RISK ASSESSMENT OF THE SEAFOOD SAFETY SCHEME

Department of Primary Industries
Food Authority

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Executive summary

The first risk assessment underpinning the NSW Food Authority's (Food Authority) Seafood Safety Scheme (the Scheme) was published in March 2009. Then a periodic review of the risk assessment was published in July 2012. The risk assessment was part of a comprehensive review of food safety schemes undertaken during the remake of Food Regulation 2004. This revised risk assessment of the Scheme forms a part of the latest version of Food Regulation 2015.

Seafood consumption is increasing globally as well as in New South Wales (NSW). According to the Australian Health Survey 2011-2012, average per capita consumption of seafood in NSW was 17.5 kg and 19.2 kg per year by male and female consumers, respectively. Interestingly, average per capita seafood consumption in NSW was higher than the national average of seafood consumption.

Seafood supply in NSW comes from three major sources, i.e. wild catch, aquaculture and imported products. Recent figures show that almost two-thirds of the seafood demand is met through imported seafood products, primarily frozen fish fillets, frozen prawns and canned fish. Wild catch and aquaculture contribute approximately 75% and 25% of the local supply. However, the volume of aquaculture products is predicted to grow and could reach up to 50% by 2025.

The risk assessment considered only those risks that can impact upon food safety of the seafood in NSW. Imported seafood products are required to meet the same national food standards. This risk assessment was conducted using the Codex Alimentarius Commission approach that consists of the following steps: (i) hazard identification, (ii) hazard characterisation, (iii) exposure assessment, and (iv) risk characterisation. Data used in this risk assessment process was extracted from multiple sources including OzFoodNet (foodborne outbreaks and illnesses), Food Standards Australia New Zealand (recalls, risk assessment, analysis and standards), NSW Health (foodborne outbreaks and illnesses), NSW Food Authority (risk assessment, evaluation and testing), Department of Agriculture and Water Resources (imported seafood failure), Australian Bureau of Statistics (seafood consumption), national and international agencies (technical reports) and scientific journals.

Risk assessment conducted on seafood products from different supply chains identified: scrombroid poisoning, ciguatoxin and norovirus associated with wild catch; microbiological contamination *(Listeria monocytogenes)* and histamine detection in imported seafood; and potential environmental pollutants, algal biotoxins and norovirus in aquaculture products as key health hazards (Figure A).

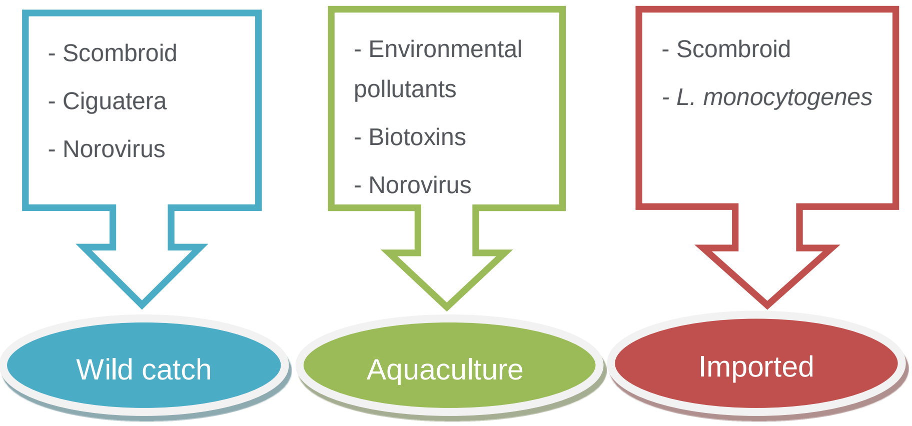

Figure A. Specific risks associated with different segments of seafood industry in NSW

The Seafood Risk Assessment (2016) also looked at the risks of different categories of seafood and found histamine (scrombroid poisoning), biotoxins and bacterial contamination (*Vibrio* spp.*)* as the major concerns in NSW, namely fish, shellfish and crustaceans, respectively. A summary of hazards and estimates of risk ranking associated with different seafood types consumed in NSW is presented in Table A.

Table A. Summary of hazards and risks with different types of seafood in NSW

Hazard	Risk	Finfish	Shellfish	Crustaceans
Biological	Bacterial contamination	*L. monocytogenes*	*E. coli*	*Vibrio* spp.
	Viral contamination		Norovirus	
	Parasitic contamination			
Chemical	Biotoxin	Ciguatoxin	Algal toxins (W) Algal toxins (A)	
	Scombroid	Histamine		
	Heavy metals			
	Pesticide			
	Environmental pollutants			
	Others			
Physical	Glass			
	Plastic			
	Metal			

Legend: W = wild catch; A = aquaculture

Low Medium High

Scombroid poisoning is a medium risk due to temperature abuse during catch/harvest, transport, storage and processing of specific fish species. There were nine outbreaks and one recall related to scombroid poisoning in NSW between 2005 and 2014. An average of twenty consignments of imported fish products were failed due to histamine detection between 2014 and 2015. Tuna, mackerel, Maldives fish, blue grenadier and mahi mahi have been identified as species involved in these outbreaks and contamination detections.

Microbial contamination of the imported seafood is well managed through border inspections. Recent border testing results of imported seafood products found *L. monocytogenes* in finfish, *Escherichia coli* in shellfish and *Vibrio* spp. in crustaceans (prawns).

Algal biotoxins are a low to medium risk for shellfish and managed through NSW marine biotoxin management plans. Algal biotoxins pose a low risk for aquaculture shellfish and a medium risk for wild catch shellfish. NSW has experienced several extensive potentially toxic cyanobacterial blooms in freshwater and brackish areas. These have resulted in a range of food safety interventions in the affected areas, including:

- Advising recreational fishers to gut, gill and wash fish before cooking
- Advising recreational fishers not to collect yabbies or freshwater mussels
- Industry voluntarily diverting commercially harvested seafood to bait
- Industry voluntarily adopting gut and gill requirements for fish before being sold
- Government mandating closure of areas used for recreational and commercial harvest of seafood.

Food safety of seafood products in NSW is managed through the Scheme developed, maintained and implemented by the Food Authority. The Food Authority runs an active verification program to ensure the implementation of the Scheme. The Food Authority also liaises with other stakeholders and agencies to manage seafood safety related issues at the state and national level.

It is important to note that seafood safety in the retail sector is not covered by the Scheme. This is managed by local councils under the food safety standards (3.2.1, 3.2.2 and 3.2.3) of the Australia New Zealand Food Standards Code (the Code).

The Food Authority plays a vital role in the overall government approach to the management of food safety challenges in NSW. This revised risk assessment of the Scheme will serve as a reference to develop and implement strategies to improve seafood safety.

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Terminology, abbreviations and symbols

Term	Description
Crustacean	A very large group of arthropods (usually treated as a subphylum), which includes such familiar animals as crabs, lobsters, crayfish, shrimp, krill and barnacles.
Food safety	Food safety is ensuring that food is safe to eat. It includes all activities to protect the food supply from biologicall, chemical, allergenic and physical hazards that may occur during all stages of food production and handling.
Finfish	A fish is most strictly used to describe any animal with a backbone that has gills throughout life and has limbs, if any, in the shape of fins. A bony fish, such as a salmon, or a cartilaginous fish, such as a shark, especially in contrast to a shellfish or other aquatic animal.
Hazard	A biological, chemical or physical agent in, or condition of, food that has the potential to cause an adverse health effect in humans.
Risk	The probability of a hazard to occur, e.g. the risk of a cooked sausage not reaching the correct temperature during a defined cooking time.
Risk analysis	Risk analysis is a systematic process to understand the nature of and to deduce the level of risk.
Seafood	All marine finfish, crustaceans, molluscs and other forms of aquatic life (including squid, sea turtle, jellyfish, sea cucumber, and sea urchin and the roe of such animals) other than birds or mammals, harvested for human consumption.
Shellfish	All edible species of oysters, clams, mussels and scallops; either shucked or in the shell, fresh or frozen, whole or in part. Scallops are to be excluded when the final product is the shucked adductor muscle.
Shelf life	The expected amount of time a seafood product will remain in high-quality condition. In general, the higher the fat content, the more prone the product is to spoilage and flavour changes.

Abbreviations

Term	Description
ASP	Amnesic Shellfish Poisoning
BMPs	Best Management Practices
CFP	Ciguatera Fish Poisoning
DPI	Department of Primary Industries
DSP	Diarrhetic Shellfish Poisoning
DAWR	Department of Agriculture and Water Resources
EPA	The Environmental Protection Agency
FAO	Food and Agriculture Organisation
FDA	The Food and Drug Administration
FRDC	The Fisheries Research and Development Corporation
FSANZ	Food Standards Australia and New Zealand
FSP	Food Safety Plan
GHPs	Good Hygiene Practices
GMPs	Good Manufacturing Practices
HACCP	Hazard Analysis and Critical Control Point
HAV	Hepatitis A Virus
IFIS	The Imported Food Inspection Scheme
JECFA	Joint FAO/WHO Expert Committee on Food Additives
KP	Kanagawa Phenomenon
LPS	Lipopolysaccharides
LWE	Live Weight Equivalent
MAP	Modified Atmosphere Packaging
ML	Maximum Level
NSP	Neurotoxic Shellfish Poisoning
PCP	Pest Control Program
PRPs	Prerequisite Programs
PSP	Paralytic Shellfish Poisoning
PTWI	Provisional Tolerable Weekly Intake

Term	Description
RTE	Ready-to-Eat
SOPs	Standard Operating Procedures
SPC	Standard Plate Count
SRO	Sydney Rock Oyster
SSOPs	Sanitation Standard Operating Procedures
UV	Ultra Violet
WHO	World Health Organisation

Names of microorganisms

Name	Symbol	Name	Symbol
Bacillus cereus	*B. cereus*	*Salmonella* Typhimurium	*S.* Typhimurium
Campylobacter jejuni	*C. jejuni*	*Staphylococcus aureus*	*Staph. aureus*
Clostridium botulinum	*Cl. botulinum*	*Vibrio cholera*	*V. cholera*
Clostridium perfringens	*Cl. perfringens*	*Vibrio parahaemolyticus*	*V. parahaemolyticus*
Escherichia coli	*E. coli*	*Vibrio vulnificus*	*V. vulnificus*
Listeria monocytogenes	*L. monocytogenes*	*Yersinia enterocolitica*	*Y. enterocolitica*

Symbols

Term/Unit	Symbol	Term/Unit	Symbol
Centimetre	cm	Milligram	mg
Colony Forming Unit	cfu	Millimetre	mm
Degrees Celsius	°C	Kilogram	kg
Metre	m	Per cent	%
Microgram	µg		

1. Introduction

The first risk assessment underpinning the NSW Food Authority's (Food Authority) Seafood Safety Scheme (the Scheme) was published in March 2009. Then a periodic review of the risk assessment was published in July 2012. The risk assessment was part of a comprehensive review of food safety schemes undertaken during the remake of Food Regulation 2004. At the completion of this process a simplified and refined Food Regulation 2010 was made, which was replaced with the latest version of Food Regulation 2015 on 30 October 2015. The regulation provides the regulatory framework for continuation of the Scheme.

Seafood products are highly perishable and likely to carry health risks if harvesting, production and processing conditions are not well managed. General food safety principles also contribute to higher quality and longer shelf life of seafood products. Several food safety systems and practices are available to ensure the safety and maximise the product quality of seafood.

Best Management Practices (BMPs): It is important for commercial fishing vessels and aquaculture farms to follow BMPs during harvest, handling/processing, storage, and shipping.

Food Safety Plan (FSP): Development and implementation of a FSP is required to slow-down or eliminate microbial activity and to retard quality-degrading chemical reactions after harvest and during processing. A FSP can be based on Hazard Analysis and Critical Control Point (HACCP) principles or a similar food safety system. HACCP is a food safety management system for food manufacturers, processors and suppliers. This system is universally accepted and designed to prevent, eliminate or reduce (to an acceptable level) the potential food safety hazards that may be present in food products including seafood.

Pre-requisite Programs (PRPs): Several support programs such as Good Manufacturing Practices (GMPs), Good Hygiene Practices (GHPs), Sanitation Standard Operating Procedures (SSOPs), Pest Control Program (PCP), water control, traceability systems and recall procedures are needed and play a vital role for effective and efficient functioning of the FSP.

Regulations and monitoring: Seafood safety is regulated through the *Food Act 2003* (NSW) and Food Regulation 2015. Management and monitoring of the seafood safety is done through the Food Authority's Seafood Safety Risk Assessment Scheme, NSW Shellfish Program and NSW Marine Biotoxin Management Plan (MBMP).

Seafood can be contaminated and carry potential food safety hazards. Several different types of spoilage and pathogenic microorganisms are found on all surfaces of seafood, particularly in the intestines of the fishery products. Spoilage bacteria are generally harmless. However, uncontrolled growth leads to poor product quality due to changes in the colour, flavour, odour, texture, and short shelf life. On the other hand, the presence of pathogenic bacteria is a threat to consumer's health as these bacteria can produce toxins or cause infections. Therefore, controlling both types of microorganisms (spoilage and pathogenic) is important for good quality and safe seafood products. However, it requires science-based and sound understanding, diligence and attention to detail.

Natural toxins and environmental contaminants are also concerns for seafood safety. Scombroid toxin is an example of a natural toxin. Growth of histidine decarboxylase-producing bacteria in the contaminated fish could lead to production of high levels of histamine. Post-catch temperature abuse is an important factor. However, it is possible for histamine to be formed before the fish is landed and chilled. Industrial chemicals, pesticides and many toxic elements and metals are major environmental pollutants that could pose food safety risks.

Storage (both refrigerated and frozen), over an extended period in particular, can bring chemical/enzymatic changes in seafood that cause reduction in shelf life and quality deterioration. For example, fish species contain many long-chain omega-3 fatty acids, which are good for cardiovascular health. Long-chain, fatty acids are also much more susceptible to oxidation and hydrolysis. Good care is required to maintain nutritional value and avoid undesirable changes, i.e. quick cooling/quick freezing and stable low storage temperatures will slow down the deleterious changes in texture, colour and flavour due to chemical/biochemical activity. It is recommended that producers pay attention to the three Ps – product characteristics, processing methods and package types – as these can have a profound effect on the quality and shelf life of chilled and frozen seafood products.

This document includes the updated seafood risk assessment and covers significant scientific developments on seafood safety for the Scheme in NSW since the release of 2009 assessment and periodic review in 2012.

2. Seafood

Seafood generally refers to fish, shellfish, crustaceans and other marine life (some examples are given in Figure 1 and classification in Table 1). Seafood definitions adopted by Food Standard Australia New Zealand (FSANZ) and the Food Authority are given below.

According to Standard 4.2.1 in the FSANZ Code (the Code), seafood refers to all aquatic vertebrates and aquatic invertebrates intended for human consumption, but exclude amphibians, mammals, reptiles, and aquatic plants.

According to clause 133 of Food Regulation 2015, the definition of seafood includes aquatic vertebrates and aquatic invertebrates, and any product of, or anything containing a product of, aquatic vertebrates and aquatic invertebrates, intended for human consumption. However, it excludes amphibians, mammals or reptiles, and aquatic plants, and any product of, or anything containing a product of, an amphibian, mammal or reptile, or an aquatic plant.

Seafood, being a source of high-quality protein and other essential nutrients like omega-3 fatty acids, is an important part of a healthy diet. Seafood is also low in saturated fat content. Dietary recommendations suggest that fish or shellfish should be an essential part of well-balanced diets due to the many nutritional and health benefits (Table 2). A variety of fish and shellfish can contribute to a healthy heart and a child's growth and development. The Food Authority encourages pregnant or breastfeeding women to eat enough fish (NSW Food Authority, 2016). Pregnant, breastfeeding women and women planning pregnancy should eat two to three serves (150 g per serve) of low mercury fish (http://www.foodauthority.nsw.gov.au/foodsafetyandyou/life-events-and-food/pregnancy/mercury-and-fish).

However, careful consideration should be given to the food safety risks associated with seafood consumption. RTE chilled seafood, such as raw sushi, sashimi, oysters, pre-cooked prawns and smoked salmon, can be dangerous for pregnant women due to the risk of listeriosis. Mercury in fish can harm a child's developing nervous system, Therefore, pregnant or breastfeeding women are advised to avoid, or reduce, the consumption of some fish species, such as catfish, deep sea perch, shark (flake) or billfish (swordfish, marlin). The Food Authority website says all fish contain some methylmercury, but most fish in Australian waters have very low mercury levels (NSW Food Authority, 2016)

 **Freshwater finfish – lake trout**	 **Saltwater finfish – mackerel**
 **Shellfish – mussels**	 **Cephalopods – squid**

Figure 1. Examples of common seafood products

Table 1. Classification of seafood

Major category	Sub-category	Examples
Freshwater fish	Finfish	catfish, lake trout, perch, crappie
Saltwater fish	Round finfish	mackerel, salmon, snapper, weakfish, whiting, haddock, tuna, mahi mahi, whitefish
	Flat finfish	sole, flounder, diamond turbot, halibut, sanddabs
	Cartilaginous finfish	shark, grey smooth hound
Shellfish	Univalve molluscs	conch, abalone, whelks
	Bivalve molluscs	clams, oysters, mussels, scallop
Crustaceans		crayfish, crawfish, shrimp, lobster, prawns, snow crab, Dungeness crab, blue crab
Others	Cephalopods	squid, octopus, cuttlefish, Humboldt squid
	Gastropods	snails, limpets, slugs

Table 2. Benefits of seafood in diet (CESSH, 2009)

Benefit/nutrient	Description
Health benefits	
Asthma	Children who eat fish may be less likely to develop asthma
Cardiovascular disease	Consuming recommended serves of fish per week has been shown to reduce the risk of heart disease and stroke by reducing blood clots and inflammation, improving blood vessel elasticity, lowering blood pressure, lowering blood fats and boosting “good” cholesterol
Dementia	Elderly people who consume fish regularly have a lower risk of developing dementia, including Alzheimer's disease
Diabetes	Consumption of fish may help to manage blood sugar levels in diabetes patients
Inflammatory conditions	Increased consumption of fish may help to reduce the inflammatory condition and relieve the symptoms of rheumatoid arthritis, psoriasis and autoimmune disease
Prematurity	Fish and seafood consumption during pregnancy may reduce the risk of delivering a premature baby
Nutritional elements	
Omega-3 fatty acids (DHA and EPA)	Fish is a good source of omega-3 fatty acids which maintain our hearts, brain tissue and retinas
Vitamin D	Saltwater fish is a sunless source of vitamin D
Vitamin B	Fish and seafood are source of vitamin B12 (cobalamin) that is needed for good neurological function and blood formation
Minerals	Zinc, copper, iodine, calcium and other minerals have functionalities in physiological and metabolic processes
Selenium	Selenium protects against mercury toxicity

2.1 Seafood as a global industry

According to Food and Agriculture Organisation (FAO), world fish production is important for sustainable food supply, global food security and food trade (FAO, 2014). In 2011, per capita, food fish supply was recorded as the highest on record at 18.8 kg (live weight equivalent [LWE]) from two sources – wild catch and aquaculture. A modest increase of 17.95% in total world fish production, from 128 million tonnes in 2002 to 156 million tonnes in 2011, was achieved during a 10-year period (Table 3). Fish production from wild catch remained stable around 90 million tonnes, whereas global aquaculture production reached 64 million tonnes in 2011 compared to 37 million tonnes in 2002. At the same time, the demand for fish and fishery products has continued to rise, as total consumption has more than doubled since 1973. A robust growth in aquaculture production, 42% increase from 2002 to 2011, has helped to meet the increasing global demand. In 2014, total fish production and per capita consumption were 164.3 million tonnes and 20 kg, respectively (FAO, 2015).

Table 3. World fisheries and aquaculture production and utilization, 2002-2011

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Million tonnes									
PRODUCTION										
Inland										
Capture	8.4	8.6	8.7	9.4	9.8	10.1	10.2	10.4	11.2	11.1
Aquaculture	23.3	24.9	27.2	29.1	31.3	33.4	36.0	38.1	40.9	43.9
Total inland	31.7	33.5	35.9	38.5	41.1	43.4	46.2	48.5	52.1	55.0
Marine										
Capture	82.6	79.7	84.1	83.1	80.4	80.7	79.9	79.6	77.7	82.4
Aquaculture	13.5	14.0	14.7	15.2	16.0	16.6	16.9	17.6	18.1	18.8
Total marine	96.2	93.7	98.8	98.2	96.4	97.3	96.8	97.2	95.9	101.2
TOTAL CAPTURE	*91.0*	*88.3*	*92.7*	*92.5*	*90.2*	*90.7*	*90.1*	*90.0*	*89.0*	*93.5*
TOTAL AQUACULTURE	*36.8*	*38.9*	*41.9*	*44.3*	*47.3*	*49.9*	*52.9*	*55.7*	*59.0*	*62.7*
TOTAL WORLD FISHERIES	*127.8*	*127.2*	*134.6*	*136.8*	*137.5*	*140.7*	*143.0*	*145.7*	*148.0*	*156.2*
UTILIZATION										
Human consumption	100.5	103.6	106.7	109.8	114.5	117.7	120.1	124.0	127.8	131.8
Non-food uses	27.3	23.6	27.9	27.0	23.0	23.0	22.9	21.8	20.2	24.3
Population (billions)	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8	6.9	7.0
Per capita food fish supply (kg)	16.0	16.3	16.6	16.9	17.4	17.7	17.8	18.2	18.5	18.9

Note: Fishery production data presented in the above table exclude the production for marine mammals, crocodiles, corals, sponges, shells and aquatic plants.
Source: FAO Fisheries and Aquaculture Statistics and Information Branch (2013).

adapted from FAO (2014)

Data presented in the FAO (2014) report showed a tremendous increase in total world trade of fish and fishery products during the last three decades, from US$8 billion in 1976 to US$126 billion in 2011 (Figure 2). It is also reported that current world seafood trade has a diverse range of products and many participants. For instance, 194 countries were exporters of fish and fishery products in 2006, including 97 net exporters throughout the world. A net exporter is a country or territory whose value of exported fish products was higher than its value of imported fish products in 2006. Overall, an average of 5% annual increase in the export value was recorded globally in the period 1996-2008. However, there was a decline in export value globally in 2009 that rebounded in 2010-2011. According to more recent data, the total world seafood trade reached a record US$143.9 billion in 2014 and was forecast to grow modestly to US$144.5 billion in 2015 (FAO, 2015).

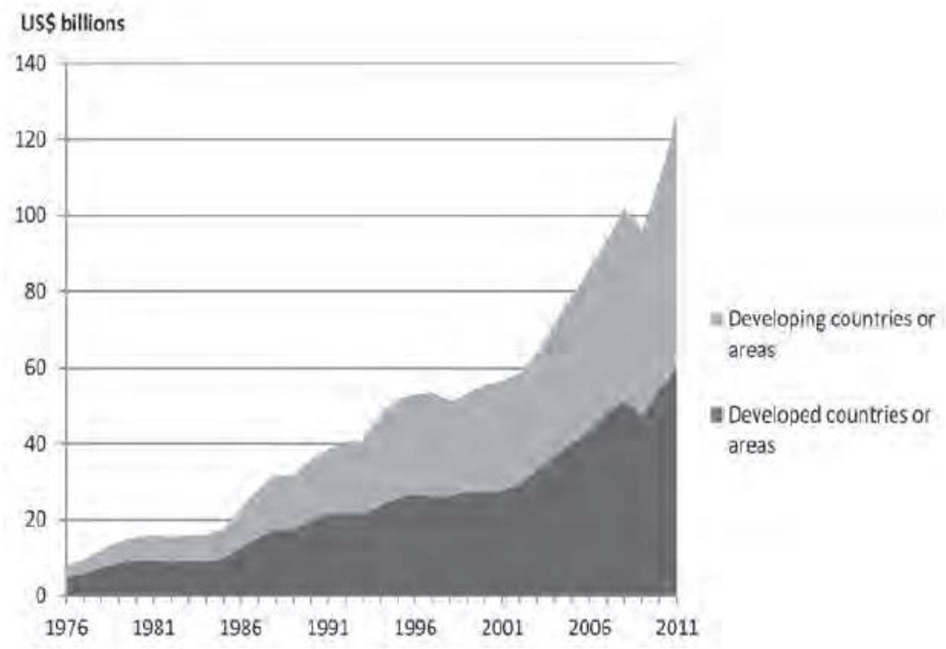

Figure 2. Fish export by value from 1976 to 2011 (Source: FAO, 2014)

Note: Fishery production data presented in the above figure excludes marine mammals, crocodiles, corals, sponges, shells and aquatic plants.

The FAO (2014) report also pointed out that developing countries have become the major players in the international fish trade. Figure 2 shows that export values between developed and developing countries have remained fairly equal over the years. According to 2006 fish and fish products export data, the developing countries had a share of 49% (US$42.6 billion) in value and 59% (31.6 million tonnes LWE) in volume. In 2014, China, Norway, India, USA and Vietnam were the five major exporters of fish and fishery products while USA, Japan, China, Spain and France were the top five importers (Table 4). In terms of fish products value, shrimp (prawn) are the most important commodity traded and account for 15% of the total value of international trade in 2009. Salmon and trout had a share of 14% each in the same year. Most recent seafood international import and export data (2014) is given in Table 4.

Table 4. International seafood imports and exports in 2014 (top five countries in each category).

Export		**Import**	
	Value ($ billion)		Value ($ billion)
World	112.1	World	111.2
China	14.1	USA	16.7
Norway	10.8	Japan	11.4
India	5.4	China	6.6
USA	5.3	Spain	5.9
Vietnam	5.0	France	5.1

Source: http://www.worldsrichestcountries.com/top-fish-exporters.html

2.2 Australian seafood industry

Seafood consumption is increasing each year in Australia. Current per capita seafood consumption is over 15 kg, which has increased from 13 kg in 2000. Fisheries are Australia's fifth most valuable food industry after meat, grains and oilseeds, fruit and vegetables, and milk.

Australian seafood industry has two major components – wild capture and aquaculture. In terms of seafood production, Australia ranks 46th with total production (wild catch and aquaculture) of 241,123 tonnes in 2009-2010. Figure 3 was adapted from The Fisheries Research and Development Corporation (FRDC) website to show Australia's share in global fish production. Australia ranks 60th in the world's commercial catch and it makes 0.2% of the world's total tonnage of 90 million. Australia has the world's third largest Exclusive Economic Zone[1]. However, the comparatively low catch is due to low levels of nutrients found in Australian ocean waters. Australian waters are less productive than other countries and do not support the high tonnage of finfish. In comparison, the annual Alaskan Pollock catch is 1.5 million tonnes, which is 8.5 times of Australia's entire wild catch production (174,000 tonnes).

Total seafood production in Australia remained relatively unchanged (average 230,000 tonnes per annum) over the last 20 years. Interestingly, the proportion of wild catch volume reduced by almost 20% and the volume of aquaculture production has increased by almost 20% over the past two decades.

Total estimated Australian consumption of seafood products was around 345,000 tonnes in 2012-2013 (Stephan and Hobsbawn 2014). Only one-third of seafood demand is met from domestic sources. Imported seafood products account for 66% of domestic consumption (Stephan and Hobsbawn 2014). Australia imports lower value seafood products such as frozen fillets, frozen prawns and canned fish from Thailand, New Zealand and China. On the other hand, Australia exports high value products such as rock lobster, abalone and tuna to Japan, Hong Kong and the USA.

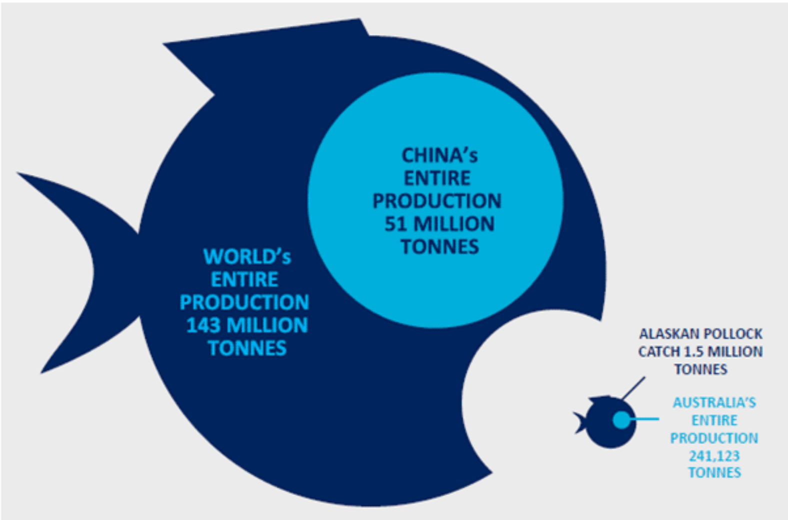

Figure 3. Graphical presentation of Australia's fisheries volume in the world (Source: FRDC website http://frdc.com.au/knowledge/q_and_as/Pages/size-of-Australian-seafood-industry-compare.aspx)

[1] An Exclusive Economic Zone (EEZ) is a sea zone prescribed by the United Nations Convention on the Law of the Sea over which a state has special rights regarding the exploration and use of marine resources, including energy production from water and wind ("Part V - Exclusive Economic Zone, Article 56". Law of the Sea. United Nations. Retrieved 25 May 2016).

The Australian Government takes food safety very seriously and applies strict regulations for domestic and imported seafood products. The Department of Agriculture and Water Resources inspects imported food (including seafood) to ensure Australian requirements are met for public health and safety. Compliance with Australian food standards is required as detailed in the Code (see section 4). Table 5 lists major food safety issues found in domestic and imported seafood products.

Table 5. Food safety issues with seafood products in Australia

	Biological	Chemical
Domestic products[1]	Norovirus	Ciguatera
	Salmonella spp.	Histamine
	Hepatitis A	Algal biotoxins
Imported products[2]	*L. monocytogenes*	Histamine
	Vibrio spp.	Malachite green
	E. coli	Ciprofloxacin/Norfloxacin

[1] Based on foodborne outbreaks data (see tables 10 and 30)
[2] Based on imported seafood failing data (see table 18)

The NSW fishing and aquaculture industry offers diverse and high quality seafood to consumers. Finfish, prawns, lobster, oysters and crabs are popular species in NSW. Wild catch and aquaculture are the major fish supply chains for domestic products. Recreational fishing has no commercial contribution in NSW and, therefore, not covered in the Scheme. However, it must be noted that recreational fishing has made a significant contribution to the NSW economy in terms of tourism. Table 6 summarises key features of the NSW seafood industry.

Table 6. Key features of NSW seafood industry

	Total	Wild catch	Aquaculture
Production (tonnes)	15783 (2012-13)	11597 (73.48%)	4186 (26.52%)
Value ($)	123.7 million (2012-13)	76.2 million (61.58%)	47.5 million (38.42%)
Key species	Finfish Prawns Crabs Lobsters Oysters	Finfish: snapper, yellowfin bream, flathead, sea mullet, ocean jacket, yellowtail kingfish, blue-eye trevalla Prawns: Eastern king prawns, school prawn, black tiger prawns Crabs: Spanner crab, blue swimmer crab, mud crab Lobster: Eastern rock lobster	Finfish: silver perch, snapper, yellowtail kingfish, mulloway, rainbow trout, barramundi Prawns: tiger prawns Oysters: Sydney rock oysters, pacific oysters, native oysters

2.3 Food safety and seafood

In recent years, seafood has received a lot of attention to help industry and consumers understanding the possible food hazards, and improve its food safety status. Table 7 lists some recent documents developed on seafood safety by various national and international agencies.

Table 7. Recent technical publications on seafood safety by different agencies

Year	Title	Publishing agency/reference
2015	Environmental contaminants of emerging concern in seafood - European database on contaminant levels	Vandermeersch et al. 2015
2014	Assessment and management of seafood safety and quality (Current practices and emerging issues)	FAO (Fisheries and Aquaculture Technical Paper – ISSN 2070-7010)
2014	Seafood Industry Risk Assessment	MWH Australia Pty Ltd (MWH), PrimeSafe and the Department of Environment and Primary Industry (DEPI) (Project No: 83501434)
2013	A Guide to the Identification of Food Safety Hazards and Determination of Shelf-life of Packaged Seafood	South Australian Research and Development Institute, SARDI Food Safety & Innovation
2013	Protocol for Seafood Risk Assessment to Support Fisheries Re-opening Decisions for Marine Oil Spills in California	Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (OEHHA 2013)
2012	Seafood safety scheme Periodic review of the risk assessment	NSW Food Authority (NSW/FA/CP064/1208)
2011	Food Safety Risks Associated with Prawns Consumed in Australia	SARDI Food Safety group (Seafood CRC Project: 2009/787)
2011	Fish and Fishery Products Hazards and Controls Guidance (Fourth Edition)	Center for Food Safety and Applied Nutrition, FDA, U.S. Department of Health and Human Services
2005	Primary Production & Processing Standard for Seafood	FSANZ 2005a (Proposal P265/02-05)
2001	SeaQual's Guide to Food Safety Risks in Seafood	Seafood Services Australia (PDF-PU006)

2.3.1 Major hazards associated with seafood consumption

Increase in global consumption of seafood has also highlighted interest in the risks associated with certain hazards that may be present in a seafood product. These are:

- Biological hazards
- Biotoxins
- Naturally occurring toxins
- Environmental pollutants
- Emerging hazards
- Unexpected/ Unconventional agents.

A general ranking of seafood safety hazards developed by Ashwell (1990) showed that microbial hazards are of most concern (Table 8).

Table 8. Ranking of seafood safety hazards

Ranking	Hazard	Relative risk
1	Microbial content	100,000
2	Pollutant chemicals	100
3	Natural toxins	100
4	Pesticide residue	1
5	Food additives	1

Adapted from Ashwell (1990)

2.3.1.1. Biological hazards

Seafood related illnesses may be caused by biological agents, most commonly pathogenic bacteria, viruses and parasites. Table 9 shows biological hazards associated with seafood and related products worldwide. The severity of a hazardous agent depends on the type, size, geographic source, age and diet of the fish or shellfish.

Bacterial pathogen contamination and growth are important causes of foodborne illnesses. Disease-causing bacteria may be naturally present in seafood, or enter seafood as environmental contaminants via cross-contamination by human or animal sources. *Bacillus cereus*, *Campylobacter jejuni*, *Clostridium botulinum*, *Cl. perfringens*, pathogenic *Escherichia coli*, *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., pathogenic *Staphylococcus aureus*, *Vibrio cholerae*, *V. parahaemolyticus*, *V. vulnificus* and *Yersinia enterocolitica* are common bacteria associated with seafood.

Viruses, especially Hepatitis A and Norovirus (previously known as Norwalk-like virus) Norwalk, are also commonly found in seafood. These viruses can come from seawater or enter via cross-contamination. Viruses have been shown to survive more than one year in marine sediment. Viruses survive better at low temperatures and it is the reason that most outbreaks of hepatitis occur during winter and early spring. Hepatitis A outbreaks generally have occurred due to the consumption of raw and steamed clams, oysters and mussels, whereas norovirus has been associated with eating clams (raw and steamed), oysters and cockles. Parasitic hazards associated with seafood are *Anisakis simplex*, *Pseudoterranova decipiens* and *Diphyllobothrium latum*.

Table 9. Common biological hazards associated with seafood worldwide

Biological hazard	Nature	Organism and characteristics
Pathogenic bacteria	Naturally present	*Vibrio* spp. (*V. parahaemolyticus*, *V. cholerae*, *V. vulnificus*) non-proteolytic *Cl. botulinum* type B, E and F *Plesiomonas shigelloides* *Aeromonas* spp.
	Environmental contaminant	*L. monocytogenes* proteolytic *Cl. botulinum* type A and B *Cl. perfringens* *Bacillus* spp.
	Human or animal origin	*Salmonella* spp. Shigella spp. *E. coli* *C. jejuni* *Staph. aureus*
Viruses	Human or animal origin: Seawater or cross-contamination	Hepatitis A Norovirus
Parasites	Animal origin	Anisakis simplex Pseudoterranova decipiens Diphyllobothrium latum

2.3.1.2. Biotoxins

Biotoxins (natural toxins) are produced by specific algae, which are part of the beginning of the marine food chain. Some molluscs, crustaceans and finfish are known to concentrate these biotoxins in their bodies during the feeding process. Also, known as marine biotoxins, they comprise many distinct compounds and produced by a species of naturally occurring marine algae. NSW has experienced several extensive potentially toxic cyanobacterial blooms in fresh water and developed a range of food safety interventions for the affected areas (see section 3.3.2.2.). Consumption of fish and fishery products contaminated with biotoxins pose a significant threat to human health. However, currently these are a managed risk in NSW. Common algal biotoxins include:

- Amnesic Shellfish Poisoning (ASP)
- Diarrhetic Shellfish Poisoning (DSP)
- Neurotoxic Shellfish Poisoning (NSP)
- Paralytic Shellfish Poisoning (PSP)
- Ciguatera Fish Poisoning (CFP)
- Gempylotoxin
- Tetrodotoxin.

2.3.1.3. Naturally occurring toxins

Scombroid toxin is described as a combination of histamine and histamine-like poisonous chemicals. Scombroid poisoning is a disease due to the ingestion of contaminated food, primarily fish. Production of scombroid toxin is associated with bacterial growth during incorrect temperature control of the dark meat of the fish. Heat treatment (cooking) kills the bacteria, although toxins are heat stable. It is important to note the enzyme histidine decarboxylase remains active at chill temperatures, even though the bacteria are killed. Once the enzyme has been formed at higher temperatures, the conversion of the histidine to histamine is possible even at low temperature. Therefore, proper temperature control right from post-catch is important to minimise toxin production. Even properly cooked contaminated fish will have toxins in the tissues and can cause disease if ingested. Histamine hazards have the following characteristics:

- a metallic or peppery taste in the contaminated fish
- the toxin does not affect everyone
- there is no analytical method that gives 100% reliable results for assessing fish for this toxin or poison.

Fish or fishery products known to cause scombroid poisoning include albacore, amberjack, anchovy, Australian salmon, bluefish, bonito, kahawai, herring, mackerel, mahi mahi, needlefish, saury, sardine, skipjack, wahoo, and yellowfin tuna.

2.3.1.4. Environmental pollutants

Seafood is produced and harvested from water resources (lakes, rivers, estuaries, ponds, farms and oceans) that are exposed to varying amounts of a range of natural chemicals and environmental contaminants such as industrial chemicals, pesticides and many toxic elements and metals. Fish generally accumulate some of these pollutants (mainly mercury) at levels that can cause public health problems. Of the greatest concern are fish harvested from fresh water, estuaries, and near-shore waters rather than from the open ocean.

Nearly all fish and shellfish contain traces of mercury. For most people, the risk from mercury by eating fish and shellfish is not a health concern. However, some fish and shellfish contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. Therefore, the Food Authority advises pregnant and breastfeeding women, women planning a pregnancy, and children up to 6 years to eat fish and shellfish that are lower in mercury (NSW Food Authority, 2016). Further information on mercury poisoning is available in section 3.4.2).

2.3.1.5. Emerging hazards

Vandermeersch et al. (2015) recently reviewed a selection of contaminants that are considered as emerging concerns (hazards) in seafood. Some of them are:

- Organic pollutants that are known to act as endocrine disruptors, i.e. bisphenols, alkyphenols, estrogen and perfluorinated compounds.
- Brominated flame retardants that lack clarity on toxicokinetics and toxicodynamics, i.e. polybrominated diphenyl ethers (PBDEs), polybrominated biphenyls (PBBs), hexabromocyclododecanes (HBCD), exabromobenzene (HBB), TBBPA and other phenols, as tribromophenol (TBP), decabromodiphenyl ethane (DBDPE) and 1,2-Bis(2,4,6-tribromophenoxy) ethane (BTBPE).

- Polycyclic aromatic hydrocarbons (PAHs) and derivatives. Personal care products such as disinfectants, fragrances, insect repellents, preservatives and UV filters.

Other emerging hazards in aquaculture and fish processing include the following:

- Animal drugs (veterinary medicine) used in aquaculture for different reasons, i.e. to treat or prevent disease, to control parasites, to affect reproduction, and to tranquilize.
- Illegal residues of drugs that occur in aquaculture species due to ill-practices in the industry, i.e. use of unapproved drugs, use of drugs not in accordance with the approved labelling directions, failure to follow approved withdrawal times, and use of general purpose chemicals not labelled.
- Pesticides and herbicides used near aquaculture operations may enter into food supply chain as a hazard.
- Food and colour additives (sulfiting agents and FD&C Yellow #5) that are used on fish and fishery products. These additives can cause an allergic-type reaction (food intolerance) in consumers.
- Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are man-made chemicals that have been widely used in industrial and consumer products since the mid-1900s. There is no consistent evidence of any human health effects related to PFAS exposure but these chemicals take a long time to break down in humans and the environment.

2.3.1.6. Unexpected/unconventional contaminants

Microplastics: Plastic particles smaller than 5 mm are considered as microplastics and can enter the environment from both primary sources (industrial abrasives, exfoliants and cosmetics) and secondary sources (degradation of larger plastic material). These plastic particles are ubiquitous in various environmental compartments. i.e. the water column, sediment and biota (Vandermeersch et al. 2015).

Glass pieces: Glass fragments (7-25 mm) are a type of physical hazards and can cause injury to the consumer. Processed seafood has a higher risk of glass inclusion through handling and packaging, especially the products packed in glass containers.

Metal pieces: Some mechanical operations can introduce metal fragments into seafood products. Parts of equipment used for cutting and blending can accidentally break off and fall into the product, such as wire-mesh belts. These fragments serve as a physical hazard to the consumer and can be controlled using metal detectors and regular inspection and maintenance of at-risk equipment.

2.3.2 Seafood outbreaks and illnesses in Australia

2.3.2.1 Outbreaks

OzFoodNet annual reports for 2002-2006 tabulated 85 foodborne illness outbreaks linked to seafood, with 558 people affected and 77 hospitalisations (data not shown). Table 10 includes a summary of Australian foodborne illness outbreaks attributed to fish and seafood products from 1995 to 2008. An updated overview of NSW outbreaks from 2005 to 2015 is provided in Table 30.

Table 10. Summary of Australian foodborne outbreaks attributed to seafood 1995-2008

Hazard	Australian outbreaks (1995-2008)	Cases	Hospitalisations	Deaths
Ciguatoxin	85	449	83	0
Scombroid	32	126	17	0
Norovirus	9	303	1	0
Salmonella spp.	9	64	29	0
Wax ester	6	72	0	0
Hepatitis A	5	517	64	1
Vibrio spp.	3	15	3	0
B. cereus	2	41	0	0
Cl. perfringens	2	58	1	0
DSP	2	115	0	0
Toxin	2	11	0	0
Unknown	23	208	9	0
Total	180	1979	207	0

Several large food poisoning outbreaks related to consumption of oysters occurred in NSW:

- In the mid-1980s there was a series of outbreaks of Norwalk virus from oysters harvested from the Georges River. The largest outbreak affected over 2000 people.
- In 1997, an outbreak of Hepatitis A virus (HAV) from Wallis Lake oysters affected 467 people with one death.

It is estimated the cost to the industry from the Wallis Lake outbreak was around $30 million and was the catalyst for the introduction of the NSW Shellfish Quality Assurance Program, the forerunner to the current NSW Shellfish Program operated by the Food Authority. Prior to 1997, there was some voluntary monitoring by shellfish farmers but no consistent testing of water quality in harvest areas. The implementation of harvest area management plans has helped minimise the risk from shellfish (Food Science Australia and Minter Ellison Consulting, 2002).

The National Risk Validation Project highlighted raw, ready-to-eat seafood (including shellfish) as one of five high risk foods (Food Science Australia and Minter Ellison Consulting, 2002). FSANZ (2005) reports that 3 outbreaks (with 102 people affected) of shellfish poisoning occurred in Australia in 1990-2000. Mussels with levels of PSP toxin exceeding regulatory limits were detected in Victoria in 1988 and every year between 1990 and 1995. PSP toxins exceeding regulatory limits have been reported in Tasmanian mussels, oysters and scallops. Outbreaks of DSP were caused by NSW pipis in 1997 and 1998. There has been a detection of ASP toxin (domoic acid) above regulatory limits in scallop viscera from Victoria.

Since the commencement of routine biotoxin testing in 2004, there have been two occasions when algal biotoxins have exceeded regulatory limits in classified NSW aquaculture areas. In 2010, Amnesic Shellfish Toxins (ASTs) were detected in *Saccostrea glomerata* (Sydney rock oyster) in Wagonga Inlet at 60% above the regulatory limit (20 mg/Kg domoic acid). In 2016, Paralytic Shellfish Toxins (PSTs) were detected (max: 7.2 mg/Kg saxitoxin equivalent, regulatory limit: 0.8 mg/Kg saxitoxin equivalent) in *Mytilus galloprovincialis* (blue mussels) in Twofold Bay. No illnesses were associated with either event and mandatory closures were implemented for the affected harvest areas until toxin levels had dropped to below regulatory limits.

Ross and Sanderson (2000) prepared detailed risk assessments on 10 hazard/product pairs. Current national and international data suggests that their selections remain appropriate.

The periodic review of the NSW seafood risk assessment scheme (2012) identified several issues relating to seafood safety. For the years 2009 and 2010, OzFoodNet reported the following outbreaks attributed to seafood:

- Ciguatera, 10 outbreaks, all from Queensland.
- Scombroid poisoning, four outbreaks (ACT, NSW, Qld, Vic) and one suspected outbreak (NSW).
- Escolar/rudderfish keriorrhoea, two incidents (ACT, Vic).
- Salmonellosis, one outbreak, (multi-state) possibly linked to barramundi.

The medical literature includes two reports of parasitic infection from Australian fish:

- An incident (2 cases) of nematode infection following the consumption of fresh water fish from remote northern Western Australia (Jeremiah et al, 2011).
- A woman of Tongan descent developed anisakidosis after eating raw, locally caught South Australian mackerel. (Shamsi and Butcher, 2011).

Further reports and data of the latest national outbreaks are available at OzFoodNet website. An update on recent foodborne outbreaks occurred in NSW is given in section 3.4.1 and table 30.

2.3.2.2 Foodborne illness

Ciguatera poisoning heads the OzFoodNet 2009-2011 list of foodborne illness incidents attributed to seafood. All reported outbreaks were in Queensland which reflects the consumption of large reef fish from tropical areas consistent with the known aetiology. Outbreaks were attributed to a mix of commercially caught and recreationally caught fish, including one fish that was caught by a recreational fisherman but then sold through a market. OzFoodNet last reported a ciguatera outbreak in NSW in 2002. Investigations into suspected ciguatera poisoning outbreaks in NSW by the Food Authority in 2005 and 2009 were linked to fish originating from Fiji and Queensland, respectively (NSW Food Authority, unpublished data). Since 2014, 24 individuals have been affected by 5 outbreaks relating to Spanish mackerel (Harmful Algal News, 2016). Sydney Fish Market (SFM) has imposed guidelines to restrict fish potentially contaminated with ciguatoxin from being sold at the wholesale auction. The restrictions include rejection of potentially contaminated fish from prohibited supply regions and the introduction of maximum size limits for some tropical reef fish. Since implementing these guidelines in 2005, there have been no known cases of ciguatera poisoning from fish sold through SFM (Sydney Fish Market, 2005; 2012). The marketing restrictions mean that ciguatera risk in NSW is better managed now than when Ross and Sanderson (2000) completed their assessment.

Scombroid poisoning is second on OzFoodNet's seafood list for the same period. NSW had one reported outbreak and one suspected outbreak in the period and there were six reports for the period 2001-2008. With up to eight outbreaks over a ten-year period, it is considered that the hazard is well managed. This is attributed to the use of an effective cold chain that uses ice and refrigeration to preserve both quality and safety. Guidance on control of histamine in seafood is available on the Food Authority website (NSWFA, 2011a).

Escolar/rudderfish keriorrhoea is third on the list. OzFoodNet last reported a keriorrhoea incident in NSW in 2001 but there have been occasional anecdotal reports of keriorrhoea in the intervening period. Guidance regarding the sale and labelling of escolar is available on the Food Authority website (NSWFA, 2011b).

An outbreak of salmonellosis associated with barramundi was also reported in the period. A variety of foods and meals were associated with illness, with barramundi having the highest relative risk (RR= 3.8, 95% CI 1.0-14.2) but the cause of illness was not definitively identified (OzFoodNet, 2010). Five reports of *Salmonella* associated with seafood appear in OzFoodNet reports from 2001 to 2010 with two of the reports having 'suspected' status.

A husband and wife were infected with *Gnathostoma*, a nematode parasite, after eating a fresh water fish in remote northern Western Australia. The fish had been pan-fried whole over a camp fire, but the duration and thoroughness of cooking is unclear. Gnathostomiasis is a foodborne zoonosis resulting from ingestion of larvae. The larvae are unable to mature further in humans and they migrate through visceral and cutaneous tissues. Patients can develop fever, anorexia, abdominal discomfort, nausea and vomiting. The disease may show up in the skin (with red, pus-filled or painful swellings) or the viscera (which may involve almost any part of the body including lungs, eyes or central nervous system) depending on the larval migration pattern. These are the first confirmed human cases of gnathostomiasis acquired in Australia, although there have been cases in other mammals (Jeremiah et al. 2011).

A woman of Tongan descent developed anisakidosis after eating raw, locally caught South Australian mackerel. Upon detailed microscopic examination, the anisakid nematode, *Contracaecum,* was identified. Anisakidosis can result in severe gastrointestinal disorders, allergic reaction and even death. The allergic response can occur against live anisakids or food in which worms were killed by cooking or pasteurisation (Shamsi and Butcher, 2011).

Further data on national foodborne illnesses can be found on the OzFoodNet website.

3. Risk assessment of seafood

3.1 Hazard identification

The food safety hazards of seafood have been extensively studied. The former SafeFood Production NSW (predecessor organisation of the Food Authority) commissioned several studies in preparation for the introduction of the Food Production (seafood safety scheme regulation) 2001. Subsequent studies have been undertaken by NSW, South Australian and Australian governments, and by international agencies. Walsh and Grant (1999) identified hazards as shown in Table 11.

Table 11. Hazards in seafood and seafood products

Priority	Sector	Hazard
High	Wild catch finfish	Histamine/Scombroid ☑
		Ciguatera ☑
		Mercury ☑
	Bivalve molluscs	Pathogenic bacteria ☑
		Viruses ☑
		Algal toxins: Paralytic shellfish poisoning (PSP), Diarrhoetic shellfish poisoning (DSP), Amnesic shellfish poisoning (ASP), Neurotoxic shellfish poisoning (NSP) ☑
	Cold smoked fish RTE	*L. monocytogenes* ☑
	Hot smoked fish RTE	*L. monocytogenes* ☑
	Smoked fish vacuum packed or modified atmosphere packaged (MAP)	*Cl. botulinum* ☑
Medium High	Bivalve molluscs	*Vibrio* spp.
Medium	Wild catch finfish (raw)	Parasites ☑
	Bivalve molluscs	Agrichemicals
	Aquaculture crustaceans	*Vibrio* spp. ☑
	Raw fish – vacuum packaged or MAP	*Cl. botulinum*
	Surimi RTE	*L. monocytogenes*
	Cooked whole prawns	Post-cooking contamination by pathogenic bacteria
	Cooked peeled prawns or crabmeat	*L. monocytogenes*, *Staph. aureus*, general pathogens
	Salted seafood	*Staph. aureus*

adapted from Walsh and Grant (1999)

☑ Those marked were subsequently evaluated by Ross and Sanderson (2000).

Ross and Sanderson (2000) prepared a risk assessment of selected seafood in NSW. The seafood selected for their study was extracted from the lists developed by Walsh and Grant (1999). The report noted that the incidence of foodborne illness due to most hazards was low, but recognised that oysters and other shellfish have repeatedly been involved in outbreaks. Ciguatera and scombroid poisonings are also relatively common and generally less severe in their outcomes (Ross and Sanderson, 2000). However, chronic cases of ciguatera poisoning may cause severe health problems, commonly hypersomnolence (chronic fatigue syndrome) and rarely peripheral neuropathy and polymyositis (Pearn, 2001).

Ross, Walsh and Lewis (2002) studied the food safety risks associated with cold smoking and marination processes used by Australian businesses. This report identified and ranked hazards with *L. monocytogenes*, *Cl. botulinum*, scombroid and parasites as most significant.

Sumner (2002) undertook a risk profile on seafood and aquaculture products in South Australia and, based on outbreak data and recalls, reported ciguatera, scombroid, viruses, bacterial pathogens and algal toxins as the hazards of concern.

Huss, Ababouch and Gram (2004) considered the management of seafood safety and quality from an international viewpoint. The risks they identified were based on cases of foodborne illness traced to seafood and rejections of seafood imports (Table 12).

During development of Standard 4.2.1 – *Primary Production and Processing Standard for Seafood, A Risk Ranking of Seafood in Australia* was prepared (FSANZ, 2005) to underpin the Standard. The report identifies hazards along the seafood supply chain and includes details on imported food testing failures and epidemiological data. The identified hazards were consistent with those mentioned in other risk assessment work.

Detailed information on the nature of the hazards associated with wild catch, aquaculture and imported seafood is included in the sections to follow.

Table 12. Summary of international hazard identification studies for seafood

Data analysed	Hazard
USA, fish, foodborne illness	Scombroid
	Ciguatera
	Cl. botulinum
	Bacterial pathogens
	Norovirus
	Poisonous fish (puffer fish)
	Chemical contaminants
USA, molluscan shellfish, foodborne illness	*Vibrio* spp.
	Norovirus
	Algal toxin
	Bacterial pathogens
	Scombroid
	Ciguatera
	Parasite
UK, seafood, foodborne illness	Scombroid
	Algal toxin
	Virus
	Bacterial pathogens
	Unknown
USA, seafood, import refusals	Bacterial pathogens
	Scombroid
	Poison
	Other
EU, seafood, import rejection/detention	*Vibrio* spp.
	Bacterial pathogens
	Hepatitis virus
	Algal toxins
	Pesticides
	Metal contaminants
	Antibiotics
	Other chemical contaminants
	Parasites

adapted from Huss, Ababouch and Gram (2004)

3.1.1 Commercial fishing (wild catch)

As a general principle, the risk of contamination of seafood products by chemical and biological agents is greater in freshwater, coastal ecosystems and aquaculture when compared to the open seas (wild catch). At the point of harvest, hazards potentially present in finfish include heavy metals (e.g. arsenic and mercury) and indigenous pathogens from the estuarine or marine environment which are naturally present in live fish.

3.1.1.1 Freshwater finfish hazards

Freshwater ecosystems are very vulnerable to environmental contamination and invasion by aquatic pests and weeds. NSW inland waterways are known to get blue-green algal blooms. Non-native fish have been accidentally or deliberately introduced into NSW waterways since European settlement and some native Australian fish have been taken out of their natural habitats for recreational fishing enhancement or aquaculture.

Freshwater finfish species are found in rivers and in freshwater lakes, ponds and dams. Trout and native fish such as Murray cod are present in inland waterways in NSW. In general, Australian freshwater reservoirs are clean and pose minimum risk as a source of hazards in harvested seafood. In commercial terms, freshwater fish represent a very minor segment (less than 0.5% of total commercial wild catch) of total fisheries products in NSW. Most freshwater fishing is for recreational purposes to relax and unwind. However, a small number of recreational fishers use their catch for food.

An interesting and comprehensive investigation by Rose et al. (2015) analysed a range of contaminants in freshwater fish from selected locations on the chosen waterways in UK. Fish species samples were analysed for the presence of heavy metals, chlorinated dioxins (PCDD/Fs), polybrominated biphenyls (PBBs), polychlorinated biphenyls (PCBs), brominated dioxins (PBDD/Fs), polychlorinated naphthalenes (PCNs), polybrominated diphenylethers (PBDEs), OC pesticides, organotin compounds and organo-fluorine compounds. Some samples exceeded regulatory limits for contaminants that apply to fish sold for human consumption. Potentially harmful chemicals found in the freshwater fish samples were polychlorinated biphenyls (PCBs), man-made organic chemicals whose manufacture in the UK was banned more than 30 years ago, and polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDF), both industrial by-products and environmental contaminants. This study showed the existence of hazards in freshwater fish and warned that regular consumption of coarse fish from unmanaged waterways, especially those in areas with an industrial history, could pose a higher risk to health.

Major hazards attributed to freshwater fish include pathogenic bacteria, environmental contaminants or chemical contaminants from human activity. Considering the low volume of wild catch freshwater finfish from NSW inland waters and consumption, it is not regarded as a food safety threat. However, it is still important to keep recreational fishers and the public aware of the health of inland waterways and emergence of any potential contamination issue.

3.1.1.2 Saltwater finfish hazards

Biological hazards: Several parasites may be associated with fish species harvested from certain locations. Parasites are important hazards that may cause an illness in humans after ingestion of raw or undercooked fish. *Cl. botulinum* (type E non-proteolytic strains), which causes botulism, is associated with the marine environment. As spores tend to be associated with the gut of the fish, evisceration will reduce the risk of exposure. Other strains may also be present in the processing environment. Cold smoked fish have many significant hazards. Processing temperatures are too low to ensure freedom from pathogens or parasites. *L. monocytogenes* contamination may occur post-harvest and during processing and prolonged storage may allow numbers to increase.

With sushi, the primary concern is related to product prepared in advance and stored without refrigeration. Hazards include *Vibrios*, other bacterial pathogens and viruses. Sashimi hazards of concern are parasites and *V. parahaemolyticus*.

Chemical hazards: Marine toxins such as ciguatoxin may be a significant hazard in tropical reef fish. Ciguatoxin is heat stable, and is not inactivated by normal cooking.

Histamine is a hazard in certain species of fish, particularly if the fish are harvested from warmer waters, die before landing or are subject to time/temperature abuse after landing. Histamine is heat stable.

3.1.1.3 Shellfish hazards

Shellfish possess unique ecological and physiological characteristics. Therefore, the nature of hazards associated with this kind of seafood is different from finfish. Major hazards associated with wild shellfish include *Vibrio* spp., Norovirus, algal toxins and biotoxins. A comprehensive risk assessment of phytoplankton and biotoxins in shellfish was recently completed by the Food Authority (NSW Food Authority, unpublished).

Bivalve molluscan shellfish are filter feeders, extracting marine algae, bacteria and nutrients from surrounding waters. Because of this they are prone to contamination from the growing environment. Some pathogenic bacteria, especially *Vibrio* spp. are endogenous to aquatic environments and can survive and grow in oysters, presenting a risk to health if ingested.

Bacterial pathogens may also be introduced into shellfish growing areas through pollution from sewage and animal waste. These organisms can multiply quickly, particularly at higher temperatures, potentially rendering oysters unsafe. Pathogenic viruses may be introduced into shellfish growing waters through sewage pollution and can survive for long periods in shellfish.

Oysters can bio-accumulate chemical contaminants from their growing waters. Certain species of toxin-producing algae present a food safety risk due to shellfish consumption. Toxins can accumulate to high levels in shellfish especially, particularly during an algal bloom.

Consumption of bivalves was frequently reported as the cause of PSP (Paralytic Shellfish Poisoning) cases worldwide. There have been no PSP cases recorded that were related to the consumption of univalves like abalone (*Haliotis* spp.). Results of Australian risk assessment of whole Australian abalone and abalone food products (canned, dried and frozen meat) for PSP, DSP (Diarrhetic Shellfish Poisoning) and ASP (Amnesic Shellfish Poisoning) classified the hazard risk extremely low to low (Webb and Turnbull, 2014).

3.1.1.4 Crustacean hazards

Prawns (wild catch) are also potentially exposed to a range of indigenous microbial contaminants from the water environment. *Vibrios* are known to utilise the chitinous exoskeleton of crustacean as points of attachment and to metabolise it as a carbon/energy source (Karunasagar et al. 1986). *V. parahaemolyticus*, *V. vulnificus* and *V. cholerae* are considered part of the indigenous microflora of estuarine prawns. Enteric pathogens derived from faecal contamination may become established as environmental contaminants in water from which prawns are harvested and have the potential to contaminate free-living prawns prior to catch.

During on-board processing, dipping of prawns in metabisulphite to inhibit formation of blackspot can present a risk to asthmatics. Prawns may also be exposed to chemical hazards from the environment, including the metals arsenic and mercury. Other chemical residues may be present in wild catch crustaceans due to industrial pollution and agricultural run-off. This was considered a greater risk in estuarine prawns than those caught in open marine waters (Ross and Sanderson, 2000).

Processing of prawns can lead to the potential for contamination with marine pathogenic bacteria, other pathogenic bacteria or chemical contaminants. Cooked prawns can be subject to cross-contamination between raw and cooked prawns.

3.1.1.5 Other seafood hazards

A few cases of PSP have resulted from the consumption of non-traditional vectors such as gastropods, which occurred in Malaysia, China and the USA. The victims of outbreaks associated with gastropod reportedly ate the following: sitka periwinkles (*Littorina sitkana*), northern moon snail (*Lunatia heros*), waved whelk (*Buccinum undatum*), spider conch (*Lambis lambis*), olive (*Oliva vidua fulminans*), tekuyong (*Natica* spp.) and nassa (*Nassarium* spp.) (Deeds et al. 2008; Shumway 1995).

Overall, the risk associated with cephalopods and gastropods is low or very low due to the very small amount consumed and cooking prior to serving. Moreover, information on risk assessment of these types of seafood in NSW is scarce.

3.1.2 Aquaculture

Aquaculture is a growing source of fish and seafood and has a different profile of hazards that can enter products. Hazards associated with commercial shellfish aquaculture are covered in section 3.1.1.3. Commercial fish farming uses many different methods ranging from extensive small-scale or subsistence systems to intensive commercial operations. A rapid growth rate of aquaculture has led to widespread dissemination of traditional semi-intensive farming systems, particularly in rural areas, including various integrated and wastewater-fed systems. Food safety hazards will depend on the system of culture, management practices and environment. Microbiological (pathogenic bacteria) and chemical (residues of agro-chemicals, veterinary drugs and heavy metal organic or inorganic) contamination have been identified as major hazards associated with aquaculture seafood. The contributing factors to these food safety concerns are complex and diverse including waste-fed aquaculture practices, environmental pollution and cultural habits of food preparation and consumption.

FSANZ conducted a survey in 2005 to determine whether residues of antimicrobials and other substances are present in both local and imported aquaculture products. A total of 60 samples of local and imported aquaculture finfish were collected (from late April until early June 2005) from all Australian States and Territories and analysed for a range of substances (more than 50) and their metabolites, including nitrofurans, chloramphenicol, sulphonamides, tetracyclines, malachite green, penicillins, macrolides, trimethoprim, quinolones and PCBs.

The survey results were very good with no detections for 54 of the 56 chemicals in the aquaculture products sold in Australia. Although the number of samples was very small, the outcomes suggested both local and imported aquaculture products posed low risks of chemical food safety. Detection of low levels (<0.14 mg/kg) of two chemical substances, malachite green and leucomalachite green, in 10 samples was also not a major concern (Figure 4). Among the 10 positive fish samples, 3 fish were grown in Australia and 7 Basa fish were imported from Vietnam. The local positives samples of farmed fish were 1 Rainbow Trout sample produced in NSW and 2 Silver Perch samples produced in NSW and WA. In summary, 21% (3 out of 14) and 15% (7 out of 46) of local and imported fish samples (all Basa from Vietnam) were found positive for the presence of malachite green and leucomalachite green, respectively.

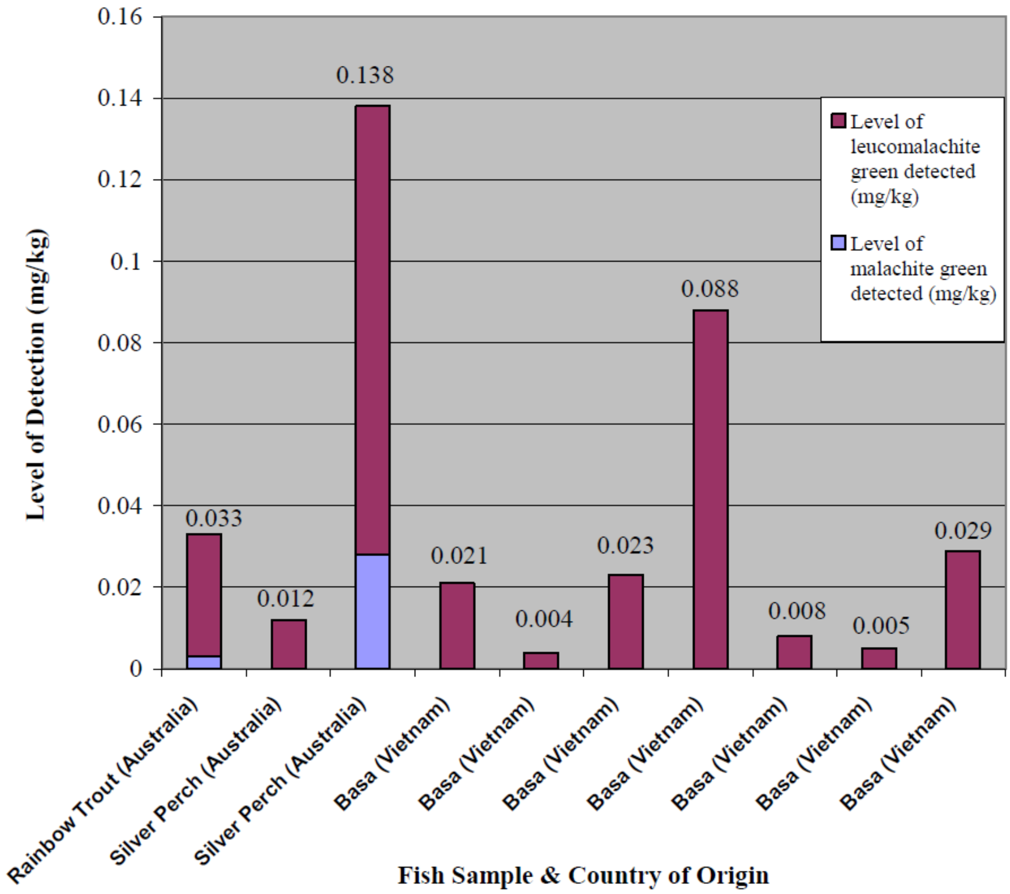

Figure 4. Levels of leucomalachite green and/or malachite green found in Australian and imported aquaculture fish samples in chemical residue survey (FSANZ, 2005b).

3.1.3 Imported seafood products

The food safety assurance of imported food is a joint responsibility by many Australian government agencies. The Department of Agriculture and Water Resources (DAWR) monitors imported seafood as part of a broader food regulatory system. Previously, the independent agency Australian Quarantine and Inspection Services (AQIS) was responsible for administering the pre- and at border controls of seafood under the *Imported Food Control Act*. Imported food must meet Australian food standards as is the case with food produced domestically. Post border food safety of imported food is managed by the states and territories through relevant state legislation.

FSANZ is responsible for determining and reviewing the list of potential hazards and risks related to foods through the Imported Food Notices. High risk foods are routinely inspected and analysed for the identification of hazards by the DAWR. Table 13 summarizes the hazards that resulted in the non-compliances of seafood imports in 2008. Three major hazards with the highest non-compliance rates of 6.6%, 5.7% and 4.5% were *E. coli*, SPC and *L. monocytogenes,* respectively.

Table 13. Identified hazards associated with non-compliances of imported seafood in 2008

Test type	Number of non compliant /compliant results	Compliance rate (%)	Type of non-compliant food	Country of origin
Histamines	36/1598	97.7	Dried fish (16); mackerel (3); tuna (3); other (14)	Sri Lanka (23); Indonesia (3); Thailand (3); Fiji; Italy; Japan; Korea, Myanmar, Norway; South Africa
Nitrofurans	8/519	98.5	Prawns or shrimp (8 total)	China (8)
Fluoroquinolones	17/1241	98.6	Frozen basa and catfish	Vietnam (17)
Malachite green	4/228	98.2	Giant catfish, frozen (3); fish fillets, frozen	Vietnam (3); China
Sulphur dioxide	1/75	98.7	Prawns (raw, breaded, frozen)	Thailand
E. coli	8/121	93.4	Clam, mussel and oyster, (dried, frozen) and other bivalve molluscs (8 total)	Hong Kong (2); New Zealand (2); Vietnam (2); Taiwan; Korea
Listeria monocytogenes	17/379	95.5	Smoked fish (10); dried fish (2); mackerel (2); brined sprats; salmon	Denmark (7); Japan (4); New Zealand (2); Norway (2); Russia; USA
Salmonella	3/308	99.0	Prawns (2);crab (1)	Indonesia; Taiwan; Vietnam
Staphylococci	1/306	99.7	Crab meat, frozen	Indonesia
Vibrio cholerae	3/219	98.6	Prawns, cooked and frozen	Vietnam (2); Thailand
Standard plate count	33/580	94.3	Crab, canned (8); prawns, frozen (6); bivalve molluscs, dried (8); crab, frozen, mussels/lobster (6); other (3)	Vietnam (10), Malaysia (7), Hong Kong (4), China (3), Indonesia (3), Taiwan (2), Thailand (2), Japan, Korea
Composition	19/27	29.6	Prepared roe (6); squid salad (5); Bonito (2); dried fish (4); fish cake; crispy dilis	Japan (11); China (5); Phillipines; Taiwan; Thailand
Total tests	**150/5960**	**97.5**		
Number of consignments	**14,313**			

adapted from Moir (2009)

An overseas study demonstrates that it is very important from a food safety point of view to evaluate the status of imported seafood products through an ongoing monitoring program. Abdellrazeq et al. (2014) found that imported raw catfish could be a significant source of *L. monocytogenes* and potential health risk for listeriosis in Egypt. The study showed 56.9% of imported raw catfish samples were positive for *Listeria* spp. with 11.9% prevalence of *L. monocytogenes*.

A scientific report authored by Sumner (2011) evaluated the human health impact of chemical and microbial hazards associated with prawns consumed in Australia. The report identified a range of chemical and microbiological hazards associated with imported prawns:

- Nitrofurans
- Sulphites
- Chloramphenicol
- Cadmium
- *V. parahaemolyticus*
- *V. cholerae*
- *Salmonella*
- Hepatitis A.

Several food poisoning outbreaks were listed that were associated with the consumption of imported prawns in Australia (Table 14). The two major outbreaks of *V. parahaemolyticus* gastroenteritis in Australia linked with consumption of prawns are:

- In 1990 an outbreak that affected more than 100 people and caused one death was linked to fresh, cooked prawns from Indonesia.
- In 1992 two outbreaks affecting more than 50 people were linked to the same wholesale supplier of cooked prawns.

Table 14. Food poisoning outbreaks associated with the consumption of imported prawns in Australia 1990-2010

Source	Hazard	Country	Cases (deaths)	Year	Reference
Retail	*V. parahaemolyticus*	Indonesia.	27	1990	NSW Health
Caterer	*V. parahaemolyticus*	Indonesia	100 (1)	1990	NSW Health; Kraa, 1995
Importer	*V. parahaemolyticus*	Indonesia	>50	1992	Kraa, 1995
Eating est.	*S.* typhi	Thailand	4	1995-1996	NSW Health
Eating est.	Hepatitis A	Burma	23	1997	NSW Health
Eating est.	Hepatitis A	Burma	17	1997	Anonymous, 1997
Eating est.	*V. cholerae* non 01, non 139*	Not recorded	10	1999	OzFoodNet
Eating est.	Hepatitis A	Not recorded	2	2003	OzFoodNet
Eating est.	Unknown	Not recorded	2	2009	OzFoodNet

* Red claw crayfish

adapted from Sumner (2011)

3.2 Exposure assessment

3.2.1 Consumption of seafood

Production data (2012-2013) for seafood in Australia and NSW is summarised in Table 15. Data on the consumption of fish and seafood products by sex and age from the Australian Health Survey 2011-2012 (ABS, 2014) is shown in Table 16.

This data showed that seafood was consumed by approximately 20% of the population, with consumption levels varying between different age groups. The FRDC Fish and Aquaculture Sector Overview Report (2014) compared seafood consumed per year in 1993 and 2011 by Australian consumers, 13.5 kg and 24 kg respectively. The report also states that around 72% of Australian seafood demand is met through imported products consisting mainly of fresh and frozen fish fillets, prawns, and canned tuna from Vietnam, Thailand, China and New Zealand. The predictions in the report suggest that consumption will continue to increase in the coming years (FRDC, 2014). The data collected in the Australian Health Survey (2012) on proportion (%) of persons consuming fish and seafood products and dishes in NSW showed an average consumption of 17.5 and 19.2 kg per year for the male and female population, respectively (Table 17).

Table 15. Production volumes for seafood in Australia and NSW 2012/13

Sector	Australia		NSW	
	Tonnes (gross)	Value ($000)	Tonnes (gross)	Value ($000)
Wild catch	156,023	1,360,775	11,597	76,220
Aquaculture	79,917	1,052,515	4,186	47,547
Seafood imports	228,391	1,427,679		
Seafood exports	35,304	1,002,341		

adapted from Australian Fisheries and Aquaculture Statistics 2014 (ABARE, 2014)

Table 16. Consumption of fish and seafood products in Australia

Sex	Age	Proportion of persons consuming fish and seafood products and dishes (%)	Median daily intake for consumers of fish and seafood products and dishes (g/day)
Male	2 - 3	8.0	104.3*
Male	4 - 8	10.6	67.0
Male	9 - 13	10.7	94.1
Male	14 - 18	9.7	81.8*
Male	19 - 30	18.2	155.8
Male	31 - 50	17.7	128.0
Male	51 - 70	20.1	130.0
Male	71+	18.4	129.5
Female	2 - 3	8.5	64.8
Female	4 - 8	12.9	70.3
Female	9 - 13	11.3	95.8
Female	14 - 18	15.2	78.7
Female	19 - 30	12.1	104.9
Female	31 - 50	19.3	100.0
Female	51 - 70	23.3	95.3
Female	71+	23.3	90.0

adapted from Australian Health Survey – Foods and Nutrients 2011-2012 (ABS, 2014)

Table 17. Proportion (%) of persons consuming fish and seafood products and dishes in NSW

Product	Age Group (years)		
	2 - 18	19 and over	Total 2 and over
Males			
Finfish (excluding commercially sterile)	2.8	7.2	6.2 (5.3)
Crustaceans and molluscs (excluding commercially sterile)	1.2	2.6	2.3 (1.5)
Other sea and freshwater foods	0.0	0.5	0.4 (0.3)
Packed (commercially sterile) fish and seafood	3.6	5.0	4.7 (5.0)
Fish and seafood products (homemade and takeaway)	2.3	4.1	3.7 (4.5)
Mixed dishes with fish or seafood as the major component	1.2	2.2	2.0 (1.5)
Fish and seafood products and dishes	11.1	19.3	17.5 (16.6*)
Females			
Finfish (excluding commercially sterile)	3.4	6.7	6.0 (5.3)
Crustaceans and molluscs (excluding commercially sterile)	0.0	1.7	1.3 (1.6)
Other sea and freshwater foods	0.0	0.5	0.4 (0.2)
Packed (commercially sterile) fish and seafood	2.5	7.6	6.5 (5.5)
Fish and seafood products (homemade and takeaway)	2.7	3.6	3.4 (4.5)
Mixed dishes with fish or seafood as the major component	0.4	3.3	2.7 (2.0)
Fish and seafood products and dishes	9.1	21.9	19.2 (17.8*)

adapted from Australian Health Survey – Foods and Nutrients 2011-2012 (ABS, released 9 May 2014), *National average consumption

3.2.2 Prevalence of hazards in seafood

Imported seafood is inspected by DAWR under the Imported Food Inspection Scheme (IFIS). The department compiles failed food reports and publishes data monthly from inspections of imported food consignments under the IFIS. Table 18 provides a summary of failing imported seafood products and associated hazards in 2014 and 2015. Overall imported seafood products made up 31.85% (115 out of 361) and 23.24% (63 out of 271) of the total failed food products in 2014 and 2015, respectively. In addition, information from FSANZ (2005a) on Australian and international surveys of seafood used to rank risk is included in Table 19.

Table 18. Number of failing imported seafood products under the Imported Food Inspection Scheme in 2014 and 2015[1]

Commodity	Hazard	2014	2015
Fish	*L. monocytogenes*	23 (20%)[2]	11 (17.5%)
	Scombroid	23 (20%)	18 (28.6%)
	Leuco-malachite green	4 (3.5%)	2 (3.2%)
	Enrofloxacin	4 (3.5%)	1 (1.6%)
	Norfloxacin		1 (1.6%)
	Ciprofloxacin		1 (1.6%)
	Composition		3 (4.8%)
Shellfish	*E. coli*	4 (3.5%)	3 (4.8%)
	Composition	1 (0.9%)	
Crustaceans	Standard Plate Count	12 (10.4%)	12 (19%)
	V. cholerae	6 (5.2%)	1 (1.6%)
	Ciprofloxacin	15 (13%)	2 (3.2%)
	Enrofloxacin	12 (10.4%)	2 (3.2%)
	Nitrofurans/Nitrpfurazone	1 (0.9%)	2 (3.2%)
	Furazoldone	1 (0.9%)	
	Composition		1 (1.6%)
Others	Iodine (seaweed)	6 (5.2%)	3 (4.8%)
	Arsenic (seaweed)	1 (0.9%)	
	Composition (squid)	2 (1.7%)	
Total		115	63

[1] Data source: Monthly failing food reports 2014 and 2015, available online (http://www.agriculture.gov.au/import/goods/food/inspection-compliance/failing-food-reports#2015)

[2] Percent of total failed imported seafood products

Table 19. Summary of Australian seafood testing results

Hazard	Commodity	Detected/Sampled
V. parahaemolyticus	Marine fish at market	39/66 (59%)
	Unopened oysters	16/16 (100%)
	Opened oysters	13/14 (93%)
	Pacific oysters	(69-74%)
	Scallops, mussels, oysters, fish	20/80 (25%)
V. vulnificus	Oysters	Detected at low numbers
L. monocytogenes	Smoked salmon fillets and slices	1/285 (0.4%) 2/433 (0.4%)
	Salmon pâté	8/61 (29.5%) sic
	Smoked fish and mussels	2/49 (4.1%)
	Marinara mix	(31%)
	Smoked fish	(10%)
	Seafood salad	(3%)
	Flake	(1.5%)
	Smoked salmon*[2]	10/56 (17.9%)
	Other smoked fish*	0/11
	Salmon cheese*	3/5 (60%)
	Salmon dip*	10/21 (47.6%)
	Salmon mousse/ pâté*	2/8 (25%)
	Cooked prawns	12/380 (3.2%)
Scombroid	Retail seafood	1/11 (9%) <100mg/kg
	Smoked fish	0/13
	Dried fish	3/5 (60%) <100mg/kg 1/5 (20%) 653 mg/kg
	Canned fish	1/7 (15%) <100mg/kg
	Canned tuna	3/107 (2%) 50-100mg/kg
Mercury	Several species exceed the regulatory limit – see Table 21	

adapted from (FSANZ, 2005a)

[2] Results marked with * is data is from a NSW retail survey. The report includes international information on Hepatitis A virus and the parasite *Anisakis simplex*

The Food Authority has a verification program for seafood processed under the Scheme. From July 2009 to December 2016, 305 samples of cooked/smoked seafood, opened oysters and packaged oysters were tested (Table 20). A total of sixteen samples (5.2%) were found to be non-compliant against the regulatory requirements. This level of non-compliance was higher than the level recorded from 2005 to June 2009. During that period, a total of 101 samples were tested and they were all compliant.

The non-compliant samples were:

- Two smoked fish contained *L. monocytogenes*.
- Eight opened oyster samples and six packaged oyster samples contained elevated level of *E. coli*, ranging from 4.3 to 240 cfu/g.

Table 20. NSW Seafood products tested and level of non-compliance 2009-2016

Product group	Number of samples tested	Number of non-compliant samples (%)
Cooked/smoked seafood	218	2 (0.9%)
Opened oysters	64	8 (12.5%)
Packaged oysters	23	6 (26.1%)

adapted from NSW Food Authority (unpublished)

In another survey, undertaken by the Food Authority from 2004 to 2007, 658 samples of 60 fish species were tested to gauge the extent of exposure to mercury from NSW retail seafood (NSW Food Authority, unpublished). The higher-level results summarised in Table 21 do not necessarily imply non-compliance with Standard 1.4.1 – *Contaminants and natural toxicants* of the Code. The maximum level (ML) is applicable to the mean of results for a prescribed number of sampling units (determined by the size of the sample lot). Overall 85% of individual samples were below the appropriate ML but the results suggest that limiting intake of some fish types remains a valid risk management strategy.

Table 21. Summary of high mercury levels in NSW seafood 2004-2007

Fish type	Number of samples	Maximum (mg/kg)[3]	Mean (mg/kg)[4]
Angel fish	5	1.002	0.712*
Flake	41	3.35	0.880
Ling	5	1.03	0.503
Marlin	22	1.682	0.851
Shark	23	3.47	0.690
Swordfish	37	4.092	1.454*

adapted from NSW Food Authority (unpublished)

[3] Results for individual samples exceed the maximum level (ML) specified in *Standard 1.4.1 – Contaminants and Natural toxicants* of the *Food Standards Code*

[4] Results marked with *, the mean exceeds the ML specified by *Standard 1.4.1 – Contaminants and Natural toxicants* of the *Food Standards Code*, which is generally 0.5 mg/kg for most fish and 1mg/kg for some fish, rays and sharks

Heavy metal testing in NSW shellfish is part of the NSW Shellfish Program. A triennial survey of heavy metals and persistent organic pollutants is conducted under the program in classified shellfish aquaculture zones along the NSW coastline. The concentrations of heavy metals found in shellfish between 1999 and 2014 were generally low and comparable to previous independent studies of heavy metal concentrations in NSW. No results were above the MLs outlined in the Code.

3.2.2.1. L. monocytogenes in smoked fish

The UK Food Standards Agency surveyed *L. monocytogenes* in smoked fish (UKFSA, 2008) and the results are summarised in Table 22. Detection of *Listeria* spp. and *L. monocytogenes* were relatively common in cold smoked fish. Detections were less common in hot smoked fish but *L. monocytogenes* at levels higher than 100 cfu/g were only found in hot smoked fish. These results are consistent with Ross and Sanderson (2000) who reported that cold smoked fish were more prone to contamination by *L. monocytogenes* but, due to lower levels of background flora, there is potential for growth to higher numbers in hot smoked fish.

Table 22. Prevalence of *L. monocytogenes* in UK retail smoked fish

	Cold smoked fish	Hot smoked fish
Number of samples	1,344	1,878
Listeria spp. detected	282 (20.5%)	96 (5.2%)
L. monocytogenes detected	236 (17.4%)	66 (3.4%)
L. monocytogenes > 100cfu/g	0	3 (0.06%)

adapted from UKFSA (2008)

3.2.2.2. Algal biotoxins

The Shellfish Program of the Food Authority averaged 15-16 shellfish harvest areas closures each year attributable to biotoxin. Between July 2005 and December 2016, there were 166 closures of classified harvest areas (oysters and mussels, but not wild harvest) due to algal (99) or biotoxin (67) detections (unpublished data). The closures were based on either very high levels of potentially toxic phytoplankton or positive results from screening tests for algal biotoxins.

The NSW pipi industry also experiences closures due to potential biotoxin issues, typically in summer or early autumn. Eight biotoxin closures were recorded from 2012 to 2015 (unpublished data). Pipi biotoxin management plans were introduced following the 1997 and 1998 DSP outbreaks and there has been no subsequent outbreak of DSP attributed to NSW pipis.

3.3 Hazard characterisation

3.3.1 Biological hazards characterisation in seafood

This section discusses the characteristics of major bacterial, viral and parasitic hazards associated with all kinds of seafood (fish, crustaceans and molluscs) consumed from different sources, i.e. wild catch (sea and freshwater), aquaculture and imports in NSW.

3.3.1.1 Bacterial hazards

***L. monocytogenes* in RTE smoked fish products**

Tocmo et al. (2014) published a comprehensive review on *L. monocytogenes* in smoked fish products. The article acknowledges that the occurrence of *L. monocytogenes* in RTE fish products is well documented and represents an important food safety concern. In the concluding remarks, the unique ability of some *L. monocytogenes* strains to survive sanitation procedures and persist as "in-house" strains is the main contributing factor to their prevalence in smoked fish products.

Indications of the nature of foodborne listeriosis have emerged from outbreak data, animal studies and mathematical modelling of illness. Knowledge is incomplete because of difficulties such as:

- some strains of *L. monocytogenes* are pathogenic but others are not
- the determinants of pathogenicity are not well understood and so the distribution of pathogenic strains in food is not known.

However, there is general acceptance of some elements of the disease process (Ross and Sanderson, 2000):

- The infectious dose of *L. monocytogenes* cannot be stated with precision but it appears that human listeriosis does not usually occur in the absence of a predisposing risk factor (such as compromised immunity)
- Most commentators regard doses of <1000 organisms as highly unlikely to cause illness in normal individuals, and this has been reflected in food safety regulations
- Attempts to link exposure to the organism to observed levels of illness suggest the infective dose is much higher than 1000 organisms – but it appears in some cases fewer than 1000 organism may cause illness
- This difference between observed and predicted cases of illness suggests that the human population susceptible to listeriosis is a much smaller sub-group of the immunocompromised population. However, it could also be an artefact of under-reporting of listeriosis cases, due to some cases only developing mild flu-like symptoms.

***Cl. botulinum* in vacuum-packed RTE fish products**

Foodborne botulism results from eating food contaminated with preformed botulinum toxin due to the presence and growth of *Cl. botulinum* bacteria. Botulism varies from a mild illness to an acute disease which can be fatal. With treatment, death due to respiratory failure or airway obstruction is rare. The case fatality rate in North America has fallen from 60% to 20% due to the availability and prompt administration of antitoxin. Provision of artificial respiration greatly increases the chances of recovery from intoxication. Nonetheless, recovery may take many months.

Internationally, the aquatic environment of fish can be contaminated with *Cl. botulinum* spores and so fish might be contaminated also. The organism only grows in the absence of air, and represents a risk only in those products which exclude oxygen by their packaging (e.g. vacuum packaged, MAP) or which contain anaerobic regions (e.g.

gut left intact). The toxin is heat labile, so the hazard is primarily limited to RTE seafood that is stored in vacuum or anaerobic packaging.

For seafood, botulism is most commonly associated with *Cl. botulinum* type E. This type is capable of growth and toxin production at refrigeration temperatures but generally needs weeks of growth to produce amounts of toxin to cause foodborne illness. This is significantly greater than the shelf life generally observed for seafood and seafood products. Botulism is a concern in extended shelf life products and thus the concern with vacuum packaging and canning.

***V. parahaemolyticus* in molluscs and crustaceans**

Illness is caused when the ingested organism attaches itself to an individual's small intestines and secrets a toxin. Not all strains of the organism are pathogenic. There appears to be a lack of correlation between pathogenicity and serotype of *V. parahaemolyticus* isolates. Virulence correlates with the ability to produce a thermostable direct haemolysin termed the Kanagawa Phenomenon (KP) haemolysin. KP negative strains appear to be non-pathogenic (Sanyal and Sen, 1974).

Human volunteer studies have established an infectious dose for KP positive strains between 2×10^5 and 3×10^7 cfu. *V. parahaemolyticus* can multiply rapidly in seafood at permissive temperatures. In a study numbers of *V. parahaemolyticus* on octopus stored at 30°C increased from 10^2/g to 10^8/g in 6 hours.

Sydney rock oyster storage temperatures

Time and temperature have been identified as critical control points to reduce the risk of *V. parahaemolyticus* in oysters. However, the time and temperature criteria that were being considered in international forums were developed using a model for the American oyster (*Crassostrea virginica*) grown in USA shellfish-growing waters. As this had the potential to disadvantage the Australian industry, the Australian Seafood Cooperative Research Centre (CRC) undertook a project to produce a validated and robust *V. parahaemolyticus* model (Tamplin et al. 2011). The Food Authority contributed funding towards the research.

The research project produced validated predictive models for *Vibrio* and standard plate count growth in both Pacific oyster (PO) and Sydney rock oyster (SRO). Microbial growth in PO was as expected based on international work for other shellfish species. However, the results for SRO demonstrated that microbial growth does not occur until storage temperatures reach above 25˚C.

Additional work undertaken specifically on SRO assessed the growth of *E. coli* and *Salmonella* bacteria up to 35˚C. This work demonstrated that growth of these bacteria did not occur for storage temperatures up to 25˚C. Bacterial growth was observed above 25˚C.

The previous storage temperature requirement for SRO was:

a) <25˚C within 24 hours of harvest, then

b) <15˚C within 72 hours of harvest.

As a consequence of the study the storage temperature requirement for SRO was amended to:

a) <25˚C within 24 hours of harvest, then

b) <20˚C within 72 hours of harvest.

When considering the amended storage temperature regime, the provision of a safety factor of 5˚C was considered appropriate to account for variations in actual storage temperatures in commercial applications.

Non-*vibrio* bacterial contamination of shellfish

Walsh and Grant (1999) found that bacterial pathogens of faecal origin to be high priority for risk assessment.

Ross and Sanderson (2000) assessed the risks of non-*vibrio* bacterial contamination of shellfish. They estimated the potential risk to be 0.25-1.35 for depurated shellfish and possibly 0.5-2.7 for shellfish that are not depurated and ranked the risk as 6th out of 10 hazards assessed.

FSANZ (2005a) relative risk ranking for raw oysters was lower for *L. monocytogenes*, *E. coli* (non-EHEC), *Staph. aureus*, *Salmonella* (non-typhoid), *Campylobacter* spp, *Shigella* spp. or *Yersinia* spp.

Shellfish harvesting controls stressed by Ross and Sanderson (2000) are central to the activities of the Food Authority's Shellfish Program. The requirements for sanitary surveys, microbial water and shellfish testing, and monitoring environmental parameters to inform the open or closed status of harvest areas provide substantial control of most faecal contamination issues. Oysters consumed raw are the main risk and yet there is little evidence of foodborne illness. OzFoodNet reports from 2001 to 2010 contain only one outbreak of bacterial illness where oysters were suspected to be the vehicle. The outbreak occurred in Victoria in December 2001. Six people were sick and the evidence of oyster involvement was 'descriptive' (other categories of evidence are 'statistical' after a formal epidemiological study, or 'microbiological' confirmation of the agent and cases).

Ross and Sanderson's conclusion that 'the presence of existing control strategies suggest that faecal bacteria in shellfish constitute a low risk to the health of NSW consumers relative to other identified hazards' still appears to be correct.

3.3.1.2. Viral hazards

Enteric viruses can be introduced into aquatic environments through contamination with sewage. They may persist longer than enteric bacteria in marine environments and can be accumulated in bivalve molluscs. Therefore, their presence in shellfish does not always correlate with bacterial indicators of faecal pollution in marine environments. Viruses may also take longer to depurate from contaminated shellfish than enteric bacteria and viruses are more resistant to inactivation during cooking than bacteria. Outbreaks of viral food poisoning associated with shellfish continue to occur in Australia and worldwide. In general, the incidence of seafood associated viral food poisoning is low, suggesting that existing control strategies are effective. Australian outbreaks have been associated with failures or non-implementation of control strategies.

Noroviruses cause human gastrointestinal illness. Symptoms in children are generally mild and self-limiting. A more severe gastroenteritis with dehydration as the result of vomiting or diarrhoea may occur. Mortality in the absence of other compromising factors is extremely rare. Infections in adults typically manifest as explosive projectile vomiting and/or diarrhoea. Incubation times are dose dependant, typically 15-50 hours with a mean of 24-48 hours (Ross and Sanderson, 2000).

Hepatitis A (HAV) is usually a mild illness characterised by sudden onset fever, malaise, nausea, anorexia and abdominal discomfort followed in several days by jaundice. The incubation period for HAV varies from 10 to 50 days (mean 30 days), and is dependent upon the number of infectious particles consumed. Many infections with HAV do not result in clinical illness, especially in children. When illness does occur, it is usually mild and recovery is complete in one or 2 weeks. Occasionally the symptoms are severe and convalescence can take several months. Patients suffer from chronic tiredness during convalescence, and their inability to work can cause financial loss. Less than 0.4% of the reported cases in the USA are fatal. These rare deaths are usually in the elderly (Ross and Sanderson, 2000).

Now food is a recognised vehicle for transmitting certain viruses to humans, which are responsible for highly contagious infections and widespread outbreaks. European Food Safety Authority (EFSA) released scientific opinion on foodborne viruses and looked at Norovirus and Hepatitis A virus in fresh produce, ready-to-eat foods and bivalve molluscs such as oysters, mussels and scallops (EFSA, 2011). Figure 5 shows the number of viral contamination of food products, and shellfish was clearly identified as a major vehicle. It was also noted in the report that total number of outbreaks caused by foodborne viruses has been increasing since 2007. The recommendations made by the EFSA Panel include:

- Focusing controls on preventive measures to avoid viral contamination rather than trying to remove/inactivate these viruses from food
- Introducing microbiological criteria for viruses in bivalve molluscs, unless they are labelled “to be cooked before consumption”.

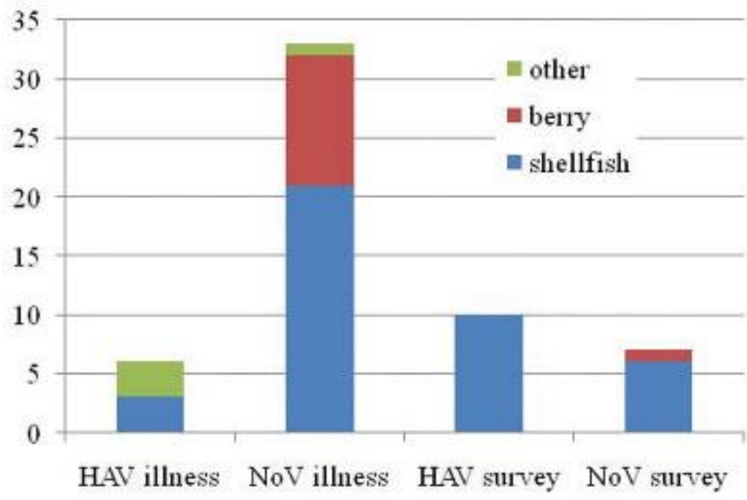

Figure 5. Number of notifications (2000-2010) for suspected viral contamination of food products, based on illness reports or virus detection in products. (Adapted from EFSA, 2011)

3.3.1.3 Parasitic hazards

Parasites in raw fish for sushi/sashimi

Parasites are only a seafood safety concern where fish is eaten raw or partly cooked (Walsh and Grant, 1999; Shamsi, 2016). It is important to note that the demand of raw and exotic seafood is increasing due to the growth in its consumption. Recent scientific literature recommends that the specific risks associated with the preparation and sale of raw fish for consumption raw should be investigated (Shamsi, 2016).

Ross and Sanderson (2000) assessed the risks of parasites in raw fish for sushi/sashimi in NSW. They stated the risk appears currently to be low, but the growth in consumption of raw fish suggests that increased incidence of foodborne parasitic infections might be expected. They assigned a Potential Risk (PR) score of 0.35 - 0.70 and overall ranking of 9th out of 10 hazards assessed. They suggested a PR score of less than one probably represents a risk that is currently well managed.

FSANZ (2005a) undertook a relative risk ranking for seafood. Helminthic parasites in chilled/frozen fish and fish fillets and in marinated, pickled, brined, dried or fermented fish products ranked low. The report stated there were no epidemiological data indicating foodborne illness due to the presence of helminthic parasites in raw finfish products in Australia. However, two incidents have since been reported (see section 2.3.2; Jeremiah et al. 2011; Shamsi and Butcher, 2011).

Globally, fish-borne parasitic zoonosis is responsible for large numbers of human infections. In the past these diseases were limited for the most part to populations living in low- and middle-income countries, but the geographical limits and populations at risk are expanding and changing because of growing international markets, improved transportation systems and demographic changes (such as population movements). Chai et al. (2005) reviewed the fish-borne parasitic diseases considered by the WHO to be most important. Their review provides a useful overview of the hazards and the summary of key information is given below:

Liver flukes

Liver flukes have long been known to cause serious disease in certain areas of the world (Table 23). Cholangitis, choledocholithiasis, pancreatitis, and cholangiocarcinoma are the major clinical problems, associated with the long chronic pattern of these infections.

Table 23. Trematodiases (the liver flukes) association with seafood and geographic distribution

Species	Molluscan and piscine hosts	Geographic distribution
Clonorchis sinensis	Freshwater fish and snails	Korea, China, Taiwan, Russia
Opisthorchis viverrini	Freshwater fish and snails	Thailand, Laos, Cambodia, Vietnam
Opisthorchis felineus	Freshwater fish and snails	Spain, Italy, Albania, Greece, France, Macedonia, Switzerland, Germany, Poland, Russia, Turkey, Caucasus
Metorchis conjunctus	Freshwater fish and snails	Canada, USA

adapted from Chai et al. 2005

The prevalence of liver flukes in endemic areas is related to the custom of eating raw fish or shrimps. Examples include congee with slices of raw freshwater fish (southern China and Hong Kong); raw freshwater fish with red pepper sauce; half roasted or undercooked fish in Guangdong Province; Koi pla in north-eastern Thailand and Laos. Korean immigrants in Canada ate wild-caught fish in undercooked traditional dishes not realising that *M. conjunctus* was endemic in fish in the area.

Intestinal flukes – heterophyids

These minute intestinal flukes of the family Heterophyidae are parasites of birds and mammals. Many species have been reported from humans. However, because an extraordinary number of heterophyid species are zoonotic (about 35 species) and have very similar transmission patterns, this group is in the aggregate a very significant food safety and quality problem. Table 24 provides information on the association of intestinal flukes (heterophyids) with seafood and geographic distribution.

Table 24. Trematodiases (the intestinal flukes – heterophyids) association with seafood and geographic distribution

Species	Molluscan and piscine hosts	Geographic distribution	Comment
Metagonimus yokogawai	Freshwater snails and fish	Korea, China, Taiwan, Japan, Russia, Indonesia, Israel, Spain	Infection prevented by not eating uncooked fresh water fish
Metagonimus takahashii	Freshwater snails and fish	Korea, Japan	
Metagonimus miyatai	Freshwater snails and fish	Korea, Japan	
Heterophyes heterophyes	Brackish water snails and fish	Egypt, Sudan, Palestine, Brazil, Spain, Turkey, Iran, India, Russia	Linked to salted or insufficiently baked fish
Heterophyes nocens	Brackish water snails and fish	Korea, Japan, China	
Haplorchis taichui	Freshwater snails and fish	Taiwan, Philippines, Bangladesh, India, Palestine, Egypt, Malaysia, Thailand, Laos, Vietnam, China	
Haplorchis pumilio	Freshwater snails and fish	Thailand, Laos, China	
Haplorchis yokogawai	Freshwater snails and fish	Taiwan, Philippines, China, Malaysia, Egypt Indonesia, Thailand, Laos, India, Australia	
Pygidiopsis summa	Brackish water snails and fish	Korea, Japan	

adapted from Chai et al. 2005

Although generally not considered of significant clinical importance relative to the liver flukes, several heterophyid species, including *Stellantchasmus falcatus*, *Haplorchis* spp., and *Procerovum* spp., can cause significant pathology, and often fatal, in the heart, brain and spinal cord of humans.

Chai et al. (2005) provide information on another trematode, *Nanaphyetus salmincola*, which is associated with a freshwater snail and salmonid (trout, salmon) and non-salmonid fish. Human disease is endemic in the far-eastern part of Russia.

The intestinal flukes – echinostomes

Trematodes, of the family Echinostomatidae (Poche, 1926), are intestinal parasites of birds and mammals. At least 30 genera and more than 200 species are known, of which 15 species infect humans. There are 11 reported fish-borne echinostome species. Table 25 provides information on the association of intestinal flukes (echinostomes) with seafood and geographic distribution.

The disease is generally mild, but ulcerations and bleeding in the stomach or duodenum may occur.

Table 25. Trematodiases (the intestinal flukes – echinostomes) association with seafood and geographic distribution

Species	Piscine hosts	Geographic distribution
Echinostoma hortense	Freshwater snail and fish	Korea, Japan, China
Echinochasmus japonicus	Freshwater snail and fish	Korea, Japan, China
Echinochasmus perfoliatus	Freshwater snail and fish	Japan, China, Taiwan, Hungary, Italy, Rumania, Russia
Echinochasmus liliputanus	Freshwater snail and fish	Egypt, Syria, Palestine, China
Echinochasmus fujianensis	Freshwater snail and fish	China

adapted from Chai et al. 2005

Diphyllobothriasis

This is the most important fish-borne zoonosis caused by a cestode (tapeworm) parasite (Table 26). Although not generally considered a serious zoonosis, there are indications that its frequency and distribution are increasing in some regions, probably because of social and economic change. These tapeworms are among the largest parasites of humans and may, as adults in the intestine, grow to 2-15 m in length.

Infection is linked to the consumption of raw or insufficiently cooked or marinated fish. The zoonosis occurs most frequently in communities that have food preferences for wild catch seafood prepared as sushi, sashimi, gravalax (gravlax), strogonina, gefilte fisch, and ceviche. There is little to implicate farm-raised salmonids in transmission of diphyllobothriids to humans. Wild salmonids are at highest risk of becoming infected and represent a major reservoir of infection.

Table 26. Seafood association and geographic distribution of Cestodes (tapeworms) *Diphyllobothrium* species reported from humans

Species	Piscine hosts	Geographic distribution
Diphyllobothrium alascense	Burbot, Smelt	Kuskokwim Delta, Alaska
Diphyllobothrium cameroni	Marine fishes	Japan
Diphyllobothrium cordatum	Marine fishes	Northern Seas, Greenland, Iceland
Diphyllobothrium dalliae	Freshwater fish (Dallia pectoralis)	Alaska, Siberia
Diphyllobothrium dendriticum	Freshwater fish (Salmonids, Coregonids, Burbot, Grayling)	Circumpolar; introduced elsewhere
Diphyllobothrium hians	Marine fishes	North Atlantic; North Sea?
Diphyllobothrium klebanovski	Salmonids	Eastern Eurasia, Sea of Japan, Sea of Okhostsk; Alaska?
Diphyllobothrium lanceolatum	Coregonus	North Pacific, Bearing Sea
Diphyllobothrium latum	Pike, Burbots, Percids	Fennoscandia, western Russia, North and South America; reported from Cuba, Korea
Diphyllobothrium nihonkaiense	Salmon	Japan
Diphyllobothrium pacificum	Marine fishes	Peru, Chile, Japan
Diphyllobothrium ursi	Red salmon	Alaska, British Columbia
Diphyllobothrium yonagoensis	Salmon	Japan, eastern Siberia

adapted from Chai et al. 2005

Anisakiasis

Anisakiasis (anisakidosis) refers to infection of people with larval stages of nematodes belonging to the families Anisakidae or Raphidascarididae. Although cases of human infection have been reported with worms from many species within these families, the two genera most often associated with anisakiasis are *Anisakis* and *Pseudoterranova*. Anisakiasis occurs when people ingest third stage larvae found in the viscera or muscle of a wide range of fish and cephalopod mollusc species. Humans are accidental hosts in the life cycle, and the parasites almost never develop further within the human gastrointestinal tract. General life cycle of anisakid nematodes is shown in Figure 6 as described by Shamsi (2016). Nevertheless, anisakiasis is a serious zoonotic disease, and there has been a dramatic increase in its reported prevalence throughout the world in the last two decades.

Human anisakiasis can take many forms, depending on the location and histopathological lesions caused by the larvae. Larvae may remain in the gastrointestinal tract, without penetrating the tissues, causing an asymptomatic infection, which may only be discovered when the worms are expelled by coughing, vomiting or defecating. In invasive anisakiasis, larvae penetrate the gastric or intestinal mucosa, or more rarely other sites such as the throat. There is some evidence that gastric invasion is more often associated with infections by *Pseudoterranova* spp. and intestinal invasion with infections by *Anisakis* spp.

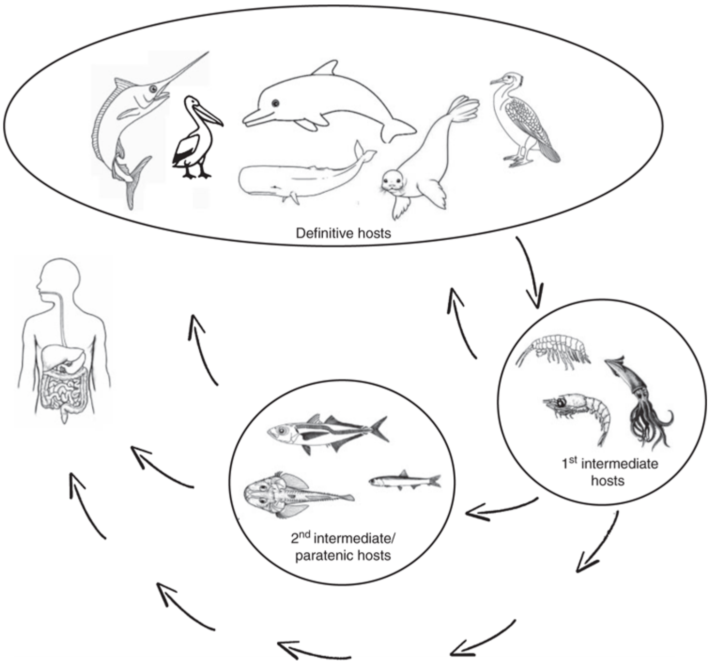

Figure 6. General life cycle of anisakid nematodes

Adult nematodes inhabit the stomach of definitive hosts, including marine mammals, piscivorous birds and large predatory fish in which they reproduce and lay eggs. Eggs pass through faeces to the water. Embryonated eggs or hatched larvae are ingested by first intermediate hosts, including a wide range of aquatic invertebrates. Larvae develop further when infected first intermediate hosts are predated upon by second intermediate or paratenic hosts, including a broad range of fish species. The larval stages of Anisakids are not host specific and a wide range of fish species can become infected as intermediate or paratenic hosts. This allows the parasite to be widely distributed by passing through several fish species and to infect a wide range of marine mammals and fish-eating birds where they complete their life cycle and become adults. Thus, infection with anisakids is not limited to one simple food chain but rather a wide network of species, increasing the impact and importance of these parasites. As shown in the picture humans become infected by consuming infected seafood (fish and invertebrates such as crustaceans). (Adapted from Shamsi, 2016)

Symptoms of gastric anisakiasis usually appear 1-7 hours after consumption of fish, while intestinal anisakiasis usually manifests 5-7 days after fish consumption. In both cases, there is severe pain, with nausea and vomiting. Histopathological examination of invasive anisakiasis usually reveals the worm embedded in a dense eosinophilic granuloma in the mucosa, often with localized or diffuse tumours in the stomach or intestinal wall.

In recent years, it has become clear that anisakiasis is often associated with a strong allergic response, with clinical symptoms ranging from isolated swellings to urticaria and life threatening anaphylactic shock.

Live anisakid larvae may be ingested when people eat raw, insufficiently cooked, smoked or marinated fish or cephalopod molluscs. Human anisakiasis can take many forms depending on whether the parasite remains in the gastrointestinal tract or invades other organs. Freezing and cooking might not provide protection against allergic response (Chai et al. 2005).

Anisakiasis occurs throughout the world. Of the total cases (about 20,000 when Chai et al published their report in 2005), over 90% are from Japan (where 2000 cases are diagnosed annually) with most other cases from the Netherlands, Germany, France and Spain. As diagnostic methods improve, more cases are being reported from other areas of the world, including a report from New Zealand. Larval anisakid infections can be found in fish from Australian waters (for example Doupe et al. 2003 and Shamsi et al. 2011).

Nawa et al. (2005) point out that sushi and sashimi served in Japanese restaurants and sushi bars are preferentially, but not exclusively, prepared from relatively expensive marine fish such as tuna, yellow tail, red snapper, salmon and flatfish/flounder. These species are less contaminated or are even free of *Anisakis* larvae, although salmon is an important intermediate host for the fish tapeworm *Diphyllobothrium latum*. In contrast, other popular and cheap marine fish, such as cod, herring, mackerel and squid, tend to be heavily infected with *Anisakis* larvae. Except for *Anisakis* and *D. latum*, marine fish transmit few parasite species that infect humans. The authors conclude that the risk of infection with fish-borne parasites by dining in Japanese restaurants and sushi bars is not as significant as is generally feared.

Nawa et al. (2005) were writing about travel medicine and noted that raw or undercooked freshwater or brackish-water fish, frogs, land snails, snakes, backyard chicken and wild boar are served in rural Japan and many Asian countries as well. Thus, travellers dining in local restaurants or street shops can be expected to have much higher risks of infections with various parasites.

Broglia and Kapel (2011) explore the themes of demographic change in relation to food generally. They contend that changing dietary habits in a changing world are emerging drivers for transmission of foodborne parasitic zoonoses. Among other things the authors point to:

- changing eating habits, such as the consumption of raw or lightly cooked food, and the demand for exotic foods, such as bush meat
- rapid population growth, concentrating in urban areas
- an increasingly global market in vegetables, fruit, meat, ethnic foods, and even farm animals, some of which originate from countries without appropriate food safety procedures
- improved transport logistics and conditions, which enable parasites to survive on food products and reach the consumer in a viable form

- an increasingly transient human population carrying its parasitic fauna worldwide
- the shift from low- to high-protein food consumption as nations develop economically with a concomitant and global greater dependency on meat and fish products.

There appears to be a clear consensus in parasitology literature about the hazards associated with eating raw and undercooked fish (see Dorny et al. 2009). However, several authors contend that traditionally prepared sushi or sashimi has a low level of risk. Oshima (1987) asks 'anisakiasis – is the sushi bar guilty' and suggests the risk is low and that rising reports of anisakiasis are due to advances in diagnosis rather than the commercialisation of sushi.

Overall it seems that the higher risk factors in contracting parasitic illness from seafood consumption are associated with:

- low and middle income countries
- cultural traditions related to the consumption of raw and undercooked seafood
- freshwater fish more than marine fish
- wild caught marine fish more than farmed (pellet feed) marine fish
- lower cost marine fish more than higher value marine fish.

At this stage the risk from parasites from seafood served raw and undercooked remains low in Australia. However, Japanese food, including sushi and sashimi, is very popular in Australia and cultural diversity means that consumption of other forms of raw seafood is likely to increase. If the increase leads to higher consumption of raw or undercooked wild catch, low-value marine fish or freshwater fish, the risk will increase. The recognition of anisakis-related anaphylaxis could well change the risk rankings in the future.

3.3.2 Chemical hazards characterisation in seafood

3.3.2.1 Algal toxins in shellfish

Shellfish poisoning is caused by a group of toxins elaborated by planktonic algae upon which the shellfish feed. The toxins are accumulated and sometimes metabolised by the shellfish. Since shellfish toxins are heat stable, the form in which shellfish are consumed does not affect the level of the hazard. All individuals are susceptible to shellfish toxins, although elderly people may be more severely affected, particularly by Amnesic Shellfish Poisoning (ASP).

ASP is caused by the unusual amino acid, domoic acid, produced by chain-forming diatoms of the *Pseudonitzschia* spp. The toxicosis is particularly serious in elderly patients. All fatalities (up to a report date of 2003) involved elderly patients. During an outbreak in Canada, the affected people consumed mussels containing 300-1200 µg/g of domoic acid.

There are about 20 toxins responsible for Paralytic Shellfish Poisoning (PSP), and all are chemical derivatives of saxitoxin, but differ in the type and localisation of the derivation. PSP toxins are also produced by species of cyanobacteria found in Australian freshwater rivers and lakes.

PSP toxins block the sodium channels of excitable membranes of the nervous system and associated muscles. The extreme potency of PSP toxins has, in the past, resulted in an unusually high mortality rate. In humans 120-180 µg of PSP toxin can produce moderate symptoms, 400-1060 µg can cause death, and 2000-10,000 µg is more likely to constitute a fatal dose.

Diarrhetic Shellfish Poisoning (DSP) is caused by a group of high molecular weight polyethers, including okadaic acid, the pectenotoxins and yessotoxin produced by the armoured dinoflagellate algae, including *Dinophysis* spp., and *Prorocentrum* spp. These species are omnipresent but their toxicity is variable and unpredictable. Dense blooms can sometimes be completely non-toxic, but at other times shellfish can become toxic even when only sparse dinoflagellate populations are present.

No human fatalities have been reported due to DSP and patients usually recover within 3 days. Recovery is generally complete with no after effects and the poisoning is generally not life threatening. In extreme cases, chronic exposure may promote tumour formation in the digestive system.

3.3.2.2 Cyanobacterial toxins in seafood

The *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008) includes a comprehensive overview of cyanobacteria and their toxins. It includes the following extracts:

- Cyanobacteria (blue‑green algae) are bacterial photosynthetic autotrophs that form a common and naturally-occurring component of most aquatic ecosystems. Cyanobacteria have some of the characteristics of bacteria and of algae. Their capacity to photosynthesise with the aid of green and blue–green pigments, and their size and tendency to occupy a similar habitat, make them look much like algae, hence the historical classification of the group as blue–green algae. They can occur singly or grouped in colonies and can increase to such large numbers that they colour the water (a 'bloom') and form highly visible thick scums.
- Cyanobacteria are a public health concern because some types produce toxins that have harmful effects on body tissues, cells or organs. These toxins are a potential hazard in waters used for human and animal drinking-water supplies, aquaculture, agriculture and recreation. Furthermore, production of toxins is unpredictable, making it difficult to identify the toxicity of waters and define the restrictions that should be placed on their use.

When toxins produced by cyanobacteria are present in the aquatic environment, seafood harvested from this water may present a health hazard to consumers (Mulvenna et al. 2012). Table 27 summarises evidence from the literature on cyanobacterial toxins in seafood.

Table 27. Literature reports of cyanobacterial toxins (Tx) in seafood

Reference	Country	Toxin	Animal	Comment
Negri (1995)	Australia	PSP (Anabaena)	Mussel (freshwater)	Feeding trial; tx above regulatory limit; 95% of toxin in viscera
Vasconcelos (1999) (includes secondary sources)	Portugal	Microcystin	Mussel (marine)	Feeding trials; tx was 10.5 ppm dry weight
	Finland	Hepatotoxin	Mussel (freshwater)	Probable cause of muskrat mortality
	Finland	Microcystin	Mussel	Laboratory trial
	Australia	Nodularin	Mussel (marine)	From natural bloom
	Portugal	Microcystin	Cray fish (freshwater)	
	Portugal	Microcystin	Fin fish	Low in edible parts
Van Buynder (2001)	Australia	Nodularin	Prawn	Tx at 60% of health alert level in whole prawns. Suggested 60,000/mL closure. Tx stored in viscera, small amount enters flesh when cooked, 90% discarded in offal.
			Mussel	Tx 1.5 ppm; derived health alert level. Exceeded health level cell count of 40,000/mL.
			Finfish	Tx levels remained low and concentrated in viscera
Vasconelos (2001)	Portugal	Microcystin	Crayfish (freshwater)	Tx accumulated in viscera and no significant risk if gut removed
Yokoyama (2003)	Japan	Microcystin	Freshwater bivalve	Depurate slowly in winter. 250 ppm tx (dry wt) in hepatopancreas accumulated in 25°C water.
Kankaanpaa (2005)	Australia	Hepatotoxins	Prawns farmed	Fed prawns accumulated tx – but not in muscle. Low natural tx in 2001/02

The most common toxic cyanobacteria in Australia are:

Microcystis aeruginosa, *Anabaena circinalis*, *Cylindrospermopsis raciborskii*, and *Aphanizomenon ovalisporum* in fresh water; and *Nodularia spumigena* and *Lyngbya majuscula* in estuarine and coastal marine water.

The health problems associated with cyanobacteria are due to the cyanotoxins that they produce (Newcombe et al. 2010). The three main groups of cyanotoxins are:

- cyclic peptides – microcystins and nodularin,
- alkaloids – such as neurotoxins and cylindrospermopsin, and
- lipopolysaccharides.

Cyclic peptides

The microcystins and nodularin are known to cause liver damage (hepatotoxins). They block protein phosphatases 1 and 2a, which are “molecular switches” in all eukaryotic cells, with an irreversible covalent bond. For vertebrates, a lethal dose of microcystin causes death by liver damage within hours to a few days.

There are two potential mechanisms for long-term microcystin damage to the liver, progressive active liver injury as described above, and promotion of tumour growth. Tumour-promoting activity of microcystins is well documented in animals, although microcystins alone have not been demonstrated to be cancer causing. The literature indicates that hepatotoxic blooms of *Microcystis aeruginosa* containing microcystins occur commonly worldwide (Newcombe et al. 2010).

Alkaloids

The alkaloid toxins produced by cyanobacteria include a range of compounds that interfere with nerve cell function (neurotoxins), including anatoxins and saxitoxins, as well as cylindrospermopsin, which is a recognised hepatotoxin, but which also causes general cell damage (cytotoxin).

While the neurotoxins have different modes of action, all have the potential to be lethal at high doses by inhibiting the ability to breathe – anatoxin-a and anatoxin-a (S) through cramps, and saxitoxins through paralysis. However, no human deaths from exposure to cyanobacterial neurotoxins are known.

The neurotoxic saxitoxins or PSPs are one of several groups of toxins produced by dinoflagellates in the marine environment. Shellfish feeding on toxic dinoflagellates can themselves become toxic and hazardous. Poisoning incidents usually coincide with the sudden proliferation of these organisms to produce visible blooms, the so-called "red tides" (Newcombe et al. 2010).

Saxitoxins are also the neurotoxins present in *Anabaena circinalis*, the only cyanobacterium found to be neurotoxic in Australia. The widespread occurrence of saxitoxins, especially in Australian neurotoxic *A. circinalis*, makes them a very important class of cyanobacterial toxins, at least in this country. In relation to *A. circinalis* in Australia, toxin profiles appear to be relatively constant and dominated by the C toxins. There is also some limited evidence that this cyanobacterium can produce neurotoxins and hepatotoxins, a phenomenon which has been reported overseas with *Anabaena flos-aquae*.

Cylindrospermopsin is a hepatotoxic alkaloid toxin that was first isolated from *C. raciborskii* and therefore named after it. It is a general cytotoxin (cell toxin) with relatively slow onset of symptoms resulting in kidney and liver failure. Results suggest that cylindrospermopsin may also act directly as a tumour initiator, which has implications for long-term exposure (Newcombe et al. 2010).

Lipopolysaccharides

Lipopolysaccharides (LPS) are an integral component of the cell wall of all cyanobacteria (as well as other types of bacteria), and help to determine and maintain the size and shape of the cell. As LPS are always present in cyanobacteria it would appear to make LPS a potential issue of concern for exposure in recreational situations, relative to the other known toxins. These compounds have been shown to produce irritant and allergenic responses in human and animal tissues. They are pyrogenic (fever-causing agents) and toxic. An outbreak of gastroenteritis is suspected to have been caused by cyanobacterial LPS. Interestingly, cyanobacterial LPS are considerably less potent than LPS from some other types of bacteria such as *Salmonella* (Newcombe et al. 2010).

No confirmed reports of human illness have been found. However, Van Buynder (2001) reported anecdotal evidence that acute affects were observed in a bloom in the Gippsland Lakes after eating large quantities of prawns. Mulvenna et al. (2012) report there have been twelve cyanobacterial blooms in Gippsland since 1985. All three-common bloom-forming cyanobacteria in the Gippsland lakes are toxic species.

In order to provide advice and to define acceptable levels of cyanobacterial toxins in seafood in Victoria, Australia, the Victorian Department of Health convened a scientific advisory group to carry out a risk assessment regarding commercial and recreational seafood safety in the Gippsland Lakes. The seafood of concern was fish, prawns and mussels harvested from the lakes. The identified toxins for the risk assessment were microcystins, nodularin, saxitoxins and cylindrospermopsin, all of which have been found in Australian aquatic environments and are distributed worldwide.

A report of the scientific advisory group's findings has been published (Mulvenna, 2012). The health guidelines from the report are shown in Table 28. In November 2011, the NSW State Algal Advisory Group (a whole-of-government group that responds to algal issues in NSW (see Appendix 1) endorsed the recommendations for use in the event of cyanobacterial blooms NSW.

Table 28. Health guideline values for cyanobacterial toxins in seafood (based on consumption by 2-16 year age group)

Toxin	Health guideline value (µg/kg of whole organism sample)		
	Fish	Prawns	Mussels or Molluscs
Cylindrospermopsin and deoxycylindrospermopsin	18	24	39
Microcystin-LR or equivalent toxins, including Nodularin	24	32	51
Saxitoxins	800	800	800

The Gippsland Lakes experienced a *Nodularia spumigena* bloom from December 2011 to May 2012. Seafood samples were tested for nodularin and the results compared to the health guideline value. The results are available online (VicHealth, 2012) and an extract is included in Appendix 2. Table 29 is a summary of those results.

The results are consistent with previous observations, with toxin levels highest in molluscs followed by prawns and whole fish. Toxin was not detected in fish that had been gutted and gilled. Consumption of fish offal occurs in some communities and the sale of whole fish harvested from a bloom introduces an element of risk.

Prawns collected from oceanic waters (outside of a lake's entrance) contain levels of toxin comparable to those collected in the lake. Fishers were advised not to catch prawns in the lake or from Victorian oceanic waters from Wilson Promontory to the NSW border.

Table 29. Summary of nodularin toxin results of testing in seafood during Gippsland Lakes bloom 2011/12

Sample	Nodularin toxin µg/kg		
	Average[1]	Median[1]	Maximum
Black bream – whole	42.2	31	203
Black bream – gutted and gilled			<16
Black mussels	186.6	139.5	740
Prawns collected within the lakes	108.4	88	299
Prawns collected outside of Lakes Entrance	105.1	103	270

[1] Average and median values of samples where nodularin was detected.

Prawns are a migratory species and some species of Victorian prawns will migrate to the commercial prawn harvest areas in NSW (Montgomery et al. 2010). The risk to consumers of NSW caught prawns was thought to be low because the oceanic prawn trawl harvest areas are north of Newcastle, which is towards the upper limit of migration for Victorian king prawns, and oceanic king prawns are a mixed population that originates from a wide range of estuaries.

NSW also has cyanobacterial blooms. Parts of the Hawkesbury–Nepean river system consistently have moderate levels of cyanobacteria, and blooms are often reported in late summer or autumn. The Murray River experienced extensive blooms, impacting approximately 1000 km of the river, in 2010 and 2011. Blooms occurred in the Myall Lakes in 1999 and 2012. Blooms are reported on the NSW Office of Water (2016) website.

The response to algal and cyanobacterial blooms in NSW is coordinated by a network of Regional Algal Coordinating Committees (RACCs). The committees include representatives of state and local governments, water utilities, community/tourism bodies and, where appropriate, federal and interstate governments. Each RACC maintains a contingency plan which sets out appropriate responses to alerts.

One key task of the RACCs is to keep their local communities informed of hazards arising from blooms. This is particularly important during 'red alerts' which are described on the NSW Office of Water (2012) website as:

'This alert level represents 'bloom' conditions. The water will appear green and may have strong, musty or organically polluted odours. Blue-green algae may be visible as clumps or as scums. The 'blooms' should be considered to be toxic to humans and animals, and the water should not be used for potable water supply (without prior treatment), stock watering or for recreation'.

Media releases issued during red alerts include advice for recreational fishers that freshwater mussels and crayfish from areas affected by the bloom should not be eaten and fish should be gutted and thoroughly washed prior to cooking. Issues with commercial fisheries have usually been handled cooperatively between the Department of Primary Industries (DPI), the Food Authority and the fishing industry.

During previous red alerts in the brackish prawn harvest areas of the Hawkesbury River, fishers have agreed to divert the catch to bait. When the 2012 Myall Lakes bloom was first recognised, higher value fish were gutted and gilled prior to sale and mullet was diverted to bait. These actions were recommended by the Food Authority and endorsed by seafood marketers and representatives of professional fishers.

As the Myall Lakes bloom was widespread and cyanobacterial scums were present, a regulatory closure of recreational and commercial fishing was imposed by DPI until the toxicity of the bloom could be determined. The closure was supported by industry because it protected both public health and the reputation of seafood. The fishery reopened promptly when toxin was not detected.

NSW has experienced several extensive potentially toxic cyanobacterial blooms in freshwater and brackish areas. These have resulted in a range of food safety interventions in the affected areas, including:

- Advising recreational fishers to gut, gill and wash fish prior to cooking
- Advising recreational fishers not to collect yabbies or freshwater mussels
- Industry voluntarily diverting commercially harvested seafood to bait
- Industry voluntarily adopting gut and gill requirements for fish prior to sale
- Government mandating closure of areas to recreational and commercial harvest of seafood.

As the result of toxic cyanobacterial blooms in Gippsland Lakes, the Victorian Department of Health developed a health risk assessment for cyanobacterial toxins in seafood (Vic Health, 2011). Recently, a risk assessment of phytoplankton and biotoxins in shellfish was completed by the Food Authority (unpublished).

Overall the risk to seafood consumers from cyanobacterial toxins is low. However, there is a hazard and management activities ranging from issuing advisory information through to recreational and commercial fishing closures is warranted during cyanobacterial blooms.

Pinnatoxins

In 2007 a batch of Australian shellfish submitted for biotoxin testing by mouse bioassay demonstrated toxicity. Subsequent studies isolated and determined the structure of several pinnatoxins associated with the incident (Selwood et al. 2010).

Pinnatoxins were discussed at the International Conference of Molluscan Shellfish Safety in 2011. The prevailing view at the time was that there is significant evidence that pinnatoxins do not cause acute illness in humans (A. Zammit, *pers comm* 17 May 2012). Internationally, the issue of human toxicity remains under review.

3.3.2.3 Ciguatera poisoning

Ciguatera is a form of human poisoning caused by the consumption of subtropical and tropical marine finfish which have accumulated naturally-occurring toxins through their diet. In the US, ciguatera intoxication is one of the two most common sources of foodborne illness associated with finfish. Human populations of tropical and subtropical marine regions have a much higher incidence of ciguatera intoxication.

A relatively high incidence of ciguatera poisoning has been reported in Queensland. Only a small volume of reef fish from Queensland and other problem areas is sold in NSW. There have been 5 documented outbreaks in NSW since 2014 and 24 individuals affected. These outbreaks were related to Spanish mackerel consumption (Harmful Algal News, 2016). The illness has only recently become known to the general medical community and there is a concern that the incidence is largely under-reported because of the general non-fatal nature and short duration.

The ciguatoxins are lipid-soluble toxins that are relatively inert molecules and remain toxic after cooking and exposure to mild acidic and basic conditions. The minimum toxic dose is estimated to be about 1 ng/kg body weight. In one incident, 6 US soldiers became ill after eating fish containing approximately 20 ng ciguatoxin/g flesh.

3.3.2.4 Scombroid poisoning

Scombroid poisoning (also known as histamine poisoning) is associated with the ingestion of food that contains high concentrations of histamine and possibly other vasoactive amines and compounds. Histamine is the physiological amine involved in allergic reactions and is the main toxin involved in scombroid fish poisoning. A “missing factor” might be required to produce illness.

Due to uncertainty about its aetiology, it is difficult to determine the susceptible population for scombroid poisoning. A wide range of histamine concentrations in implicated food, particularly the increasing number of incidents associated with low histamine concentrations, suggests that some individuals are more susceptible to the toxin than others. Symptoms can be severe for elderly people and those taking medications such as isoniazid, a potent histamine inhibitor.

3.3.2.5 Mercury in seafood

The commentary provided by Ross and Sanderson (2000) on mercury in NSW seafood has not lost currency:

“Based on acute mercury food poisonings in Japan and Iraq, it is known that high levels of dietary mercury may cause measurable deficits in mental and physical development of young children exposed during gestation. Low levels of mercury are naturally present in the environment and in all foods. Inorganic mercury is poorly absorbed via the diet, however, in aquatic environments bacteria can convert inorganic mercury to methylmercury (MeHg) which is readily absorbed by the human body. MeHg is bio-accumulated in aquatic food chains, so all fish contain small amounts of mercury in their muscle tissue. Predatory fish or mammals such as whales at the top of the food web have the highest amounts. Mercury levels in most commercially harvested oceanic fish in the US and Australia are <0.5 mg/kg MeHg, but some large predators such as sharks, marlin and swordfish may have higher levels. Numerous studies have shown that nearly all the human exposure to MeHg occurs via seafood (predominantly finfish) consumption. Therefore, individuals who regularly consume large amounts of fish (particularly those fish with high mercury levels) could be exposed to dangerous levels of mercury”.

Corbett and Poon (2008) reported on cases in NSW where elevated mercury levels were found in three infants, who had eaten fish congee (rice and fish porridge) as a weaning food and ate fish regularly as toddlers. The parents had sought medical advice because of the children displaying either developmental delay or neurological symptoms. Fish congee is a common weaning food in coastal regions of southern China and South-East Asia. The authors recommended that multilingual information about fish and mercury be made available to pregnant and breastfeeding women, especially groups who are likely to be frequent consumers of fish and who use fish in weaning and infant foods.

3.4 Risk characterisation

3.4.1 General population

NSW foodborne illness outbreaks data for 2005-2015 (Table 30) showed 308 people affected and 45 hospitalisations linked to consumption of seafood. Further breakdown of the outbreak data revealed 65.11%, 23.25% and 11.63% outbreaks were linked to finfish, shellfish and crustaceans, respectively.

Most recent food poisoning outbreaks related to consumption of seafood that occurred in NSW were related to ciguatera poisoning. A brief description of recent seafood outbreaks is below:

- In February 2015, seven cases of scrombroid poisoning were identified. All victims had onset of symptoms (red face, headache, tingling, sweating, vomiting and palpitations) within 10-15 minutes after consuming a tuna salad from the same local food outlet. A trade recall of the canned tuna product was implicated as results of NSWFA investigation. (OzFoodNet, First Quarter Summary NSW – June 2015)
- In April 2015, four people were affected by ciguatera poisoning by eating Spanish mackerel in a private function and one was hospitalised. (OzFoodNet, Second Quarter Summary NSW – September 2015)
- In June 2015, an outbreak of *Salmonella* Agona from tuna sushi roll affected hree people with no hospitalisations recorded. Inspection of the incident revealed that samples from one of the sushi outlets were positive for *S.* Agona. Further investigation and analysis suggested that the source of the *S.* Agona was chicken meat. Investigation concluded chicken used by the two sushi venues, at the time of the outbreak, came from a common source and cross-contamination of the *Salmonella* from raw chicken likely occurred in the businesses. (OzFoodNet, Second Quarter Summary NSW – September 2015)
- In September 2015, three cases of ciguatera poisoning were reported due to the consumption of red throat emperor fish. The victims were members of a single family who ate the fish that was purchased whole from a local fish market, cleaned and eviscerated in-store, and cooked and consumed on the same day. The fish was caught off a regularly fished seamount off the Queensland coast. The husband experienced the onset of symptoms within a few hours of eating the head of the fish. His condition progressively worsened during the week and he ended up in a hospital emergency department for treatment. The wife and a child also developed milder symptoms after eating a small portion of the fish. (NSW Government, Communicable Diseases Weekly Report 21-27 September 2015)
- In 2016, the Food Authority received advice on two incidents of ciguatera poisoning affecting three people after consuming a Spanish mackerel caught off the coast of Crowdy Head and one person who consumed Spanish mackerel caught off the coast at Crescent Head in March and April, respectively. In both cases, the fish consumed were caught by recreational fishermen. In response to these incidents the Food Authority advised fishers to avoid eating Spanish mackerel above 10 kg, as advised by NSW industry experts. Consumption of Spanish mackerel poses an increased risk of ciguatera poisoning. (http://www.foodauthority.nsw.gov.au/news/newsandmedia/departmental/2016-04-11-ciguatera-advice-to-fishers).

Table 30. Summary of NSW foodborne illness outbreaks (2005-2015) attributed to seafood

	Hazard	Outbreaks	Cases	Hospitalisations	Deaths
Seafood total	Ciguatoxin	4	21	14	0
	Scombroid	11	35	19	0
	Salmonella non-typhi[1]	9	41	9	0
	Norovirus	3	22	0	0
	Hepatitis A	0	0	0	0
	Others – bacterial	2	35	2	0
	Unknown	14	154	1	0
	Total	43	308	45	0
Finfish	Ciguatoxin	4	21	14	0
	Scombroid	11	35	19	0
	Salmonella non-typhi[1]	8	37	7	0
	Norovirus	0	0	0	0
	Hepatitis A	0	0	0	0
	Others -bacterial	2	35	2	0
	Unknown	3	10	1	0
	Sub-total	28	138	43	0
Shellfish	Ciguatoxin	0	0	0	0
	Scombroid	0	0	0	0
	Salmonella non-typhi[1]	0	0	0	0
	Norovirus	3	22	0	0
	Hepatitis A	0	0	0	0
	Others – bacterial	0	0	0	0
	Unknown	7	43	0	0
	Sub-total	10	65	0	0
Crustacean total	Ciguatoxin	0	0	0	0

	Hazard	Outbreaks	Cases	Hospitalisations	Deaths
	Scombroid	0	0	0	0
	Salmonella non-typhi[1]	1	4	2	0
	Norovirus	0	0	0	0
	Hepatitis A	0	0	0	0
	Others – bacterial	0	0	0	0
	Unknown	4	101	0	0
	Sub-total	5	105	2	0

[1] Seafood outbreaks associated with *Salmonella* were due to cross-contamination from egg or egg was used as an ingredient.

3.4.1.1 Risks of wild catch consumption

***L. monocytogenes* in RTE smoked fish products**

Based on models developed by Ross and Sanderson (2000), it is estimated that 6-7 cases of listeriosis in NSW per annum are attributable to smoked salmon. This estimate is about the same order of magnitude as the overall level of incidence observed from all potential avenues of exposure. The estimate was noted to be conservative because Australian regulations are tighter than those countries on which the models were based. Their revised estimate was, at most, a few cases of listeriosis from smoked vacuum-packed seafood per annum in NSW. The outcome of the FDA/USDA (2003) risk assessment for *L. monocytogenes* predicted cases of listeriosis from RTE seafood products to occur very rarely (Table 31). However, the risk per serving for cooked RTE crustaceans was considered high.

Ross and Sanderson (2000) then estimated the likely effect of a single, high contamination event. Depending on the assumptions used for different scenarios, a single batch of contaminated product was predicted to impact <1, about 20 or 65 immunocompromised consumers.

FSANZ found that contamination of cold smoked products with *L. monocytogenes* at levels representing a health risk to the general population is considered ‘unlikely’. This rose to ‘likely’ where there is insufficient management of risk through the food chain and for susceptible sub-populations. This rises further to ‘very likely’ when both conditions apply.

Other than scrupulous factory hygiene, there is no critical control point (CCP) available to prevent contamination of RTE cold smoked seafood products. Hot smoking can reduce the levels of *L. monocytogenes* on the product, but post-processing contamination can occur. It appears that some factories can achieve very low levels of contamination relatively consistently, but others cannot and rapidly become recolonised.

Table 31. Risk ranking for seafood products contaminated with *L. monocytogenes*

Plant product	Risk ranking (per serve)	Predicted cases of listeriosis per serve (in Australia)[5]	Risk ranking (per annum)	Predicted annual number of listeriosis cases (in Australia)[6]
Cooked RTE crustaceans	High	5.1×10^{-9}	Moderate	0.2
Smoked seafood	High	6.2×10^{-9}	Moderate	0.1
Raw seafood	Low	2.0×10^{-11}	Low	0
Preserved fish	Low	2.3×10^{-11}	Low	0

adapted from FDA/USDA (2003)

Cl. botulinum in vacuum-packed RTE fish products

On the basis of the low incidence of spores in products likely to be available in the Australian market and, in particular, the typical salt levels in these products, type E botulism risk from these products is considered to be negligible. Product shelf life also mitigates against the risk of sufficient growth of *Cl. botulinum* – potentially able to reach toxic doses. Ross and Sanderson (2000) note that other products (including those with the gut intact) and products from other regions (where *Cl. botulinum* spores could be more frequent) may represent a greater risk.

FSANZ (2005a) ascribes a medium relative risk rating for *Cl. botulinum* in smoked fish products. This reflects the balance between severity (severe) and likelihood (unlikely).

Ciguatera poisoning

Ciguatoxins are responsible for many outbreaks of foodborne illnesses due to fish consumption in Australia. Queensland and NSW account for the majority of the outbreaks, reflecting both the linkage of the illness with fish caught near tropical reefs in Queensland and the role of Sydney as the hub for marketing seafood on the east coast of Australia. Several fish species were involved, predominantly coral trout, queen fish, Spanish mackerel and cod species. As mentioned, 24 individuals have been affected by five outbreaks relating to Spanish mackerel since 2014 (Harmful Algal News, 2016).

FSANZ (2005a) rates the relative risk as medium for tropical fish species (larger members of particular species from certain fishing areas).

Scombroid poisoning

If fish die before landing, or are subject to time/temperature abuse after landing during transport, processing, storage or display, this will potentially allow for the formation of histamine. Some fish species that have high levels of histidine are more likely to accumulate high concentrations of histamine under conditions of temperature abuse, but many non-scombroid species have also been involved in outbreaks of histamine fish poisoning. Data from testing fish samples in the retail environment, and results from testing imported fish products, indicate a low level of

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[5] The risk per serving is inherent to the particular food category, and is therefore assumed to be the same in Australia as that calculated for the USA (FDA/USDA, 2003). This is based on the assumption that consumption patterns for these foods are identical in Australia and the USA

[6] The risk per annum has been adapted from USA population data contained in the FDA/USDA (2003) risk assessment of 260 million and extrapolated to Australian population data of approximately 21.6 million (ABS, 2009) by dividing by a factor of 12

histamine in whole fish and fish fillets available in Australia. However, epidemiological data shows a significant number of outbreaks in commercial and restaurant settings, indicating potential problems in the cold chain and resultant time/temperature abuse. Tuna, blue grenadier and mahi mahi have been identified as species involved in these outbreaks.

FSANZ allocated a relative risk rating of low, due to a moderate severity of disease and the probability of occurring as ‘likely’ (FSANZ, 2005a).

Viral contamination of shellfish

There is very little information available about levels of enteric viruses in shellfish on which to base a risk characterisation. Some of the uncertainties in assessing the risk are the levels of the viruses (HAV and Norovirus) in contaminated shellfish, the frequency of shellfish contamination, and the rate of loss of infectivity of the viruses in the environment and the shellfish (Ross and Sanderson, 2000). In 2014, South Australian Research Development Institute (SARDI) completed the first comprehensive survey for Norovirus and Hepatitis A virus in water taken from Australia's commercial oyster farms. In this survey 300 samples from Australian oyster production areas were tested and all samples were negative for Norovirus and Hepatitis A virus detection.

FSANZ concluded that the overall public health risk for bivalve molluscs is relatively high for products harvested in polluted waters and/or waters not subject to a monitoring scheme such as the Australian Shellfish Quality Assurance Program (ASQAP). The relative risk ranking is not significantly reduced when these products are lightly cooked or steamed prior to consumption (FSANZ, 2005a).

Where the implementation of shellfish safety management schemes such as ASQAP is considered, the relative risk ranking for oysters and other bivalves is reduced to medium. The Seafood Safety Scheme requires shellfish harvesters to comply with the harvest area management plans developed by the Food Authority. These plans are established to ensure compliance with ASQAP requirements.

Algal toxins in shellfish

Ross and Sanderson (2000) assessed the risk of algal biotoxins as low from commercial harvest areas and medium from recreational harvest areas. The difference was due to the algal monitoring and area management that occurs in commercial harvest areas.

FSANZ found the relative risk is medium for waters that are subject to pollution but the harvesting of shellfish is controlled under an effective management system. The risk rating is elevated to high if there is no effective management system in place (FSANZ, 2005a).

***V. parahaemolyticus* in molluscs and crustaceans**

Levels of *V. parahaemolyticus* in Australian seafood are like those found in other parts of the world. It has been estimated that a meal of raw shellfish would contain no more than 10^4 cfu KP positive cells, based on typical numbers of *V. parahaemolyticus* present in fish and shellfish and the low incidence of KP positive isolates in the marine environment. For an infectious dose to be reached, mishandling of food at temperatures allowing the growth of the bacterium would be required.

As *Vibrio* spp. are sensitive to heat, it is raw or inadequately cooked product that poses the greatest risk of vibriosis. However, several documented cases have involved post processing contamination. The rapid growth rate of the organism at ambient temperatures exacerbates the consequences of post-processing contamination.

Although pathogenic *Vibrio* spp. are often found in bivalve molluscs and on crustaceans, the incidence of illness is low. For healthy individuals, doses of organisms higher than those normally found on food are required. The risk of contamination is seasonal, corresponding to the increased levels of *Vibrio* spp. in growing areas as water temperatures rise. The risk of thermal abuse also increases during summer.

The FSANZ relative risk ranking for *V. parahaemolyticus* is low but *V. vulnificus* and *V. cholerae* are rated medium based on severity of illness. The ranking for *V. parahaemolyticus* might change if the pandemic O3:K6 strain naturalises in Australian waters.

Mercury in seafood

Ross and Sanderson (2000) approached a risk assessment for mercury in seafood by calculating the weight of fish required to equal the provisional tolerable weekly intake (PTWI) of methylmercury for consumers of varying body weights and various mercury levels. Their tables are reproduced in Table 32, except that the Joint FAO/WHO Expert Committee on Food Additives (JECFA) provisional tolerable weekly intake (PTWI) estimate has been reduced following a review (JECFA, 2004). Estimates in Table 32 are based on the JECFA PTWI and US EPA reference dose, for comparison. The table shows that for non-predatory fish (average mercury level 0.15 mg/kg - Ross and Sanderson 2000) significant consumption is required to exceed the PTWI. Average consumption figures quoted above equate to 200-300g of seafood per week. Consumers who predominantly consume predatory fish or those consuming above average levels of fish are at risk.

JECFA noted the existing PTWI of 1.6 µg/kg body weight was set in 2003 based on the most sensitive toxicological end-point (developmental neurotoxicity) in the most susceptible species (humans). However, life stages other than the embryo and foetus may be less sensitive to the adverse effects of methylmercury (JECFA, 2006).

Table 32. Seafood consumption required to reach reference doses for methylmercury

Mercury level mg/kg	**Body weight**							
	13 kg	40 kg	60 kg	70 kg	13 kg	40 kg	60 kg	70 kg
	Weekly consumption (g) required to reach JECFA PTWI of 1.6ug/kg body weight/week				Weekly consumption (g) required to reach to USEPA reference dose of 0.7ug/kg body weight/week			
0.15	146	449	674	786	63	196	295	344
0.5	44	135	202	236	19	59	88	103
1.0	22	67	101	118	10	29	44	52
1.5	15	45	67	79	6	20	29	34

adapted from Ross and Sanderson (2000); JECFA (2004)

In the case of adults, intakes of up to about two times higher than the existing PTWI of 1.6 µg/kg body weight would not pose any risk of neurotoxicity. Although in the case of women of childbearing age, the intake should not exceed the PTWI, to protect the embryo and foetus.

JECFA's data did not allow firm conclusions to be drawn regarding the sensitivity of infants and children compared to adults. While it is clear, they are not more sensitive than the embryo or foetus, they may be more sensitive than adults because significant development of the brain continues in infancy and childhood. The joint committee could not identify a level of intake higher than the existing PTWI that would not pose a risk of developmental neurotoxicity for infants and children (JECFA, 2006).

3.4.1.2 Risks of aquaculture seafood consumption

Microorganisms, associated with fish disease and hygiene, and environmental pollutants, are the major food safety hazards in aquaculture seafood. However, all risks related to the farming and handling of fish during catching, slaughter and processing for human consumption should be considered carefully. For instance, the safe production of farmed fish starts with fish feed. Therefore, feed products free from undesirable substances are essential to minimise the risks. Several reports suggest that feed is the main source of POPs (e.g. dioxins and BFRs) and metals (e.g. methylmercury) in farmed fish with a demonstrated correlation between their concentrations in farmed fish fillets and feed (EC, 2000; Berntssen et al., 2004; Karl et al., 2003; Lundebye et al. 2004). Risk assessments of fish consumption performed in the UK and the EU indicated that methylmercury, the PCDD/Fs and the dioxin-like PCBs are the principal contaminants of concern in aquaculture seafood (UKFSA, 2004). The Australian National Dioxins Program found that detected levels for dioxins and dioxin-like PCBs in farmed tuna were well below the known action levels set by overseas countries. This is an indirect indicator of the quality of fish feed used in Australia. However, it was recommended that the Australian tuna industry should carefully manage the feed sources with a view to reducing total dioxin (i.e. dioxin, furan and PCB) in fish (Australian Government Department of Agriculture, Fisheries and Forestry, 2004).

3.4.1.3 Risks of imported seafood consumption

FSANZ and the Australian Department of Agriculture coordinate the assessment of seafood safety risks for consumers and implement the management options for seafood imports into Australia. Limited information is available on the risk ranking of imported seafood commodities.

Risk of microbiological hazards in imported prawns

Sumner (2011) used “Risk Ranger” ranking tools to assess risk rating (predicted illnesses) of *V. cholerae*, *V. parahaemolyticus* and *Salmonella*. Table 33 summaries risk rating of different types of prawns imported into Australia. For prawns consumed raw, risk of illness due to *V. cholerae* was given a rating of 28 with 1.7 illnesses every decade. Risk rating of *V. parahaemolyticus* in imported cooked prawns was 37, with six illnesses predicted per annum. Cooked prawns were given risk rating of zero for *Salmonella* as the organism is not heat tolerant. For prawns consumed raw, risk of salmonellosis had a rating of 16 with 1.5 illnesses every century.

Table 33. Risk rating of microbiological hazards in prawns imported into Australia

Hazard	Product	Qualitative Assessment	Semi-quantitative Assessment	
			Risk Rating	Estimated Illnesses
V. cholerae	Raw prawns	Very low	28	1.7/decade
	Prawns cooked at the plant and eaten without further heat treatment	Very low	0	0
	Prawns cooked immediately before consumption	Very low	0	0
V. parahaemolyticus	Raw prawns	Very low	22	1.5/decade
	Prawns cooked at the plant and eaten without further heat treatment	Very low	0	0
	Prawns cooked immediately before consumption	Very low	0	0
Salmonella	Raw prawns	Very low	16	1.5/decade
	Prawns cooked at the plant and eaten without further heat treatment	Very low	0	0
	Prawns cooked immediately before consumption	Very low	0	0

adapted from Sumner (2011)

3.4.2 Vulnerable populations

Vulnerable populations are young children, pregnant women, elderly and immunocompromised individuals. Table 34 lists some of the risks for vulnerable populations due to seafood consumption.

Table 34. Major risks for vulnerable populations from seafood consumption

Risk	Health implications	People at risk	Sources
Mercury	Harm to an unborn baby or young child's developing nervous system	Pregnant women Young children	Shark, Swordfish, King Mackerel, Tilefish
Salmonella	Serious infection and even death	Pregnant women Young infants Older adults (>60 years)	Seafood dishes
L. monocytogenes	Premature labour, neonatal sepsis, or meningitis for pregnant women Higher risk of death in older adults	Pregnant women Older adults (>60 years)	RTE seafood

3.4.2.1. Mercury

Mercury is a common natural chemical and pollutant in the environment. It can be released into the air through industrial pollution and ends up in streams and oceans. In the water, it is converted into a harmful form of mercury (i.e. methylmercury) that can cause health implications to an unborn baby or young child. Fish in the contaminated water absorb methylmercury through feeding and it then builds up inside them. A majority of fish (and shellfish) contain traces of methylmercury. However, larger fish (swordfish, shark, king mackerel and tilefish) pose the greatest risk. Most fish in Australian waters have very low mercury levels (NSW Food Authority, 2016).

So, what is the risk? Regular consumption of fish that are high in methylmercury can lead to an accumulation in the blood stream over time. Even though the body excretes the methylmercury naturally, it may take more than a year for the levels to drop significantly. High levels of methylmercury can harm an unborn baby or young child's developing nervous system. This is the reason why women planning a pregnancy should not consume types of fish that are likely to contain an accumulated level of methylmercury. Young children should also avoid these fish.

The Food Authority has published advice for pregnant and breastfeeding women, and children up to 6 years, to help reduce their exposure to the harmful effects of mercury when eating fish (NSW Food Authority, 2016).

The Food Authority recommends pregnant and breastfeeding women, and children up to 6 years, have 1 serve per week (150 g for women and 75 g for children) of catfish or orange roughy (deep sea perch), or 1 serve per fortnight of shark (flake) or billfish (swordfish, marlin). The Food Authority recommends 2-3 serves per week of fish that are lower in mercury (mackerel, silver warehou, herrings Atlantic salmon, canned salmon, canned tuna, prawns, lobsters and bugs).

Corbett and Poon (2008) reported elevated mercury levels in three children who were fed fish congee, rice and fish porridge as a weaning food. All were single children of Chinese families living in Sydney and ate fish regularly as toddlers. The medical diagnosis found symptoms of mercury poisoning in these children:

- A 2-year-old boy had aggressive behaviour problems for the past 6 months. He was fed fish at least 5 times a week. Test results showed his blood mercury level was 158 nmol/L (normal range [NR], < 50 nmol/L), a random urine mercury/creatinine (Hg/Cr) ratio was 9 nmol/mmol (NR, <6 nmol/mmol*), and his hair mercury level was 1.42 mg% (NR, < 0.18 mg%). Both parents also had elevated mercury levels in their blood.
- A boy aged 2 years and 10 months had delayed speech and some autistic features. He was fed fish (barramundi, sea perch, salmon and rock cod) up to eight times a week. His test results showed a high blood mercury level (350 nmol/L) and urine Hg/Cr ratio (14 nmol/mmol) (NR, < 10 nmol/mmol*). The mother, who ate fish regularly, also had high levels of mercury in her blood.
- A 15-month-old boy had consumed fish 4-5 times a week since he was 8 months old and had delayed development. Test results showed that he had a blood mercury level of 143 nmol/L.

3.4.2.2. Salmonella

Older adults (>60 years), pregnant women and young children have a much greater risk of hospitalisation and death from salmonellosis. Certain seafood and egg-based meals can put these vulnerable populations at risk of acquiring a *Salmonella* infection.

3.4.2.3. L. monocytogenes

The hormonal changes associated with pregnancy make pregnant women and newborn babies more susceptible to foodborne pathogens such as *L. monocytogenes*. A pregnant woman is about 13 times more likely than the general population to acquire listeriosis. Listeriosis can result in premature labour, neonatal sepsis or meningitis. The risk of listeriosis in people aged 65 years or older is higher than any other age group (CDC, 2012), and they have a higher mortality rate (up to 60%). Seafood, especially RTE, has a greater risk of carrying *Listeria* compared to other types of products. RTE chilled seafood, such as raw sushi, sashimi and oysters or pre-cooked prawns and smoked salmon can be a risk for pregnant women because of *Listeria*.

Further details can be found in the Food Authority's Vulnerable Population Risk Assessment Scheme online: http://www.foodauthority.nsw.gov.au/industry/vulnerable-persons

3.4.3 Overall risk analysis

A risk ranking approach based on the elements of risk, and the likelihood and severity of the adverse health effects, is employed. This method is defined by Codex and previously adapted by FSANZ (2006). Table 35 shows a likelihood and severity matrix. Their description is given in Table 36. A severity ranking scheme of different hazards adapted by FSANZ (2006) is used in this risk analysis (see Appendix 3). Relative risk ranking estimates of seafood in NSW with respect to industry sectors and product categories is shown in Table 37 and Table 38, respectively.

Table 35. A likelihood/severity matrix for ranking food safety risks in seafood

		Likelihood of illness		
		Unlikely	Likely	Very likely
Severity of illness	Moderate	Low	Low	Medium
	Serious	Low	Medium	High
	Severe	Medium	High	High

adapted from FSANZ 2006

Table 36. Description of severity and likelihood of adverse health effects

Severity	Likelihood
Moderate Not usually life threatening No sequelae Normally short duration Symptoms are self-limiting Can include severe discomfort	Unlikely Little or no evidence that the hazard has caused foodborne illness in Australia or overseas Limited consumption of the commodity by the general population, or consumption primarily by selected sub-populations, and/or Limited or no data demonstrating presence of the hazard in seafood.
Serious Incapacitating but not life threatening Sequelae infrequent Moderate duration	Likely Limited evidence that the hazard has caused foodborne illness in Australia or overseas Eaten periodically Availability of data demonstrating the presence of the hazard in seafood, and/or Availability of evidence from other data sources, for example, Imported Foods Inspection

Severity	Likelihood
	Program, FSANZ recall database, environmental surveillance, etc.
Severe Life-threatening or Substantial chronic sequelae or Long duration	Very likely Evidence that the hazard is associated with reported incidents of Foodborne illness in Australia Widely and/or frequently eaten by the general population Availability of data demonstrating the presence of the hazard in Australian seafood, and/or Availability of significant evidence from other data sources, for example, Imported Foods Inspection Program, FSANZ recall database.

adapted from FSANZ 2006

Table 37. Relative risk ranking estimates for wild catch, aquaculture and imported seafood in NSW

Commodity type	Hazard	Severity	Likelihood of adverse health effects	Relative risk ranking[4]	Measure of exposure			Exposure risk[10]	Overall risk ranking[11]
					Outbreaks[5]	Recalls[6]	Failed[7]		
Wild catch	Scombroid[1]	Moderate	Likely	Low	9	1		High	Medium
	Ciguatoxin[2]/ Tropical species	Serious	Likely	Medium	2	5		Low	Medium
	Salmonella (non-typhoid)	Serious	Unlikely	Low	7	0		High	Medium
	L. monocytogenes[3]	Serious	Unlikely	Low	0	6		High	Low
	Shigella spp.	Serious	Unlikely	Low	0	0		Low	Low
	Yersinia spp.	Serious	Unlikely	Low	0	0		Low	Low
	Campylobacter spp.	Serious	Unlikely	Low	0	0		Low	Low
	Staph. aureus	Moderate	Unlikely	Low	0	0		Low	Low
	V. parahaemolyticus	Moderate	Unlikely	Low	0	0		Low	Low
	V. cholerae	Moderate	Unlikely	Low	0	1		Low	Low
	E. coli (non-EHEC)	Moderate	Unlikely	Low	0	0		Low	Low
	Noroviruses	Moderate	Unlikely	Low	3	0		High	Medium
	Hepatitis A virus[3]	Serious	Unlikely	Low	0	0		Low	Low
	Parasites[8]	Serious	Unlikely	Low	0	0		Low	Low
	Mercury[3]	Serious	Unlikely	Low	0	0		Low	Low
Aquaculture	Environmental pollutants[9]	Severe	Unlikely	Medium	0	0		Low	Medium
	V. parahaemolyticus	Moderate	Unlikely	Low	0	0		Low	Low

Commodity type	Hazard	Severity	Likelihood of adverse health effects	Relative risk ranking[4]	Measure of exposure			Exposure risk[10]	Overall risk ranking[11]
					Outbreaks[5]	Recalls[6]	Failed[7]		
	E. coli (non-EHEC)	Moderate	Unlikely	Low	0	0		Low	Low
	Staph. aureus	Moderate	Unlikely	Low	0	0		Low	Low
	Salmonella (non-typhoid)	Serious	Unlikely	Low	0	0		Low	Low
	Campylobacter spp.	Serious	Unlikely	Low	0	0		Low	Low
	Shigella spp.	Serious	Unlikely	Low	0	0		Low	Low
	Yersinia spp.	Serious	Unlikely	Low	0	0		Low	Low
	L. monocytogenes[3]	Serious	Unlikely	Low	0	0		Low	Low
	Noroviruses	Moderate	Likely	Low	0	0		Low	Low
	Hepatitis A virus[3]	Serious	Unlikely	Low	0	0		Low	Low
	Parasites[8]	Serious	Unlikely	Low	0	0		Low	Low
	Mercury[3]	Serious	Unlikely	Low	0	0		Low	Low
Imported seafood	Scombroid	Moderate	Likely	Low			20	High	Medium
	V. cholerae	Moderate	Likely	Low			3	Low	Low
	V. parahaemolyticus	Moderate	Unlikely	Low			0	Low	Low
	E. coli (non-EHEC)	Moderate	Unlikely	Low			3	Low	Low
	L. monocytogenes[3]	Moderate	Unlikely	Low			17	High	Medium
	Standard Plate count	Serious	Unlikely	Low			12	Low	Low
	Noroviruses	Serious	Unlikely	Low			0	Low	Low
	Hepatitis A virus[3]	Serious	Unlikely	Low			0	Low	Low
	Leuco-malachite green	Moderate	Unlikely	Low			3	Low	Low
	Enrofloxacin	Moderate	Unlikely	Low			9	Low	Low
	Ciprofloxacin	Moderate	Unlikely	Low			8	Low	Low
	Mercury[3]	Serious	Unlikely	Low			0	Low	Low

Table 38. Relative risk ranking estimates for fish, molluscs and crustaceans in NSW

Commodity type	Hazard	Severity	Likelihood of adverse health effects	Relative risk ranking[4]	Measure of exposure			Exposure risk[10]	Overall risk ranking[11]
					Outbreaks[5]	Recalls[6]	Failed[7]		
Fish and fish products	Scombroid[1]	Moderate	Likely	Low	9	1	20	High	Medium
	Ciguatoxin[2]/ Tropical species	Serious	Likely	Medium	2	0		Low	Medium
	Salmonella (non-typhoid)	Serious	Unlikely	Low	6	0		High	Medium
	L. monocytogenes[3]	Serious	Unlikely	Low	0	5	17	High	Medium
	Shigella spp.	Serious	Unlikely	Low	0	0		Low	Low
	Yersinia spp.	Serious	Unlikely	Low	0	0		Low	Low
	Campylobacter spp.	Serious	Unlikely	Low	0	0		Low	Low
	Staph. aureus	Moderate	Unlikely	Low	0	0		Low	Low
	V. parahaemolyticus	Moderate	Unlikely	Low	0	0		Low	Low
	E. coli (non-EHEC)	Moderate	Unlikely	Low	0	0		Low	Low
	Noroviruses	Moderate	Unlikely	Low	0	0		Low	Low
	Hepatitis A virus[3]	Serious	Unlikely	Low	0	0		Low	Low
	Parasites[8]	Serious	Unlikely	Low	0	0		Low	Low
	Mercury[3]	Serious	Unlikely	Low	0	0		Low	Low
Molluscs	Algal biotoxins	Severe	Unlikely	Medium	0	5		Low	Medium
	V. parahaemolyticus	Moderate	Unlikely	Low	0	0		Low	Low
	E. coli (non-EHEC)	Moderate	Unlikely	Low	0	0	3	Low	Low
	Staph. aureus	Moderate	Unlikely	Low	0	0		Low	Low
	Salmonella (non-typhoid)	Serious	Unlikely	Low	0	0		Low	Low
	Campylobacter spp.	Serious	Unlikely	Low	0	0		Low	Low
	Shigella spp.	Serious	Unlikely	Low	0	0		Low	Low
	Yersinia spp.	Serious	Unlikely	Low	0	0		Low	Low
	L. monocytogenes[3]	Serious	Unlikely	Low	0	1		Low	Low
	Noroviruses	Moderate	Likely	Low	3	0		High	Medium
	Hepatitis A virus[3]	Serious	Unlikely	Low	0	0		Low	Low
	Parasites[8]	Serious	Unlikely	Low	0	0		Low	Low
	Mercury[3]	Serious	Unlikely	Low	0	0		Low	Low

Commodity type	Hazard	Severity	Likelihood of adverse health effects	Relative risk ranking[4]	Measure of exposure			Exposure risk[10]	Overall risk ranking[11]
					Outbreaks[5]	Recalls[6]	Failed[7]		
Crustaceans	*V. parahaemolyticus*	Moderate	Likely	Low	0	1	0	Low	Low
	V. cholerae	Moderate	Likely	Low	0	0	3	Low	Low
	E. coli (non-EHEC)	Moderate	Unlikely	Low	0	0		Low	Low
	Staph. aureus	Moderate	Unlikely	Low	0	0		Low	Low
	Salmonella (non-typhoid)	Serious	Unlikely	Low	1	0		Low	Low
	Campylobacter spp.	Serious	Unlikely	Low	0	0		Low	Low
	Shigella spp.	Serious	Unlikely	Low	0	0		Low	Low
	Yersinia spp.	Serious	Unlikely	Low	0	0		Low	Low
	L. monocytogenes[3]	Serious	Unlikely	Low	0	0		Low	Low
	Noroviruses	Moderate	Unlikely	Low	0	0		Low	Low
	Hepatitis A virus[3]	Serious	Unlikely	Low	0	0		Low	Low
	Scombroid	Moderate	Unlikely	Low	0	0		Low	Low
	Mercury[3]	Serious	Unlikely	Low	0	0		Low	Low

Legends: for Tables 37 and 38

1. Tuna, mackerel, Maldives fish, blue grenadier and mahi mahi have been identified as species involved in outbreaks and contamination detection in imported fish.
2. Ciguatoxin is mainly found in larger members of species of tropical and sub-tropical finfish from certain fishing areas.
3. For certain vulnerable populations (pregnant women and young children) the relative risk ranking is medium (severe x unlikely). Mercury is a problem in large, long-living or predatory fish, such as swordfish, shark/flake and some tuna. These fish tend to accumulate higher levels of methylmercury than other species. The relative risk ranking is medium for the at-risk sub-population (the foetus) when the mother consumes mainly large, predatory or long-lived fish species.
4. Relative risk ranking is assigned according to FSANZ likelihood/severity matrix (see Table 35).
5. Foodborne outbreaks in NSW during 2005-2014 reported by OzFoodNet.
6. Seafood related recalls in NSW during 2005-2014 reported by FSANZ.
7. Average failed consignments of imported seafood products in 2014 and 2015 reported by the Department of Agriculture, Australia.
8. Parasites are a risk if seafood is served raw and undercooked.
9. Environmental and natural pollutants such methylmercury, the dioxins and the dioxin-like PCBs are the contaminants of most concern in aquaculture, based on the literature. Australian data on pollutants in seafood is very limited.

10. Exposure risk was considered low if total outbreaks were two or less in the last ten years, or recalls were five or less in the last ten years, or failed consignments in a calendar year were 15 or less.

11. Overall risk ranking based on relative risk ranking and exposure risk: low (low/low); medium (medium/low or medium/medium or low/high); high (high/low or high/high).

3.4.3.1 Finding of the risk analysis

- Scrombroid poisoning is a major risk associated with specific finfish species (tuna, mackerel, Maldive fish, blue grenadier and mahi mahi) sourced locally (wild catch) or imported from overseas. Histamine was implicated in nine outbreaks and one recall in NSW (2006-2014) as well as an average of 20 failing products at border inspections during last two years. The risk of scrombroid poisoning is ranked medium.
- In NSW during 2006-2014, two outbreaks of ciguatoxin poisoning and three outbreaks of Norovirus were associated with finfish and shellfish, respectively. The risks of both hazards were ranked medium due to the serious impact on health and the high exposure risk.
- Biotoxins (algal toxins) presence in shellfish caused five recalls in NSW (2006-2014) and no outbreak was reported. The risk of biotoxin is ranked as low (aquaculture products) to medium (wild catch) due to the severe nature of this hazard.
- *L. monocytogenes* contamination was the reason for six recalls in NSW (2006-2014) and an average of 17 failing products at border inspections during the last two years. There was no seafood linked to *L. monocytogenes* outbreaks reported in NSW during the past ten years. The risk of *L. monocytogenes* for vulnerable populations (pregnant women, young children and elderly people >65 years) and for imported products (smoked salmon) ranked as medium.
- *V. cholerae* was detected in an average of three failed imported prawns at border inspections during the last two years. There was one recall issued due to *V. parahaemolyticus* contamination in NSW. The risk of *Vibrio* spp. in imported crustacean is generally low.
- *Salmonella* infections caused seven outbreaks in NSW (2006-2014) primarily due to the consumption of seafood cooked with egg. The risk of *Salmonella* due to cross-contamination from egg is ranked medium. Management of *Salmonella* in seafood cooked with egg needs more coordinated approach to implement seafood and egg and egg products safety schemes.
- There were only three outbreaks of Norovirus associated with seafood and no recent record of a Hepatitis A outbreak related to seafood in NSW (2006-2014). Overall, the risk of viral infections due to seafood consumption remained low.
- Consumption of large predatory fish (swordfish, shark, king mackerel and tilefish) by pregnant women and young children may put them at risk of mercury poisoning. The risk of mercury poisoning for these vulnerable populations is ranked as medium.
- International risk assessments indicated that methylmercury, the dioxins and the dioxin-like PCBs are the contaminants of most concern in aquaculture seafood. Limited data is available on the prevalence of hazards in aquaculture products in Australia. It was difficult to assign risk ranking to aquaculture products. However, reports from international surveys and assessments suggest environmental pollutants could be the major concern in the aquaculture products. However, the levels of these contaminants in Australian aquaculture products were found much lower than other countries as reported in the National Dioxin Programme.

- The risk of parasites from seafood remains low in Australia as well as NSW. However, an increase in the consumption of raw and undercooked seafood (e.g. sushi and sashimi) will increase the risk in the future, in particular due to the use of low value marine fish or freshwater fish.

3.4.3.2 Data limitations

It is acknowledged here that availability of limited data from some sources and insufficient data on the identification and prevalence of hazards in seafood consumed in NSW were the major difficulties faced during the risk assessment process. For example, it was hard to find information on the risks of imported seafood to NSW consumers. Data and studies on the prevalence of hazards in aquaculture products (domestic as well as imported) were extremely limited.

The risk assessment conducted in this report is qualitative in nature and based on the information available on foodborne illnesses, outbreaks, recalls, hazard identification and prevalence as well as risk assessment reports from multiple sources.

4. Seafood safety management in NSW

4.1 The Food Authority

Role: Managing the overall risks through the Seafood Safety Scheme

The Food Authority's seafood safety scheme manages the production, harvest, storage, transport, sale and consumption of fish and shellfish, to ensure the supply of safe products in NSW. The following programs and monitoring schemes are implemented across the industry:

- NSW Shellfish Program
- NSW Marine Biotoxin Management Plan (MBMP)
- Audit program for licenced seafood businesses.

4.2 Sydney Fish Market

Sydney Fish Market (SFM) is a major seafood supply chain in NSW. It is the largest market of its kind in the Southern Hemisphere and the third largest seafood market (in terms of variety) in the world. On average, 50 tonnes of fresh seafood are traded through SFM every day. SFM prides itself as being Australia's seafood centre of excellence and strives for the highest levels of quality and customer satisfaction. SFM has maintained a Quality Assurance Program and HACCP system since 1998 to ensure the seafood for sale is:

- safe to eat
- accurately labelled
- satisfies the customer.

4.3 The Department of Agriculture and Water Resources

Role: Managing the safety of seafood imported into Australia

DAWR manages the compliance of food imported into Australia to meet Australian food standards and public health and safety requirements. All imported food into Australia is subject to compliance control through three legislative tiers – the *Imported Food Control Act* (1992), (Australian Government Attorney-General's Department, Commonwealth of Australia Law, 2009); the Imported Food Control Regulations (1993); and the Imported Food Control Order (2001).

DAWR uses several options for managing the safety of imported food into Australia. These are:

- Imported Foods Inspection Scheme (IFIS)
- Foreign government certificates
- Quality assurance arrangements
- Compliance arrangements.

The Imported Food Control Order (2001) specifies high risk food under the IFIS of the Act must be inspected, or inspected and analysed. The Order is a list of high risk food categories. Some examples are below:

- Crustaceans, including prawns that are cooked (chilled or frozen) but not canned

- Specific kinds of fish (e.g. tuna, including canned tuna (dried) and tuna products, mackerel and ready-to-eat finfish),
- Marinara mix (chilled or frozen), and
- Molluscs bivalve (cooked or uncooked).

4.4 Food Standard Australia New Zealand

Role: Develop all domestic food standards based on scientific/technical criteria consistent with Ministerial Council policy and advise DAWR on the risk categorisation of food for the purpose of inspection under the IFIS.

The Code has several standards and requirements that apply to domestic or imported seafood:

The relevant sections of the Code pertaining to seafood are:

- Standard 4.2.1. – *Primary Production and Processing Standard for Seafood* (PPPS Seafood)
- Standard 1.3.1 – *Food Additives (specific to sulphur dioxide levels)*
- Standard 1.4.1 – *Contaminants and Natural Toxicants*
- Standard 1.6.1 – *Microbiological Limits for Food*
- Standard 2.2.3 – *Fish and Fish Products* (compositional standard specific to histamine levels).

The following requirements of the Code apply to seafood:

- Limits for residues present in seafood from the use of agricultural and veterinary chemicals
- Maximum levels for certain potential chemical contaminants as per the contaminant standard
- Microbiological limits for known human pathogens and other microorganisms that are indicators for human pathogens
- Permissions to use certain additives in seafood as per the food additives standard (maximum levels are prescribed for some permissions)
- Labelling requirements that apply to all foods
- Primary production and processing standard for seafood which applies to seafood businesses, including seafood importers and seafood handlers.

FSANZ has responsibility for assessing food safety risks to consumers and prioritising seafood commodities for hazard combinations, for control and/or testing of any future food import regimen using a risk-based approach.

FSANZ ensures the criteria and limits specified for imported foods are consistent with those developed for domestic food.

4.5 Seafood safety management at retail level

The Scheme does not cover food safety management in the retail sector of the seafood industry in NSW. It is managed under the Code for retail food products. Part 3.2 of the Code specifies the food safety requirements for handling and selling food products through different standards:

- Standard 3.2.1 – *Food safety programs*
- Standard 3.2.2 – *Food safety practices and general requirements*
- Standard 3.2.3 – *Food premises and equipment.*

The seafood retail sector is primarily managed by Local Government Environmental Health Officers to ensure businesses comply with hygiene and good food handling practices under section 37 of the NSW *Food Act 2003*.

The Food Authority has developed guidelines to help seafood retailers meet the food safety and labelling requirements outlined in the Code, which is law in Australia. (http://www.foodauthority.nsw.gov.au/_Documents/retail/guideline_seafood_retailers.pdf)

SFM has also produced *Seafood Handling Guidelines*, which provide a benchmark and specifications for the grading and safe handling of seafood. SFM has distributed this publication to its employees and suppliers.

5. Conclusion

The Seafood Risk Assessment Scheme (2016) identified scrombroid poisoning, algal biotoxins and *Vibrio* spp. as the major areas of concern for fish, shellfish and crustaceans in NSW, respectively. When the risks of different seafood supply chains were assessed, these were identified as the key hazards; scrombroid poisoning, ciguatoxin/marine biotoxins and scrombroid poisoning associated with wild catch; microbiological contamination *(L. monocytogenes, Vibrio* spp.) and histamine detection in imported seafood; and potential environmental pollutants in aquaculture products,

The management of food safety hazards associated with seafood, such as minimising the risk of scrombroid poisoning, requires general food safety control measures, e.g. hygiene and sanitation, and the application of appropriate storage temperatures. The Scheme requires businesses processing seafood to implement a food safety program to ensure appropriate control measures are implemented for hazards such as *L. monocytogenes.*

The Wallis Lake Hepatitis outbreak in 1997 graphically demonstrated the need for tighter food safety controls on commercial harvesting of shellfish for human consumption. Since that time, the implementation of the Scheme and the NSW Shellfish Program has significantly improved the safety of shellfish through the classification of harvest areas and the implementation of harvest area management plans which identify high risk events such as heavy rainfall and holiday periods that may contribute to pollution of the waterways and compromise shellfish safety.

As coastal populations continue to increase and place additional pressure on local infrastructure, such as sewage treatment plants, the future role of the NSW Shellfish Program to ensure the continued safety of shellfish is vital. This was acknowledged by FSANZ when it ranked shellfish harvested from managed areas as a medium risk, as opposed to a high risk when these controls were not in place.

The conclusion of the 2016 assessment contains the familiar and the new elements:

- Consumption of large predatory reef fish from ciguatera hot spots has risks that commercial and recreational fishers should recognise
- Scombroid poisoning, which is generally linked to failures in temperature control, remains an occasional problem but not a serious problem
- Mercury naturally occurs in seafood and the issue is addressed through consumer education campaigns, particularly targeting vulnerable populations, such as pregnant women.
- Environmental pollutants such the dioxins and the dioxin-like PCBs are the potential contaminants of concern in aquaculture products
- Those preparing raw or undercooked seafood for consumption must be aware of the risk of parasites. Food safety is improved by using high-value marine fish, buying sashimi grade product, checking the intestinal cavity for parasites, candling fish muscle for parasites, freezing fish prior to preparation according to the guidelines issued by European Food Safety Agency (EFSA, 2010), and by cooking processes (EFSA, 2010)
- Risk of viral infections due to seafood consumption was found low. However, the protection of shellfish harvest areas from contamination by sewage remains of critical importance for the prevention of shellfish-borne viral illnesses
- Escolar occasionally enters the commercial food chain without adequate warning to consumers.
- There is a role for the Food Authority in the whole-of-government approach to the management of cyanobacterial blooms

- Good science can assist food safety management with benefits for the food industry and consumers
- Studies of pathogen+ growth in Sydney rock oysters at various temperatures allow for new and lower cost approaches to oyster safety
- Pinnatoxin studies prevent aberrant results in bioassays leading to unnecessary harvest closures and the associated costs
- Studies of cyanobacterial toxins provide a solid basis for the imposition of interventions to protect consumers and reduce the need for precautionary closures

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Appendix 1: Algal management in New South Wales

These extracts from the NSW Office of Water website provide information on algal management in NSW (http://www.water.nsw.gov.au/Home/default.aspx).

Algal management strategy

In response to the occurrence of the largest recorded blue–green algal bloom in the Darling River in 1991, the NSW Blue–Green Algal Task Force was formed. The Task Force was made up of representatives from a number of key NSW government agencies. In 1992, the Task Force made 30 recommendations to the government which were developed into a comprehensive integrated Algal Management Strategy to minimise the occurrence and impact of algal blooms in New South Wales.

The NSW Algal Management Strategy integrated a large number of measures into five key elements: State Algal Contingency Plan; Management of Blooms; Land and Water Management; Education and Awareness Raising; and Research. The Strategy included Algal Contingency Plans to minimise the effects of blue–green algal blooms, and short to medium term measures to control the factors leading to algal bloom development. It also covered short to long term nutrient and water management measures to minimise nutrient inputs to waterways. These measures were strengthened by education and research, and by increasing community awareness. The Strategy involves Catchment Management Authorities, NSW Office of Water and other state government agencies, local government, communities, industry, researchers and landholders.

The NSW Algal Management Strategy forms the basis of the work of the Regional Algal Coordinating Committees.

NSW State Algal Advisory Group

The NSW Algal Management Strategy is administered by the NSW State Algal Advisory Group (SAAG) and the nine regional algal coordinating committees.

The State Algal Advisory Group provides the overarching policy advice and framework for the management of fresh water and marine blooms. Membership of the State Algal Advisory Group is made up of the relevant NSW State agencies, NSW local government and the Murray Darling Basin Authority.

While each member is responsible for a specific area of management and technical information, the NSW Office of Water is the lead agency for water management in NSW and coordinates both the State Algal Advisory Group and the Regional Algal Coordinating Committees.

Technical Advisory Group

The Technical Advisory Group (TAG) of the SAAG is a panel of scientists who have expertise in various aspects of the ecology and management of nuisance phytoplankton blooms, in both freshwater and marine environments.

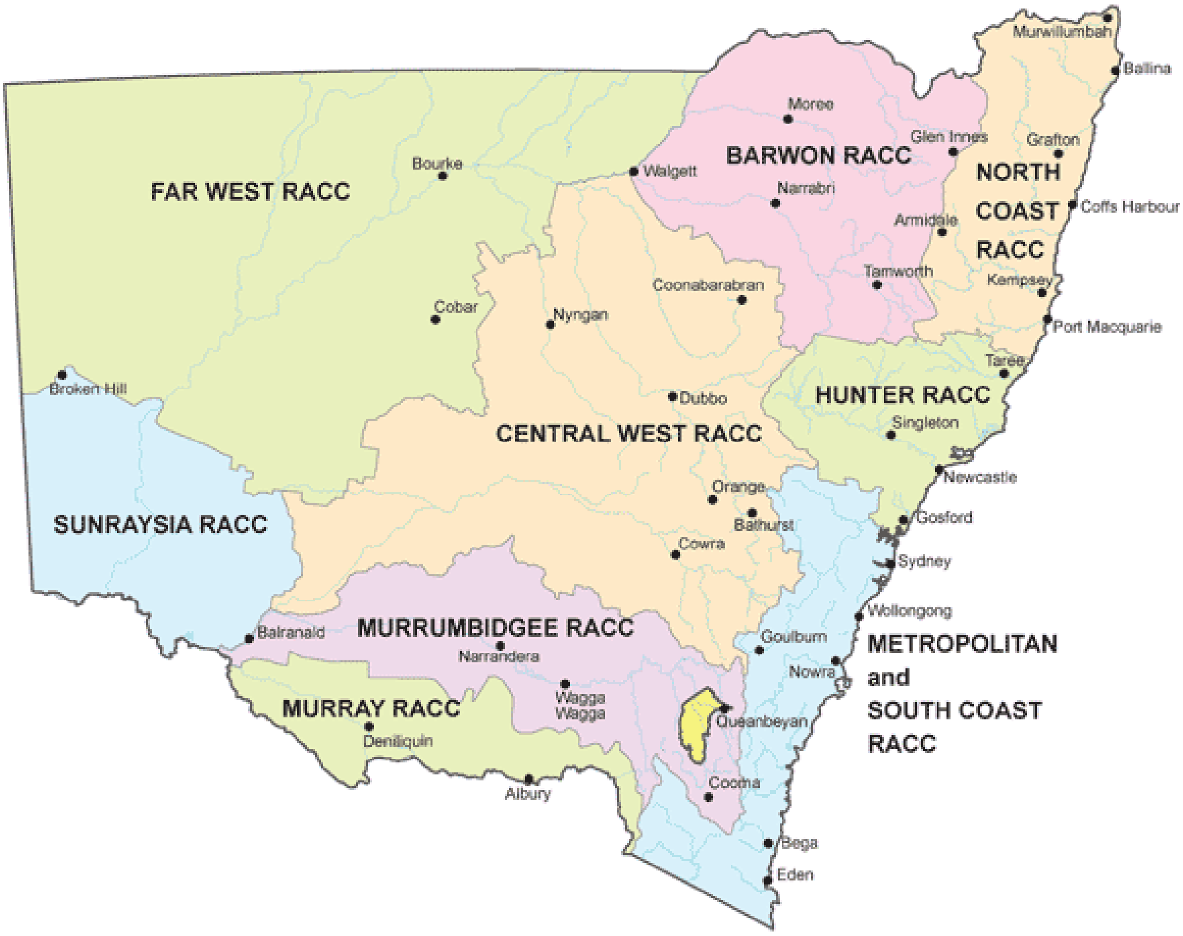
Current TAG membership comprises staff from several key NSW government agencies that have roles in the management of nuisance phytoplankton blooms and in protecting the public from the adverse health effects of these blooms: NSW Department of Primary Industries (Office of Water and NSW Food Authority), NSW Health, Office of Environment and Heritage and Sydney Catchment Authority, plus external expertise from universities and local government (University of New South Wales, Macquarie University, Port Macquarie-Hastings Council).

The TAG reports its findings to the SAAG, who can incorporate its findings into strategic responses to algal blooms. The TAG will also respond to questions from and report back to the nine Regional Algal Coordinating Committees

(RACCs) and their stakeholders on technical issues confronting these RACCs and stakeholders. By these avenues, the TAG aspires to provide relevant and transparent advice to inform algal bloom management across NSW fresh and marine waters.

Regional Algal Coordinating Committees (RACC)

RACC details are available on the NSW Office of Water webpage http://www.water.nsw.gov.au/Water-Management/Water-quality/Algal-information/Algal-contacts/default.aspx#racc .



Appendix 2: Results of seafood analysis during Gippsland Lakes bloom December 2011 to March 2012

All results in this appendix are from the Victorian Department of Health website (VicHealth, 2012). Non detections are only included where they provide useful information. Results in bold face exceed the health guideline value.

Table 2: Black bream

Date of collection	Sample location	Nodularin toxin whole black bream µg/kg	Nodularin toxin G&G black bream µg/kg
7/12/2011	Point Turner	16	
7/12/2011	Eagle Bay/ Split Jetties	43	
7/12/2011	Tambo Bay	47	
21/12/2011	Eagle Bay	41	< 16
21/12/2011	Tambo Bay	52	< 16
16/01/2012	Jones Bay	111	< 16
17/01/2012	Wattle Point	20	< 16
17/01/2012	Metung	203	< 16
25/01/2012	Eagle Bay	19	< 16
30/01/2012	Tambo Bay	19	< 16
30/01/2012	Jones Bay	30	< 16
31/01/2012	Metung	27.4	< 16
6/02/2012	Wattle Point	44.4	-
7/02/2012	Metung	54	< 16
8/02/2012	Eagle Bay	40	< 16
10/02/2012	Waddy Point	74	< 16
13/02/2012	Tambo Bay	24	< 16
13/02/2012	Eagle Bay	39	< 16
14/02/2012	Metung	28	< 16
15/02/2012	Waddy Point	145	< 16
21/02/2012	Tambo Bay	17	< 16
21/02/2012	Jones Bay	39	< 16
27/02/2012	Waddy Point	42	< 16
6/03/2012	Bancroft Bay	25	< 16
6/03/2012	Nungurner	33	< 16
7/03/2012	Eagle Bay	32	< 16
8/03/2012	Eagle Bay	17	< 16
13/03/2012	Jones Bay	18	< 16
13/03/2012	Eagle Bay	30	< 16
19/03/2012	Jones Bay	21	< 16
19/03/2012	Tambo Bay	53	< 16
26/03/2012	Tambo Bay	17	< 16
26/03/2012	Waddy Point	28	< 16
27/03/2012	Waddy Point	32	-
10/04/2012	Tambo Bay	20	< 16
23/04/2012	Tambo Bay	17	< 16

Table 3: Black mussels

Date of collection	Sample location	Nodularin toxin black mussels µg/kg
13/12/2011	Metung Jetty	36
13/12/2011	Nungurner Jetty	63
13/12/2011	Kalimna Jetty	740
18/12/2011	Metung Jetty	102
18/12/2011	Nungurner Jetty	107
18/12/2011	Kalimna Jetty	506
5/01/2012	Metung Jetty	168
5/01/2012	Nungurner Jetty	170
5/01/2012	Kalimna Jetty	189
11/01/2012	Nungurner Jetty	71
11/01/2012	Metung Jetty	126
11/01/2012	Kalimna Jetty	330
16/01/2012	Metung Jetty	183
16/01/2012	Nungurner Jetty	215
16/01/2012	Kalimna Jetty	338
30/01/2012	Metung Jetty	187
30/01/2012	Nungurner Jetty	306
30/01/2012	Kalimna Jetty	525
6/02/2012	Metung Jetty	149
6/02/2012	Kalimna Jetty	334
6/02/2012	Nungurner Jetty	351
13/02/2012	Metung Jetty	73
13/02/2012	Kalimna Jetty	100
13/02/2012	Nungurner Jetty	130
20/02/2012	Metung Jetty	77
20/02/2012	Kalimna Jetty	135
20/02/2012	Nungurner Jetty	249
27/02/2012	Kalimna Jetty	111
27/02/2012	Metung Jetty	241
27/02/2012	Nungurner Jetty	642
5/03/2012	Kalimna Jetty	152
5/03/2012	Nungurner Jetty	274
5/03/2012	Metung Jetty	328
13/03/2012	Kalimna Jetty	88
13/03/2012	Nungurner Jetty	133
13/03/2012	Metung Jetty	188
19/03/2012	Metung Jetty	62
19/03/2012	Nungurner Jetty	121
19/03/2012	Kalimna Jetty	144
27/03/2012	Metung Jetty	34
27/03/2012	Kalimna Jetty	39
27/03/2012	Nungurner Jetty	39
2/04/2012	Kalimna Jetty	64
2/04/2012	Metung Jetty	150
10/04/2012	Nungurner Jetty	34
16/04/2012	Nungurner Jetty	31
16/04/2012	Metung Jetty	40
16/04/2012	Kalimna Jetty	83

Table 4: Prawns collected within the Gippsland Lakes

Date of collection	Species	Sample location	Nodularin toxin prawns from within the lakes µg/kg
13/01/2012	School Prawns	Gippsland Lakes	88
29/01/2012	School and King Prawns	Nungurner	299
6/02/2012	School Prawns	Nungurner	102
13/02/2012	King Prawns	Cunningham Arm	75
13/02/2012	King Prawns	Bell's Point	91
27/02/2012	King Prawns	Barrier Landing	111
6/03/2012	King Prawns	Nungurner	77
6/03/2012	King Prawns	Cunningham Arm	77
14/03/2012	King Prawns	Nungurner	56

Table 5: Prawns collected outside of Lakes Entrance

Date of collection	Species	Sample location	Nodularin toxin prawns from ocean outside the lakes µg/kg
30/12/2011	School Prawns	6.5 Nautical miles west of Lakes Entrance	30
10/01/2012	School Prawns	Eastern Beach	124
15/01/2012	School Prawns	Eastern Beach	137
17/01/2012	School Prawns	Eastern Beach	270
29/01/2012	School and King Prawns	Eastern Beach Channel	224
30/01/2012	School Prawns	Off Lake Bunga	81
30/01/2012	School Prawns	2 Nautical miles east of Lake Tyers	107
2/02/2012	School Prawns	Between 0.5 and 2.2 nautical miles east of Lake Tyers	119
4/02/2012	School Prawns	7 Nautical miles west of Lakes Entrance	77
4/02/2012	King Prawns	1.5 miles straight out from Lakes Entrance	107
4/02/2012	School Prawns	11 Nautical Miles east of Lakes Entrance 3.5 fathoms	130
6/02/2012	School Prawns	Lakes Entrance	98
16/02/2012	King Prawns	2 Nautical miles east of Lakes Entrance	35
16/02/2012	King Prawns	0.5 Nautical miles east of Lakes Entrance	55
16/02/2012	King Prawns	5 Nautical miles east of Lakes Entrance	110
26/02/2012	King Prawns	6.5 Nautical miles east of Lakes Entrance	44
27/02/2012	King Prawns	Eastern Beach Channel	99
27/03/2012	King Prawns	6 Nautical miles east of Lakes Entrance	44

Many of the locations listed in these tables may be found at
http://maps.google.com.au/?ll=-37.907908,147.790489&spn=0.197202,0.491638&om=1&t=m&z=12

Appendix 3: Ranking of foodborne hazards by severity of adverse health effects

(adapted from FSANZ 2006)

Severity	Description	Food-borne hazards in seafood	
Moderate	Not usually life threatening; no sequelae; normally short duration; symptoms are self-limiting; can include severe discomfort.	*Staphylococcus aureus* enterotoxin	Histamine
		Enteropathogenic *Escherichia coli*	*Vibrio parahaemolyticus*
		Enterotoxigenic *E. coli*	Zinc*
		V. cholerae non-O1/non-O139	Wax esters*
		Norwalk-like viruses (noroviruses)	
Serious	Incapacitating but not life threatening; sequelae infrequent; moderate duration.	Non-typhoid *Salmonella* spp.	*Yersinia* spp.
		Non-dysenteric *Shigella* spp.	*Listeria monocytogenes*
		*Aeromonas hydrophila**	*V. vulnificus**
		Hepatitis A virus	Helminthic parasites*
		Algal biotoxins* (DSP, NSP)	Mercury*
		Ciguatoxin*	
Severe	Life-threatening or substantial chronic sequelae or long duration.	**General population**	
		S. Typhi *S.* Paratyphi	Cadmium*
		Shigella dysenteriae	*V. cholerae* O1/O139
		Enterohaemorrhagic *E. coli*	Aflatoxins
		Clostridium botulinum neurotoxin	Arsenic*
		Algal biotoxins* (ASP, PSP)	Lead*
		Cadmium*	
		Susceptible populations	
		L. monocytogenes	*V. vulnificus*
		Enteropathogenic *Escherichia coli* and Enterotoxigenic *E. coli*	Hepatitis A virus
		Mercury	

* Hazards not originally listed in the International Commission on Microbiological Specifications for Foods severity ranking table.

Key: ASP = amnesic shellfish poison; DSP = diarrhoetic shellfish poison; NSP = neurotoxic shellfish poison; PSP = paralytic shellfish poison.

See Appendix 4 for discussion of the different severity rankings amongst the algal biotoxins.

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