Since then many human cases of "anisakiasis" have been reported from Canada and the United States, but few cases of anisakiosis have been confirmed by identification of specimens as *Anisakis* spp. (Smith, 1999; Couture and others, 2003). Most identified specimens from human cases in the Western Hemisphere are reported as *Pseudoterranova* spp., thus infections are called pseudoterranovosis (Amin and others, 2000).

Table 2. Timeline of events in the discovery of human anisakidosis.

1845	Genus of *Anisakis* is established by Félix Dujardin to group nematodes causing lesions in the stomachs of cetaceans.
1867	**Ascarid**-like or anisakine infections are reported from Inuit people in Greenland (Martin, 1921 cited in Jackson, 1975).
Early 1940s	Gastrointestinal lesions in humans, with small *Ascaris*-like larvae in a few cases are documented in Japanese medical journals (Oshima, 1972).
1949	Ascarid-like or anisakine infections are reported from Inuit people in Alaska (Hitchcock, 1950).
1955	The first human cases of anisakiosis are observed in Holland (van Thiel and others, 1960; Rodenburg and Wielinga, 1960; Kuipers and others, 1960).
1955–67	Almost 150 cases of human anisakiosis are documented in Holland.
1965	The first human case of anisakiosis in Japan is described (Asami and others, 1965).

Pseudoterranovosis has been reported in Japan, but it is less common than anisakiosis (Ishikura and others, 1992). Three hundred thirty-five human cases of pseudoterranovosis in Japan and 19 in other countries, including the United States, Canada, Greenland, Chile, the United Kingdom, and Korea, have been reported (Ishikura and others, 1992). Pseudoterranovosis has been reported frequently in northern Japan (Hokkaido) and attributed to dietary differences compared to southern Japan and the presence of populations of pinnipeds, such as sea lions and seals. Recently, pseudoterranovosis has been reported from Mexico and South America (Torres and others, 2007).

For further reading, the bibliographic citations of key publications that address various aspects of anisakiosis and pseudoterranovosis are listed in appendix 2.

Culture, Technology, and Anisakiosis

Anisakiosis in a human was first observed in 1955 in Holland (van Thiel and others, 1960; Rodenburg and Wielinga, 1960; Kuipers and others, 1960). Although larval forms of roundworms in the Anisakidae family are common in marine fish, the apparent sudden appearance of anisakiosis in Holland was attributed to changes in fish processing and marketing practices during the early 1950s. Traditionally, fresh-caught herring were **eviscerated** at sea, but with the advent of refrigeration, onboard ship processing changed to icing whole fish and eviscerating them when ships returned to port, sometimes days later. In addition, so called "green herring," which was lightly salted raw herring, was introduced to the Dutch market and became very popular. These two practices led to larval *Anisakis* spp. migrating after the death of the fish host from the viscera into the muscles, surviving further inadequate processing and remaining alive for days. Consequently, almost 150 cases of human anisakiosis were documented between 1955 and 1967 in Holland. Dutch **parasitologists** eventually linked larval nematodes from herring with cases of anisakiosis in humans and finally identified them as *Anisakis* spp. As a result of these findings, in 1968 Dutch legislation required that fish be frozen within 12 hours of catch at –20 °C and kept frozen for 24 hours before further processing (Oshima, 1972). Although cases of anisakiosis fell in Holland after these measures were implemented, anisakiosis still affects fish consumers in Europe. Consumption of gravlax (cured salmon, often dried) in Nordic countries and boquerones (an appetizer of fish, often anchovies, macerated in vinegar) in Spain has been implicated in infections of anisakiosis (Audicana and others, 2002).

Traditionally, the Japanese have consumed raw fish (sashimi) and raw squid (ikasashi) as a delicacy for many years (Ishikura and others, 1992). Gastrointestinal lesions in humans were documented in Japanese medical journals in the early 1940s (Oshima, 1972). In a few cases small "Ascaris-like" larvae were reported, but it was not until 1965, after the Dutch anisakiosis cases were published, that the first authoritative case of human anisakiosis in Japan was described (Asami and others, 1965). Since then thousands of cases have been reported in Japan (Oshima, 1972; Ishikura and others, 1992; Sugimachi and others, 1985; Nagasawa, 1993).

Causative Agent

Although larval anisakines were known in marine fish for a long time (Myers, 1976), it was not until the mid-1800s that nematodes causing **lesions** in the stomachs of cetaceans were grouped under the genus name *Anisakis* by Félix Dujardin. Initially, larval nematodes from the first human cases of anisakiosis in Holland were identified as *Eustoma rotundatum*, later changed to *Anisakis marina*, and then finally changed to *Anisakis simplex*.

The *Anisakis* genus, which at one time included 21 **species**, was reviewed in the 1960s, and 3 valid species were accepted based on studies of the parasite's form and structure (**morphology**): *Anisakis simplex, Anisakis typica*, and *Anisakis physeteris* (Davey, 1971). Over the past three decades, the number of species has increased based on examination of material from intermediate and definitive hosts and the use of molecular and genetic methodologies (see Mattiucci and Nascetti, 2008, for review). *Anisakis simplex* **sensu lato** broadly refers to a group of three sibling species, including *Anisakis simplex* sensu stricto specifically, *Anisakis berlandi*, and *Anisakis pegreffi*. In addition to *A. typica* and *A. physeteris*, at least five other nominal species have been described (table 1). It is very likely that further research will reveal new species in cetaceans not yet examined for parasites and expand the host range of known species of *Anisakis* (table 3).

Parasitic worms from the stomachs of seals were first described by Harald Krabbe in 1878 as *Ascaris decipiens*. The species was then taxonomically moved into and out of the genera, *Porrocaeum*, *Terranova*, *Phocanema*, and finally into *Pseudoterranova*. Recent research using molecular and genetic methodologies (see Paggi and others, 1991; Brattey and Davidson, 1996; Paggi and others, 2000; Zhu and others, 2002; Mattiucci and Nascetti, 2008 for reviews) has also determined that *Pseudoterranova decipiens* sensu lato consists of at least six sibling species: *Pseudoterranova decipiens* sensu stricto, *P. krabbei*, *P. bulbosa*, *P. azarasi*, *P. cattani*, and *P. decipiens* E (not given a name at present). Two other species were described, *P. kogiae* in the pygmy sperm whale and *P. ceticola* in the dwarf sperm whale (Johnston and Mawson, 1939; Deardorff and Overstreet, 1981) (table 4). The definitive host range of known species of *Pseudoterranova* is shown in table 4, but future work may identify new pinniped hosts or new species of *Pseudoterranova*.

Some species of *Anisakis* and *Pseudoterranova* are found in the same geographic area and infect the same individual definitive host, indicating inbreeding, which should not occur if a species is biologically valid. In a few of these cases, hybrids of species of *Anisakis* and hybrids of species of *Pseudoterranova* are found, suggesting the taxonomic status of these species is still evolving (Paggi and others, 1991; Abollo and others, 2003; Martín-Sánchez and others, 2005; Mattiucci and others 2004; Mattiucci and others, 2014).

Table 3. Marine mammal hosts and geographic range of *Anisakis* spp.

[Species listed are those identified and described based on molecular identification except where indicated. See D`Amelio and others (2000); Mattiucci and Nascetti (2008); Mattiucci and others (2009); Iniguez and others (2009); Colón-Llavina and others (2009); Mattiucci and others (2014)]

Species of *Anisakis*	Host	Geographic range
Anisakis simplex sensu stricto	Minke whale	Northeast Atlantic Ocean.
	Common dolphin	East Atlantic Ocean (Iberian coastal waters).
	Long-finned pilot whale	Atlantic Ocean (Iberian coastal waters, South African coastal waters).
	White beaked dolphin	Northeast Atlantic Ocean.
	Killer whale	Northeast Pacific Ocean.
	False killer whale	Northeast Pacific Ocean.
	Striped dolphin	East Atlantic Ocean (Iberian coastal waters).
	Beluga	Northwest Atlantic Ocean.
	Harbor porpoise	Northeast Pacific Ocean.
Anisakis berlandi	Long-finned pilot whale	Southeast Atlantic Ocean (South African coastal waters), Southeast Pacific Ocean (New Zealand coastal waters).
	Northern right whale dolphin	Northeast Pacific Ocean.
	False killer whale	Northeast Pacific Ocean.
	Southern elephant seal	Sub-Antarctic waters.
	Northern elephant seal	Northeast Pacific Ocean.
Anisakis brevispiculata	Pygmy sperm whale	Atlantic Ocean (Florida, coastal waters, Iberian coastal waters, South African coastal waters).
	Dwarf sperm whale	Caribbean Sea.
Anisakis nascetti	Gray's beaked whale	Southwest Pacific Ocean (New Zealand).
	True's beaked whale	Southeast Atlantic Ocean (South African coastal waters).
	Strap-toothed beaked whale	Southwest Pacific Ocean (New Zealand coastal waters).
	Andrew's beaked whale	Southwest Pacific Ocean (New Zealand coastal waters).
Anisakis paggiae	Dwarf sperm whale	Atlantic Ocean (Florida coastal waters), Southeast Atlantic Ocean (South African coastal waters), Caribbean Sea.
Anisakis pegreffi	Mediterranean monk seal[1]	Mediterranean Sea.
	Common dolphin	Atlantic Ocean (Iberian coastal waters), Western Mediterranean Sea.
	Long-finned pilot whale	Southeast Pacific Ocean (New Zealand coast).
	Striped dolphin	Mediterranean Sea.
	Bottlenose dolphin	Central Mediterranean Sea, South African coastal waters.
	Pygmy right whale	Southeast Atlantic Ocean (South African coastal waters).
Anisakis physeteris	Sperm whale	Central Mediterranean Sea.
Anisakis schupakovi[1]	Caspian seal	Caspian Sea.
Anisakis typica	Short-finned pilot whale	Atlantic Ocean (Florida coastal waters).
	Striped dolphin	East Mediterranean Sea.
	Bottlenose dolphin	Atlantic Ocean (Florida coastal waters), Caribbean Sea.
	Tucuxi	Southwest Atlantic Ocean (Brazilian coastal waters).
	Costero	Southwest Atlantic Ocean (Brazilian coastal waters).
	Pantropical spotted dolphin	Northwest Atlantic Ocean (Florida coastal waters), Caribbean Sea.
	Spinner dolphin	Southwest Atlantic Ocean (Brazilian coastal waters).
	Rough-toothed dolphin	Caribbean Sea.

Table 3. Marine mammal hosts and geographic range of *Anisakis* spp.

[Species listed are those identified and described based on molecular identification except where indicated. See D`Amelio and others (2000); Mattiucci and Nascetti (2008); Mattiucci and others (2009); Iniguez and others (2009); Colón-Llavina and others (2009); Mattiucci and others (2014)]

Species of *Anisakis*	Host	Geographic range
Anisakis ziphidarum	Strap-toothed beaked whale	Southeast Atlantic Ocean (South African coastal waters).
	Blainville's beaked whale	Southeast Atlantic Ocean (South African coastal waters).
	Gervais' beaked whale	Caribbean Sea.
	Cuvier's beaked whale	Central Mediterranean Sea, South African coastal waters, Caribbean Sea.
	Gray's beaked whale	Southeast Atlantic Ocean (South African coastal waters).
	True's beaked whale	Southeast Atlantic Ocean (South African coastal waters).
	Andrew's beaked whale	Southwest Pacific Ocean (New Zealand coastal waters).

[1] Based on morphology only.

Table 4. Marine mammal hosts and geographic range of *Pseudoterranova* spp.

[Species listed are those identified and described based on molecular identification except where indicated. See Johnston and Mawson (1939); Deardorff and Overstreet (1981); Nadler and others (2005); Mattiucci and Nascetti (2008)]]

Species of *Pseudoterranova*	Host (common name)	Geographic range
Pseudoterranova decipiens sensu stricto	California sea lion	Northeast Pacific Ocean.
	Harbor seal	Northeast Pacific Ocean.
	Harbor seal	Northeast Atlantic Ocean.
	Harbor seal	Northwest Atlantic Ocean.
	Gray seal	Northeast, Northwest Atlantic Ocean.
	Hooded seal	Northeast, Northwest Atlantic Ocean.
	Northern elephant seal	Northeast Pacific Ocean.
Pseudoterranova decipiens E	Weddell seal	Antarctic coastal waters.
Pseudoterranova azarasi	Northern (Steller) sea lion	Northwest Pacific Ocean, Japan Sea.
	California sea lion	Northwest Pacific Ocean.
	Harbor seal	Northeast Pacific Ocean.
	Bearded seal	Northwest Pacific Ocean, Japan Sea.
Pseudoterranova bulbosa	Bearded seal	Northeast Pacific Ocean, Northeast Atlantic Ocean, Northwest Atlantic Ocean, Labrador Sea.
Pseudoterranova cattani	South American sea lion	Southeast Pacific Ocean.
Pseudoterranova ceticola[1]	Dwarf sperm whale	Gulf of Mexico (Mississippi).
Pseudoterranova kogiae[1]	Pygmy sperm whale	Southwest Pacific Ocean (Queensland, Australia coastal waters), Southeast Atlantic Ocean (South African coastal waters).
Pseudoterranova krabbei	Harbor seal	Northeast Atlantic Ocean.
	Gray seal	Northeast Atlantic Ocean.

[1] Based on morphology only.

Geographic Distribution

Species of *Anisakis* and *Pseudoterranova* are widely distributed in the marine environment, but most reports are from the Northern Hemisphere and probably reflect research interest. Most human cases of anisakiosis and pseudoterranovosis are from Japan, Europe, and North America; however, recent work in the Southern Hemisphere reports these parasites in various intermediate and definitive hosts as well as in humans (Palm, 1999; Mercado and others, 2001; Berón-Vera and others, 2007; Torres and others, 2007). The reported low **prevalence** or absence of *Anisakis* spp. in Antarctic fish may be related to the distribution of definitive hosts and environmental conditions such as temperature (Measures, 1996; Klimpel and others, 2010). It is safe to assume that both *Anisakis* and *Pseudoterranova* can be found wherever suitable hosts live and favorable environmental conditions permit. Consequently, humans who consume improperly prepared infected wild fish or squid are at risk, especially people with cultural culinary practices that do not kill larvae.

Patterns and Trends

Although cases of anisakiosis fell in Holland after legislative measures were implemented to protect consumers of fish, anisakiosis is still reported in Europe (Smith, 1999; Eskesen and others, 2001; Johansson and others, 2001; Alonso-Gómez and others, 2004), numbering approximately 500 human cases to date (Audicana and others, 2002). In Japan, more than 2,000 cases are reported by physicians annually (Kagei and others, 1995). In Canada and the United States, some 50 cases of "anisakiasis" have been reported (McKerrow and others, 1988), although the total may now be approaching 300 (Amin and others, 2000). An increasing number of cases are reported from South America (Mercado and others, 2001; Torres and others, 2007). A small number of cases of anisakiosis are documented from native peoples in the north (Alaska, Canada, Greenland), but cases are probably under-reported and misdiagnosed (Food Safety Network, 2009; Bhat and Cleland, 2010; Jenkins and others, 2013).

Increased reports of anisakidosis in Japan since 1972 have been attributed to improved medical diagnostic methods such as **gastroendoscopy** and **radiology**, in addition to increasing populations of marine mammals, particularly pinnipeds in northern Japan (Oshima, 1987). In addition, associations between the prevalence of sealworm infections in commercial fish and seal populations are not fully understood (McClelland, 2002). Other **abiotic** factors, such as water temperature, are important in transmission (McClelland, 1982, 1990, 1995; Measures, 1996; McClelland and Martell, 2001; McClelland, 2002).

When "sushi bars" became popular in North America during the mid-1970s, cases of anisakidosis appeared, but pseudoterranovosis was reported more commonly than anisakiosis (Little and MacPhail, 1972; Little and Most, 1973; Kates and others, 1973; Chitwood, 1975; Lichtenfels and Brancato, 1987; Margolis, 1977; Kliks, 1983; Desowitz, 1986; Oshima, 1987; Amin and others, 2000). Eleven cases of anisakiosis and 14 cases of pseudoterranovosis were reported in North America between 1974–87 (Oshima, 1987). The large populations of pinniped definitive hosts of the parasites on the Atlantic and Pacific coasts of North America, as well as cultural dietary differences, may explain some of these cases. Dozens of cases of pseudoterranovosis due to consumption of raw fish (ceviche, also spelled cebiche) have been reported from Chile, Brazil, and Mexico (Torres and others, 2007). Many cases, however, probably go unreported or are incorrectly diagnosed. The ease of removing *Pseudoterranova* spp. from the person's stomach by **endoscopy** for identification and the frequency by which the worm is coughed or spit out by the human consumer probably accounts for the increasing number of reports of pseudoterranovosis. Many sealworms are removed during commercial processing of fish or are seen by the consumer before consumption, thus many infections are likely avoided. In Atlantic Canada it has been estimated that annual costs to the fishing industry to remove sealworms and losses due to reduced value of fish products are $27–50 million Canadian dollars (see McClelland, 2002).

Increasing populations of whales and seals, changes in their distribution or that of their prey, and enhanced parasite transmission due to favorable environmental factors, combined with the growing popularity of sushi, sashimi, and ceviche, are expected to raise the risk of human exposure to anisakids and the frequency of diagnosed anisakidosis (due to improved medical diagnostics).

Species Susceptibility

Humans and other nondefinitive hosts are accidentally infected by ingesting infected fish or invertebrates. Because *Anisakis* spp. and *Pseudoterranova* spp. do not mature and reproduce in humans or other nondefinitive hosts, these hosts may be considered **dead-end host**s even though they are **susceptible** to infection.

Human Infections

Four forms of human anisakidosis (anisakiosis and pseudoterranovosis) have been described (Smith, 1999) (table 5). The most commonly reported form is gastric or intestinal anisakidosis in which larvae penetrate the **gastrointestinal tract,** causing severe damage, pain, and discomfort.

The least invasive of these forms is transient **luminal** anisakidosis, in which larvae do not penetrate tissues but may remain in the open spaces (lumen) of the gastrointestinal tract for some time, causing mild, temporary discomfort. These mild cases, while not uncommon, typically are caused by

A Case of Human Anisakiosis

A man purchased a fresh wild salmon from a local grocery store. The salmon had been caught in the Pacific Ocean near the coast of British Columbia, Canada, gutted, and shipped whole on ice by air to Québec, Canada where the man lived. He consumed some raw salmon while cutting fillets to make marinated salmon. Within 24 hours, he experienced constipation, nausea, and acute abdominal pain, and after 2 days he went to a hospital emergency clinic. Blood samples were taken and x-rays and CT scans performed. Tests revealed he had a slightly above normal number of **eosinophils**, a type of white blood cell sometimes associated with parasitic infections, and distension and thickening of part of the wall of the small intestine. The man was diagnosed with acute abdominal syndrome, and surgery was performed. The surgeon removed a 15-centimeter (cm) section of thickened small intestine (figure). The man was discharged from the hospital 6 days after surgery. Laboratory analysis of the resected intestine revealed the presence of minute abscesses (arrows) containing sections of a nematode, later identified as a third-stage larval *Anisakis* spp. This human infection is typical of intestinal anisakiosis. Refer to Couture and others (2003) for further details on this case.

Section of thickened small intestine removed during surgery. The arrows point to minute abscesses containing sections of third-stage larval *Anisakis* spp. (Photo by Dr. Christian Couture, Hôpital Laval)

Table 5. Forms of human anisakidosis.

Form	Relative occurrence	Targeted location	Tissue penetration	Degree of disease effects
Gastric or intestinal	Most common	Gastrointestinal tract	Yes	Mild to severe.
Outside of the gastrointestinal tract	Relatively rare	Penetrates the wall of the gastrointestinal tract and enters the body cavity	Yes	Severe.
Mouth and pharynx (throat)	Rare	Mouth and pharynx cavity	Yes	Mild.
Transient luminal	Common	Inner or open space of the gastrointestinal tract	No	No symptoms to mild.

Pseudoterranova spp. In contrast, *Anisakis* spp. are generally more invasive and disruptive than *Pseudoterranova* spp. and are commonly associated with parasites both within and outside of the stomach and intestines. Most human infections are caused by third-stage larvae, rarely fourth-stage larvae (*see* “Disease Ecology”). Symptoms and observable signs are described in the section “Obtaining a Diagnosis.”

Marine Mammal Infections

The natural definitive hosts of *Anisakis* spp. are cetaceans. Based on the literature, at least 53 cetacean species are reported infected with *Anisakis* spp. Recently, 28 cetacean species infected with *Anisakis* spp. have had identifications of *Anisakis* to the species level based on molecular analyses (table 3). Immature *Anisakis* stages are often found in pinnipeds, where they rarely mature (Brattey and Stenson, 1993; Machida, 1969 cited in Kuramochi and others, 1996; Klimpel and others, 2008). *Anisakis schupakovi* in the Caspian seal is considered a valid species based on morphology alone (D'Amelio and others, 2000). Similarly, *Pseudoterranova* spp. are reported as parasites of at least 28 pinniped species, and 11 pinniped species with *Pseudoterranova* spp. have had identifications of *Pseudoterranova* to the species level based on molecular analyses (table 4). Immature *Pseudoterranova* spp. stages are occasionally found in cetaceans and sea otters, where they rarely mature (Measures and others, 1995; Smith, 1999). Two species, *P. kogiae* in pygmy sperm whales and *P. ceticola* in dwarf sperm whales, are known based on morphology alone.

Evidence suggests that some definitive hosts differ in how susceptible they are to the parasites, the number of worms they harbor (intensity of infection), the ability of the parasites to grow and reproduce in them, and their responses to *Anisakis* spp. or *Pseudoterranova* spp. For example, based on field data from the North Atlantic Ocean and experimental work, grey seals infected with *P. decipiens* have greater numbers of worms, less intense tissue reaction, greater parasite growth, greater parasite egg production, and higher worm survival than harbor seals infected with *P. decipiens* (McClelland, 1980a; Aspholm and others, 1995; McClelland, 2002). The numbers of *P. decipiens* within a host are low, and few mature worms are found in harp, hooded, and ringed seals (McClelland, 2002). Some cetaceans such as minke whales and beluga can harbor large numbers of *A. simplex* of considerable size with high egg production, while fewer worms often are observed in porpoises or dolphins that harbor only larvae or small adults with comparatively low egg production (Brattey and Stenson, 1995; Measures and others, 1995, Kuramochi and others, 1996; Simard, 1997; Ugland and others, 2004; Berón-Vera and others, 2008). Infections of anisakids in marine mammals are influenced by the availability of infected intermediate or **transport host**s, host diet, host **immune** and **physiological status**, whether the host lives in or migrates through inshore or offshore habitats, as well as seasonal and environmental factors.

In the gastrointestinal tract of definitive hosts, anisakids are generally harmless (Stroud and Roff, 1979; McClelland, 1980b; Smith, 1989; Babin and others, 1994; Abollo and others, 1998) even when present in high numbers, but severe damage has been reported in some hosts. Pathologic lesions caused by anisakids in marine mammals were reviewed by Smith (1999). Generally, anisakids provoke gastric craterlike ulcers or erosions where they attach to the mucous membranes (**mucosa**) in clusters of dozens to hundreds (figs. 1, 2).

In cetaceans, *Anisakis* spp. are found primarily in the first chamber of the stomach (forestomach), sometimes in the second chamber (main stomach), and rarely in the third chamber (pyloric stomach). Worms in the intestine are indicative of aberrant migrations, failed infections, or aging of the worm. Inflammation of the stomach (gastritis) and the intestine (enteritis) due to *Anisakis* spp. and *Pseudoterranova* spp. have been reported. In extreme cases, worms may penetrate the gut, enter the body cavity, and cause hemorrhage, secondary bacterial infections, inflammation of the covering of the stomach, intestines, and nearby organs (**peritonitis**), and death (Ridgway and others, 1975; Stroud and Dailey, 1978; Martineau and others, 1988; Baker and Martin, 1992; De Guise and others, 1995; Lair and others, 2014).

In unusual hosts, such as the sea otter, *P. decipiens* (primarily larvae) is associated with stomach ulcers, holes or **perforations** in the intestines, and death due to peritonitis (Rausch, 1953; Fay and others, 1978 in Smith, 1999). Lesions in the pyloric region of the simple stomach may cause narrowing, physically preventing the movement of food or leading to an abnormal accumulation of blood in the veins (Smith, 1999). Ulceration and gut perforation by parasites such as *A. simplex* can provide portals of entry for viruses or bacteria, some of which may lead to **abscesses**, systemic infections of the entire body, or possibly other chronic diseases (Martineau and others, 1988; Baker and Martin, 1992; De Guise and others, 1994, 1995; Harper and others, 2002a, 2002b; Lair and others, 2014).

Fish and Invertebrates

Larval *Anisakis* spp. have been reported from a variety of naturally infected invertebrate intermediate hosts, mostly **crustaceans** such as small shrimplike crustaceans (**euphausiids** and **amphipods**), crayfish, crabs, lobsters, and shrimp (**decapods**), and squid and cuttlefish (**cephalopods**). Larval *Pseudoterranova* spp. have been reported in amphipods, decapods, and small, shrimplike crustaceans (**mysids**) (Uspenskaya, 1963; Oshima and others, 1968; Smith, 1971; Nagasawa and Moravec, 1995; Hays and others, 1998; McClelland, 2002). *P. decipiens* is known from over 75 fish species belonging to 29 families, 10 orders, and 3 classes of fish (McClelland, 2002). *Anisakis* spp. are reported from a wide range of marine, **estuarine,** and occasionally freshwater fish (Oshima, 1972; Smith and Wootten, 1978) and occur in approximately 200 species of fish and 25 species of cephalopods worldwide (Klimpel and others, 2004). However, these figures may be inaccurate due to confusion in larval identification (Oshima, 1972; Smith and Wootten, 1978). For example, one report states that one *Anisakis* "larval type 1" is known from 123 different fish species in Japanese waters (Oshima, 1972), yet another report states that more than 166 species of fish are infected with anisakids in Japanese waters (Ishimura and others, 1992).

Figure 1. Adult *Anisakis simplex* in the stomach of a pilot whale. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)

Figure 2. Adult *Pseudoterranova decipiens* in the stomach of a grey seal. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)

Freshwater fish are likely to become infected if they are fed the infected internal organs of marine fish in aquacultural operations or if wild fish such as salmon spend part of their life cycle in salt or estuarine waters where they may acquire infections. Seven cephalopod species can act as transport hosts of *A. simplex* and *A. physeteris* in Japanese waters (Nagasawa, 1993), and seven cephalopod species have been infected with *A. simplex* in Spanish waters (Abollo and others, 1998). In cephalopods, *Anisakis* spp. larvae are found in the internal organs and muscles, and in a few cases, destroy the testes or ovaries of mature squid (Abollo and others, 1998). Although *Anisakis* spp. and *Pseudoterranova* spp. are reported from a wide range of fish hosts, it is believed that primarily fish that live in the water column (**pelagic** fish) are ecologically important for transmitting *Anisakis* spp. to cetaceans, and fish that live near or on the bottom (**benthic** fish) are ecologically important for transmitting *Pseudoterranova* spp. to pinnipeds.

To understand the role of invertebrates and fish in the life cycles of these two anisakids, various experimental infections have been conducted since the early 1950s. For example, 12 different species of fish (marine, **anadromous**, and freshwater) including Atlantic salmon, brook trout, rainbow smelt, and Atlantic cod were susceptible to experimental infections by *P. decipiens* using experimentally infected amphipod intermediate hosts (McClelland, 1995). In some fish such as rainbow smelt, tissue responses to infections were absent. In other fish, larvae were surrounded or **encapsulated** by cells of the immune system and eventually killed. *Anisakis* spp. larvae are rapidly encapsulated in fish, and some larvae die and become hardened by deposited calcium salts (Smith, 1974). Although *Anisakis* spp. appear to cause few pathologies in fish—unless the liver is heavily infected or there are large numbers of worms—sealworms can kill small fish, particularly when vital organs are damaged by migrating larvae (McClelland, 1995). Experimental evidence indicates that *P. decipiens* infection of some fish species affects their ability to swim and thus escape predators (Sprengel and Lüchtenberg, 1991).

An unusual condition called red-**vent** syndrome (RVS; fig. 3), associated with heavy infections by larval *Anisakis* spp. in the skin and muscle tissues of the vent area of wild Atlantic salmon, has been reported in the North Atlantic (Beck and others, 2008) including recently in Canada (Larratt and others, 2013). Lesions appear as small red spots (small hemorrhages) with reddening around the vent in light infections to pronounced swelling, hemorrhage, erosion of the skin's outer layer, loss of scales, and skin inflammation (**dermatitis**) in severe infections. It is currently unknown why this occurs, but RVS may be an external sign of heavily parasitized fish (Murphy and others, 2010). However, the intensity of larval *Anisakis* infections in wild Atlantic salmon was only weakly associated with RVS, suggesting other factors may be involved in this syndrome such as immune status, stress, water temperature and timing of infections (Larrat and others, 2013). Increased levels of infections have been observed in adult salmon returning to fresh water to **spawn** (Murphy and others, 2010). Apparently, after Atlantic salmon spawn, red vent lesions subside somewhat. There is no evidence that RVS causes mortality or prevents salmon from spawning but further research is warranted.

Figure 3. Red-vent syndrome in Atlantic salmon. (Photo by Ministère des resources naturelles et de la faune [Station piscicole de Tadoussac]).

Birds

There are a few records of *Anisakis* spp. larvae in fish-eating birds, particularly in Japanese waters. Larval *Anisakis* spp. have been reported from the herring gull, black-tailed gull, tufted puffin, Swinhoe's storm petrel, Japanese cormorant, and northern fulmar (Riley, 1972; Smith and Wootten, 1978). A single immature adult female *Anisakis* spp. was reported from the esophagus of a northern fulmar in northern Europe (Riley, 1972). The occurrence of these parasites in fish-eating birds is regarded as accidental.

Other Animals

Experimentally or inadvertently, frogs, turtles, cats, dogs, rabbits, rats, guinea pigs, domestic pigs, and monkeys were susceptible to infection with *Anisakis* spp. or *Pseudoterranova* spp., but results varied (Smith and Wootten, 1978; Smith, 1999). In some cases, worms migrated through various tissues and caused pathologies; in other cases, worms died and were encapsulated by strong tissue responses. Natural infections of a brown bear (Smith and Wootten, 1978; Smith, 1999) and a dog (Kitayama, 1962 in Oshima, 1987) have been reported.

Obtaining a Diagnosis

Many human cases of anisakiosis and pseudoterranovosis likely go unreported, and probably many worms die or are passed in the feces without causing any symptoms or clinical signs. Diagnosis is difficult, but clinical infections are usually suspected based on symptoms, clinical presentation, and history of recent consumption of improperly prepared seafood. Symptoms in acute cases of gastric anisakidosis include intense upper abdominal pain, nausea, and vomiting within 5 hours of consuming infected fish or squid.

Intestinal anisakidosis has less specific symptoms, but usually the victim experiences low abdominal pain, particularly in the lower right quadrant; nausea; vomiting; fever; diarrhea or constipation; and inapparent blood in the stool, usually within 1–7 days after consuming infected fish or squid. Infections, either gastric or intestinal, may become chronic, and intestinal blockage and tumors (swellings) have been reported (Smith and Wootten, 1978; Smith, 1999). Transient infections with *Pseudoterranova* spp. are often diagnosed based on the reported symptom of a "tingling" sensation in the throat or mouth or mild abdominal discomfort, and the worms are vomited or coughed up by the patient days to weeks after ingestion (Smith, 1999).

In clinical cases of gastric infection, *Pseudoterranova* spp. may be diagnosed using **gastroendoscopy**, whereby a **fiberscopic** tube equipped with a small camera and forceps is passed through the person's mouth into the stomach to observe the surface of the mucous membranes (Oshima, 1987). Worms can then be removed by using fine biopsy forceps. The same method can be used for gastric infections of *Anisakis* spp. (Bhat and Cleland, 2010), but not for most intestinal infections due to the physical limit of endoscopy. Fifty-six larval *Anisakis* spp. were removed by gastroendoscopy from the stomach of a Japanese patient who had prepared her own sashimi (Kagei and Isogaki, 1992). Other medical imaging such as **radiology**, **computed tomography** (CT) scans, and abdominal ultrasound may help in diagnoses (Oshima, 1987; Couture and others, 2003).

Blood and blood serum tests such as enzyme-linked immunosorbent assay (ELISA) have been used to detect specific **immunoglobulin E (IgE) antibodies** to *A. simplex* (Lorenzo and others, 2000; Valiñas and others, 2001) in blood samples. **Histological** analysis of biopsied lesions caused by *Anisakis* spp. or *Pseudoterranova* spp. attaching to the gastrointestinal wall usually contain eosinophils, a type of white blood cell indicative of parasitic infection. Severe allergic reactions such as dermatitis, subcutaneous swelling, rashes, throat swelling, and low blood pressure, particularly in response to *A. simplex,* have been reported in acute cases, especially in Spain where more than 150 cases have been reported since 1995 (Audicana and others, 2002). In these cases, specific IgE and skin prick tests have been used in diagnosing allergic reactions to *A. simplex,* but acute parasitic infections and allergies are still under investigation (Alonso-Gómez and others, 2004; Reddy and Fried, 2008).

Where clinical infections are rarely encountered by the medical profession, such as in North America and Europe, infections may be misdiagnosed as gastrointestinal cancer, ulcers, obstruction or inflammation such as Crohn's disease, appendicitis, and acute abdominal syndrome. Consequently, abdominal surgery is often performed. It is during surgery that worms, often alive, may be found (Clavel and others, 1993), and usually affected tissues are removed. Histological, morphological, and molecular analyses can be used to identify the cause of tissue inflammation as well as identify the genus, and sometimes the species, of recovered worms (Maejima and others, 1992; Eskesen and others, 2001; Couture and others, 2003; Mattiucci and Nascetti, 2008). Identification of larval *Anisakis* spp. and *Pseudoterranova* spp. is based principally on morphology of the digestive system of the worm studied using **light microscopy** (fig. 4).

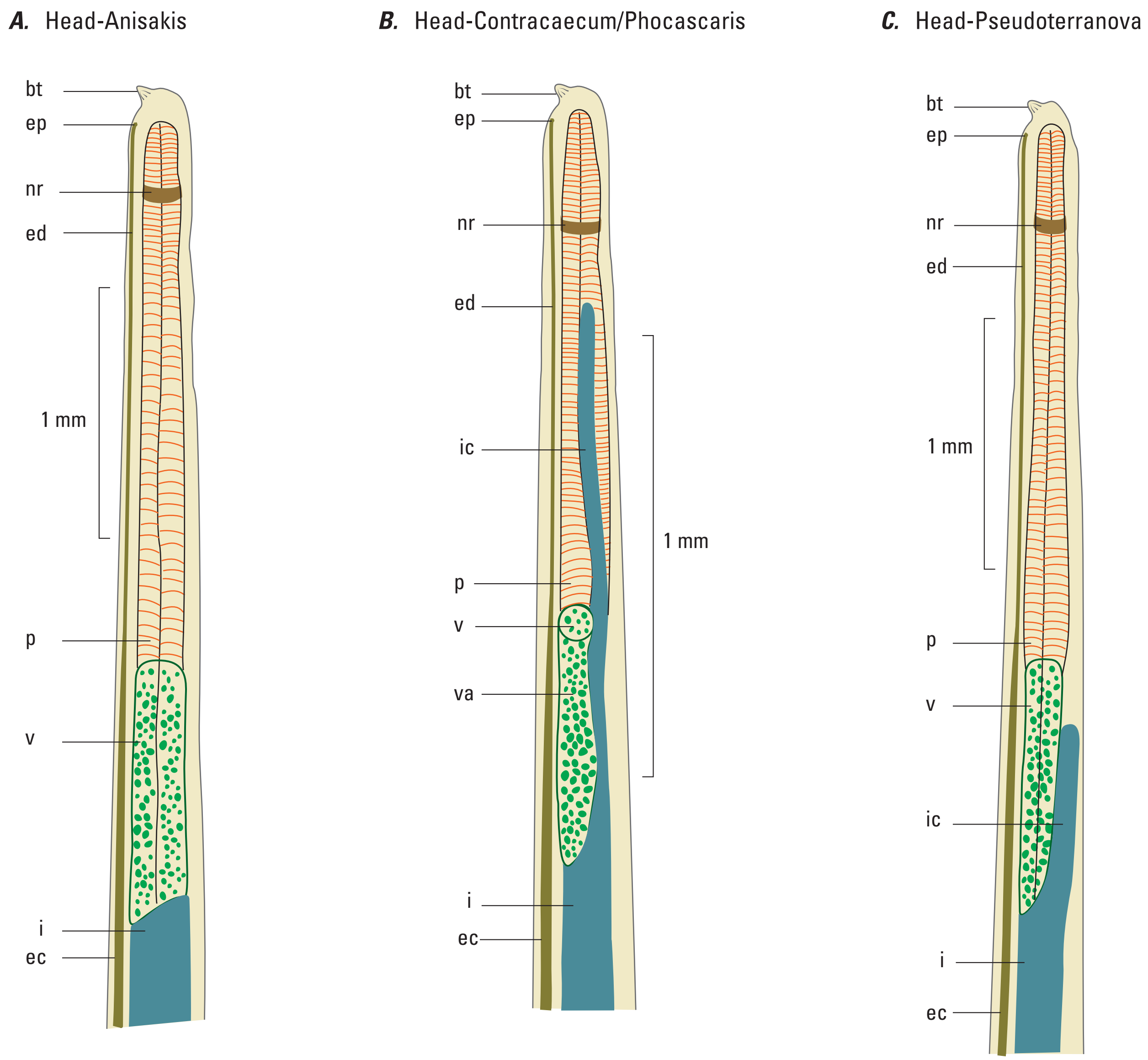

Figure 4. Key morphological features of anisakid larvae removed from fish: *A*, *Anisakis*; *B*, *Contracaecum/Phocascaris*; *C*, *Pseudoterranova*. Note proventriculus (p), ventriculus (v), intestine (i), intestinal caecum (ic), ventricular appendage (va), boring tooth (bt), excretory pore (ep), nerve ring (nr), excretory duct (ed), excretory canal (ec).

Disease Ecology

The life cycle of *Anisakis* spp. is complex and involves pelagic invertebrates such as small shrimplike crustaceans or euphausiids (commonly called **krill**) or squid and pelagic fish such as capelin, herring, salmon, or redfish as intermediate or transport hosts, with cetaceans as definitive hosts. The life cycle of *Pseudoterranova* spp. is similar but involves benthic invertebrates such as amphipods (commonly called **scud)**, and benthic fish such as flatfish and cod as intermediate hosts, with pinnipeds as definitive hosts.

Anisakis spp. reproduce in the stomach of cetaceans such as minke whales and beluga and harbor porpoises (fig. 5). Female worms produce eggs, which enter the sea with the feces of the cetacean. A period of development is required in the sea before larval stages hatch from eggs. These larvae are then eaten by a necessary, or "obligate," first intermediate host such as krill, where larvae develop and grow considerably, reaching 7– 39 millimeters (mm) in length. Infected krill are subsequently eaten by a transport host such as squid or small pelagic fish (capelin, mackerel, herring). These infected fish or squid are in turn eaten by large pelagic predatory fish such as redfish, salmon, or silver hake, which can accumulate large numbers of infective larvae. Finally, the life cycle is completed when the definitive cetacean host eats fish (small or large fish) or krill containing infective larvae. Larval stages

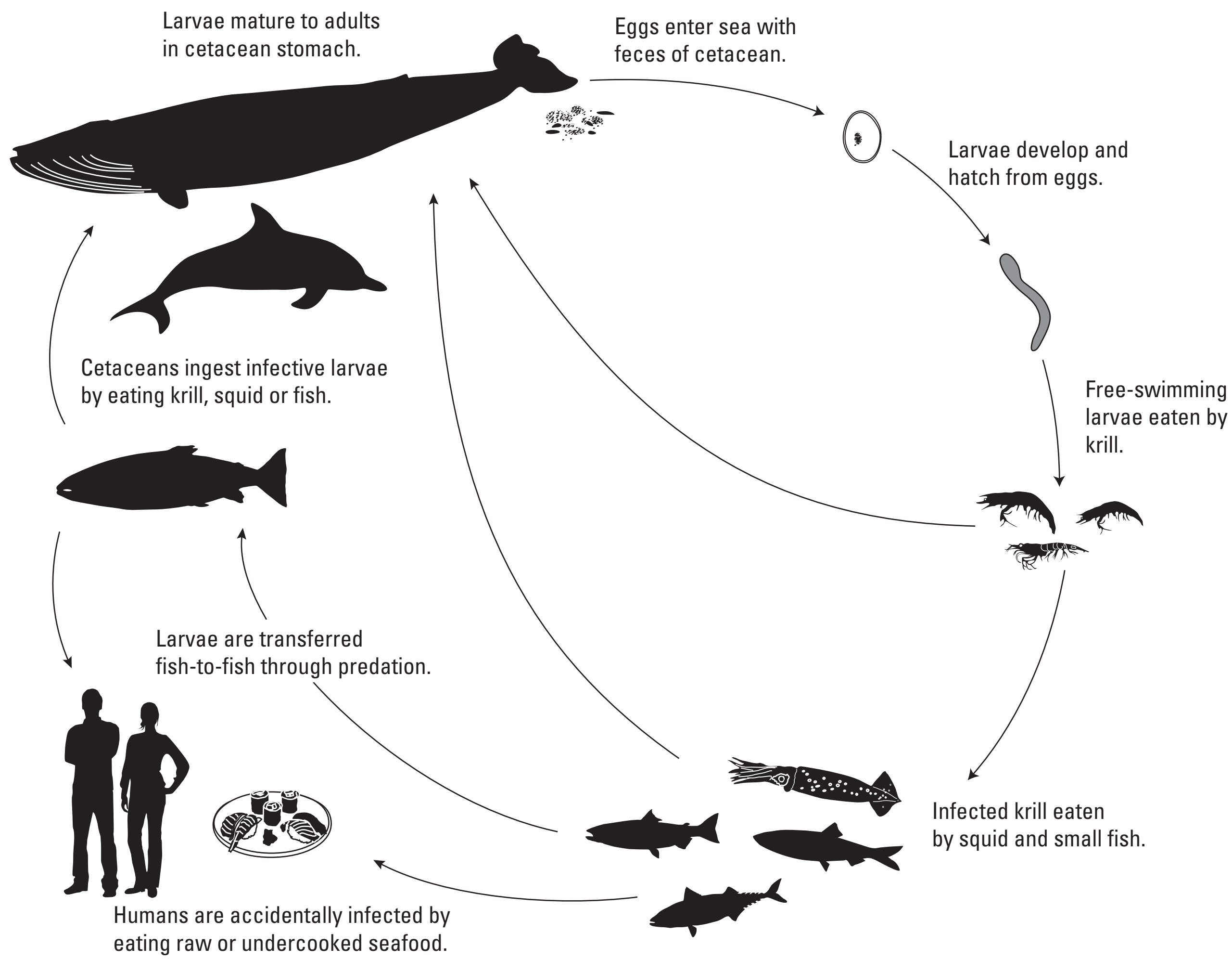

Figure 5. The life cycle of *Anisakis simplex*. (Adapted from Anderson, 2000)

in fish are small (9–39 mm long) and are usually found in a flat coil on the visceral organs (fig. 6). They may also occur in the flesh of fish where they are difficult to see, because they are transparent or white in color. Larvae may migrate from the visceral organs into the muscle after death, especially if the fish is allowed to warm to room temperature.

Pseudoterranova spp. reproduces in the stomach of pinnipeds such as grey seals (fig. 7). Female worms produce eggs that enter the sea with the feces of the seal. A period of development is required in the sea before larval stages hatch from eggs. These larvae attach to sand or rocks by their tails and are eaten by a first host such as **copepods** or immature or mature invertebrates such as mysids, amphipods, **isopods**, and **polychaetes**. Infected invertebrates are subsequently eaten by a second host such as small benthic fish (sculpins, smelt, juvenile cod, and flatfish). These small infected fish are in turn eaten by large benthic predatory fish such as large cod, monkfish, and eelpout, which can accumulate large numbers of infective larvae. Finally the life cycle is completed when the definitive seal host eats small or large fish containing infective larvae. The biology of *Pseudoterranova* spp. is not completely understood, particularly the role of invertebrates and small fish (McClelland, 2002; Smith and Hemmingsen, 2003). Larval stages in fish grow considerably, from more than 2– 60 mm long, depending on the size of fish and its age when it is infected. Larvae may also reside in the gut wall, liver, or body cavity of fish, but most are found in the muscles (fig. 8). As larvae are yellow to red in color and relatively large, they are often seen in the fillets, much to the alarm of consumers. Larvae may or may not be encapsulated and may lie coiled or fully extended in tissues, but this may be a function of host species, temperature, or age of infection (Ramakrishna and Burt, 1991; McClelland, 1995). *Pseudoterranova* spp. larvae may also migrate after the death of the fish. Similarly, another related anisakid, *Hysterothylacium aduncum*, which matures in the intestine of fish such as cod, can migrate after the host dies by exiting from its anus, mouth, or gills and is often misidentified as *Pseudoterranova* spp.

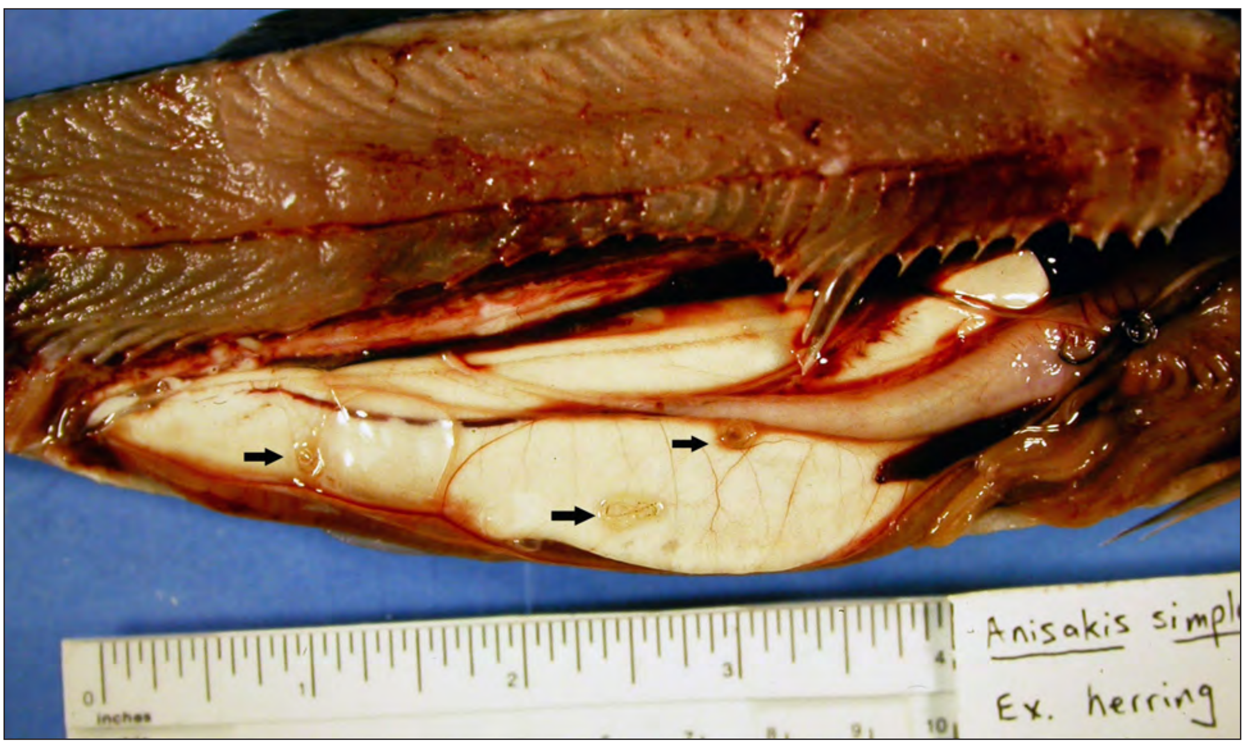

Figure 6. Larval *Anisakis* sp. (arrows) in the abdominal cavity of an Atlantic herring. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)

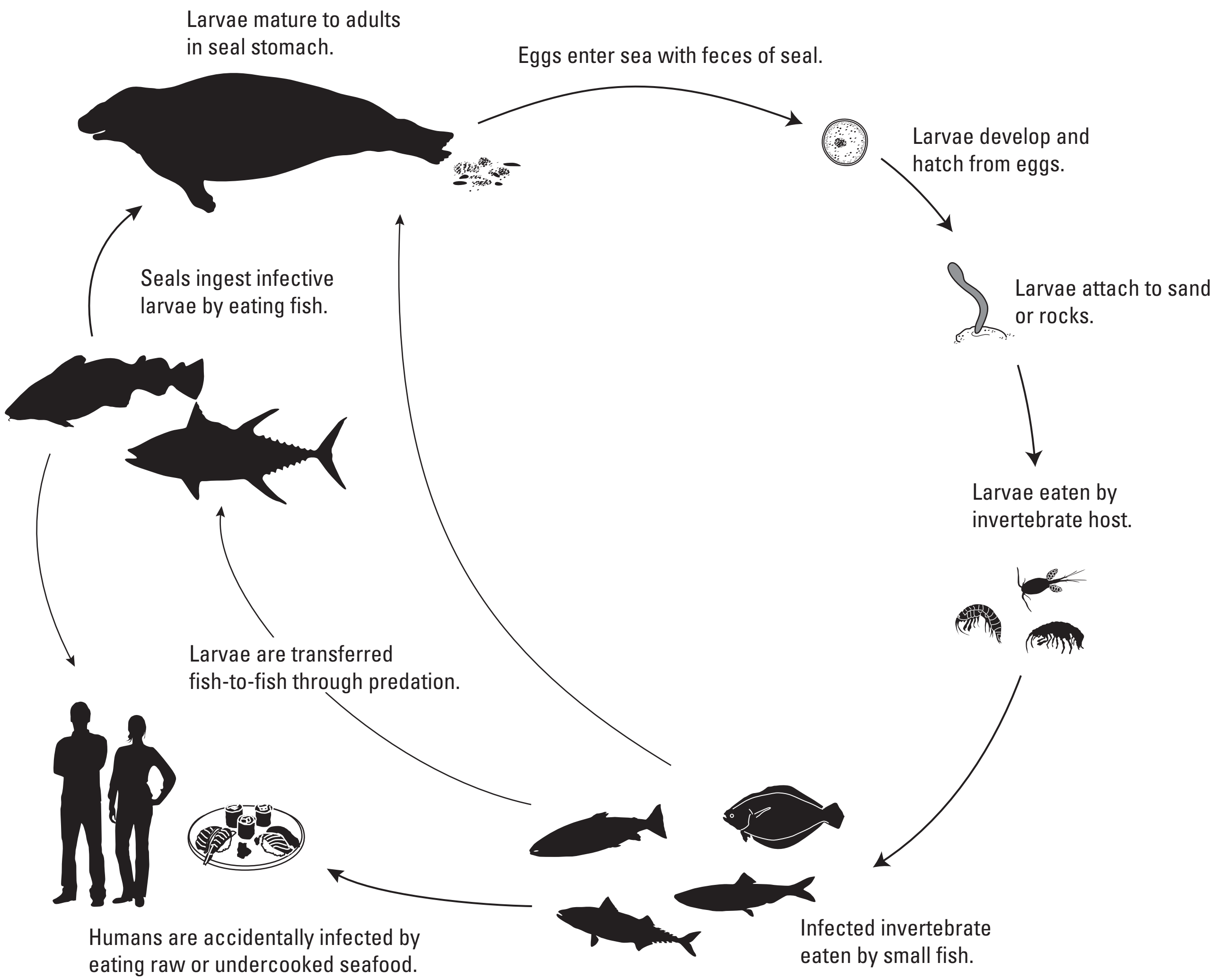

Figure 7. The life cycle of *Pseudoterranova decipiens*. (Adapted from McClelland, 2002, and Anderson, 2000)

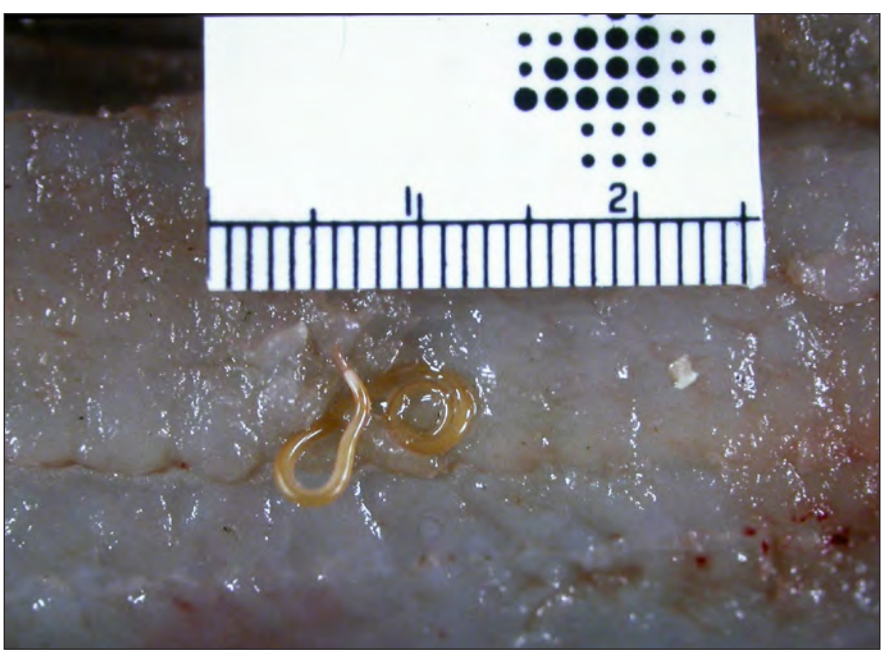

Figure 8. Larval *Pseudoterranova* sp. in muscle of an American plaice. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)

Migration of Adult *Hysterothylacium aduncum* in Atlantic Cod After Host Death

Post-mortem migration of nematodes is a well recognized phenomenon observed by parasitologists, fishermen, hunters, wildlife biologists, and others. It is particularly common in cold-blooded animals such as fish when the temperature of a recently caught fish increases above that of its original habitat in water. The rise in temperature stimulates some parasites in fish tissues to migrate within the body of the fish or even to exit the body completely. In the figure below, *Hysterothylacium aduncum*, a parasitic nematode found as adults in the digestive tract of Atlantic cod, the definitive host, leave the fish via the vent, mouth, or gills. Many marine fishermen are familiar with sealworm, *Pseudoterranova decipiens*, which uses cod as an intermediate host in which larval stages occur in the muscles. Although sealworm larvae migrate within the tissues of cod, even when cod are still alive, many fishermen mistake *H. aduncum* for sealworm when they observe a fish as illustrated in the figure below. Post-mortem migration by *H. aduncum* can be eliminated by gutting fresh cod immediately after capture.

***Hysterothylacium aduncum,* a parasitic nematode of Atlantic cod, may be mistaken for *P. decipiens* as they exit the body of a dead fish through the vent, mouth, or gills. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)**

Commercial Candling of Fish Fillets to Visualize and Extract *Pseudoterranova decipiens*

Candling of fish in fish-processing plants is commonly carried out in areas of the world where fish are frequently infected with parasitic nematodes such as sealworm, *Pseudoterranova decipiens*, because worms look unsavory to fish consumers. Candling allows the workers to see the worms and remove them from fish fillets. Fillets are sliced to a predetermined thickness and placed on a light table. Light passing through the fillet from below enables workers to see large, yellow to red larval sealworms and then remove them using forceps. As the efficacy of detection and removal depends on various factors such as the thickness of the fish fillet, the number of worms present, their size, the intensity of light used, and observer experience, candling is not 100 percent efficient. Candling involves considerable cost to fish processers and diminishes the quality and value of fillets.

Candling of fish fillets to visualize and remove larval worms. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)

Points to Ponder

Most professional chefs in “sushi-bars” or high quality restaurants that serve sashimi, ikasashi, or ceviche are trained in the proper handling of raw fish or squid for safe consumption by their customers. It is more commonly the home chef preparing his own fish dish that has an intimate experience with parasitic worms (Kates and others, 1973; Oshima, 1987; Kagei and Isogaki, 1992; Maejima and others, 1992; Couture and others, 2003). The risk of anisakid infection from consuming farmed fish (those raised in sea pens, cages, or sea nets in aquacultural operations where fish are fed a commercial food, usually dry or expanded pellets) is considered low (Deardorff and Kent, 1989; Inoue and others, 2000).

Disease Prevention and Control

Infective larval Anisakis spp. and Pseudoterranova spp. are remarkably resistant to various environmental conditions. In fish flesh they can survive cold smoking, insufficient marination or salting, and freezing temperatures (Hauck, 1977; Bier, 1976; Deardorff and Throm, 1988; Gardiner, 1990; Wharton and Aalders, 2002). Several methods of fish preparation can be used to reduce the chance of acquiring infections (table 6). Rapid **evisceration** of freshly caught fish is important should there be larvae in the viscera or body cavity (Smith and Wootten, 1975). Larval Anisakis spp. in fish flesh is problematic for consumers, because its small size and transparent or white color makes it difficult to detect. On the other hand, larval *Pseudoterranova* spp., which is commonly commonly found in fish flesh, is often seen by the consumer, depending on the thickness of fish fillets. Slicing fish fillets and using a strong light source to visualize larvae and then remove them manually (a process called candling) is still used commercially in some fish processing plants, but candling is costly, diminishes the value of the product, and is inefficient as its efficacy depends on the thickness of the fillet being examined (Power, 1958, 1961; Valdimarsson and others, 1985; Hafsteinsson and Rizvi, 1987). An effective research tool to detect and obtain live larval anisakids from infected invertebrates, fish, or other tissue is artificial digestion using a Baermann apparatus.

Research has shown that commercial blast-freezing of infected fish to at least –35 degrees Celsius (°C) for 15 hours will kill larvae (Deardorff and Throm, 1988). However, larval survival in fish flesh is dependent on the mass of the fish being frozen. For example, 20-kilogram (kg) boxes of monkfish required more than 28 hours to reach the commercial blast freezer temperature of –35 °C to –38 °C (Wharton and Aalders, 2002). Furthermore, it is important that all parts of the fish freeze solid at these temperatures and for the required time to ensure killing any larvae that may be present. According to the U.S. Food and Drug Administration, raw, raw-marinated, partially cooked, or marinated partially cooked fish must be frozen at –35 °C or below until solid and stored at this temperature or below for 15 hours to destroy larvae. Similarly, freezing these products at –20 °C or below for a minimum of 168 hours (7 days) will also destroy larvae (U.S. Food and Drug Administration, 2009). Cooking fish thoroughly so that the internal temperature of the fish attains 60–63 °C for a few minutes will kill larvae (Oshima, 1972; U.S. Food and Drug Administration, 2009).

Table 6. Methods to reduce risk of infection by anisakid larvae for consumers of fish.

[°C, degrees Celsius]

- Rapid evisceration of fish to prevent postmortem migration of larvae into muscles.
- Candling and manual removal of larvae.
- Solid freezing of fish. The time required to freeze fish solid depends on the mass of the fish. Recommended to freeze fish at –20 °C for a minimum of 7 days.
- Thorough cooking of fish to an internal temperature of 60–63 °C for several minutes.

The Baermann Technique

The Baermann technique is a method commonly employed in laboratories to concentrate and collect live organisms from a large sample of soil, water, or tissue. It was developed by G. Baermann in 1917 to recover hookworm larvae from soil samples (Baermann, 1917). It consists of a funnel with a plastic tube at the bottom that is closed with a stopcock, which can be opened to remove small samples or liquids containing organisms that have accumulated in the plastic tube. A sample of soil or tissue may be placed on a sieve or filter suspended in the top part of the funnel. A liquid medium such as water may or may not be used. There are various modifications of the Baermann apparatus. A light may be suspended above the funnel to encourage light-averse organisms to migrate downward, a technique frequently used by **entomologists** to collect some insects or soil organisms. In parasitology, a modified version may involve preparing a **pepsin** solution to simulate the digestive juices in the stomach of a mammal or bird. This solution is poured into the funnel with the stopcock closed, and infected tissue such as that from a fish or invertebrate is placed on a sieve or filter within the fluid at the top of the funnel. The apparatus may be kept at room temperature, 37 degrees Celsius (°C) or 42 °C depending on the sample. **Enzymes** in the pepsin solution slowly digest the tissue, such as fish muscle containing larval *Anisakis simplex*, and the enzymes and warm solution stimulate the larvae to migrate out of the tissues and fall downward into the plastic tube where, after a few hours incubation, they may be collected. Samples of krill can also be digested in this manner to collect larval *Anisakis* spp. (Hays and others, 1998).

Baermann apparatus. (Photo by Dr. Lena Measures, Fisheries and Oceans Canada)

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Glossary

A

aberrant Departing from the usual course; unusual.

abiotic Nonliving.

abscess A localized collection of pus (thick, yellowish fluid made of white blood cells, dead tissue cells, and cellular debris) surrounded by inflamed tissue.

amphipod A small, shrimplike crustacean within the taxonomic order Amphipoda, having a laterally compressed body and living mainly in aquatic habitats. *See* crustacean, scud.

anadromous Migrating up rivers from the ocean to breed in fresh water.

anisakid A roundworm within the family Anisakidae, including members of the genera *Anisakis* and *Pseudoterranova*. *See* genera, taxonomic.

antibody A protein formed in the body of a vertebrate that is used by the immune system to identify and neutralize the effects of foreign invading proteins (antigens), such as those in bacteria and viruses.

ascarid Any parasitic nematode worm of the family Ascaridae. *See* parasite, nematode.

B

benthic Pertaining to the bottom of the ocean or lake or the organisms that live there.

C

cephalopod A mollusk within the taxonomic class Cephalopoda having a large head and tentacles, for example, octopus, squid, cuttlefish, and nautilus. *See* taxonomic.

cetacean A marine mammal within the taxonomic order Cetacea having no hind limbs, flippers as forelimbs, and a blowhole for breathing, for example, whales, dolphins, and porpoises. *See* taxonomic.

copepod A tiny, aquatic crustacean within the taxonomic subclass Copepoda, having an elongated body and a forked tail. *See* crustacean, taxonomic.

crustacean An invertebrate animal within the taxonomic class Crustacea, having a segmented body, chitinous exoskeleton, and jointed limbs, for example, lobsters, crabs, shrimp, barnacles, and pill bugs. *See* invertebrate, taxonomic.

computed tomography (CT) scan An imaging method used to construct a cross-sectional image of body structures in a body plane produced by x-ray absorption of the structures in the image plane.

D

dead-end host A host in which a parasite cannot complete its development and transmission in order to continue its life cycle. *See* host, definitive host, intermediate host, parasite.

decapod A crustacean within the taxonomic order Decapoda, having 10 legs, for example, crab, lobster, and shrimp. *See* crustacean, taxonomic.

definitive host An organism in which sexually mature stages of a parasite occur. Also called the final host. *See* host, parasite.

dermatitis Inflammation of the skin.

E

encapsulated Enclosed within a protective layer of cells.

endoscopy Visual examination of the inside of organs and cavities of the body using an illuminated, flexible optical tube.

entomologist A scientist who studies insects.

enzyme A protein produced by a living cell that functions to increase or decrease the rate of metabolic processes.

eosinophils The white blood cells involved in combating parasitic infections and controlling allergic reactions. *See* parasitic.

estuarine Pertaining to an estuary, an area where a river nears the ocean and fresh water mixes with tidal salt water.

euphausiid A small shrimplike crustacean within the taxonomic order Euphausiacea. *See* crustacean, taxonomic, krill.

eviscerate To remove the internal organs; disembowel.

F

fish Refers to finfish, which are cold-blooded strictly aquatic vertebrates with a well differentiated skull and a bony skeleton, rather than shellfish (*see* invertebrates) and jawless fishes.

G

gastric Pertaining to the stomach.

gastroendoscopy Endoscopy of the stomach. *See* endoscopy.

gastrointestinal tract The tubular organs that form a digestive pathway from the mouth to the anus, including the esophagus, stomach, and intestines.

genera Plural of genus. *See* genus.

genus A taxonomic group between family and species containing organisms that share common characteristics. *See* taxonomic, genera.

H

histologic Pertaining to histology, the study of the microscopic structure of tissues.

host An organism that harbors or nourishes microbes, viruses, and parasites. *See* parasite.

I

Immunoglobulin E (IgE) A type of antibody that is important in allergic reactions. *See* antibody.

immune status Refers to the host's ability to fight infections. *See* host.

intensity Number of parasites in an infected host. *See* parasite, host.

intermediate host An organism in or on which the larval stage of a parasite develops but does not sexually reproduce. *See* host, parasite, larva/larval.

Inuit Native people of northern North America, inhabiting areas from Greenland and eastern Canada to Alaska.

invertebrates Animals lacking a spinal column, for example, insects and crustaceans; vertebrates, in contrast, possess a spinal column. *See* crustacean.

isopod A crustacean within the taxonomic order Isopoda, characterized by a flattened body and gills located on abdominal appendages; most are aquatic bottom-dwellers in fresh or salt water. *See* crustacean, taxonomic.

J

K

krill A small shrimplike crustacean within the taxonomic order Euphausiacea. *See* crustacean, taxonomic, euphausiid.

L

larva/larval The immature, early form of an organism that at birth or hatching is not like its parent and has to undergo a series of form and size changes before assuming adult features.

lesion An abnormal change in tissue or an organ due to disease or injury.

light microscopy A technique using visible light and single or multiple lenses (microscope) to obtain a magnified view of a sample.

luminal Pertaining to the lumen, the inner open space of a tubular organ.

M

morphology The study of the form and structure of an organism or its parts.

mucosa A mucous membrane or moist tissue layer lining hollow organs such as the stomach and cavities of the body.

mysid A small, shrimplike crustacean within the taxonomic orders Mysida or Lophogastrida found in salt and fresh water. *See* crustacean, taxonomic.

N

nematode An unsegmented, cylindrical parasitic worm within the taxonomic class Nematoda; roundworm. *See* parasitic, taxonomic.

O

P

parasite An organism that lives in or on another organism of a different species from which it derives nutrients and shelter.

parasitic Pertaining to parasites. *See* parasite.

parasitologist A scientist who studies parasites. *See* parasite.

pelagic Pertaining to the upper waters of the open ocean or the organisms that live there.

pepsin An enzyme produced in the stomach that breaks down proteins.

perforation An abnormal hole in an organ or the act of creating such a hole.

peritonitis Inflammation of the peritoneum, the membrane lining the abdominal cavity and internal organs.

physiological status Refers to the host`s physiology, the normal functioning of an organism.

pinniped A marine mammal within the taxonomic suborder Pinnipedia having finlike flippers as feet, such as walrus, sea lions, fur seals, and earless seals. *See* taxonomic.

polychaete A segmented worm, generally marine, within the taxonomic class Polychaeta. *See* taxonomic.

prevalence The total number of cases of a disease divided by the number of hosts examined in a population at a given time. *See* host.

Q

R

radiology The science of using electromagnetic radiation or sound waves to make images of structures within the body, including x-rays, computed tomography (CT) scans, magnetic resonance imaging (MRI), and ultrasound. *See* computed tomography scan.

roundworm *See* nematode.

S

scud A tiny crustacean resembling a shrimp. *See* crustacean, amphipod.

sensu lato In a broad or wide sense.

sensu stricto In a strict or narrow sense.

spawn To deposit eggs or produce offspring.

species A population or populations of closely related and similar organisims that freely interbreed with one another in natural conditions but not with members of other species.

susceptibility/susceptible Pertaining to the ability of an animal to become infected by a disease-causing organism or to develop disease after becoming infected.

T

taxonomic Pertaining to taxonomy. *See* taxonomy.

taxonomy The systematic principles and procedures of grouping and arranging organisms into a hierarchical order (below).

Taxonomic hierarchy, from general to specific
Kingdom
Phylum
Class
Order
Family
Subfamily
Genus
Species

transport host An organism in which a parasite survives without further development. *See* parasite, host.

U

V

vent The common opening of the intestinal, genital, and urinary tracts in fish, reptiles, and birds. *See* fish.

viscera The internal organs, particularly of the thoracic and abdominal cavities, such as the heart, lungs, liver, kidneys, and intestines.

visceral Pertaining to viscera. *See* viscera.

W

X

Y

Z

zoonotic Transmissible between animals and humans, and vice versa.

Appendixes

Appendix 1. Common and Scientific Names for Species Cited

Common name	Scientific name
Birds	
Black-tailed gull	*Larus crassirostris*
Herring gull	*Larus argentatus*
Northern fulmar	*Fulmarus glacialis*
Swinhoe's storm petrel	*Oceanodroma monorhis*
Tufted puffin	*Fratercula cirrhata=Lunda cirrhata*
Japanese cormorant	*Phalacrocorax capillatus*
Crustaceans	
Crabs	Order Decapoda
Crayfish	Order Decapoda
Krill	Order Euphausiacea
Amphipods	Order Amphipoda
Lobsters	Order Decapoda
Shrimp	Order Decapoda
Fish	
American plaice	*Hippoglossoides platessoides*
Anchovy	Family Engraulidae
Atlantic cod	*Gadus morhua*
Atlantic salmon	*Salmo salar*
Brook trout	*Salvelinus fontinalis*
Capelin	*Mallotus villosus*
Eelpout	Family Zoarcidae
Flatfish	Order Pleuronectiformes
Herring	Family Clupeidae
Mackerel	*Scomber scombrus*
Monkfish	Family Lophiidae
Rainbow smelt	*Osmerus mordax*
Redfish	*Sebastes scombrus*
Salmon	Family Salmonidae
Sculpin	Family Cottoidei
Silver hake	*Merluccius bilinearis*
Smelt	Family Osmeridae

Common name	Scientific name
Mammals	
Andrew's beaked whale	*Mesoplodon bowdoini*
Bearded seal	*Erignathus barbatus*
Beluga	*Delphinapterus leucas*
Blainville's beaked whale	*Mesoplodon densirostris*
Bottlenose dolphin	*Tursiops truncata*
Brown bear	*Ursus arctos*
California sea lion	*Zalophus californianus*
Caspian seal	*Phoca caspica*
Common dolphin	*Delphinus delphis*
Costero	*Sotalia guianensis*
Cuvier's beaked whale	*Ziphius cavirostris*
Dog (domestic)	*Canis lupus familiaris*
Dwarf sperm whale	*Kogia sima*
False killer whale	*Pseudorca crassidens*
Gervais' beaked whale	*Mesoplodon europaeus*
Gray's beaked whale	*Mesoplodon grayi*
Gray seal	*Halichoerus grypus*
Harbor porpoise	*Phocoena phocoena*
Harbor seal	*Phoca vitulina*
Harp seal	*Pagophilus groenlandicus*
Hooded seal	*Cystophora cristata*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
Mediterranean monk seal	*Monachus monachus*
Minke whale	*Balaenoptera acutorostrata*
Northern elephant seal	*Mirounga angustirostris*
Northern right whale dolphin	*Lissodelphis borealis*
Northern (Steller) sea lion	*Eumetopias jubatus*
Pantropical spotted dolphin	*Stenella attenuata*

Common name	Scientific name
Mammals—Continued	
Pygmy right whale	*Caperea marginata*
Pygmy sperm whale	*Kogia breviceps*
Ringed seal	*Pusa hispida*
Rough-toothed dolphin	*Stenella longirostris*
Sea otter	*Enhydra lutris*
Short-finned pilot whale	*Globicephala macrorhynchus*
South American sea lion	*Otaria flavescens*
Sperm whale	*Physeter macrocephalus*
Spinner dolphin	*Stenella longirostris*
Southern elephant seal	*Mirounga leonina*
Strap-toothed beaked whale	*Mesoplodon layardii*
Striped dolphin	*Stenella coeruleoalba*
True's beaked whale	*Mesoplodon mirus*
Tucuxi	*Sotalia fluviatilis*
Weddell seal	*Leptonychotes weddellii*
White beaked dolphin	*Lagenorhynchus albirostris*
Mollusks	
Squid	Class *Cephalapoda, Order Teuthida*
Cuttlefish	Class *Cephalapoda, Order Sepiida*

Appendix 2. Important Literature About *Anisakis* spp. and *Pseudoterranova* spp.

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