Seafood Consumption in Australia: Risks and Benefits

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[1] M&S Food Consultants Pty Ltd

[2] Seafood Safety Assessments

June 2015

SafeFish

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Abstract

The traditional belief that seafood consumption, especially for pregnant consumers and newly-born children, should be curtailed because of deleterious side effects caused by the presence of methyl mercury has been counterbalanced in recent years by information suggesting that beneficial aspects of seafood consumption can outweigh those caused by mercury.

An FAO/WHO study found that:

- There is *convincing* evidence of adverse neurological/neurodevelopmental outcomes in infants and young children associated with MeHg exposure during foetal development due to maternal fish consumption during pregnancy.
- There is *possible* evidence for cardiovascular harm and for other adverse effects (e.g. immunological and reproductive effects) associated with MeHg exposure.

On the benefits side, the FAO/WHO expert panel established that:

- There is *convincing* evidence of beneficial health outcomes from fish consumption for reduction in risk of cardiac death, and for improved neurodevelopment in infants and young children when fish is consumed by the mother before and during pregnancy.
- Evidence of other health benefits ranges from *probable* (e.g. ischaemic stroke) to *possible* (e.g. mood and depression) to *insufficient* (e.g. cancer).

The present review applies information published by FAO/WHO to consumption of seafood by Australian consumers in the context of risk management strategies employed by Australian and other regulators. Epidemiological evidence from Australia indicates a need for multilingual information about fish and mercury for pregnant women and mothers, especially targeting groups who are likely to be frequent consumers of fish and who use fish in weaning and infant foods.

1 Introduction

Traditionally, a degree of risk has been ascribed to consumption of seafoods because of the toxic effects of methyl mercury (MeHg), which is absorbed from the gut and enters the brain of adults and foetuses where it accumulates and is converted to inorganic mercury. MeHg is highly toxic and it has adverse effects over the lifetime of an individual.

Severe effects were seen following the MeHg incident in Japan during the 1950s (Harada, 1995) in which there were more than 700 cases of poisoning and 46 deaths. Finfish and shellfish harvested from the highly-polluted waters of Minamata Bay had mercury levels up to 29 mg/kg and were eaten at least daily by most people to give an estimated average MeHg intake of 0.3 mg/day (Coultate, 1992). The effects included mental retardation, cerebral palsy, deafness, blindness and dysarthria in individuals who were exposed *in utero*, and sensory and motor impairment in exposed adults. In addition, chronic, low-dose prenatal exposure to MeHg from maternal consumption of fish has become associated with impaired performance in young children based on neurobiological tests to measure attention, language, memory and fine-motor function.

More recently, the possible beneficial effects of seafood consumption have been weighed against the traditionally-accepted negative aspects by regulators prompting the Codex Alimentarius Commission to seek scientific advice from the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) on the risks and benefits of fish consumption. To this end, in 2010, at an Expert Consultation on the Risks and Benefits of Fish Consumption, seventeen experts in nutrition, toxicology, epidemiology, dietary exposure and risk-benefit assessment discussed the risks and the benefits of fish consumption (FAO, 2010).

The purpose of the present paper is to present contemporary information on the risks and benefits of seafood consumption to Australian consumers.

2 Methodology

Key agencies including Food Standards Australia and New Zealand (FSANZ), the Imported Food Program and the National Residue Survey of the Department of Agriculture provided survey information on MeHg in seafood consumed in Australia, both domestically-caught and imported.

Volumes of relevant seafood categories consumed in Australia were obtained by reference to ABARES Annual Fisheries Statistics.

Seafood consumption patterns of Australians were obtained from reports published by the Fisheries Research and Development Corporation (FRDC) and FSANZ.

Development of a risk:benefit equation for consumption of Australian seafoods is based on information stemming from the expert consultation of the FAO (see above) together with the investigations by the South Australian Research and Development Institute (SARDI) on fatty acid composition of Australian seafoods.

3 Hazard identification: Methyl mercury in seafood

Inorganic mercury is poorly absorbed *via* the diet but, in aquatic environments, bacteria can convert inorganic mercury to MeHg which is readily absorbed by the human body. Since it is accumulated in aquatic food chains, all fish contain small amounts of MeHg in their muscle tissue and fish at the top of the food web, long-living fish or mammals such as whales have the largest amounts.

The FAO/WHO consultation focused on risks to the foetus and neonate from maternal seafood intake and considered recent studies on maternal MeHg body burden *versus* child Intelligence Quotient, IQ (Cohen *et al*. 2005; Axelrad *et al*. 2007; USFDA, 2009).

The expert panel (FAO, 2010) found that:

- There is *convincing* evidence of adverse neurological/neurodevelopmental outcomes in infants and young children associated with MeHg exposure during foetal development due to maternal fish consumption during pregnancy.
- There is *possible* evidence for cardiovascular harm and for other adverse effects (e.g. immunological and reproductive effects) associated with MeHg exposure.

4 Benefits of seafood consumption

On the benefits side, the FAO/WHO expert panel established that:

- There is *convincing* evidence of beneficial health outcomes from fish consumption for reduction in risk of cardiac death, and for improved neurodevelopment in infants and young children when fish is consumed by the mother before and during pregnancy.
- Evidence of other health benefits ranges from *probable* (e.g. ischaemic stroke) to *possible* (e.g. mood and depression) to *insufficient* (e.g. cancer).

The perceived health benefits from seafood consumption are most likely due in large part to long chain omega-3 polyunsaturated fatty acids (LCn3PUFAs) such as eicosapentaenoic (EPA) and docosahexaenoic acid (DHA). Fish, however, contain other nutrients (e.g. protein, selenium, iodine, vitamin D, choline and taurine) that may also contribute to health benefits.

Based on the available data, the panel calculated that a child's IQ was increased an average 4.0 points if its mother consumed 100 mg DHA/day as part of a fish diet during gestation, with the maximum IQ gain identified as 5.8 points from fish consumption.

5 The risk:benefit equation

5.1 Child IQ

The expert panel estimated the effect of seafood consumption by a pregnant mother-to-be on the IQ score of her child by measuring her frequency of consumption and the quantity of MeHg consumed.

The net gain in IQ score was most pronounced when seafood with low mercury and high LCn3PUFAs was consumed (Table 1). Consuming seafood with a low Hg content during pregnancy resulted in net increases in the child's IQ, irrespective of the number of 100 g servings consumed in a week or of the LCn3PUFA content, though the increases in IQ were higher when the LCn3PUFA content is high.

Table 1: Summary of IQ improvement due to seafood intake for low MeHg seafood (after FAO/WHO, 2010)

Weekly 100g serves	MeHg	EPA+DHA	IQ change due to Hg	IQ change due to EPA+DHA	Net IQ change
1	Low	Low	-0.08	+0.77	+0.69
1	Low	High	-0.08	+5.8	+5.72
2	Low	Low	-0.2	+1.5	+1.3
2	Low	High	-0.2	+5.8	+5.6
4	Low	Low	-0.31	+3.1	+2.6
4	Low	High	-0.31	+5.8	+5.49
7	Low	Low	-0.5	+5.4	+4.9
7	Low	High	-0.5	+5.8	+5.3

It should be emphasised however that the effect of MeHg on IQ is significant and if the seafood is high in MeHg, consumption of even one serving/week will result in a net loss in IQ score, though the loss is mitigated when LCn3PUFA content is also high (Table 2).

Table 2: Summary of IQ improvement and loss due to seafood intake for high MeHg seafood (after FAO/WHO, 2010)

Weekly 100g serves	MeHg	EPA+DHA	IQ change due to Hg	IQ change due to EPA+DHA	Net IQ change
1	High	Low	-2.3	+0.77	-1.53
1	High	High	-2.3	+5.8	+2.5
2	High	Low	-4.7	+1.5	-3.2
2	High	High	-4.7	+5.8	+1.1
4	High	Low	-9.3	+3.1	-6.2
4	High	High	-9.3	+5.8	-3.5
7	High	Low	-16.3	+5.4	-10.9
7	High	High	-16.3	+5.8	-10.5

5.2 Coronary Heart Disease

The FAO/WHO expert panel considered the effect of seafood intake on coronary heart disease (CHD) mortality, drawing on the meta-analyses of Mozaffarian & Rimm (2006) and USFDA (2009). The consultancy concluded that there was convincing evidence for the benefits of EPA+DHA intake on CHD mortality.

For intakes up to 250 mg of EPA+DHA/day, a 36% reduction in CHD mortality was estimated; at intakes >250 mg/day no further decrease in CHD mortality was estimated.

The consultancy quantified reduction in CHD mortality according to:

$$\text{Deaths prevented/million people} = \frac{\underline{(EPA+DHA)*100*x/7}}{250}*0.36*D$$

Where:

- (EPA+DHA) is the total concentration (mg/g) in fish
- 100 is the serving size (g)
- x is the number of servings/week
- 0.36 is the proportional reduction in CHD deaths, with reduction considered to be linearly related to DHA intake up to 250 mg/day
- D is the estimated number of CHD deaths/million people

In Section 10 of this paper the risk;benefit equation is applied to the consumption of seafood in Australia.

6 Mercury levels in seafoods consumed in Australia

Standard 1.4.1 of the Australian Food Standards Code sets a maximum level (ML) for mercury in seafood, based on a mean level resulting from testing a prescribed number of samples, which is specified in clause 6 of the Standard.

Australian seafoods are arranged in two categories: those required to have a mean THg less than 0.5 mg/kg and those required to have a mean THg less than 1.0 mg/kg, the primary purpose of this division being to assist in risk management (Table 3).

Table 3: Mean level of THg in Australian seafoods (FSC Standard 1.4.1)

Mean level THg (mg/kg)*	Species
0.5*	Crustacea
0.5*	Fish (as specified in Schedule 4 to Standard 1.4.2) and fish products, *excluding* gemfish, billfish (including marlin), southern bluefin tuna, barramundi, ling, orange roughy, rays and all species of shark
0.5*	Molluscs
1.0*	Gemfish, billfish (including marlin), southern bluefin tuna, barramundi, ling, orange roughy, rays and all species of shark Fish for which insufficient samples are available to analyse in accordance with clause 6 – Sampling plan for mercury in fish, fish products, crustacea and molluscs

- Mean is based on the sampling plan set out in the Standard

Over the past three decades there have been several surveys of Australian finfish (Tables A1-A7), all of which found that most seafood contains low levels of mercury (Working Group on Mercury in Fish, 1979; Western Australian Food Monitoring Program, 1993; Bureau of Resource Sciences, 1997a, 1997b; White, 1999; Padula *et al*. 2012).

However, these surveys also established that sharks, particularly warm water sharks (*Carcharinus*) and large game fish such as swordfish and marlin can have mercury levels much higher than the maximum recommended level of 1 mg/kg in the Food Standards Code. Interestingly, although tuna is a large predatory fish it generally has mercury levels <0.5 mg/kg.

In a New South Wales survey (White, 1999) 3/26 shark samples and 3/8 swordfish samples exceeded 1 mg/kg (Table A1), with maxima of 2.3 mg/kg and 1.65 mg/kg, respectively; nearly 3% of 1,095 fish samples, all shark and swordfish, exceeded 1 mg/kg (Table A1).

Data obtained by FSANZ and used in the 23rd Australian Total Diet Study (FSANZ, 2011) were based on popular meal choices (battered fillets, frozen fish portions, prawns and canned tuna and indicated extremely low MeHg levels (Table A2).

The present study was facilitated by the provision of large databases of Hg concentration in Australian seafoods commissioned by FSANZ, the National Residue Survey (NRS) and the Imported Food Program of the Department of Agriculture (DA). In total more than 13,000 test results are presented in Tables A3-A7.

Crustaceans and molluscs generally had very low THg concentrations with only 1/2106 samples exceeding 0.5 mg/kg (Table A3). In Tables A4 and A5, respectively, the THg for Australian finfish are presented in two categories: those designated in Standard 1.4.1 as not to exceed an ML (based on a sampled mean) of 0.5 mg/kg (n=5953) and those ascribed an ML (again based on a sampled mean) of 1 mg/kg (n=1260).

Of the 19 fish contained in Table A4, three had maxima which exceeded 0.5 mg/kg: catfish, snapper and red emperor, leading to the former being specified as a species to be eaten on a restricted basis (note that the catfish referred to is not *Pangasius*, large quantities of which are imported from Viet Nam, and which has very low THg levels). Of further interest from Table A4 is that, while almost all of the 19 fish listed had low median and mean levels, there were occasional very high levels e.g. canned tuna 3.4 mg/kg, 'ocean fish' 4.1 mg/kg and red emperor 4.1 mg/kg.

In Table A5 are presented THg concentrations for nine finfish with assigned MLs of 1 mg/kg. Two finfish, barramundi and southern bluefin tuna (SBT), both increasingly being raised by aquaculture, had low median and mean levels indicating that their ML may warrant reclassification to 0.5 mg/kg. By contrast, samples of others e.g. gemfish, shark and billfish had maxima greater than 1 mg/kg.

In Table A6 are presented NRS data for 12 finfish (n=2104) caught in Australia and probably representative of product which is exported, while in Table A7 are presented data assembled by the Imported Food Program of the DA for seven finfish (n=2007). In general, NRS and Imported Food Program data align with those of FSANZ (Tables A4, A5) with barramundi and SBT having THg profiles (median, mean and maximum) which suggest they should be reclassified to the grouping required to have an ML of 0.5 mg/kg. By contrast, some samples of shark, swordfish and yellowfin tuna samples exceeded their assigned ML of 1 mg/kg (note that ML as stated here is based on a mean of units sampled in accordance with Clause 6 of Standard 1.4.1).

In summary, the large volume of data summarised in Tables A1-A7, are valuable because they inform on following sections on Risk Benefit of Australian seafoods (Section 10) and Risk Management (Section 11).

7 Long chain omega-3 polyunsaturated fatty acids in Australian seafoods

Data available for EPA and DHA concentrations in some Australian fish have been published by Padula *et al*. (2012) with the highest levels being found in farmed finfish: Atlantic salmon, ocean trout and yellowtail kingfish (Table 4).

Table 4: EPA and DHA concentrations in selected Australian seafood (after Padula *et al*. 2012)

	Concentration (mg/g)		
	EPA	DHA	Total
Ocean trout	19.1	11.9	31.0
Yellowtail kingfish	8.7	9.9	18.6
Atlantic salmon	10.3	7.9	18.2
Barramundi	3.7	4	7.7
Australian sardine	4.5	1.8	6.3
Sydney rock oyster	3.9	3	6.9
Pacific oyster	3.1	2.7	5.8
Banana prawn (wild caught)	0.6	0.8	1.4
Southern rock lobster	0.5	0.9	1.4
Gummy shark	1.1	0.2	1.3
Wild black lip abalone	0.01	0.4	0.4
Wild green lip abalone	0	0.2	0.2

The above data are important in estimating risks and benefits associated with consuming Australian seafoods (see Section 10).

8 Consumption of seafoods in Australia

A number of surveys have been carried out on seafood consumption in Australia. Ruello (2005) surveyed retail seafood consumption in Melbourne. Overall, 96% of respondents ate fish or seafood in the last year and 65% in the previous week consuming, on average, 240g of fish/seafood/week (150g in-home and 90g out-of-home).

Canned fish was eaten by almost 38% of Melbourne households at least once a week, by 77% at least once a month and by 89% at least once a year. Fresh fish was eaten in 31% of households at least once a week, in 68% at least once a month and in 91% at least once a year. One in four (24%) respondents ate fresh fish out-of-home at least once a week, 54% at least once a month and 84% at least once a year. Out-of-home consumers (25%) indicated they ate canned fish at least once a week, while 48% ate it at least once a month and 67% at least once a year.

Danenburg and Remaud (2010) undertook an internet survey in 2009 of 2,643 people aged 18 to 70. The data collection was monitored to ensure that responses were received from all states, age groups and genders, broadly in line with population demographic characteristics. When asked about their consumption in the previous year, the top 10 species consumed identified were:

- Prawns (73%)
- Canned tuna (66%)
- Crumbed or battered fish but unsure of species (53%)
- Barramundi (53%)
- Squid (49%)
- Salmon, fresh (47%)
- Oysters (44%)
- Canned salmon (42%)
- Flake (36%)
- Crab (35%)

The authors estimated the ‘market share’ (as a combination of the penetration level and the average frequency of consumption) of each species:

- Canned tuna (14%)
- Prawns (6%)
- Canned salmon (6%)
- Crumbed or battered fish but unsure of species (6%)
- Salmon, fresh (5%)
- Squid (4%)
- Sardines (4%)
- Sushi or sashimi but unsure of species (3%)
- Smoked salmon (3%)
- Barramundi (3%)
- Flake (3%)
- Fish fingers (3%)
- Oysters (2%)

It has long been the fact that the vast bulk of seafood consumed in Australia is imported. Ruello (2011) undertook a wide-ranging survey of imported seafoods estimating that 193,000 t of seafood (72% of the seafood flesh consumed) was imported in 2008/9 of which almost all was used by the retail and the food service sector with little used for food manufacturing.

9 Exposure Assessment

In Australia there is significant production of species associated with elevated levels of mercury, of which more than 30 million servings (150 g) are consumed (Table 5) with shark comprising >50% of high-Hg fish consumed. Note that barramundi is included in the category of fish with elevated levels of Hg, in spite of data indicating the species should be included with those fish with an ML (based on a sampled mean) of 0.5 mg/kg.

Based on data presented by the ABARES 2011 report, in Table 6 are presented volumes of seafood with low-Hg fish (<0.5 mg/kg) consumed by Australians. Conversion of landings, both domestic and imported, to edible portions is based on assumptions of 40% of the landed weight for domestic finfish, 80% for imported crustaceans and molluscs (crustaceans are imported in various stages of processing from whole to ready-to-eat) and 100% for imported finfish and canned tuna. As can be seen from Table 6, in total, Australians consume around 1.8 billion servings (150 g) of low-Hg seafoods.

Table 5: Australian production (t/annum) and calculated consumption (number of 150 g servings) of species associated with elevated mercury levels as specified in Standard 1.4.1 (after ABARES, 2011)

	Production (t)*	Exported (t) **	Consumed (t) ***	Number of servings consumed****
Barramundi	1,996	0	1,996	5,322,667
Gemfish	247	0	247	658,667
Ling	1,105	0	1,105	2,946,667
Orange roughy	280	0	280	746,667
Shark	6,652	0	6,652	17,738,667
Tuna	9,133	7,809	1,324	4,080,000
Totals	19,611	7,809	11,604	31,493,333

* Data taken from Tables 2, 5 and 17 of ABARES Production data
** Data taken from Table 19 of ABARES Production data
*** Assumes no wastage
****Assumed 40% yield edible portion consumed as 150 g servings

Data compiled by FSANZ (2011) determined that the estimated dietary exposures to MeHg for each age category were below the Provisional Tolerable Weekly Intake (PTWI) of 1.6 µg/kg bw for all age groups at the 90th percentile and consequently within the health based guidance value. The highest level of exposure was for 2-5 year olds at 80% of the PTWI, due to their high food consumption relative to body weight.

FSANZ concluded their analysis of Hg exposure in the 23rd ATDS by stating: *"Dietary exposure to methyl mercury for all groups was below the respective reference health standard. On this basis, there is no human health and safety risk with regard to current intakes of methyl mercury by Australian consumers. Due to the potential adverse effects of methyl mercury on vulnerable population groups, such as pregnant women and young children, methyl mercury will continue to be monitored in future studies."*

In support of the FSANZ concern regarding vulnerable populations, there have been instances in Australia where consumption of seafood has led to clinical symptoms which align with high levels of Hg intake.

Three boys of Chinese parents (three different families) were fed fish congee (a rice and fish porridge) as a weaning food, and also ate fish regularly as toddlers (Corbett & Poon, 2008). Each boy had high blood mercury levels (143, 158 and 350 nmol/L) compared with the normal maximum < 50 nmol/L and each family reported eating fish at least five times a week, usually including barramundi, ling and orange roughy. Corbett & Poon (2008) point out that fish congee is usually made with either freshwater species or locally caught fish and is a common weaning food in coastal regions of southern China and S-E Asia. However, fish, particularly the large pelagic and long-lived species more likely to be bought in Australia, are known to contain mercury at >0.5 mg/kg.

Another case (based on anecdotal, confidential information) involved a young woman who had a five-year history of symptoms consistent with Chronic Fatigue Syndrome and Multiple Chemical Sensitivity Syndrome. In an effort to ameliorate her discomfort she began a fish diet, gradually increasing to three meals of fish per day and excluding all else except some fruits and vegetables. The diet lasted for two years by which time she had become bed bound and, although she could walk under duress, she was unable to perform most activities of daily living and remained in a darkened room. Her high blood mercury concentration was treated by avoidance of fish and by chelation with DMPS (Dimercaptopropanesulfonic acid) and she recovered.

The foregoing illustrates that, while FSANZ can point to current estimates of population intakes being within the reference health standard, when consumers have unusually high seafood intakes they may incur symptoms of Hg-related illness. This aspect will be discussed further in Section 11 (Risk Management).

Table 6: Statistics (t/annum) and calculated consumption (number of 150 g servings) for Australian seafoods which are low in Hg (after ABARES, 2011)

	Production (t)	Exported (t)	Production-Exports	150 g servings	Imports (t)	150 g servings	Total servings
Finfish (wild caught & aquaculture)	83,422	14,125	69,297	184,792,000*	86,731	578,206,667***	762,998,667
Crustaceans and molluscs	71,001	19,617	51,384	274,048,000**	62.038	330,869,333**	687,917,333
Canned fish	185	185	0	0	60,460	403,066,667***	403,066,667
Totals	154,608	33,927	120,681	458,840,000	209,229	1,312,142,667	1,770,982,667

* Assumed 40% yield edible portion and no wastage
** Assumed 80% edible portion and no wastage
*** Assumed 100% edible portion and no wastage
Production data are taken from ABARES Table 2; Export data from Tables 18; Import data from Table 29

10 Risks and benefits in the Australian context

As may be determined from Tables 1 and 2, there is a balance on the one hand, between seafood intake benefiting the consumer, particularly pregnant women, nursing mothers and toddlers by enhancing the latters' IQ score and, on the other hand, by increasing the risk of Hg-associated illness (as described in Sections 1 and 3).

As shown in Tables 5 and 6, Australians consume more than 1.7 billion serves/annum of low THg seafoods, plus 31 million serves of high THg seafood, a ratio around 550:1. As indicated in Section 5, providing at-risk groups consume only those seafoods containing low MeHg seafoods, they will benefit from unrestricted consumption, particularly if fatty fish such as sardines and farmed trout or salmon are part of the diet.

The FAO/WHO expert consultancy constructed a matrix linking Hg and LCn3PUFAs in seafoods and this matrix is presented in Table 7, with modification to accommodate seafoods consumed in Australia.

In general, the high Total Hg (THg) fish are also low in LCn3PUFAs e.g. marlin, swordfish, orange roughy which increases their risk:benefit ratio.

By contrast, fish such as Atlantic salmon, ocean trout, yellowtail kingfish, mackerelsand sardines are high in LCn3PUFA and low in Hg, giving them a high benefit:risk ratio.

10.1 Possible effect of seafood consumption on CHD deaths in Australia

Data for CHD in Australia supplied by the Heart Foundation (www.heartfoundation.org.au), state that, in 2013 there were 19,766 deaths from CHD. In that year the population was approximately 23,130,000 (www.abs.gov.au) equating to a rate of CHD of 855 deaths/million.

If the above data are used for an Australian perspective on CHD mortality, together with a serving size of 150 g (as used by FSANZ in advice on seafood intake for Australian consumers) significant reduction in death from CHD might be expected from consumption (3-4 serves/week) of seafood with moderate concentrations (5 mg/kg) of EPA+DHA (Table 7).

Table 7: Estimated reductions in annual CHD deaths in Australia based on seafood intake

EPA+DHA (mg/g)	Servings /week	Australian deaths prevented	
		Per million population	Total*
5	2	264	6129
5	3	396	9193
5	4	528	12257

* Based on an Australian population in 2013 of 23 million

For the purpose of the present report a 'basket' of species averaging 5 mg/g EPA+DHA was constructed reflecting consumption patterns in Sections 8 and 9, where canned tuna, farmed salmon, barramundi and canned salmon were among the more popular finfish (Table 8).

In considering the benefits and risks of seafood consumption the FAO/WHO expert consultation concluded not only that the benefits outweighed any risks for the general population and for women of childbearing age, but it also went further, emphasising that advice to limit seafood consumption might actually be deleterious to health with some groups.

Table 8: Classification of the content of EPA + DHA *versus* THg content in finfish and shellfish consumed in Australia (after FAO/WHO, 2010)

THg (mg/kg)	EPA + DHA (mg/kg)*			
	≤ 3	> 3 - ≤ 8	> 8 - ≤ 15	> 15
≤ 0.1	**Fish**: Butterfish; Catfish; Atlantic cod; Pacific cod; Haddock; Pollock; Sole; Tilapia; Whiting **Shellfish**: Abalone*; Clams; Cuttlefish; Lobster*; Oysters*; Periwinkle; Prawns*; Scallops; Scampi; Sea urchin; Whelk	**Fish**: Australian sardine*; Blue sprat*; John Dory; Ocean perch; Mullet; Sweetfish; **Shellfish**: Mussels; Squid	Fish: Redfish; Atlantic Salmon (wild); **Shellfish**: Spider crab; Swimmer crab	**Fish**: Anchovy; Herring; Mackerel; Ocean trout*; Atlantic salmon* (farmed); Yellow kingfish* **Shellfish**: Crab (brown meat)
> 0.1 - 0.5	**Fish**: Blue grenadier; Bluefin tuna; Gemfish; Grouper; Gurnard; Hake; Ling; Nile perch; Skate/ray; Snapper; Yellowfin tuna	**Fish**: Barramundi*; Carp; Albacore Tuna; **Shellfish**: Crab	**Fish**: Goatfish; Halibut; Horse mackerel; Spanish mackerel; Sea bream; Tilefish; Skipjack tuna	**Fish**: Eel; Pacific mackerel
> 0.5 - 1	**Fish**: Marlin; Orange Roughy; Bigeye tuna	**Fish**: King mackerel; Shark*	**Fish**: Alfonsino	**Fish**: Pacific Bluefin tuna
> 1		**Fish**: Swordfish		

* Australian species for which THg and EPA+DHA data are available (see Tables 4 and A1-A7)

11 Risk Management

Among regulatory measures imposed by different countries there are common principles which focus on:

- Number of weekly servings for pregnant women and small children
- Serving frequencies for other consumers
- Identification of high-Hg seafood relevant for the individual country.

Thus Japan focuses on dolphin and whale consumption, Norway and Spain on pike, Canada on Escolar, specifying amounts and times between consumption by women who are pregnant or breastfeeding. Uniquely, the USA identifies that pregnant women or nursing mothers should never eat shark, swordfish, king mackerel and tilefish.

FSANZ advises that pregnant women or women planning pregnancy consume no more than one serve/week (150 g) of orange roughy and catfish, and no other fish, or one serve/fortnight of high-Hg species (Table 9).

Table 9: Advice provided to Australian consumers by FSANZ

Target group	Species	Recommended amounts for consumption/week
Pregnant women and women planning pregnancy (1 serve = 150 g) Children up to 6 years (1 serve = 75 g)	Any fish and seafood not listed below:	2 – 3 serves (300-450 g) 2 – 3 serves (150-225 g)
	Orange roughy (sea perch) or catfish and no other fish that week Or Shark (flake) or billfish (swordfish, broadbill, marlin) and no other fish that fortnight	1 serve per week 1 server per fortnight
Rest of the population (1 serve = 150 g)	Any fish and seafood not listed below:	2 – 3 serves (300-450 g)
	Shark (flake) or billfish (swordfish, broadbill, marlin) and no other fish that week	1 serve (150 g)

Advice to Australian consumers seems more conservative than those of other countries. For example, pregnant women in NZ receive advice from their Ministry of Primary Industries (NZMPI) that divides seafood into three categories:

- No restriction necessary for low-Hg fish
- 3-4 servings/week are acceptable (medium-Hg fish such orange roughy, ling)
- 1 serving every 1-2 weeks is acceptable (high-Hg fish such as shark and marlin)

USA regulators similarly have relaxed their stance on seafood consumption, issuing an advisory recommending that pregnant or nursing women, and women who may become pregnant, consume up to

340 g of fish per week overall, consume up to 170 g (6 ounces) of albacore tuna per week, but not consume four specific fish species with high mercury levels (USEPA & USFDA, 2004).

In conclusion, the approach of Corbett & Poon (2008) in the Medical Journal of Australia aligns the risk and benefits of seafood consumptions with the special needs of the multicultural population of Australia: *"It has been previously noted in the Journal that public health policy regarding fish consumption needs to balance the health benefits for cardiovascular disease and anaemia with the possible ill effects of mercury on neurological development in infants (Bambrick & Kjellstrom, 2004). We recommend that multilingual information about fish and mercury be made available to pregnant women and mothers, especially targeting groups who are likely to be frequent consumers of fish and who use fish in weaning and infant foods. Regulatory and health promotion activities could also be informed by surveillance of blood or hair mercury levels in infants from ethnic groups at high risk of mercury intoxication, and of the frequency of fish consumption in this age group (by type of fish)."*

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Appendix 1: Supplementary Data:

Table A1: Mercury levels in various seafoods in Australia

	Mean mercury (mg/kg) Number of samples in parentheses			
	Working Group on Mercury in Fish, 1979	WA Food Monitoring Program, 1993	White, 1999	Padula *et al.* 2012
Gemfish	0.68 (148)	-	-	-
Tuna, Skipjack	0.15 (20)	-	-	-
Tuna, Southern Bluefin	0.22 (219)	-	-	-
Tuna, Yellow Fin	0.38 (20)	-	-	-
Swordfish	-	-	0.98 (8)	-
Marlin, Black	7.27 (42)	-	0.57 (3)	-
Sharks				
Angel	0.36 (36)	-	-	-
Blacktip Whaler	1.48 (8)	0.41 (14)	-	-
Blue Pointer	1.93 (2)	0.83 (2)	-	-
Blue Whaler	0.41 (2)	-	-	-
Bronze Whaler	0.72 (159)	0.52 (33)	-	-
Carpet	1.02 (76)	0.69 (12)	-	-
Gummy	0.44 (507)	0.29 (4)	-	0.44 (1)
'Shark'	-	-	0.48 (26)	-
Abalone farmed	-	-		<0.01
Abalone wild	-	-		0.01
Atlantic salmon farmed	-	-		0.02
Australian sardine	-	-		0.05
Barramundi farmed	-	-		0.05
Ocean trout farmed	-	-		0.04
Oysters	-	-		0.04
Prawns farmed	-	-		<0.01
Prawns wild	-	-		<0.01-0.07
Southern rock lobster	-	-		0.09
Yellow kingfish	-	-		0.04

Table A2: MeHg concentration (mg/kg) in Australian fish (FSANZ, 2011)

	Analyses (n)	Mean	Median	Minimum	Maximum
Fish fillets, battered	10	0.015	0.016	0.0054	0.021
Fish portions, frozen	4	0.019	0.020	0.014	0.023
Prawns	8	0.012	0.011	0.0058	0.024
Tuna, canned in brine	4	0.0084	0.0064	0.0037	0.017

Table A3: Mercury (THg or MeHg) concentration (mg/kg) in Australian molluscs and crustaceans (FSANZ database, compiled in 2003)

		Concentration (mg/kg)		
		Median	Mean	Maximum
Crab	224	0.07	0.12	0.49
Lobster	353	0.04	0.05	0.33
Mollusc	278	<0.01	0.02	2.4
Mollusc, cuttlefish	22	0.03	0.06	0.13
Mollusc, periwinkle	50	<0.01	0.01	0.03
Mussel	71	0.02	0.06	0.41
Octopus	23	0.01	0.02	0.09
Oyster	267	0.01	0.02	0.12
Prawn	403	0.03	0.05	0.4
Scallop	368	<0.01	0.01	0.11
Squid	47	0.03	0.06	0.8

Table A4: Mercury (THg or MeHg) concentration (mg/kg) in Australian finfish with assigned Maximum Level 0.5 mg/kg* (FSANZ database, compiled in 2003)

		Concentration (mg/kg)		
		Median	Mean	Maximum
Atlantic salmon	111	0.03	0.03	0.07
Bream	103	0.07	0.11	0.56
Canned tuna	1090	0.09	0.1	0.55
Catfish	187	0.37	0.42	1.3
Dory	78	0.03	0.08	0.48
Flathead	107	0.07	0.08	0.33
Hake	62	0.05	0.07	0.76
Hoki	70	0.14	0.15	0.35
Jobfish	232	0.1	0.15	1
Mackerel	33	0.04	0.07	0.32
Mullet	135	0.01	0.02	0.31
“Ocean fish”	1871	0.1	0.19	4.1
Ocean perch	226	0.09	0.14	0.7
Red emperor	187	0.16	0.5	4.1
Snapper	255	0.2	0.3	1.1
Trevally	40	0.06	0.08	0.48
Trout	25	0.06	0.11	0.3
Tuna, non canned, non bluefin	845	0.13	0.2	3.4
Whiting	296	0.06	0.08	0.46

* Mean is based on the sampling plan set out in the Standard

Table A5: Mercury (THg or MeHg) concentration in Australian finfish with assigned Maximum Level 1 mg/kg* (FSANZ database, compiled in 2003)

	n	Concentration (mg/kg)		
		Median	Mean	Maximum
Barramundi	57	0.1	0.1	0.37
Billfish (broadbill, swordfish, marlin)	36	0.9	0.99	1.85
Bluefin tuna	105	0.35	0.37	1.2
Gemfish	143	0.33	0.49	2.18
Ling	75	0.12	0.18	1
Orange Roughy	233	0.54	0.53	0.97
Shark	506	0.4	0.73	6.5
Tuna, Aquaculture	74	0.3	0.33	0.8
Tuna, wild caught	31	0.45	0.47	1.2

* Mean is based on the sampling plan set out in the Standard

Table A6: Mercury (THg or MeHg) concentration (mg/kg) in Australian finfish (NRS database)

	n	Concentration (mg/kg)		
		Median	Mean	Maximum
Atlantic salmon	132	0.03	0.03	0.06
Blue Grenadier	43	0.13	0.18	0.62
Mullet	234	0.01	0.01	0.04
Snapper	47	0.2	0.23	0.5
Tuna, Yellowfin	109	0.28	0.35	2.62
Whiting	249	0.06	0.07	0.46
Barramundi	11	0.03	0.08	0.06
Orange roughy	291	0.49	0.48	0.95
Orange roughy	291	0.49	0.48	0.95
Shark	279	0.55	0.69	4.1
Swordfish	41	0.39	0.73	3.53
Tuna, Southern bluefin (aquaculture)	234	0.32	0.32	0.8
Tuna, Southern bluefin (wild caught)	143	0.37	0.38	0.75

Table A7: Mercury (THg or MeHg) concentration (mg/kg) in imported finfish (Imported Food Program database)

	n	Concentration (mg/kg)		
		Median	Mean	Maximum
Canned tuna	1025	0.06	0.08	1
Barramundi	32	0.09	0.09	0.18
Billfish	213	0.61	0.68	6.1
Gemfish	26	0.64	0.62	1.2
Ling	200	0.42	0.51	1.7
Orange roughy	77	0.4	0.44	1
Shark	434	0.25	0.38	2.2