# A Semi-Quantitative Risk Assessment of Harmful Parasites in Australian Finfish

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# Abbreviations

| | |
|---|---|
| ABARE | Australian Bureau of Agricultural and Resource Economics |
| AQIS | Australian Quarantine and Inspection Service |
| CNS | Central Nervous System |
| EFSA | European Food Safety Authority |
| EU | European Union |
| HACCP | Hazards Analysis and Critical Control Points |
| FDA | Food and Drug Administration |
| FAO | Food and Agriculture Organisation |
| FSA | Food Science Australia |
| PCR | Polymerase Chain Reaction |
| WHO | World Health Organisation |

# Glossary

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| Accidental host | One that accidentally harbours an organism that is not ordinarily parasitic in the particular species |
| Allergy | A hypersensitive reaction to an allergen; an antigen-antibody reaction is manifested in several forms–anaphylaxis, asthma, hay fever and urticaria |
| Anaphylaxis | A violent allergic reaction characterized by sudden collapse, shock, or respiratory and circulatory failure after injection of an allergen |
| Anisakid | Common name for nematodes of the family Anisakidae |
| *Anisakis* | A genus of nematodes (family Anisakidae) |
| Anisakidosis | Disease caused by any member of the family Anisakidae |
| Anisakiasis | Disease caused by members of the genus *Anisakis* |
| Cestode | A class of parasitic tapeworms |
| Definitive host | The organism in which a parasite passes its adult and sexual existence |
| Dermatitis | Inflammation of the skin. Dermatitis can result from various animal, vegetable and chemical substances, from heat or cold, from mechanical irritation, from certain forms of malnutrition, or from infectious disease. |
| Eosinophil | A type of white blood cell containing granules that can be stained by eosin (a chemical that produces a red stain). |
| Eosinophilia | A condition in which the eosinophil count in the blood exceeds 450/µl or $0.45\times10^9$/L |

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| Endoscopy | The visualization of the interior of organs and cavities of the body with an illuminated, flexible optical tube (endoscope) |
| GAA | Anisakiasis with allergy |
| Gastroallergic anisakiasis | An acute IgE-mediated generalized reaction |
| Gastroenteritis | Inflammation of the lining of the stomach and the intestines. Symptoms may include nausea, vomiting, diarrhoea, and abdominal cramps (dull or sharp pains). Gastroenteritis may be caused by infection with bacteria, parasites, or viruses. |
| Gnathostomes | Common name for nematodes of the family Gnathostomatidae |
| Gnathostomiasis | Disease caused by members of the family Gnathostomatidae |
| Intermediate host | The organism in which a parasite passes its larval or nonsexual existence |
| Myalgia | Muscular pain or tenderness, typically of a diffuse and/or non-specific nature |
| Nematode | Common name for any roundworm of the phylum Nematoda |
| Paratenic host | An animal acting as a substitute intermediate host of a parasite, usually having acquired the parasite by ingestion of the original host |
| Protozoa | Group of extremely small single cell (unicellular) or acellular organisms that are found in moist soil or water. They tend to exist as parasites, living off other life forms |
| Respiratory arrest | The cessation of breathing |
| Rhinorrhea | A discharge from the nasal mucous membrane, especially if excessive |
| Sensitisation | Being hypersensitive or reactive to an antigen, such as pollen, especially by repeated exposure |
| Surgical excision | Surgical removal by cutting away or taking out as of a tumour or a portion of a structure or organ |
| Skin prick test | A method for medical diagnosis of allergies that attempts to provoke a small, controlled, allergic response |
| Subcutaneous swelling | An accumulation of an excessive amount of watery fluid in cells, tissues, or body cavities |
| Trematode | Common name for a fluke or flatworm of the class Trematoda |

# Contents

# Executive Summary


1. A risk assessment has been undertaken of parasites in Australian finfish, for which the statement of purpose was to:

   - Undertake a screen of parasites present in Australian finfish and identify those which may be able to cause illness among consumers.
   - For those parasites identified as potentially able to cause illness, to estimate the risk of contracting gastrointestinal disease and allergenic reactions from the consumption of Australian fish contaminated with parasitic worms.

2. Following the Hazard Identification process, cestode and trematode worms, plus protozoans were eliminated as possible hazards in Australian fish.

3. A risk assessment was undertaken of nematode worms in commercially produced Australian fish consumed raw as sushi and sashimi and found:

   - Several genera of the *Anisakidae* (*Contracaecum, Anisakis, Pseudoterranova and Hysterothylacium)* have been found in Australian finfish.
   - One case of anisakidosis had occurred in Australia following home consumption of mackerel.
   - One outbreak of gnathostomiasis involving two people was attributed to consumption of bream.
   - The likelihood of contracting anisakidosis from sushi/sashimi consumption was estimated as extremely low in a qualitative risk assessment.
   - In a semi-quantitative assessment the likelihood was rated 31 (low) with an estimated 4.8 cases/year.
   - Since freshwater fish are not used for sushi or sashimi the likelihood of contracting gnathostomiasis was extremely low.
   - Among some populations e.g. the northern Basque region of Spain, allergic reactions are apparently common in individuals sensitised to anisakid antigens.
   - In the light of the significant exposure to anisakids via Australian fish, attempts were made to determine whether allergic reactions were encountered among the Australian population.
   - Expert information could provide no evidence because none can be gathered in the absence of a commercial test for anisakid-induced allergy.
   - The above is a major data gap in the present study.

The risk associated with anisakids and gnathostomes resulting from the consumption of Australian finfish is considered low; however, there is a large knowledge gap regarding the prevalence of Anisakiasis with allergy (GAA) in the Australian population from locally harvested seafoods.

# 1. Introduction

## 1.1 Background

While there are standard tests available for microbiological and chemical contaminants of seafood, visual inspection following harvest is recognised internationally by regulators (section 2.3); however, this is unlikely to guarantee zero risk to human health for internal seafood parasitic hazards. Due to the high prevalence of fish-borne parasitic infections in some countries (Murrell, 1995), some importing nations require an attestation from the regulatory agency that fish are free of parasites (Mark Schipp, DAFF, personal communication, 2010). Therefore, this risk assessment was undertaken to provide an assessment of the potential human health risk associated with parasites in Australian seafood.

## 1.2 Statement of Purpose

The purposes of the present risk assessment are to:

1. Undertake a screen of parasites present in commercially produced Australian finfish and identify those which may be able to cause illness among consumers.
2. For those parasites identified as potentially able to cause illness, to estimate the risk of contracting gastrointestinal disease and allergenic reactions from the consumption of Australian fish contaminated with parasitic worms.

# 2. Hazard Identification

## 2.1 Hazards of Concern

Endoparasites of fish include parasitic worms in the Phylum Platyhelmintha Class Trematoda (flat worms, Class Cestoda (tapeworms) and Class Nematoda (round worms) and protozoa (which form cysts).

With respect to protozoa, there have been notifications of foodborne illnesses due to *Cryptosporidium*; however, the food sources were unknown. Although, *Cryptosporidium* has been found in shellfish (as the cyst can pass through the shellfish filtration system), there have been no illness notifications linked to the consumption of shellfish (Gilbert *et al*., 2007).

Parasitic worms (or helminths) are reported to occur more frequently than protozoa in fishery products, especially in developing countries (FDA, 2011) where they are found in the muscle, viscera and intestines of fish. An overview of the main fish parasites that pose a risk to humans, their global distribution and clinical features that characterise illness is presented in Table 1.

### *2.1.1 Cestoda*

Cestodes live in the gut of vertebrates. Human infections occur from underprepared meat (*Taenia*) and fish (*Diphyllobothrium*) where the tapeworm can grow to 15 m in the intestine. The most common infection from fish consumption is caused by *D. latum*, with *D. pacificum*, *D. dalliae*, *D. dendriticum* and *D. nikonkaiense* also causing disease in many parts of the world (Scholz *et al*., 2009). No records exist for any of the species in Australia (Anon., 2009) and Scholz *et al*. (2009), in a review of global diphyllobothriosis, state: *"There are no reliable recent reports on the occurrence of broad fish tapeworms in humans from Africa and Australia"*.

Given the foregoing a decision was made not to proceed with an assessment of the risk of illness from consumption of Australian fish infested with *Diphyllobothrium*.

### *2.1.2 Trematoda*

Trematodes are known as flukes, small worms which may grow to a few centimetres in length and infect the lungs (*Paragonimus*), liver (*Fasciola* and *Clonorchis*) or blood (*Schistosoma*). Fish-borne trematode disease caused by *Clonorchis sinensis* affects an estimated 7,000,000 people worldwide and is endemic in Asia, particularly in southeast China; 30-60% of the population of Hong Kong is believed to be infected. Opisthorchiasis (caused by *Opisthrochis viverrini*) is a major cause of death in northeast Thailand and in Laos (Durborow, 1999).

Goldsmid *et al*. (2003) state that *Brachylaima* is endemic in Australia, with snails as transmission route to water and plants. The parasite is a cause of diarrhoea when an intermediate host is consumed.

Given that there is no evidence that trematodes infest fish for human consumption or that there are cases associated with trematodes a decision was made not to proceed with a risk assessment for this hazard:product pairing.

### *2.1.3 Nematoda*

Nematodes, particularly the *Anisakidae* and *Gnathostomatidae*, may infect people who consume fish via third-stage larvae. Symptoms include diarrhoea, vomiting, abdominal pain and allergic reactions. Genera most commonly associated with disease include *Anisakis*, *Terranova* and *Contracaecum*. These genera, most commonly associated with disease and the leading cause of parasitic infection in salt water fish (FAO/WHO, 2012), are found throughout the world including Australia (Cannon, 1977; Setyobudi *et al*., 2010; Gutiérrez-Galindo *et al*., 2010; Ceballos-Mendiola *et al*., 2010; Chou *et al*., 2010).

*Anisakis simplex* is the only parasite in marine fish and mammals (e.g. dolphins and seals) known to cause allergic reactions in humans. The roundworm can grow up to 2 cm long in fish, almost colourless and tightly coiled, encapsulated as a cyst in the gut and belly flap, where it may migrate to the flesh, particularly in fish left ungutted after capture; the latter has reportedly occurred in herring, mackerel and blue whiting (Wootten & Cann, 2001). Anisakidosis has resulted from the consumption of raw fish in Japan (Ishikura *et al.*, 1993), pickled anchovies in Spain (Lopeź-Serrano *et al.*, 2000) and Pacific Salmon in sushi bars in the Seattle region, USA (Adams *et al.*, 1997).

*Contracaecum* has a wide global distribution, including in Queensland and South Australia (Cannon, 1977; Shamsi *et al*., 2010). There has been a single case of gastrointestinal anisakidosis reported in a 41-year old Tongan woman from South Australia who consumed raw mackerel (Shamsi & Butcher, 2010).

Gnathostomiasis is caused by third-stage larvae from the *Gnathostomatidae* when larvae penetrate the intestine and colonise widely within the body. The disease is widely distributed in South East Asia, particularly Thailand and Japan (Nomura *et al*., 2000), and Central and South America (Herman & Chiodini, 2009).

In Australia, *G. spinigerum* is endemic and larvae may be found in a range of intermediate and paratenic hosts including freshwater fish, snakes, frogs, snails and fowl (Goldsmid *et al*., 2003). Jeremiah *et al*. (2001) describe two cases of gnathostomiasis in a couple who consumed whole black bream (possibly *Acanthopagrus berda* or *Hephaestus jenkinsi*) caught in the Calder River in northern Western Australia and pan-fried whole over a camp fire. This is the first reported outbreak of gnathostomiasis in Australia, though the same authors cite suspected cases in Queensland (Moorhouse *et al*., 1970)

Accordingly, since genera of the *Anisakidae* and *Gnathostomatidae* are present in Australian fish and have been implicated in illness following fish consumption, a risk assessment is undertaken of these hazards in fish caught/harvested in Australia.

## 2.2 Description of the Food

Most parasitic illnesses result from the consumption of raw, insufficiently frozen or undercooked fishery products. For example, the Koi pla dish from north-eastern Thailand and Laos consists of raw fish flesh chopped with herbs and fish sauce. The consumption of this has resulted in liver fluke infections (EFSA, 2010). Some species of Australian fish, including Australian salmon, goldband snapper, mangrove jack, Morgan's cod, red emperor, coral trout, estuary cod, herring, mulloway, southern garfish and spangled emperor, have been found to harbour both non-infectious and infectious human parasites, (Doupé *et al*., 2003). *Gnathostoma* spp. are thought to be found in some species of freshwater fish.

While parasites have been detected in Australian finfish there have been no notifications of outbreaks from the consumption of commercially produced finfish in Australia, although two isolated illnesses have been reported.

Fishery products which are consumed raw (or almost raw), or have undergone processing insufficient to destroy nematodes, are more likely to pose a higher risk to human health. Therefore, this risk assessment will focus on the consumption of raw finfish.

## 2.3 Current Management Practices

Food and Agriculture Organization and World Health Organization (2012) have recognised the importance and the burden of foodborne parasitic infections. A preliminary report of risk management of foodborne parasites has been published in 2012, which ranks Anisakidae family as the leading cause from the consumption of salt water fish, crustaceans and cephalopods. Many countries implement food safety policies which are intended to mitigate risk to humans from parasites in finfish. Some examples of the policies include:

### *2.3.1 Australia*

Seafood producers/processors are required to have a HACCP plan which require parasitised fish and unwholesome fish to be segregated and destroyed at harvest. AQIS certifies and approves export producers/processors for HACCP and conduct an audit on a regular basis.

### *2.3.2 China*

Standards (GB 18406.4-2001 and GB 10136-2005) declare nil tolerance for detection of parasites of the *Gnathostomatidae* found in aquatic products.

### *2.3.3 Europe*

Council Directive no. 91/493/EEC states (European Union, 1991):

Prior to being released to the market, fish and fishery products must be subject to a visual inspection for detecting and removing any visible parasites. The following fish and/or fish forms must be subjected to freezing at a temperature of not more than -20°C in all parts of the product for a minimum of 24 hours:

a. *fish to be consumed raw or almost raw, e.g. raw herring 'maatje';*
b. *the following species, if they are to undergo a cold smoking process at which the internal temperature of the fish is less than 60°C:*
   - *herring,*
   - *mackerel,*
   - *sprat,*
   - *(wild) Atlantic and Pacific salmon;*
c. *marinated and/or salted herring where this process is insufficient to (95/71) kill the larvae of nematodes.*

Manufacturers must provide certification stating the type of processing the above products have undergone when they are placed on the market. Note that the European Commission has exempted farmed salmon from Norway and Scotland from the provisions of the hygiene regulations that require minimally processed fish intended for consumption without cooking to be frozen before sale (WHO, 1999).

### *2.3.4 Russia*

Regulatory standard 2.3.2.1078-01 has required certain species of fish imported into Russia to be free from *Anisakis* and *Gnathostomata* e.g. Salmon, Sturgeon, minced, tinned, jelled, salted, smoked, fried and preserved forms of fish; and hard roe (caviar). Similarly, the following must not contain live gnathostomes: Snakehead and all the fish forms mentioned in the *Anisakis* category (David Padula, SARDI, personal communication, 2011).

### *2.3.5 Codex Alimentarius*

At a global level, the code of practice for fish and fishery products states that incoming fish should be free from parasites. A combination of freezing temperature and time is suggested to inactivate parasites. Candling is a suggested mean to control parasites in a factory where fish is processed (CAC/RCP 52-2003).

## 2.4 Scope of the Present Assessment

Based on the above, the scope of the present work will focus on parasitic nematodes in Australian finfish and particularly on commercially produced Australian finfish consumed raw, as sushi and sashimi.

**Table 1: Fish-borne parasites which have regional or restricted distributions (after Murrell, 1995)**

| Class | Family | Genus/Species | Clinical Features | Distribution | Examples of Fish |
|---|---|---|---|---|---|
| **Nematoda** | *Anisakidae* | *Anisakis* | Diarrhoea, vomiting, nausea, abdominal pain<br>Allergic reaction, anaphylaxis in severe cases. | Asia, Japan, USA, Pacific Islands, NZ, Australia, Europe (especially UK, France, Spain) | Wild caught salmon, Herring, Goldband snapper, Mangrove jack, Red emperor, Coral trout, Estuary cod, Spangled emperor |
| **Nematoda** | *Anisakidae* | *Contracaecum* | Gastrointestinal symptoms | As for *Anisakis* | As for *Anisakis* |
| **Nematoda** | *Gnathostomatidae* | *Gnathostoma* | Cutaneous migration inside the body causing swelling and pain. Deterioration of central nervous system, brain and vision in fatal cases. | Australia, Asia especially Thailand and Japan | Freshwater fish, Black bream |
| **Cestoda** | *Diphyllobothriidae* | *Diphyllobothrium latum* | Competing with host for nutrients such as Vitamin B12 which leads to megablastic anaemia after several years | Northern Hemisphere, Baltics, Europe, Russia, USA, Canada, Asia | Freshwater fish especially Pike |
| **Trematoda** | *Opisthorchiidae* | *Clonorchis sinensis* | Diarrhoea, indigestion, pain, intestinal discomfort<br>Invasion of pancreatic duct may result in acute pancreatitis.<br>Severe infection results in cholangiocarcinoma. | China, Korea, Japan, Vietnam, Hong Kong, Taiwan | Freshwater snails, Carp family fish |
| **Trematoda** | *Opisthorchiidae* | *Opisthorchis viverrini* and *O. felineus* | As above | Eastern Europe, Poland, Germany, Siberia, South-east Asia | As above |
| **Trematoda** | *Heterophyidae* | *Heterophyes heterophyes* and *Metagonimus yokogawi* | Intestinal ulceration and inflammation.<br>Eggs can be trapped in the intestine and enter the circulatory system.<br>Invasion of spleen, liver, brain, spinal cord and heart may cause fibrosis and calcification of the heart valves. | Asia | Snails, fresh or brackish water fish |

# 3. Hazard Characterisation

## 3.1 Description of the Hazard

Anisakid worms require several hosts to complete their life cycles: definitive hosts, intermediate hosts and paratenic hosts.

Definitive hosts carry sexually adult worms which produce eggs that are eventually shed into water via the host's faeces; dolphins and whales are definitive hosts of anisakids. The eggs then hatch, releasing free-swimming larvae which are eaten by intermediate hosts which include marine animals such as crustaceans and molluscs. Fish and cephalopod molluscs (squids) eat the infested crustaceans and the larvae embed themselves into the intestinal wall of the host where it becomes encapsulated. Thus fish and aquatic birds become paratenic hosts; no larval development occurs in these hosts but they transport larvae from one host to another. Humans are considered accidental hosts which are not part of most life cycles; they consume infested fish or crustaceans and the adult parasites die, ending the cycle.

In the accidental host (humans) anisakid worms can cause two diseases:

1. Anisakidosis – disease caused by members of the *Anisakidae* (*Anisakis, Contrathecium, Pseudoterranova* etc).
2. Anisakiasis – disease caused by members of the genus *Anisakis.*

In practice, the distinction between anisakidosis and anisakiasis is often difficult to make (Andreas Lopata, personal communication, April 2012) with the former more often describing the illness. However, it is noted that advice to consumers on seafood allergies published by the Australasian Society of Clinical Immunology and Allergy Inc uses anisakiasis. In the present study both terms are used, with the above having been taken into account.

The main clinical responses caused by *A. simplex* are:

- Gastro-allergic anisakiasis or GAA in which allergic symptoms follow gastric parasitism after consumption of raw or undercooked fish containing live larvae; this is a reaction to the parasite.
- Allergy to *A. simplex* from fish with allergens which may not contain live larvae; this is a reaction to an antigen, not to the fish itself.

Shamsi & Butcher (2010) describe the symptoms of a 41-year old Australian woman of Tongan descent who contracted anisakidosis following consumption of raw mackerel. Initial symptoms included vomiting, diarrhoea and right-side pain with, 10 days later, sore throat, rhinorrhea, nasal congestion, cough with yellow sputum, myalgia, fevers, chills and sweats. After courses of drug treatment (described in section3.2.4) she recovered in hospital, where she passed a threadlike worm about 2 cm long indentified as a *Contracaecum* larva.

Gnathostomes cause similar clinical responses to *A. simplex* (excluding allergy), but more severe. Nausea, abdominal pain, and vomiting usually develop 24-48 hours after eating. Infection can also involve the eye or cause subcutaneous swelling (Goldsmid *et al*., 2003). The larvae migrate, and may invade the central nervous system (CNS) resulting in meningitis or neuropathy. Until recently, and as with anisakidosis, chemical treatment was considered ineffective with surgical removal of the larvae required. However, Jeremiah *et al*. (2011) describe treatment of a middle-aged Victorian couple based on repeated doses of ivermectin and albendazole (broad-spectrum anti-parasitic agents).

## 3.2 Characteristics of the Disease

### *3.2.1 Susceptible populations*

While all individuals are susceptible to parasitic worms, adults are likely to be more exposed to parasitic infection than children, as adults tend to consume raw or partially cooked fishery products more frequently. For example, over 90% of global cases of anisakidosis are reported from Japan, with most of the remainder from Spain, the Netherlands and Germany (Audicana *et al*., 2002; Bouree *et al*., 1995). The high incidence in Japan could be due to an in-home consumption and high varieties of fish species consumed as sashimi. Exposure may also occur as an occupational hazard, with South African fish-processing workers showing a high (8%) prevalence of sensitisation to *A. simplex*, resulting in dermatitis and other allergic reactions (Nieuwenhuizen *et al*., 2006).

It is possible that genetic factors within the population may also be an important predisposing factor. Audicana & Kennedy (2008) document the unusually high incidence among the Basque population in northern Spain finding a significant positive association between people with HLA haplotypes (DQB1*0601 and DRB1*1502) and *A. simplex* allergy.

There is no information available on whether individuals or groups have any predisposition to infection by gnathostomes.

### *3.2.2 Outcome of exposure*

The dose-response relationship for anisakidosis and GAA is unknown and difficult to determine due to differing sensitivity of individuals to *A. simplex* but, potentially, GAA can be initiated following consumption of one viable larva. Once sensitised to *A. simplex*, subsequent consumption can lead to allergic reactions. There is controversy on whether live larvae need to be consumed, or whether non-viable larvae can induce the allergic reaction. Audicana & Kennedy (2008) describe cases where allergic reactions, including anaphylaxis, have followed consumption of supposedly well-cooked fish. On the other hand Daschner *et al*. (2012) state: "*Challenge tests with nonviable larvae of A. simplex were always negative in patients with GAA, even in those with previous analphylaxis*", and cite studies by Alonso *et al*. (1999) and Sastre *et al*. (2000).

From a risk assessment viewpoint the implications which flow from this controversy are important: if only viable larvae can cause allergies in sensitised consumers then exposure is much reduced, stemming only from under-cooked fish which have not been frozen.

As with anisakidosis, gnathostomiasis infection can also result potentially from one viable parasite (Nomura *et al.*, 2000; Kittiponghansa *et al.*, 1987).

### *3.2.3 Severity of clinical manifestations and nature and frequency of long-term complications*

Gastrointestinal infection usually takes place in the first few hours after ingestion of viable larvae (Audicana & Kennedy, 2008). While most anisakidoses and anisakiases are not fatal, it has been reported that more than 50% of patients required emergency treatment and there was a single near fatal case of respiratory arrest (Audicana, 2002). The allergic reaction caused by *A. simplex* can range from itchy skin, through severe urticaria to anaphylaxis, the rapid onset of life-threatening symptoms including collapse and shock, leading to death. Such symptoms often appear within two hours of consumption of infested fish, but can take up to six hours (EFSA, 2010); the long-term consequence of impact on health is not certain.

In intestinal infection, anisakid larvae bury themselves into the human intestinal wall in less than an hour after consumption causing abdominal pain and diarrhoea (Audicana & Kennedy, 2008). Ulcerous lesions then appear after two weeks. Following infection, *A. simplex* is normally eliminated from the patient's body through the faeces three weeks post infection and the larvae then removed by white blood cells (FDA, 2009).

Jeremiah *et al*. (2011) describe the gnathostomiases contracted by a 52-year old male and his 50-year old wife which began 10 days after eating undercooked fish with gastric discomfort, nausea, diarrhoea and lethargy. Symptoms progressed to fevers, myalgia and pruritic subcutaneous swellings and skin thickening and, in subsequent months swellings progressed to both thighs and were associated with feelings of movement under the skin.

Jeremiah *et al.* (2011) also point to other suspect cases described by Moorhouse *et al.* (1970) as "Woodbury Disease" in coastal Queensland, a migratory form of cutaneous oedema similar to gnathostomiasis. Interestingly, Moorhouse *et al.* (1970) document the involvement of chicken, ducks, snakes, rodents and domestic cats as paratenic hosts for *G. spinigerum* but make no mention of freshwater fish.

### *3.2.4 Availability and nature of treatment*

Patients with suspected parasitic infection are usually asked by medical practitioners whether raw or partially cooked fishery products have been ingested. For allergic anisakiasis, the following tests are usually performed to assist diagnosis:

- A skin prick test
- A test indicating a lack of reaction to the host fishery products and/or a possible test investigating cross-reacting antigens such as crustaceans.

Treatment usually involves:

- Endoscopy with forceps
- Courses of treatment with broad-spectrum anti-parasitical drugs.

Shamsi & Butcher (2010) describe treatment in the Royal Adelaide Hospital for a 41-year old woman of Tongan descent who, more than two weeks after onset of illness, was suffering severe symptoms including myalgia, fever, cough with yellow sputum; she was vomiting up to six times a day and passing up to 10 bowel motions. She was treated with metoclopramide (an antiemetic used to treat nausea and vomiting), hyoscine (to reduce gastric spasms) and intravenous fluids overnight. Her condition gradually improved and her symptoms were resolved after she passed the larva in her faeces.

Diagnosis of gnathostomiasis is undertaken by assessing the presence of eosinophilia, migratory lesions and evaluating the exposure risk (e.g. travel to high risk countries). Previously, treatment generally involved surgical excision to remove live larvae. More recently, in Australia, Jeremiah *et al*. (2011) describe the continued use of albendazole and ivermectin over several months as a remedy for recurring high eosinophil counts. The low success rate of single courses of antibiotic treatments, and the need for sequential courses has been noted by Herman & Chiodini (2009).

### *3.2.5 Anisakis-induced allergic reactions in Australia*

For the present study an important consideration is whether properly-cooked fish is able to cause allergic reactions in consumers already sensitised to *Anisakis* spp. such as *A. simplex* and *A. pegreffi* (recently isolated from commercial fish in Victoria). If such is the case then, given the prevalence of both *Anisakis* spp. in Australian fish, allergic reactions should be recorded in public health statistics.

To ascertain whether *Anisakis* allergy is a recognised syndrome within Australia the following authorities were consulted:

At the First Australasian Scientific Conference on Aquatic Animal Health, Cairns, July 2011, Dr Shamsi (School of Animal & Veterinary Sciences, Charles Sturt University, Wagga Wagga) stated that, given the apparent wide distribution of fish species infected in South Australia, the public exposure to the potentially immunogenic parasite is expected to be frequent, however, no evidence of anaphylactic reactions towards anisakids has apparently been reported.

The Allergen Bureau, established in 2005 as an initiative of the Australian Food & Grocery Council Allergen Forum, operates on a membership basis and provides rapid responses to questions concerning the management of food allergen risks in food ingredients and manufactured foods in Australia and New Zealand. The Bureau has general information on anisakid-induced allergies on its website but could provide no depth of knowledge on whether there was a significant public health record in Australia.

Dr Andreas Lopata, Group Leader: Molecular Immunology, School of Pharmacy and Molecular Science, Faculty of Medicine, Health & Molecular Sciences at James Cook University's Townsville campus has a large publishing record on allergens in general and seafood allergens in particular (e.g. Lopata & Lehrer, 2009). Dr Lopata offered that there was no significant public health record for anisakid-induced allergies in Australia because there was no commercial test which could detect it. Even if a clinician considered it possible that a patient was suffering the condition and undertook an allergy test the result was invariably negative because a cod antigen was used and the genus (*Gadus*) was not a component of the Australian diet; the result would always yield a false negative.

Given the foregoing it is clear that the matter of whether anisakid-induced allergy is occurring in Australia is a major data gap for the present risk assessment.

# 4. Exposure Assessment

## 4.1 Prevalence of Anisakidae

### *4.1.1 Worldwide*

Anisakid worms have wide global presence (Huss & Embarek, 2004). Most fish have been found to harbour one or more types of worm, both harmful and harmless. *A. simplex* has been found frequently in herring, mackerel, whiting and blue whiting in the United Kingdom (RASFF, 2010). Notifications of anisakids found in other fish species have also been reported from France, Morocco, Tunisia, USA, Spain, Russia, China, Japan and many other countries (RASFF, 2010).

By contrast, a study on Atlantic salmon farmed in Norway and Scotland found no anisakid larvae in 3,700 samples tested (Angot & Brasseur, 1993). Because of the reduced risk demonstrated in these studies, the European Commission has exempted farmed salmon from Norway and Scotland from the provisions of the hygiene regulations that require minimally processed fish intended for consumption without cooking to be frozen before sale (WHO, 1999). Similarly, a study undertaken in Washington, compared wild caught and farmed salmon and found no *A. simplex* in farmed, but in 87% of the wild caught salmon (n=50) with larvae detected in the edible muscle tissue (Deardorff & Kent, 1989). Farmed European Sea Bass and Gilthead Sea Bream (n=871) were examined and did not contain anisakid larvae (Peňalver *et al*., 2010). The absence of *A. simplex* in farmed fish is thought to reflect the fact that artificial feeds contain no parasites, and the lack of intermediate hosts in the farm environment.

*Gnathostoma* spp. were first described in humans in the late 1980s in Thailand. They also appear to be endemic in Cambodia, Myanmar, Laos, Indonesia, the Philippines and Malaysia (Herman & Chiodini, 2009). In more recent years, *Gnathostoma* spp. have also been found in Central and South America, Zambia and Botswana (Herman & Chiodini, 2009). There are many species of *Gnathostoma* but only five have been recorded in humans: *G. spinigerum, G. hispidum, G. doloresi, G. binucleatum* and *G. nipponicum* (Nawa & Nakamura-Uchiyama, 2004). *G. spinigerum* is primarily found in cats and dogs in Japan, India, China and South East Asia, especially Thailand (Nawa & Nakamura-Uchiyama, 2004).

### *4.1.2 Australia*

In Australia, there have been several studies on the distribution (prevalence and/or concentration) of anisakids in fish sourced from the Northern Territory, Queensland, Western Australia, South Australia and Victoria. As indicated in Table 2, *Anisakis, Terranova, Thynnascaris, Contracaecum, Hysterothylacium* and *Raphidascaris*) have been detected in studies by Cannon, 1977; Lymberry *et al*., 2002; Moore *et al*., 2003; Doupe *et al.,* 2003; Butcher & Shamsi, 2010 and Shamsi *et al*., 2010. Together, these studies indicate a wide distribution of anisakids in finfish taken from Australian waters. Some commercial species have a high prevalence and concentration of anisakids. For example, Spanish mackerel (*S. commerson*) was shown by Cannon (1997) to have *Anisakis* and *Terranova* I and II at 100% prevalence and "high" concentration (>20 larvae/fish) while Moore *et al*. (2003) detected *A. simplex* and *Terranova* with an average of 60 larvae/fish. The apparent lack of anisakids in farmed versus wild-caught fish has been demonstrated in Australia. In a recent study of fish from Southern Australian waters, Yellow-eye mullet, Tiger flathead, Sand flathead, Pilchard and Kingfish were sampled and examined (Shamsi *et al*., 2010). Seventy-five percent of the samples (n=40), excluding king fish (which was farmed and fed with commercial pellets), were found to harbour at least one species of *Contracaecum*, *Hysterothylacium* and *Anisakis pegreffi*. By contrast, wild-caught king fish have been shown to contain anisakid larvae (Hutson *et al.*, 2007).

In relation to risks due to Australian species, Humphrey (1995) reported that *A. simplex* has been isolated from Flathead (*Platycephalus speculator*) and anisakids have also been recovered from other flatheads, mackerel (*Scomberomorus* spp.*)*, mackerel tuna (*Euthynnus alleteratus)*, striped trumpeter and farmed salmonids from Tasmania (Ross, 2000). It is not known, however, whether the strains isolated are pathogenic to humans. In Tasmania, the incidence of anisakids in wild caught striped trumpeter and farmed Atlantic salmon (Humphrey, 1995) was 91% (39/43) and 1/6, respectively. At that time striped trumpeter were being used and promoted for raw fish dishes, as were Atlantic salmon and Jack mackerel (Mure and Mure, 1993).

In Victoria, Jabbar *et al*. (2012) surveyed 50 specimens of *Sillago flindersi* (silver whiting) and extracted anisakids from 46 (92%) with concentration ranging from 1-26 larvae per host. Of a total of 194 larvae extracted, 24 (12%) were *A. pegreffi* (the first isolation in Australian fish), *Hysterothylacium* Type 4 accounted for 90/194 (46%) and *Hysterothylacium* Type 8 for 81/194 (42%) of larvae.

While *G. spinigerum* is endemic in Australia, and larvae may be found in a range of intermediate and paratenic hosts including freshwater fish, snakes, frogs, snails and fowl (Goldsmid *et al*., 2003), its distribution in freshwater fish makes it unlikely that it will enter the sushi/sashimi market, which is based on marine seafood.

The prevalence of gnathostomes in Australian fish has not been widely studied but they are found in freshwater fish (Jeremiah *et al*., 2011). It has been documented that *G. hispidum* is found in wild and domestic pigs in Australia (Herman & Chiodini, 2009) and *G. spinigerum* is endemic in a range of hosts (Goldsmid *et al*., 2003).

**Table 2: Prevalence and concentration of nematode parasites in Australian finfish**

| Common name | Latin name | Location | Parasite | Prevalence | Concentration |
|---|---|---|---|---|---|
| **Cannon, 1977** | | | | | |
| **Yellowspotted trevally** | *Carangoides fulvoguttatus* | SE Qld | *Anisakis* | 1/1 | Medium* |
| | | | *Terranova* II | 1/1 | Medium |
| **Mackerel tuna** | *Euthynnus alletteratus* | SE Qld | *Anisakis* | 1/1 | High* |
| | | | *Terranova* I | 1/1 | Low* |
| **Gold spotted trevally** | *Caranx emburyi* | SE Qld | *Terranova* II | 1/1 | Low |
| **Yellow-stripe scad** | *C. leptolepis* | SE Qld | *Terranova* II | 1/16 | Low |
| **Black-tip shark** | *Carcharinus nasuta* | SE Qld | *Terranova* II | 14/17 | Medium |
| **Black-tip shark** | *Eulamia spallanzani* | SE Qld | *Terranova* II | 4/11 | High |
| **Rainbow runner** | *Elagatis bipinnulatus* | SE Qld | *Terranova* II | 1/1 | Medium |
| **Jewfish** | *Johnius antarctica* | SE Qld | *Terranova* II | 1/6 | High |
| **Bottlenose jewfish** | *J. australis* | SE Qld | *Terranova* II | 3/12 | Low |
| | | | *Thynnascaris* IV | 3/12 | Low |
| **Threadfin bream** | *Nemipterus aurifilum* | SE Qld | *Terranova* II | 4/4 | Medium |
| | | | *Thynnascaris* III | 4/4 | Medium |
| | | | *Thynnascaris* IV | 4/4 | Medium |
| **Pinkbanded grubfish** | *Parapercis nebulosus* | SE Qld | *Terranova* II | 1/15 | High |
| | | | *Thynnascaris* III | 1/15 | High |
| **Black pomfret** | *Parastromateus niger* | SE Qld | *Terranova* II | 1/8 | Low |
| | | | *Thynnascaris* III | 1/8 | Low |
| **Bartail flathead** | *Platycephalus indicus* | SE Qld | *Terranova* II | 1/31 | Low |
| | | | *Thynnascaris* I | 1/31 | Low |
| **Largetooth flounder** | *Pseudorhombus arsius* | SE Qld | *Terranova* II | 4/18 | Medium |
| | | | *Thynnascaris* IV | 1/18 | Low |
| **Brushtooth lizardfish** | *Saurida undosquamis* | SE Qld | *Terranova* II | 3/43 | Low |
| | | | *Thynnascaris* I | 1/43 | Low |
| **Bearded croaker** | *Sciaena dussumieri* | SE Qld | *Terranova* II | 3/3 | Low |
| | | | *Thynnascaris* II | 2/3 | Medium |

| Common name | Latin name | Location | Parasite | Prevalence | Concentration |
|---|---|---|---|---|---|
| | | | *Thynnascaris* III | 2/3 | Medium |
| Dogshark | *Scoliodon jordani* | SE Qld | *Terranova* II | 1/1 | Medium |
| | | | *Thynnascaris* IV | 1/1 | Low |
| Ribbonfish | *Trichiurus savala* | SE Qld | *Terranova* II | 2/4 | Medium |
| Goatfish | *Upeneus tragula* | SE Qld | *Terranova* II | 1/36 | Low |
| Northern bluefin tuna | *Kishinoella tonggol* | SE Qld | *Anisakis* | 4/5 | Low |
| | | | *Terranova* I | 3/5 | Low |
| Hussar fish | *Lutjanus amabilis* | SE Qld | *Anisakis* | 3/3 | High |
| | | | *Terranova* II | 3/3 | High |
| | | | *Thynnascaris* IV | 3/3 | High |
| Red emperor | *Lutjanus sebae* | SE Qld | *Anisakis* | 5/5 | Low |
| Coral trout | *Plectropomus maculatus* | SE Qld | *Anisakis* | 4/8 | High |
| | | | *Terranova* I | 5/8 | High |
| Mullet-like | *Pranesus ogilbyi* | SE Qld | *Anisakis* | 4/9 | Low |
| | | | *Terranova* I | 4/9 | Medium |
| | | | *Terranova* II | 4/9 | Medium |
| | *Amentum devisi* | SE Qld | *Thynnascaris* I | 1/13 | Low |
| Sole | *Cynoglossus bilineatus* | SE Qld | *Thynnascaris* I | 1/12 | Low |
| Silverbelly | *Gerres ovatus* | SE Qld | *Thynnascaris* I | 7/31 | Medium |
| Black bream | *Mylio australis* | SE Qld | *Thynnascaris* I | 1/6 | Low |
| Catfish | *Paraplotosus albilabris* | SE Qld | *Thynnascaris* I | 3/3 | Low |
| Threadfin salmon | *Polynemus sheridani* | SE Qld | *Thynnascaris* I | 2/7 | Low |
| Puffer fish | *Sphaeroides hamiltoni* | SE Qld | *Thynnascaris* I | 2/4 | Low |
| Tongue sole | *Synaptura orientalis* | SE Qld | *Thynnascaris* I | 1/2 | Low |
| Catfish | *Tachysurus australis* | SE Qld | *Thynnascaris* I | 1/4 | Low |
| Longspine burrfish | *Tragulichthys jaculiferus* | SE Qld | *Thynnascaris* I | 4/12 | Low |
| Short-nosed tripodfish | *Triacanthus biaculeatus* | SE Qld | *Thynnascaris* I | 3/6 | Low |
| Tuskfish | *Choerodon venustus* | SE Qld | *Thynnascaris* II | 5/6 | High |
| Sweetlip bream | *Plectorhinchus chrysotaenia* | SE Qld | *Thynnascaris* II | 1/6 | Low |

| Common name | Latin name | Location | Parasite | Prevalence | Concentration |
|---|---|---|---|---|---|
| **Spanish mackerel** | *Scoberomorus commerson* | SE Qld | *Anisakis* | 13/13 | High |
| | | | *Terranova* I, Terranova II | 13/13 | High |
| **Spanish mackerel (Japan)** | *S. niphonius* | SE Qld | *Anisakis* | 6/35 | Low |
| | | | *Terranova* I | 10/35 | Low |
| | | | *Terranova* II | 20/35 | Low |
| **Pearly-finned cardinal fish** | *Apogonichthys poecilopterus* | SE Qld | *Terranova* I | 1/8 | Low |
| **Sea mullet** | *Mugil cephalus* | SE Qld | *Contracaecum* | 1/14 | Low |
| **Mullet** | *M. dussumieri* | SE Qld | *Contracaecum* | 1/1 | Low |
| **Mullet** | *M. strongylocephalus* | SE Qld | *Contracaecum* | 1/2 | Low |
| **Humphrey, 1995** | | | | | |
| **Striped trumpeter** | *Latris lineate* | Tas | *Anisakis* | 39/43 | - |
| **Atlantic salmon** | *Salmo salar* | Tas | *Anisakis* | 1/60 | - |
| **Lymberry *et al.*, 2002** | | | | | |
| **Australian herring** | *Arripis georgianus* | WA | *Contracaecum* | 0/29 | |
| **Black bream** | *Acanthopagrus butcheri* | WA | *Contracaecum* | 1/26 | 1** |
| **King George whiting** | *Sillaginodes punctata* | WA | *Contracaecum* | 2/32 | 1.5 |
| **Samson fish** | *Seriola hippos* | WA | *Contracaecum* | 0/13 | 0 |
| **Sand whiting** | *Sillago sp.* | WA | *Contracaecum* | 0/20 | 0 |
| **Sea mullet** | *Mugil cephalus* | WA | *Contracaecum* | 47/81 | 9.8 +/- 1.5 |
| **Yellow-eyed mullet** | *Aldrichetta forsteri* | WA | *Contracaecum* | 19/19 | 12.7 +/- 3.7 |
| **Yellow-finned whiting** | *Sillago schomburgkii* | WA | *Contracaecum* | 0/13 | 0 |
| **Moore *et al.*, 2003** | | | | | |
| **Spanish mackerel** | *Scomberomorus commerson* | NT | *Anisakis simplex* | - | 0.13 |
| | *S. commerson* | NT | *Terranova* | - | 2.4 |
| **Doupe *et al.*, 2003** | | | | | |
| **Goldband snapper** | *Pristipomoides multidens* | WA | *Anisakis* | 15/15 | - |
| | | | *Terranova* | 1/15 | - |
| **Mangrove jack** | *Lutjanus argentimaculatus* | WA | *Anisakis* | 4/4 | - |
| | | WA | *Raphidascaris* | 1/4 | - |

| Common name | Latin name | Location | Parasite | Prevalence | Concentration |
|---|---|---|---|---|---|
| **Red emperor** | *L. sebae* | WA | *Anisakis* | 17/17 | - |
| | | | *Terranova* | 1/17 | - |
| | | | *Thynnascaris* | 1/17 | - |
| **Morgan's cod** | *Epinephalus malabricus* | WA | *Terranova* | 3/4 | - |
| **Coral trout** | *Plectropomus maculatus* | WA | *Anisakis* | 2/3 | - |
| | | | *Terranova* | 2/3 | - |
| **Estuary cod** | *Epinephalus coioides* | WA | *Anisakis* | 11/13 | - |
| | | | *Terranova* | 5/13 | - |
| **Spangled emperor** | *Lethrinus nebulosus* | WA | *Anisakis* | 2/2 | - |
| **Shamsi *et al.*, 2010** | | | | | |
| **Yellow-eye mullet** | *Aldrichetta forsteri* | Vic | *Contracaecum* 1, 2<br>*Hysterothylacium* | 9/10 | - |
| **Tiger flathead** | *Neoplatycephalus richardsoni* | Vic | *Anisakis*<br>*Contracaecum*<br>*Hysterothylacium* | 5/5 | - |
| **Sand flathead** | *Platycephalus bassensis* | Vic | A novel larva | 1/5 | - |
| **Pilchard** | *Sardinops sagax* | Vic | *Hysterothylacium* | 9/10 | - |
| **King fish** | *Seriola lalandi* | Vic, SA | | 0/10 | - |
| **Blue mackerel** | *Scomber australasicus* | Vic, SA | *Contracaecum* type II | - | - |
| **Butcher & Shamsi, 2010** | | | | | |
| **Mackerel** | | SA | *Contracaecum* | - | - |
| **Jabbar et al., 2012** | | | | | |
| **Silver whiting** | *Sillago flindersi* | Vic | *Anisakis pegreffi* | 12/50 | - |
| | | | *Hysterothylacium* Type 4 and Type 8 | 34/50 | - |

* Low (1-5), Medium (6-20) High (>20) larvae/fish
** Number of parasites detected per fish

**Table 3: Nematode infestation of finfish which may be consumed raw**

| Common name | Latin name | Parasite | Prev. | Conc. |
|---|---|---|---|---|
| **Longtail tuna** | *Kishinoella tonggol* | *Anisakis* | 4/5 | Low |
| | | *Terranova* I | 3/5 | Low |
| **Red emperor** | *Lutjanus sebae* | *Anisakis* | 5/5 | Low |
| | | *Anisakis* | 17/17 | - |
| | | *Terranova* | 1/17 | - |
| | | *Thynnascaris* | 1/17 | - |
| **Coral trout** | *Plectropomus maculatus* | *Anisakis* | 4/8 | High |
| | | *Terranova* I | 5/8 | High |
| | | *Anisakis* | 2/3 | - |
| | | *Terranova* | 2/3 | - |
| **Goldband snapper** | *Pristipomoides multidens* | *Anisakis* | 15/15 | - |
| | | *Terranova* | 1/15 | - |
| **Atlantic salmon** | *Salmo salar* | *Anisakis* | 1/60 | - |
| **King George whiting** | *Sillaginodes punctata* | *Contracaecum* | 2/32 | 1.5 |
| **Sand whiting** | *Sillago sp.* | *Contracaecum* | 0/20 | 0 |
| **Yellow-finned whiting** | *Sillago schomburgkii* | *Contracaecum* | 0/13 | 0 |
| **Silver whiting** | *S. flindersi* | *A. pegreffi* | 12/50 | |
| | | *Hysterothylacium* Type 4 and Type 8 | 34/50 | - |
| **Spanish mackerel** | *Scoberomorus commerson* | *Anisakis* | 13/13 | High |
| | | *Terranova* I | 13/13 | High |
| | | *Terranova* II | 13/13 | High |
| | *S. niphonius* | *Anisakis* | 6/35 | Low |
| | | *Terranova* I | 10/35 | Low |
| | | *Terranova* II | 20/35 | Low |
| | | *A. simplex* | - | 0.13 |
| | | *Terranova* | - | 2.4 |
| **Blue mackerel** | *Scomber australasicus* | *Contracaecum* II | - | - |

* Low (1-5), Medium (6-20) High (>20) larvae/fish
** Number of parasites detected per fish

### *4.1.3 Infection rates of finfish consumed raw*

Interrogation of Table 2 indicates that a number of finfish which may potentially be consumed raw have been associated with detection of nematode worms (Table 3). This is especially so for reef fish (coral trout) and breams (emperor and snapper) where prevalence of *Anisakis* was often high, as was the concentration. Longtail tuna was also infested at high prevalence and low concentration. Whiting were mainly negative for nematodes while only 1/60 Atlantic salmon was positive for *Anisakis*. These findings will be used to inform on the likelihood of infestation (section 4.1.5).

#### 4.1.4 Production of fish in Australia

In Table 4 are presented data for the production of fish for human consumption in Australia during 2007-08; note that the national catch for sardines has not been included because this is used primarily as feed for aquaculture. Of combined wild-caught and aquaculture production of 127564 t, some 22414 t were exported, primarily high-value species such as tuna, salmon and reef fish (coral trout etc).

After deduction of exports, some 105,000 t finfish are potentially available for consumption within Australia, of which a proportion may be consumed raw. The mass potentially available for use as sushi is assumed to come from high-value species as indicated in Table 4 and comprises around 28,679 t. Note that under the category "Bream" is included high-value species such as Snapper, Red Emperor, which are sometimes used for sashimi/sushi.

#### 4.1.5 Estimation of volume of potentially infested fish which may be consumed raw

Of the 28,679 t of finfish potentially available for consumption raw, 5927 t are likely to be infested because salmonids receive pelletised feed. Note that tuna, whether wild caught or farmed, are fed a fish-based diet and are therefore exposed to infestation.

Thus an estimated 2,370 t of finfish are potentially available for consumption as sushi/sashimi (Table 5). While farmed tuna receive frozen fish (oily fish such as sardines) as feed and freezing should have inactivated larvae, tuna are still considered potentially infested.

An estimation has been made of the proportion of each species which is likely to be consumed raw (Table 5) ranging from 5% for mackerel to 85% for tuna. In total, some 778 t of fish meat which may be infected with anisakid larvae is considered to be consumed as sushi or sashimi.

#### 4.1.6 Inactivation treatments for nematodes

Methods for minimising the risk to human health from parasites include both heating and freezing (see Table 1). Thermal processes of 60°C for 1-2 minutes are suggested to inactivate parasites (Huss & Embarek, 2004).

As some anisakids can survive at -20°C for a short period, the Food and Drug Administration (FDA) recommends freezing at -20°C or below for one week, or -35°C or below for a minimum of 15 hours (Audicana & Kennedy, 2008). In commercial reality frozen storage of most species is -18°C, the exception being tuna destined for sashimi use in Japan, which may be stored at -35°C or colder. Salting, (dry salting, curing, marinating and pickling), cold smoking, fermentation and modified atmosphere packaging do not inactivate anisakid larvae and are not mitigation options for inactivating anisakids (Audicana & Kennedy, 2008; Pascual *et al.*, 2010). Removing the viscera and belly flap reduces the numbers of parasites found in fish flesh, particularly with *A. simplex* in herring, mackerel and blue whiting (Wootten & Cann, 2001).

Methods for detecting parasites in fish including visual inspection, slicing, candling (inspection under UV light), pressing and real-time Polymerase Chain Reaction (PCR); visual inspection and candling are used commercially.

In preparing fish for sushi or sashimi, pieces of fish are sliced/shaved very thinly and it is likely that all larvae/worms will be detected and eliminated at this stage. However, a conservative approach is taken that 1 meal in 10,000 contains at least one larva. *Gnathostoma* larvae can be killed by the above methods for anisakid inactivation.

## 4.2 Consumption

### *4.2.1 Consumption of finfish*

As indicated in Table 3, of Australian-produced finfish, some 105,000 t are available for consumption domestically. There is no information regarding the state in which fish are landed (whole, gilled, gutted, filleted) and this can have a large influence on the mass of edible portion. For example, for large, round-bodied fish such as tuna, which are landed gilled and gutted, the edible portion comprises 70%. By contrast, a flat-bodied fish such as snapper yields 45% edible portion if landed gilled and gutted and around 30% if landed in whole form (Kane *et al*., 1994).

Thus, for the present study an arbitrary edible portion of 40% of the production weight is assumed, yielding 2,370 t meat available for consumption in all forms of preparation and around 778 t for consumption as sushi/sashimi (Table 5).

### *4.2.2 Consumption of sashimi and sushi*

Ruello (1999) researched consumption of sushi in Sydney during Spring 1998 and Summer 1999, finding that 19% of Sydney residents consumed seafood of whom 1-2% reported consuming sushi. Thus, it was estimated that, in Sydney (population 4.1 million), of the order of 16,000 sushi meals were consumed per week. Of the sushi consumed out-of-home 41% was at restaurants and 33% from a food outlet. There was a strong indication that sushi was consumed by those with higher household incomes and with a tendency towards younger consumers (<40 years old). The "in-home" consumption survey indicated no sushi consumption.

In 2005, Ruello surveyed seafood consumption in Melbourne noting that:

- Consumption had increased from 11.5 kg in 1991 to 12.5 kg/per caput
- Canned tuna accounted for 36% of seafood purchases, with shark, flathead and salmon following in popularity
- Fried fish was more popular than grilled or steamed meals
- Of 69 respondents who ate fish out-of-home in the previous week, one had consumed sushi.

In a national survey of seafood consumption Danenberg & Remaud (2010) state that sushi/sashimi was purchased on an average of 17 occasions/annum (once every three weeks). This figure equates to almost 27,000,000 servings annually by that proportion of the Australian population (16 million) estimated to consume sushi/sashimi.

A survey by Ruello (2011) of imported seafoods has relevance for the present study because it documents the increase of "sushi-ready" product: *"The sushi-ready vacuum packed cooked and peeled tails (code …19) specially cut and shaped to go straight onto the rice ball have seen strong growth in the past few years as sushi bar operators choose convenience over traditional point of sale cooking and peeling. Precise volumes are not known but are assessed at about several hundred tonnes per annum."*

Thus, in calculating the contribution of Australian finfish to sushi/sashimi consumption it must be noted that:

- Sushi and sashimi comprise ingredients other than finfish e.g. crustacean meat (prawns, crab), squid and vegetables.
- Imported product seems to be accounting for an increasing proportion of the seafood component of sushi

For the purposes of the present study consumption was calculated based on volumes of finfish identified in Tables 4-5, and the following assumptions were made:

i Sushi/sashimi is consumed by 16 million Australians (adults)

ii Of a consuming population of 16 million, 25% (4 million) consume sushi/sashimi

iii The total mass used for raw consumption is 778 t (Table 5)

iv Serving size is 100 g, which approximates 7.8 million servings per annum

Based on the above assumptions, each sushi/sashimi consumer has 2 servings each year.

These consumption data form the basis for inputs to the qualitative and semi-quantitative risk assessments undertaken in Section 5.

**Table 4: Production of finfish in Australia and volume available for domestic consumption (after ABARE, 2009)**

| | Wild-caught (t) | Aquaculture (t) | Total production (t) | Export (t) | Available domestic consumption (t) | Possible use for raw consumption | (t) |
|---|---|---|---|---|---|---|---|
| **Salmonids** | | 25527 | 25527 | 2775 | 22752 | Yes | 22752 |
| **Silver perch** | | 292 | 292 | | 292 | No | |
| **Australian salmon** | 2849 | | 2849 | | 2849 | No | |
| **Barramundi** | 1545 | 3361 | 4906 | | 4906 | No | |
| **Bream** | 1269 | | 1269 | | 1269 | Yes | 1143 |
| **Coral trout** | 1123 | | 1123 | 1000* | 123 | Yes | 1076 |
| **Dories** | 829 | | 829 | | 829 | No | |
| **Flathead** | 4348 | | 4348 | | 4348 | No | |
| **Gemfish** | 507 | | 507 | | 507 | No | |
| **Ling** | 1152 | | 1152 | | 1152 | No | |
| **Mullet** | 5535 | | 5535 | | 5535 | No | |
| **Orange roughy** | 288 | | 288 | | 288 | Yes | 534 |
| **Sharks** | 8378 | | 8378 | | 8378 | No | |
| **Spanish mackerel** | 1264 | | 1264 | | 1264 | Yes | 1286 |
| **Tuna** | 10115 | 9757 | 19872 | 12574 | 7298 | Yes | 1888 |
| **Whiting** | 3577 | | 3577 | 1291 | 2286 | No | |
| | 86388 | 41176 | 127564 | 22414 | 105150 | | 28679 |

* Estimation

**Table 5: Likelihood of infestation of finfish consumed raw**

| | Possible use for raw consumption[1] | (t) | Likelihood of infestation | Mass likely to be infested (t) | Assumed edible mass based on 4.2.1 (t) (40%) | Proportion consumed raw[2] (%) | Mass consumed raw[2] (t) |
|---|---|---|---|---|---|---|---|
| **Salmonids** | Yes | 22752 | No - farmed | 0 | | | |
| **Bream** | Yes | 1143 | Yes | 1143 | 457 | 10 | 46 |
| **Coral trout** | Yes | 1076 | Yes | 1076 | 430 | 10 | 43 |
| **Mackerel** | Yes | 1286 | Yes | 1286 | 514 | 5 | 26 |
| **Orange roughy** | Yes | 534 | nd | 534 | 214 | 10 | 21 |
| **Tuna[3]** | Yes | 1888 | Yes | 1888 | 755 | 85 | 642 |
| | | 28679 | | 5927 | 2370 | | 778 |

nd = no data available

[1]The production volumes noted are the mean of total production of each fish category minus the exports, from the three financial years (2007/08, 2008/09 and 2009/10). Data obtained to derive these estimates were obtained from ABARE Fisheries Statistics 2011.

[2]Estimated, based on industry information

[3]The Tuna category includes aquaculture and fisheries products, and species such as southern bluefin tuna, billeye tuna, yellowfin tuna, albacore tuna, skipjack and other tuna species. To avoid double counting, the total production has been reduced to allow for southern bluefin tuna caught in the Commonwealth southern bluefin tuna (as reported in the ABARE Fisheries statistics 2011).

# 5. Risk Characterisation

This risk assessment focuses on estimating the potential impact on human health in relation to nematodes that may be present in finfish consumed in Australia. To estimate the potential impact the following risk assessments are presented:

1. Anisakidosis from consumption of sushi and sashimi
2. Gnathostomiasis from consumption of sushi and sashimi

It was not possible to assess the risk of GAA because of the lack of reports of the condition. Some insight into why the condition may not be reported in Australia are provided in the Hazard Characterisation, Sections 3.2.2 and 3.2.4.

## 5.1 Anisakidosis from Consumption of Sushi and Sashimi

### *5.1.1 Qualitative Risk Assessment*

A risk framework developed by Food Science Australia (2000) was used to generate a qualitative estimate of the risk of anisakidosis and gnathostomiasis. Data collected in the hazard identification, hazard characterisation and exposure assessment are used to inform six questions.

In Table 6 is presented a qualitative risk assessment of the likelihood of anisakid gastrointestinal disease in consumers of sushi and sashimi prepared from Australian wild-caught and farmed fish. An extremely low risk is estimated, influenced largely by two reduction steps during processing for the wholesale trade and during final preparation by the sushi/sashimi chef. In the former it is highly likely that a fish showing signs of infestation during gutting/filleting will not be allowed to enter the retail trade. In the final preparation by the chef, fish is reduced to very small, thin portions (ca 10 mm) which will reveal presence of worms and larvae. The fragments of fish are further examined/arranged by the chef during presentation and the likelihood of consuming a worm/larva is small.

**Table 6: Qualitative risk assessment of anisakidosis from consumption of sushi and sashimi in Australia**

| Risk Criteria | Anisakidosis in sushi/sashimi | Note |
|---|---|---|
| Severity of hazard | Usually mild | Gastrointestinal symptoms usually do not require medical treatment as the dead parasite is eventually passed out |
| Likelihood of occurrence | Moderate | 40% of fish used for raw consumption are considered to be infested at time of processing for the trade[(i)] |
| Chronic exposure required to cause illness | None | One larva/worm is considered sufficient to cause infection[(ii)]<br>All fish consumed raw is considered to be chilled[(iii)] |
| Impact of processing, handling | Reduction during processing for wholesale trade<br>Reduction during preparation by sushi/sashimi chef | Fish with larvae/worms in gut cavity will be discarded from sushi/sashimi trade<br><br>Chef slices/shaves fish muscle and will discard fish with signs of infestation |
| Consumer terminal step | No effect | Product eaten raw |
| Epidemiological link | Yes | There has been one reported case from consumption of raw mackerel (Butcher & Shamsi, 2010) |
| **Assessed risk** | **Extremely low** | |

In the qualitative risk assessment (Table 6) there are a number of assumptions which are purposefully conservative. These are denoted by superscript and are as follows:

i At the time of processing, 40% of fish used for raw consumption are considered to be infested. While this infestation may be confined to the gut and viscera, for the purposes of the assessment it is considered that the gut cavity may also have larvae present.

ii One larva/worm may cause infection which proceeds to disease. However, at least in USA, a tolerable level exists for larval infestation (Table 7) implying that more than one cyst may be needed for infection.

iii All fish are chilled (never frozen), which is unlikely as much of the wild-caught tuna may be frozen (and therefore be free of viable parasites).

**Table 7: Guidelines for tolerable levels of parasites in fish (FDA, 1999)**

| Product | Guideline |
|---|---|
| Tullibies, ciscoes, inconnus, chubs and whitefish | 50 cysts per 45.45 kg (100 lb) |
| Blue fin and other freshwater herring averaging 1 lb or less | 60 cysts per 100 fish, if 20% of the fish examined are infested |
| Blue fin and other freshwater herring averaging >1 lb | 60 cysts per 45.45 kg (100 lb), if 20% of the fish examined are infested |
| Rose fish (red fish and ocean perch) | 3% of fillets examined contain one or more copepods accompanied by pus pockets |

### *5.1.2 Semi-qualitative Risk Assessment*

A semi-quantitative risk assessment tool called Risk Ranger (a simple, programmed spreadsheet tool developed by Ross & Sumner (2004)) can be used to characterise risk and estimate the total predicted illnesses per year in potentially at-risk populations.

From the data presented it is estimated that around 16,000 sushi meals are consumed weekly in Sydney which may be scaled to around 50,000 meals nationally. The probability of infected fish is dependent upon the species used. Assuming an infestation rate of 10% and that any parasites present are not detected, this might translate to a maximum of several thousand exposures per week. From the available demographic information, most exposures are healthy, young to middle age adults. While the diseases caused by parasitic worms are generally mild and seldom life-threatening, some may require surgery.

On the basis of the above discussion, qualitatively the risk appears currently to be low. The growth in consumption of raw fish dishes (sashimi and sushi) in Australia, however, suggests that increased incidence of seafood-borne parasitic infections might be expected, particularly if Australian chefs and consumers are not as aware of the risk as those in nations and regions in which parasitic infections from fish are more prevalent.

In Table 8 is presented a semi-quantitative risk characterisation for at-risk groups for which the following assumptions are made:

- Sushi/sashimi consumption is consumed by 16 million Australians (adults)
- Of a consuming population of 16 million, 25% (4 million) consume sushi/sashimi
- The total mass used for raw consumption is 778 t (Table 5)
- Serving size is 100 g, which approximates 8 million servings
- Each sushi/sashimi consumer has 2 servings each year which, In Risk Ranger, equates to “Some (25%)” consumes a few times each year
- The consumer may also detect any abnormalities during consumption.

Based on these assumptions, the model indicates that consumers in the selected population have total predicted annual illness of 4.8 cases and a risk ranking of 31.

**Table 8: Semi-quantitative risk characterisation of consumption of raw seafood**

| Risk criteria | General population |
|---|---|
| **Dose and severity** | |
| Hazard severity | Mild |
| Susceptibility | General – all population |
| **Probability of exposure** | |
| Frequency of consumption | Few times a year |
| Proportion consuming | 25% |
| Size of consuming population | 16 million |
| **Probability of contamination** | |
| Probability of raw product contaminated | 40% contaminated |
| Effect of processing | Reduces hazard (99%) |
| Possibility of recontamination | None |
| Post-process control | Not relevant |
| Increase to infective dose | None |
| Preparation before eating | Reduces hazard (99.99%) |
| **Total predicted illnesses in selected population** | **4.8/annual** |
| **Risk ranking (0-100)** | **31** |

In considering the output from the Risk Ranger estimates it should be emphasised that, in several areas, the inputs are not based on data, but on assumptions, around which discussion should be framed:

### 1. Proportion of raw product contaminated

A proportion of 40% was chosen based on infestation data assembled in Table 2. While this figure is considered conservative (see Section 5.1.1) it is not strongly based on data.

### 2. Reduction during processing

The wholesale market in each centre comprises facilities which prepare seafood for the retail and food service market, where fish in their landed state are prepared to varying degrees depending on the market requirement. To this end, fish may be gutted, gilled, headed, or filleted, a process in which the gut cavity is cleaned and the "bloodline" (kidneys) and roe removed. During this process the operator will note the presence of worms or cysts, which will affect the disposition of the fish. If infestation is noted the fish will be removed from the human food chain and the assumption is made that 99% of infested fish are removed at this stage.

### 3. Reduction during preparation for consumption

It is possible (though not likely) that a fish which has no overt signs of infestation in the gut cavity, has cysts present in the musculature, as it is equally possible that the operator will fail to detect infestation in the gut cavity. During preparation by the chef/operator of sushi and sashimi, prime cuts of premium fish (particularly tuna and salmon) are removed from the fish for final cutting. At this stage meat is cut thinly, <10 mm for sashimi and <5 mm for sushi and each piece receives close attention by the chef/operator. It is highly unlikely that a cyst/worm could remain undetected at this stage and a 99.9% reduction is assumed.

## 5.2 Gnathostomiasis from Consumption of Sushi and Sashimi

### *5.2.1 Qualitative risk assessment*

As may be judged from the inputs to the qualitative risk assessment (Table 9), for two reasons the likelihood of contracting gnathostomiasis from consumption of sushi/sashimi is considered extremely low:

1. Only marine fish are used for sushi and sashimi.
2. Gnathostome larvae are not salt-resistant and occur in fish only from fresh water.

The above factors are important in assessing the risk as extremely low.

**Table 9: Qualitative risk assessment of gnathostomiasis from consumption of sushi and sashimi in Australia**

| Risk Criteria | | Note |
|---|---|---|
| Severity of hazard | Moderate | Symptoms leading to discomfort and possible neuropathy is treatable only with prolonged anti-parasitic drugs. |
| Likelihood of occurrence | Highly unlikely | Due to their salt intolerance, gnathostomes can occur in freshwater fish of which none is used for sushi/sashimi |
| Chronic exposure required to cause illness | None | One larva/worm is considered sufficient to cause infection |
| Impact of processing, handling | Reduction during processing for wholesale trade<br><br>Reduction during preparation by sushi/sashimi chef | Fish with larvae/worms in gut cavity will be discarded from sushi/sashimi trade<br>Chef slices/shaves fish muscle and will discard fish with signs of infestation |
| Consumer terminal step | No effect | Product eaten raw |
| Epidemiological link | Yes | There has been one outbreak of gnathostomiasis in WA attributed to consumption of undercooked black bream |
| **Assessed risk** | **Extremely low** | |

# 6. Reality Check

In risk assessments for the NSW Food Authority (Ross, 2000) and for Seafood Services Australia (Sumner and Ross, 2001) both authors determined that there had been no reported cases of anisakidosis from fish consumption in Australia and that the likelihood of contracting the disease from consumption of sushi and sashimi was remote.

The present risk assessment reaches similar conclusions with the only documented case of anisakidosis resulting from consumption in the home of raw fish (Shamsi & Butcher, 2010). It is believed (Nick Ruello personal communication, April, 2011) that consumption of sushi and sashimi has increased at least 10-fold during the past decade. However, an increasing proportion of sushi consumption is based on imported "sushi-ready" products such as prawns and eel and it may be that consumption from Australian-caught finfish is more or less stable.

With regard to gnathostomiasis, over the past 40 years Australia has had suspected cases (Moorhouse *et al*., 1970), though fish consumption was not mentioned, plus one confirmed outbreak involving two people (Jeremiah *et al*., 2011). It is interesting that, in the only confirmed cases, the illness is attributed to consumption of freshwater fish which was pan-fried whole over an open fire, indicating that, at its centre the fish was insufficiently cooked to inactivate larvae. It may also be that the victims became infected from another source, Jeremiah *et al*. (2011) stating: *"Weaknesses of this report include that we were unable to definitively identify the fish species or determine how thoroughly the fish was cooked."*

Thus, although there have been cases of anisakidosis in the private setting from fish consumption, there has been no reports surrounding consumption of sushi and sashimi.

# 7. Uncertainty and Data Gaps

There are a number of uncertainties and knowledge gaps which have an impact on the final risk estimates:

1. Much of the prevalence/concentration data on anisakid infestation of fish predates the availability of techniques to identify species of *Anisakis* and types of other anisakid genera.
2. There are limited data on the Australian population which consumes raw fish dishes.
3. There are no data on the serving size of sushi/sashimi consumption.
4. There are no data on the proportion of fish consumed domestically as sushi/sashimi.
5. There are no data regarding the proportion of fish consumed domestically that is frozen prior to raw consumption.
6. Anisakidosis and anisakiasis are undoubtedly underreported and/or misdiagnosed, as most cases are not severe.
7. There is no skin prick test for *A. simplex* available in Australia for GAA and consequent allergic reactions, and the illness may be misdiagnosed.
8. There are no data on the dose response of *A. simplex* allergens.
9. Whether inactivated anisakid larvae in properly-cooked fish can cause allergic reactions is a major data gap and is likely to remain so until a commercial test becomes available.

# 8. Conclusions and Recommendations

The risk associated with anisakids and gnathostomes resulting from the consumption of Australian finfish is considered low; however, there is a large knowledge gap regarding the prevalence of GAA in the Australian population from locally harvested seafoods.

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