Seafood-borne parasites in Australia: human health risks, fact or fiction?

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Seafood is an increasingly popular source of healthy protein. Since 1961, the average annual increase in global food fish consumption has been twice as high as population growth and exceeds the consumption of meat from all terrestrial animals combined[1]. The following overview of seafood safety concerns is intended to help readers to understand potential risks associated with parasites in seafood products and the need for a national approach to reduce or minimise them. It is important to note that parasite infections are not limited to seafood: all other types of foods, including vegetables and red meat can also be infected with a broad range of parasites, some of which are more dangerous than parasites in seafood. The main issue is lack of science based contemporaneous safety protocols which focus on seafood-borne parasites. As a result, in Australia regulatory control of parasites in seafood lags far behind other food sectors. Seafood safety is a broad topic. The focus of this article is on an understudied field in Australia, seafood-borne parasitic diseases. The word 'seafood' in this context encompasses fish and shellfish products from marine and freshwater ecosystems that are, directly or indirectly, meant for human consumption.

Parasites and seafood

The knowns

Occurrence in seafood: A wide range of parasites transmissible to humans can be found in seafood products. Their life cycle, pathogenicity and significance has been reviewed previously[2,3]. Of over 40 transmissible parasites from seafood reported worldwide[2], this article will focus more on nematodes belonging to families Anisakidae, Raphidascarididae and Gnathostomatidae (Figure 1), which seem to be of most concern in Australia due to their common occurrence, infecting seafood products in local and global food supply chains. Recent studies showed that 86% of tiger flathead[4], 56% of anchovy[5] and 100% of pilchard sold in a fish market in Australian east coast were infected with at least one type of infective stage of potentially zoonotic anisakid/raphidascarid nematodes. These nematodes included *Anisakis, Contracaecum, Hysterothylacium* and *Terranova* larval types, all of these genera known to have species infecting humans. All of these parasites are now known[4,6] to migrate from the internal organs of the fish into other parts, including the flesh, after the fish is caught/dead, hence increasing the risk they may pose to public health. Migration of parasites into fish flesh can be minimised by evisceration of fish immediately after capture and appropriate cold storage at all times preceding consumption. Pre-freezing is recommended if fish are intended to be consumed raw or partially cooked. While a diverse range of potentially zoonotic nematodes have been found in Australian wild caught marine fish, little is known about their diversity and abundance in the freshwater fish species in Australia.

Occurrence in humans: With the frequent occurrence and abundance of these parasites, the popularity of seafood, the multicultural cuisine enjoyed in Australia and the ready availability of a variety of seafood, it is not surprising that human infections can occur regularly. In Australia, since the early 20th century, there have been numerous documented cases and many anecdotal cases of human infection[7] with a broad range of parasites acquired from seafood. This not only includes nematodes, such as *Contracaecum* sp.[8], *Gnathostoma* sp.[9,10] (possibly a misdiagnosed case, see Shamsi and Sheorey[7]) and *Dioctophyme renale*[11], but also other parasites including tapeworms, such as *Adenocephalus pacificus*[12], *Spairometra* spp.[13], and *Diphyllobothrium latum* (now accepted as *Dibothriocephalus latus*)[14], flukes such as *Clonorchis sinensis*[14], and *Paragonimus westermani*[15], and Myxosporidians such as *Myxobolus plectroplites*[16]. The reported parasites include both marine (e.g. *Adenocephalus pacificus*) and freshwater (e.g. *Clonorchis sinensis* and *Paragonimus westermani*) parasites. However, due to a decline in parasitology teaching in the Australian medical schools, many of these species of zoonotic parasites have fallen into obscurity[7,17].

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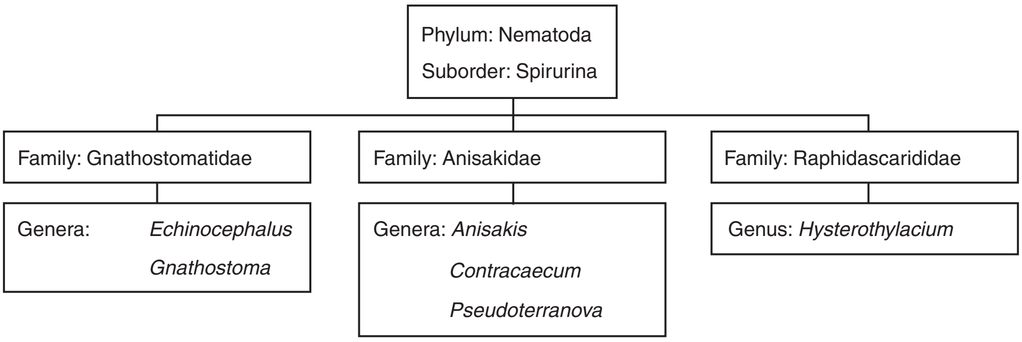

Figure 1. The relationship between the genera and families of zoonotic nematodes (according to the World Register of Marine Species, http://www.marinespecies.org/, accessed 19 February 2020) discussed in this article. Note only genera and families of high concern in regard to seafood safety are presented.

Clinical signs: Diseases due to some seafood-borne parasites can be severe to life threatening. However, many are mild, perhaps underdiagnosed, and hence not well documented. Clinical signs due to seafood-borne parasites of concern in Australia (anisakids/raphidascarids and gnathostomids) are broad mainly due to the wide range of species implicated in infections, each parasite species having unique characteristics. Clinical signs, particularly those caused by anisakid/raphidascarid nematodes, are varied and include: (1) mild vague symptoms that mimic food poisoning; and (2) acute gastrointestinal symptoms that mimic appendicitis. In addition, (3) infection/exposure with anisakid nematodes, even those killed in well-cooked seafood, can also cause allergic reactions, including anaphylactic shock[18] in sensitive consumers and workers handling seafood products. Gnathostomid nematodes are also migratory parasites which cause highly variable clinical signs. They invade a variety of tissues, including subcutaneous, pulmonary, gastrointestinal, genitourinary, auricular or ocular tissues, or the central nervous system with migratory lesions in these tissues.

Imported seafood: Some of the countries Australia imports from are known to harbour highly pathogenic parasites in their seafood products. Fresh and frozen imports are predominantly from Thailand, China and Vietnam[19] where parasites such as *Clonorchis sinensis*, the Chinese liver fluke, and *Opisthorchis viverrini*, the south Asian liver fluke are common. The safety of these products for human consumption in this country relies on Australian legislation which is reflected in the latest imported food control order. At present no additional tests are applied to detect zoonotic parasites in seafood on entry to Australia (*Imported Food Control Order 2019* in force 17 September 2019; https://www.legislation.gov.au/Details/F2019L01233). Australia relies on equivalency of the exporting countries testing procedures to provide documentary evidence of their adherence to internationally recognised food safety controls (*Imported Food Control Order 2019* in force 17 September 2019; https://www.legislation.gov.au/Details/F2019L01233) such as parasite control detailed in the Codex *Code of practice for fishery products* (Codex Code of practice for fishery products; http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXC%2B52-2003%252FCXP_052e.pdf). Freezing and cooking are effective in killing the parasites.

Human movement: Australia is a popular destination for both tourists and migrants from both developed and developing countries. Seafood-borne parasites are also common in both developing and developed countries across the globe and, unlike many other parasites, are not limited to low income communities. Several seafood-borne parasites, such as *C. sinensis*, *Heterophyes heterophyes*, *Opisthorchis* spp. and *Dibothriocephalus* spp. reach adult stage in humans, producing thousands of eggs a day. Several species of other parasites from the same family, and some from the same genus, as the aforementioned zoonotic parasites are endemic in Australia. The possibility therefore exists that their intermediate hosts may be successfully exploited by exotic zoonotic species as part of their life cycle. Australia is also home to potential gastropod intermediate hosts such as native thiarid species and *Gabbia australis*, which may make establishment of a parasite life cycle viable[20]. Currently there is no requirement to screen travellers and immigrants for infection with these parasites at the time of the entry to the country and this is seen as a viable entry point[14,21,22].

The unknowns

Transmission patterns and ecology: The detailed life cycle of zoonotic nematodes, in particular developmental stages which occur between the egg of the parasite and the infective stage (third stage larva, L3) are not fully known in Australia. These life stages may take place in a broad range of invertebrates and smaller fish (Figure 2)[24]. Also little understood are the major drivers that influence parasite distribution in these animals. Understanding life cycles of these parasites is central to determining the potential infection source, to designing effective educational campaigns for various stakeholders and to developing practical control and prevention programs.

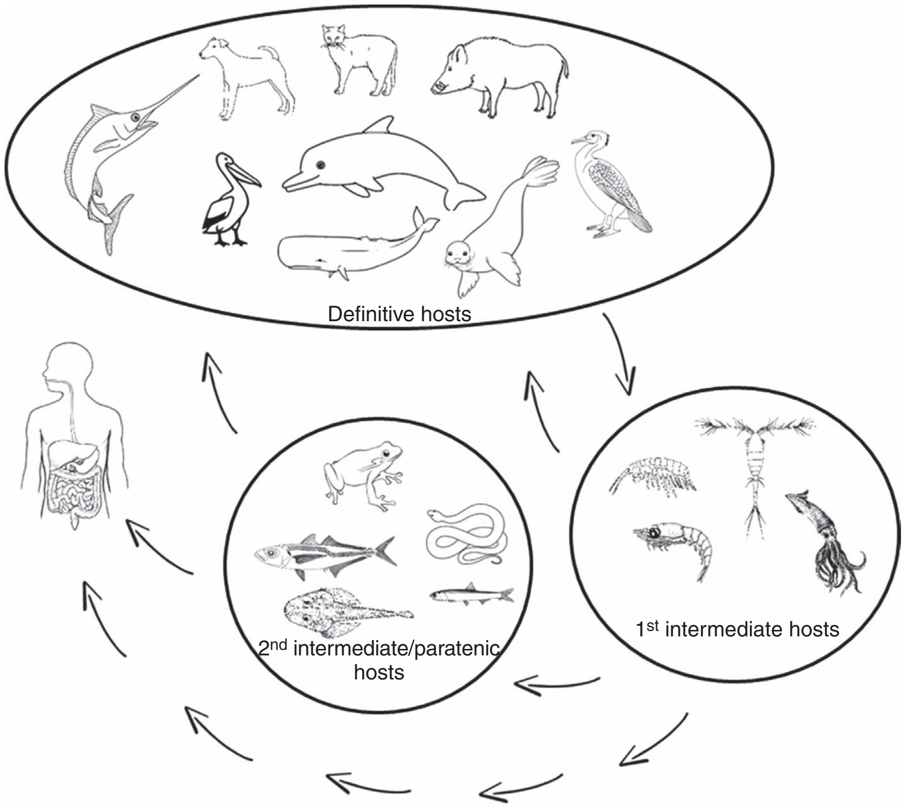

Figure 2. General life cycle of anisakid/raphidascarid/gnathostomid nematodes. Adult nematodes usually live inside the gastrointestinal track of the definitive hosts. These nematodes are oviparous. Eggs pass through the faces to the aquatic environment. Larvae (L1) may or may not hatch in the environment. Eggs or larvae are ingested by the first intermediate host, including a broad range of invertebrates, and undergo further development (L2 or L3) within these hosts. When infected first intermediate hosts are ingested by the second intermediate hosts, including fish and amphibians, L2 develops further to L3, which is the infective stage for humans. Reports on these nematodes reaching adult stage in humans is scarce[23] and humans are usually considered a dead-end host for these parasites. A wide range of fish-eating animals (definitive hosts) become infected upon eating infected second intermediate host. Infection of definitive host via consuming of the infected first intermediate host is also sometimes possible. The general life cycle pattern for tapeworms and flukes is very similar. The main differences are the type of the first intermediate host being crustaceans and molluscs, respectively and that human often is their definitive host.

Another emerging concern is understanding the effects of climate change on fish-parasite systems. Climate change unquestionably alters the prerequisites for parasite transfer, most likely to favour zoonotic parasites[25]. Increased water temperature, for example, usually results in parasites spreading more rapidly and higher infection rates in fish[26].

Clinical knowledge and diagnostics: Correct diagnosis relies on effective communication between the patient, the clinician and the laboratory personnel and their awareness of pathogens. In Australia accurate diagnosis of seafood-borne parasitic diseases is very challenging. In the author's experience one of the main reasons for this is lack of awareness and low diagnostic suspicion regarding seafood-borne parasites among key stakeholders, clinicians and laboratory personnel. As an example, when a patient presents with acute gastrointestinal signs inclusive of a history of raw seafood consumption a differential diagnosis of seafood-borne parasitism is not routinely considered[27]. Anisakids/raphidascarids nematodes are also initiators of allergic reactions in humans. In many countries it has been confirmed that many previously diagnosed seafood allergies are an allergy to the parasite rather than the seafood itself[18]. Although fish and shellfish allergy is one of the most common allergy in adulthood (https://www.health.harvard.edu/staying-healthy/adult-food-allergies) in many parts of the world[28], in Australia nothing is known of the percentage of the 'allergic population' that may be attributable to parasites of seafood.

Should clinicians consider seafood-borne parasitic diseases in their action plans, there is no standard diagnostic test for these parasites in Australia. Reliance is being placed on the diagnostic tests developed overseas which, quite often, are not suitable to diagnose cases acquired in Australia and have variable/low specificity and sensitivity. For example, the recent human cases in Western Australia[9] and Queensland[29] were diagnosed as *Gnathostoma* based on a serologic test developed in Thailand, specificity and sensitivity of this test being uncertain. Interestingly, there is no report of this parasite in any Australian fish and none of the previous reports of *Gnathostoma* in other animals (such as cat, dog, bandicoot, quoll and pig)[10,30–33] provides a description or justification for their identification. A closely related parasite from the same family as *Gnathostoma* is *Echinocephalus* and both share a high degree of morphological similarity. Parasites belonging to the genus *Echinocephalus* are commonly found in Australian fish and molluscs[34] but has not been considered as zoonotic in government risk assessment studies[35,36] due to lack of reports of human illness. In some Asian countries, following successful experimental infection of kittens and primates with *Echinocephalus* larvae, and due to popularity of consuming raw seafood, this parasite has been recommended to be considered of public health importance[37,38]. Although presence of *Gnathostoma* spp. cannot be fully ruled out in Australia because there has never been a comprehensive study on seafood-borne parasites in this country, the fundamental concern is in the utilisation of serologic tests developed overseas to accurately identify Australian endemic parasites. Hence, it is likely that seafood-borne parasitic diseases are an underrecognised/underdiagnosed and underreported condition in Australia.

Recommendations

As long as there is awareness, prevention of infection with seafood-borne parasites is simple and easily doable (Figure 3). As rightly recommended by the National Health and Medical Research Council, Australia's leading health research body, Australians should eat more fish. However, this recommendation should be supported by a strong body of research and education toward seafood safety to ensure the risk due to parasites is minimal.

Research: Some of the urgent areas for research would be:

- Determining the occurrence and the life cycle (including transmission patterns) of seafood-borne parasites in Australian marine and freshwater systems.
- Developing reliable tests specifically to detect infections both in humans and infected seafood for parasites prevalent in Australia.
- Determining factors contributing to the low awareness of these important parasites and diseases caused across multiple stakeholders.

Translation of research outcomes including education: In Australia the gap between scientists and other stakeholders involved in seafood safety is significant[2]. In the recent risk assessments[35,36] the frequent presence of zoonotic parasites reported in commonly wild caught fish[4,5,39] has been fully overlooked and the number of human infections in the country[7] has been significantly underestimated with two documented reports only! A preliminary study also shows that the lack of awareness among medical doctors in Australia is significant[27]. Another challenge is the increasing decline in expertise in parasitology[7,17] and reduction in the parasitology curriculum in Australian medical and veterinary schools[7]. Research based education, communication and decision making of all stakeholders is central to seafood safety in this country. This includes fisher people, fish farmers, importers of seafood product, chefs, aquatic veterinarians, public health experts, clinicians, diagnostic laboratory staff, general and at-risk communities, and jurisdictional and federal agencies.

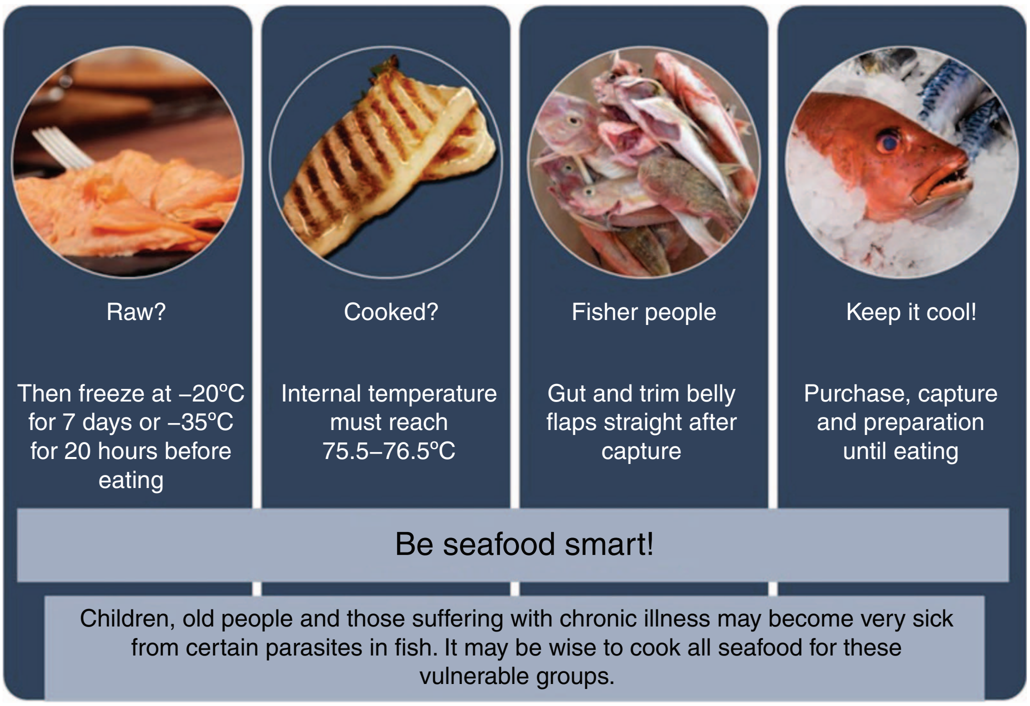

Figure 3. Some suggested methods for preventing infection with seafood-borne parasites, including anisakids/raphidascarids that are commonly found in Australian wild caught marine fish. Similar protocol and fact sheet can be easily disseminated to raise awareness. Note the temperature and duration suggested in the image is subject to the size of the fish fillet.

Conflicts of interest

The author declares no conflicts of interest.

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Biography

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