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# Risks and benefits of seafood consumption

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by

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This report provides an overview of the proven benefits of consuming seafood, then goes on to assess the potential risks. Having assessed the benefits and the risks, it continues with a risk benefit analysis to determine if seafood consumption is more beneficial than risky i.e. if the health benefits outweigh any negative health impacts resulting from consumption. Finally the issue of sustainability is briefly considered from the viewpoints of future consumers and fisheries managers, should the demonstrated benefits of seafood consumption lead to vastly increased demand. The report is intended to provide a comprehensive assessment to those associated with the seafood industry who, although they may not have a scientific background, are often challenged by negative images of their products and need to be able to understand both sides of the story.

Layout: Yvonne Davidsson and Gloria Loriente.
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| | |
|---|---|
| **ACS** | Acute cardiac syndrome |
| **AHA** | American Heart Association |
| **CHD** | Coronary heart disease |
| **COT** | Committee on Toxicity (UK) |
| **DHA** | Docosohexaenoic acid |
| **EPA** | Eicosopentaenoic acid |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FSANZ** | Food Standards Australia New Zealand |
| **HDL-C** | High density lipoprotein (the good cholesterol) |
| **HRV** | Heart rate variation |
| **IQ** | Intelligence quotient |
| **JECFA** | FAO/WHO Joint Expert Committee on Food Additives and Contaminants |
| **LC-PUFA** | Long chain polyunsaturated fatty acid |
| **LDL-C** | Low density lipoprotein (the bad cholesterol) |
| **MeHg** | Methyl mercury |
| **MHLW** | Ministry of Health, Labour and Welfare, Japan |
| **MI** | Myocardial infarction |
| **PCB** | Polychlorinated biphenyls |
| **PCDD** | Polychlorinated dibenzo-p-dioxins |
| **PCDF** | Polychlorinated dibenzofurans |
| **Pg** | Picogram – 1pg = 1 trillionth of a gram (10-12g) |
| **SACN** | Scientific Advisory Committee on nutrition (UK) |
| **RCT** | Randomized controlled trials |
| **US FDA** | Food and Drug Administration |
| **US EPA** | Environmental Protection Agency |
| **WHO** | World Health Organization of the United Nations |
| **µg** | Microgram - 1 µg = 1 millionth of a gram (10-6g) |

# 1. INTRODUCTION

A huge variety of fish and other organisms from salt water, brackish and fresh water environments, collectively termed seafood, have been much appreciated over the ages as food by humans. Shellfish middens left by the Australian aboriginal people date back 12 000 to 40 000 years and the inclusion of burnt shells indicate that these people cooked their food. Even earlier evidence is seen from Southern Africa around seven million years ago, where the availability of seafood is associated with the evolution of the hominins, the early ancestors of today's humans (*Homo sapiens).*

In a great number of communities throughout the world, the beneficial properties of eating fish have entered into folklore over the years. In earlier times this was without scientific justification, but since the 1950's an increasing amount of scientific research has been undertaken to isolate and identify the beneficial components of seafood and subsequently to demonstrate and quantify their effect on health. A very substantial body of credible evidence on the health benefits of seafood is now available.

However, along with the benefits there are also risks that can be associated with seafood consumption. Over recent years a new paradigm of food safety has been adopted that acknowledges that life cannot be risk free, but that risks can be scientifically quantified and managed as well as communicated to the consumers, allowing them to make considered choices. This process, known as risk analysis, has been incorporated into a food chain approach to food safety, which has been extended to seafood safety. The approach is based on risk analysis, traceability, harmonization of quality and safety standards and equivalence in food safety systems. Risk avoidance or prevention of risk at source is being increasingly emphasised along the whole chain from water to the table.

Recently attempts have been made to extend this analytical approach to the benefits as well as the risks, resulting in a comprehensive risk benefit assessment. An important step in this direction was taken in January 2010 when an FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption was held in Rome, Italy[1]. A group of 17 leading international experts in toxicology, medicine, nutrition and food control met to discuss the issues and prepare a report that is the basis for the information presented in this Globefish Research Report.

[1] The complete report of the Expert Consultation can be downloaded from: http://www.fao.org/docrep/014/ba0136e/ba0136e00.pdf. The Executive Summary is included as an Annex 1.

The need for the Consultation was the recognition of the growing dispute over whether seafood consumption should be encouraged and if so, how much should be eaten by particular population groups. On both sides of the argument some of the controversy has been well meaning but while the fish trade, not surprisingly, as well as the majority of nutritionists have supported increasing consumption, some quite extreme pressure groups have entered the fray to discourage eating seafood. These have included fringe environmentalists and conservationists, vegans and others with no clear agenda except opposition. As a result, international and national food safety agencies have recognized the increasing need to provide useful, clear and relevant information to populations that are concerned about making the healthiest choices when considering whether or not to eat seafood. Unfortunately, in some cases government advice on seafood consumption has been so difficult for the general population to interpret that the impact has been to cause consumers to reduce or eliminate seafood in their diets, with commensurate negative impacts on nutrition and health. In addition to the amount consumed, the health benefits and risks are likely to vary according to the species, fish size, and harvesting and cultivation practices, as well as the way in which it is served. Clearly the decisions of food safety agencies, as well as consumers, need to be based on the best available science and recent years have seen a greatly increased volume of relevant research on the topic.

This report is intended to provide a comprehensive assessment to those associated with the seafood industry who, although they may not have a scientific background, are often challenged by negative images of their products and need to be able to understand both sides of the story. Regrettably, some of the scientific arguments are complex, but an attempt has been made to present them as simply as possible but without trivialization. Over the years, many pseudo-scientific arguments have been presented by protagonists of either benefits or risks. All the evidence presented here is drawn from rigorous scientific studies.

The report starts with an overview of the proven benefits of consuming seafood, then goes on to assess the potential risks. Having assessed the benefits and the risks, it continues to their comparison through a risk benefit analysis, such as would enable a risk manager to determine if seafood consumption is more beneficial than risky i.e. if the health benefits outweigh any negative health impacts resulting from consumption. Finally the issue of sustainability is briefly considered from the viewpoints of future consumers and fisheries managers, should the demonstrated benefits of seafood consumption lead to vastly increased demand.

## 2. THE HEALTH BENEFITS OF SEAFOOD CONSUMPTION

This section reviews the scientific evidence for the health benefits of seafood consumption, particularly on cardiovascular risk factors and neural development in neonates. Simply put that is the risk of heart disease and the development of the structure of the nervous system of an infant before its birth. It should be emphasized that for much of the evidence related to the assessment of these health benefits, it was seafood consumption that was measured, which implicitly quantifies the net overall effect, including both the harm and benefit of eating seafood rather than fish oil supplements.

Seafood consumption has clear nutritional benefits as it provides high quality protein, minerals, essential trace elements, fat-soluble vitamins (Vitamin D) and essential fatty acids, particularly of the long-chain polyunsaturated variety (LC-PUFA). Although most of these nutrients can be obtained from other sources, seafood is a palatable and convenient source. However, seafood provides the main source of the longer chain length essential LC-PUFAs, that is the “good” oils with 20 or 22 carbon atoms in the chain, referred to as the omega (ώ)-3 (or n-3) LC-PUFAs. The nomenclature ώ-3 is a chemical convention indicating that the first of the six unsaturated double bonds is after the third carbon atom from the methyl end of the chain. The essential ώ-6 LC-PUFAs, i.e. those with the first double bond after the sixth carbon atom, are mainly found in plants. Frequent consumption of red meat from terrestrial animals, on the other hand, has been associated with increased levels of total, cardiovascular and cancer mortality, mainly by virtue of its higher saturated fatty acid content. White meat, principally from poultry, with lower saturated fat content, is a better choice if seafood is not available.

### 2.1. NEURODEVELOPMENT

There is convincing evidence—from large and extensive studies as well as randomized trials in humans, together with supportive retrospective, ecological, metabolic and experimental animal studies—that seafood consumption by women reduces the risk of suboptimal neurodevelopment in their offspring. The benefits are attributed to two specific essential ώ-3 LC-PUFA; those with 20 and 22 carbon atom chains that are found in seafood. They are eicosapentaenoic acid (EPA) and docosohexaenoic acid (DHA) respectively.

DHA, the most unsaturated fatty acid found in the mammalian class, is the more potent. While some animals possess the mechanism to elongate the carbon chains of the shorter chain length fatty acids, in humans this chain elongation is generally too slow to provide for the quantity needed for metabolism, except in specific instances mentioned below. Thus a dietary source of the ώ-3 LC-PUFAs is essential. Both the ώ-3 (DHA) and the ώ-6 (aracidonic acid) (AA) LC-PUFAs are necessary for neural tissue development and are incorporated into the brain, which contains 60 per cent lipid. However, dietary supply is limited, except from aquatic foods. The ώ-6 LC-PUFA, however, can be readily obtained from plant sources. It has been postulated that the massive expansion of brain size, seen first in Southern Africa, that distinguishes the hominins from earlier mammals could only have occurred close to the water, as a result of DHA obtained from aquatic species. Thus, without seafood consumption over 5-7 million years *Homo sapiens* could not have evolved.

DHA is preferentially incorporated into the rapidly developing infant brain during the last trimester of pregnancy and the first two years of infancy, concentrating in brain gray-matter and retinal membranes. Both observational studies and randomized controlled trials have assessed the relationships of maternal DHA consumption with early brain development. Multiple observational studies and randomized controlled trials have demonstrated independent beneficial associations of maternal DHA levels or seafood consumption during pregnancy with behavioral attention scores, visual recognition memory, and language comprehension in infancy and childhood. For instance, in a pooled analysis of 8 randomized controlled trials, increasing maternal consumption of DHA by 100 mg/d increased child IQ by 0.13 points. Although more studies of dose responses are required, consistent evidence already demonstrates that higher maternal consumption of ώ-3 PUFA (particularly DHA) during pregnancy and nursing improves early brain development in children.

## 2.2. CARDIOVASCULAR RISK FACTORS

Consumption both of seafood and fish oil supplements has been shown to influence several cardiovascular risk factors. This is because both EPA and DHA are incorporated into the tissue of the blood vessels where they are involved in cell membrane fluidity. At typical seafood dietary intakes, anti-arrhythmic effects on the heart are the predominant response. Such effects may reduce the risk of sudden cardiac death and coronary heart disease (CHD) death within weeks of starting consumption, although at higher intakes the benefits do not further increase. Some other risk factors (such as triglyceride-lowering) may require months to years of consumption before clinical outcomes are improved. Thus, both the dose-response and the time-for-observed-clinical-benefit may vary depending on the specific risk factor evaluated. In addition to anti-arrhythmia and tri-glyceride lowering, seafood is also associated, within weeks or months of consumption, with lowering of blood pressure and heart rate as well as heart rate variability. An anti-thrombotic action is noted in weeks.

There is also some accumulating evidence that seafood consumption reduces dementia and cognitive decline as well as depression. More evidence is also emerging that reduced ώ-3consumption is associated with an increase in violent behaviour.

The following table is based on the background material for the FAO/WHO Expert Consultation and summarizes the evidence for the beneficial effects of seafood on health, linked generally, but not entirely, to ώ-3 LC-PUFA. The strength of the evidence follows a hierarchy established by WHO that runs from convincing to probable, possible and insufficient. In each case the strength of evidence is based on the numbers of studies and trials that have shown positive impacts and may change as more research is conducted.

**Table 1. Beneficial effects of seafood on health**

| End point | Clinical Effect | Strength of Evidence | Comment |
|---|---|---|---|
| **Cardiovascular risk factors** | | | |
| **Serum triglycerides**<br>**HDL-cholesterol**<br>**LDL-cholesterol** | ↓ 25-39%<br>↑ 3%<br>↑ 5% | Convincing<br>Convincing<br>Convincing | High dose required<br>Small effect<br>Due to increased particle size |
| **Blood pressure** | | | |
| **Systolic**<br>**Diastolic** | ↓ 3-5 mm Hg<br>↓ 2-3 mm Hg | Convincing<br>Convincing | |
| **Heart rate** | ↓ 2-3 bpm | Convincing | |
| **Heart rate variability (HRV) / Autonomic function** | ↑ HRV<br>↑ Vagal activity indices | Possible<br>Possible | Inconsistent positive experimental trials |
| **Cardiac relaxation and filling** | ↑ Left ventricular efficiency<br>↑ Diastolic function | Probable | Consistent in animal trials and small trials in humans |
| **Arrhythmic risk** | ↓ 25-50 % | Probable | Positive in-vitro, animal studies + clinical trials |
| **Insulin sensitivity** | No effect | Probable | Small effect to increase hepatic glucose probable |
| **Inflammation** | ↓ Cytokine production | Possible | |
| **Endothelial function** | ↑ | Possible | |
| **Cardiovascular outcomes** | | | |
| **CHD death**<br>**Sudden death** | ↓ 35%<br>↓ 50% | Convincing<br>Convincing | Risk reduction with modest intake 250mg/d EPA/DHA. Little additional benefit if intake increased |
| **Ischemic stroke** | ↓ 30% | Probable | Strong evidence from prospective studies- no randomized clinical trials |
| **Non-fatal CHD** | ? Modest benefit | Possible | Possible benefit at v. high intakes |
| **Progression atherosclerosis** | ? Modest benefit | Possible | Mixed results |
| **Post-angioplasty restenosis** | ? Modest benefit | | |
| **Atrial fibrillation** | ↓ 30% | Possible | Mixed results |
| **Congestive heart failure** | ↓ 30% | Possible | Benefits in one study positive trends in two others |
| **Neurological effects** | | | |
| **Early neurodevelopment** | | Convincing | |
| **Cognitive decline and dementia** | | Possible | |
| **Mood and depression** | | Probable | |
| **Other effects** | | | |
| **Inflammatory diseases** | | Possible | |
| **Cancer** | | Insufficient/ Possible | See World Cancer Research Fund Report 2007 |
| **Bone Health** | | Insufficient | |

## 2.3. HEALTH BENEFITIS OF OTHER NUTRIENTS FROM SEAFOOD

As noted, the benefits of seafood consumption demonstrated in numerous studies across a wide range of populations, reflect the sum of benefits and risks from all of the constituents in the fish. These health attributes of seafood are due in large part to ώ-3 LC-PUFAs, of which seafood is the major dietary source, supported by limited synthesis by chain elongation. There is evidence that neonates and infants, as well as vegans, are able to synthesise higher levels to meet their basic needs. While the highest levels of ώ-3 LC-PUFAs are found in the high fat content marine fish species, brackish and freshwater fish species also contain significant quantities.

Seafood also contains other important nutrients, although these can also be obtained from other foods, e.g. protein, choline and essential amino acids as well as the five brain selective minerals: iron, zinc, copper, selenium and iodine, plus vitamin D, which may also contribute to the health benefits of seafood. The health effects of fish consumption may be greater than the sum of its individual constituents. Eating fish is also part of the cultural traditions of many peoples and food or food habits have a strong cultural dimension – it’s not just nutrition.

A brief review of the benefits of the other components in seafood shows that, while further studies are needed, they may well potentiate the impact of the major beneficial component, the ώ-3 LC-PUFA.

Fish muscle protein is rich in the sulphur-containing amino acid, lysine and in threonine the limiting amino acids in cereal-based diets. Seafood muscle is also rich in water-soluble compounds, including free amino acids: the main non-protein nitrogenous compounds that influence the taste of food. The main free amino acids of seafood muscle are: glutamine, proline, glycine, alanine and arginine as well as taurine, which behaves like an amino acid. Of these taurine and arginine are of particular significance. Humans have a limited ability to synthesise taurine from cysteine, so it is regarded as conditionally essential. Taurine, in which crustaceans and molluscs are particularly rich, has been shown to reduce CHD risk, either alone or in combination with ώ-3 LC-PUFA, as a result of its role in bile salt formation. Taurine combines with cholesterol derivatives to form taurocholate, removing cholesterol from blood plasma and thus reducing the risk of atherosclerosis. Arginine, also found at high levels in crustaceans and molluscs is an essential precursor for the synthesis of proteins.

Fatty fish are one of the few sources of dietary vitamin D, important for bone health. Although vitamin D is synthesised in the skin from 7-dehydrocholesterol by exposure to sunlight, populations that are deprived of sunlight, either those that live at high latitudes during winter or that clothe the body completely can suffer deficiency. Lack of vitamin D causes rickets in children and osteomalacia in adults as a result of decreased bone mineralization caused by malabsorption of dietary calcium. Vitamin D deficiency has also been related to CHD and type 2 diabetes. While studies show a consistent association between low vitamin D and type 2 diabetes further studies are required to confirm the relationship between vitamin D and CHD, stroke and congestive heart failure. Some epidemiological studies have shown that vitamin D prevents several forms of cancer, particularly colorectal cancers.

Those working in the field of human brain evolution have coined the term brain-selective nutrients to identify those nutrients that are essential for human brain development. They include some trace minerals, vitamins and ώ-3 fatty acids. The brain-selective minerals, readily available from most species of seafood, include at least the following five: iodine, iron, selenium, copper and zinc. Iodine is essential for thyroid hormone production, which regulates the body's metabolism. Hypothyoidism, the lack of thyroid hormone, also causes impaired hearing. Iodine is so important for healthy lives that most governments now legislate for the iodization of salt to ensure that the whole population gets its requirements. Iron is a component of some important proteins, such as haemoglobin, involved in the transport of oxygen in blood and myoglobin, involved in the transport of oxygen in muscle. Its deficiency leads to anaemia and appears to cause neurodevelopment delay in malnourished children. Iron deficiency is widespread particularly in the developing world. Selenium is needed for the production of the antioxidant protein, glutathione peroxidase. This protects the DHA in the brain from oxidative attack on its proteins and lipids, releasing free radicals that cause rancidity. Selenium also interacts with iodine and iron and deficiency contributes significantly to the damage caused by lack of these two minerals. The binding affinity between selenium and mercury has a protective effect when both elements are present. Copper has an essential biological role in the synthesis of the lipids in the myelin sheath that protects nerves. Without myelinisation the nerves cannot conduct signals. Like selenium, copper also interacts in the reactions of iodine and iron. Finally zinc, the deficiency of which rapidly affects the growth and development of infants and children. Meat from terrestrial animals contains zinc, but the richest source is molluscs. Although cereals contain adequate zinc it is not highly available biologically, being bound to phytate, which is indigestible to humans.

Table 2 below is not meant to imply that it would be wise to obtain all one's essential minerals from one food group and it does, in fact reinforce the wisdom of a balanced diet. The figures are based on the concentration of iodine, iron, selenium, zinc and copper in the food groups and on the daily requirements for these minerals. The limiting nutrient, identified in the right hand column determines how much of the food must be consumed to meet the daily requirements. No food group is entirely lacking in these minerals but shellfish appear to be the best source while cow's milk is the much the poorest.

**Table 2. Quantity of each major food group that would be required to meet the full daily requirement for the five essential minerals[2]**

| Food Group | Amount/day kg | Most limiting nutrient |
|---|---|---|
| **Shellfish** | 0.9 | Copper |
| **Eggs** | 2.5 | Copper |
| **Fish** | 3.5 | Iron |
| **Pulses** | 3.7 | Iodine |
| **Cereals** | 4.8 | Copper |
| **Meat** | 5.0 | Selenium |
| **Nuts** | 5.5 | Selenium |
| **Vegetables** | 8.7 | Zinc |
| **Fruits** | 9.3 | Zinc |
| **Cow's milk** | 47.0 | Zinc |

[2] Modified from a table presented by Stephen Cunnane: Cunnane, S.C. 2010. Human Brain Evolution – the influence of freshwater and marine food resources. Eds. S.C. Cunnane & K.M. Stewart. Wiley. Hoboken, New Jersey.

# 3. THE RISKS OF CHRONIC ILLNESS ASSOCIATED WITH SEAFOOD

The risks that are associated with seafood consumption can be separated into two broad categories those of food borne illness and chronic illness. To this extent illness from eating seafood is no different to illness caused by other food products. The food borne illnesses result from microbial or viral contamination, or the ingestion of naturally occurring toxins; these are of rapid onset and generally, assuming the patient survives, of short duration. An outbreak usually has very significant immediate economic impact. Chronic illness is, however, usually of slow onset with more serious long-term consequences. The causes are ingestion of toxic chemicals, heavy metals or parasites that can infest humans. It should be possible to address all the known risks by the implementation of a comprehensive risk-based system of fish inspection but regrettably there is often too little knowledge available. Such risk-based systems, grounded in risk analysis to assess, manage and communicate the risks, require trained staff and a wide range of data. While the food borne illnesses have been extensively studied and many risk assessments have been carried out, in many cases there is a lack of data for an assessment of the risks of chronic illness.

On the assumption that food borne illness, although serious, can be adequately controlled, this report will concentrate on the risks of chronic illness. An overview of other causes of chronic illness is followed by a brief look at the parasites that might be associated with seafood and their impact on human hosts. This precedes deeper consideration of the chemical risks. A more detailed analysis of risks from methyl mercury and dioxins is provided, as these are perceived to be the most serious downside of seafood consumption. The FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption held in 2010 considered in detail the risks from methyl mercury, a potent neurotoxin and dioxins and dioxin like products, which can be powerful carcinogens.

## 3.1. PARASITES

Parasites of fish, crustaceans and molluscs do not selectively include humans among their hosts. However, a number of them can either infect humans, causing chronic disease, or alternatively cause tissue damage. Nematodes, Cestodes and Trematodes are the various parasitic helminth worms found in marine, brackish and freshwater environments. They all have complex life cycles involving a varying number of hosts for the different life stages, but with one definitive host. In the past, most infections were in low-income countries, particularly Asia, but growth of international fish trade, faster transport of fresh fish and population movements have all contributed to a spread in their geographical ranges. Typically, increasing affluence and migration have led to a demand for raw or lightly processed seafood in areas where these were not familiar, perhaps because of the earlier recognition of problems with parasites.

Among the nematodes, *Anisakis* is frequently found in fish as round worms. The definitive hosts are marine mammals - seals or whales - which release the eggs into the water with their faeces. They are consumed by euphaursiids that are in turn eaten by fish, particularly in the north Atlantic by cod and herring, where they hatch as round worms and remain in the gut of the fish but increasingly enter the muscle after the fish dies. Under normal circumstances the life cycle is completed when the fish is eaten by a marine mammal but infected fish can represent a danger if they enter the human food chain. Although they do not parasitize humans they can cause damage and bleeding by penetrating the gut wall and sometimes encyst, as well as causing allergic reactions in sensitive individuals. Control measures include: routine fish inspection, adequate cooking to kill the worms or freezing, for at least 24 hours at or below -18 °C, if the product is to be consumed raw or lightly processed.

There are many species of the cestode genus *Diphyllobothrium*, the tapeworms that are seafood borne and have mammals, including humans, as their definitive hosts. The worm resides in the intestine and sheds immature eggs in the faeces. When these reach freshwater they are eaten by copepods that are typically eaten in turn by small freshwater fish where they encyst as larvae. As these species are not normally eaten by humans it is only when they pass up the food chain (as larvae) following consumption by brackish water or marine species of higher trophic levels that they are a danger. Chronic infestation causes debilitation and in a worst case scenario they can absorb all the body's vitamin $B_{12}$ resulting in anaemia. Control measures include routine fish inspection and adequate cooking.

It is the freshwater fish and crustacean borne trematode parasites, the flukes, which cause the most problems. Human infestations are widespread in Asia and Russia, mainly affecting low-income groups, but have become increasingly common in Europe and North America. They have mammalian definitive hosts and include the genus *Echinostoma,* which attaches in the intestine and the liver flukes *Clonorchis, Fasciola* and *Opistorchis,* which infest the liver, gall bladder or bile duct and *Paragonimus,* the lung fluke. They can all cause serious health problems and chronic disease. The complex life cycles involve the mammalian host shedding eggs into water, these hatch and penetrate the soft tissue of a freshwater snail where they turn into cercaria, which emerge and enter a third host, either a fish or in the case of *Paragonimus,* a freshwater crustacean, where they encyst as metacercariae, the infective stage. When the fish or crustacean is harvested for consumption the cycle back to humans can be completed. Once again proper fish inspection and thorough cooking are the control measures.

Fortunately, treatment of human parasitic infestations is relatively simple, assuming an adequate diagnosis is made. Diagnosis is by microscopic examination of faecal samples for the eggs. Treatment is typically a single dose of the drug Praziquantel at 5–10 mg/kg body weight.

### 3.2. HEAVY METALS – CADMIUM AND MERCURY

A number of metals are toxic to humans including: beryllium, cadmium, lead, mercury, silver, thallium and tin as well as the metalloid arsenic. Of these the heavy metals cadmium (Cd) and mercury (Hg) have both been demonstrated to accumulate in humans from the seafood supply. They are both widespread in the earth's crust and enter the environment from there, as a result of volcanic activity, weathering and run-off. These sources of entry to the aquatic food chain are usually considered to be normal environmental loading; however, since the advent of the industrial age these metals have also been extracted for use in industrial processes, increasing the load in the environment, particularly from pollution resulting from improper disposal of waste after use in industry.

These anthropogenic sources of pollution and the background environmental sources, characteristically enter the food chain at the level of single celled organisms from the water. A significant proportion is retained and thus the concentration increases as the food chain passes from one trophic level to the next (biomagnification). With few exceptions, the highest concentrations are found in the apical predators such as: swordfish, marlin and tunas as well as in marine mammals, such as toothed whales and seals. The larger, older individuals have the highest levels.

Arsenic has been used for a variety of purposes including timber preservation, strengthening of metal alloys and in electronics. In earlier times it was used extensively in medicine and still has some medical applications. It is, however, highly toxic to multicellular organisms. Arsenic is present in surface waters and the drilling of tube wells for drinking water supplies has increased intake, to potentially dangerous levels, in a number of developing countries. It also enters the food chain and in many countries seafood, particularly shellfish, is the major source.

Cadmium has a number of industrial uses such as electroplating and in paint, but since the recognition of cadmium toxicity in the 1950's, these uses have declined. However, the development of nickel-cadmium batteries in the 1960's has increased the use. The classic recognition of cadmium toxicity in association with seafood was made in Toyama Prefecture, Japan in the 1970's. Here long-term cadmium discharges from an industrial plant into rivers and enclosed bays, entered the food chain and the population consuming seafood from these waters, as well as rice irrigated with polluted water, suffered cadmium poisoning. It is important to recognize that the cause was massive pollution and the quantities ingested were many times higher than would normally be contained in the food supply.

While the seafood supply, specifically molluscs, can be a vector for increased cadmium consumption it must be noted, however, that much higher quantities of cadmium are contributed by tobacco smoking than by seafood. The outbreak in Japan confirmed that cadmium has toxic effects on the respiratory system, the skeleton and the kidneys as well as being a carcinogen. The symptoms of poisoning are extreme pain, respiratory distress, bone softening and kidney damage caused by neural tubule atrophy. Cadmium accumulates in mammalian kidneys and is also found in high levels in the hepato-pancreas and muscle of a number of molluscs. Levels above the permitted maximum are also found in large swordfish, marlin and tuna. Monitoring and surveillance are required to control seafood quality and safety.

While the mercury in the Earth's crust is largely in the inorganic form, as metallic mercury or its inorganic salts, once it enters the aquatic environment it can be changed to an organic form, methyl mercury (MeHg), which is soluble, mobile, and quickly enters the aquatic food chain. The process of methylation is assisted by microrganisms, particularly sulphur reducing bacteria, under aerobic or anaerobic conditions. Mercury in this form (MeHg) is accumulated to a greater extent in biological tissues than inorganic forms of mercury and usually constitutes over 90 percent of the total mercury detected in fish. However, organisms at lower trophic levels may have only about 30 percent of the total as methyl mercury.

Mercury had long been recognized as toxic but the confirmation and quantification of the extreme neurological impact was coincidently also demonstrated by industrial pollution in Japan in the 1950's. Effluent from an industrial plant in the Minamata bay area, contaminated the aquatic environment and local people consuming seafood from these waters suffered severe health effects. The other classic case was in Iraq, when in 1956 the same effects were noted after the population had consumed bread made from wheat treated with organic mercury fungicides. The wheat had been provided as seed grain for planting but due to extreme hunger it was ground into flour and used for bread making.

Much of the knowledge of the clinical signs, symptoms and neurological effects of methylmercury comes from the two extreme pollution incidents: in Japan and Iraq noted above. In Japan the neurological symptoms included prickling, tingling sensation in the extremities (paresthesia), impaired peripheral vision, hearing, taste, and smell, slurred speech, unsteadiness of gait and limbs, muscle weakness, irritability, memory loss, depression, and sleeping difficulties Elevated concentrations of methylmercury were observed in the hair and brains of victims. Children exposed in utero to high levels of MeHg had cerebral palsy, mental retardation, movement and coordination disorders, difficulty with speech, and sensory impairments. The neuropathological lesions associated with Congenital Minamata Disease (mercury poisoning) were diffuse, occurring throughout the brain. In individuals exposed only in adulthood, the lesions were highly focal, clustering in regions of the brain that controlled the parts of the body affected.

Similar symptoms were seen in Iraq and were attributed to the fungicide ethylmercury p-toluene sulphonanilide. Affected individuals had an inability to walk, speech difficulties, paraplegia, spasticity, abnormal reflexes, restriction of visual fields or blindness, tremors, paresthesia, insomnia, confusion, hallucinations, excitement, and loss of consciousness.

These two events, which resulted in acute mercury poisoning, have greatly influenced the publicity on the potential for human mercury poisoning from the small quantity of mercury that might be contributed by seafood in the diet. In recent years, the seafood industry has suffered increasingly shrill denunciation from a range of interest groups including: fringe environmentalists, vegans, etc. This has been particularly the case in the United States, where the debate has moved from the scientific to the emotional, resulting in confusion as to how much, or even if, seafood should be consumed and by whom. In some cases the publicity and concern have resulted in women of child bearing age removing seafood from their diets, therefore forgoing the potential benefits to them and to the healthy development of their infants. The confused advice from some food safety agencies, for women who expect to become pregnant to limit seafood intake has, in some cases, had a knock on effect, when other population groups consider that if seafood is bad for one group it must also be bad for them.

### 3.3. DIOXINS AND DIOXIN-LIKE PCB'S

The dioxins and dioxin-like polychlorinated biphenyls (PCBs) are an extremely complicated group of organic chemical compounds. The group includes: the true dioxins - polychlorinated dibenzo-p-dioxins (PCDDs) and the polychlorinated dibenzofurans

(PCDFs), as well as those polychlorinated biphenyls (PCBs) that exhibit "dioxin-like" activity. Only some of the 209 congeners, or possible rearrangements, of the PCB chemical structure show the same type of toxicity as dioxin – (TCDD 2,3,7,8-tetrachlorodibenzo-p-dioxin).

PCCDs and PCDFs have no known uses, but are produced as byproducts from industrial processes, particularly manufacture of herbicides and pesticides. They also result naturally from volcanic eruptions and forest fires. Perhaps the main source in the environment is from incomplete combustion during waste incineration. PCBs on the other hand have been produced since the 1920's because of their unique chemical and physical properties - they are non-flammable, stable, have a high boiling point, low heat conductivity and a high dialectric constant. They found uses as flame-retardants and in paints but mainly in heat transfer systems, hydraulic fluids, lubricants and dialectric fluids in capacitors and transformers. The discovery of their toxic effects and their persistence in the environment led to their banning in open systems in the 1970's. It is anticipated that the use in closed transformers etc. will decline. The major releases today are from improper waste disposal of domestic appliances and industrial equipment. Despite their persistence in the environment levels have declined significantly since manufacture was controlled in the 1970's, by some estimates by 50 percent per decade.

The long list of health effects of dioxin exposure in humans includes the respitatory tract as well as the cardiovascular, gastrointestinal, haematological and musculoskeletal systems; the liver, thyroid, kidneys; dermal and ocular changes; together with immunological alterations; reproductive toxicity, genotoxic effects, cancer and neurodevelopmental changes. These have been confirmed by multiple studies, including four exposure studies of herbicide producers and one follow-up to a major release from an industrial accident in Seveso, Italy in 1976.

The direct linkage of the toxicity of dioxins accumulated through the food chain was demonstrated by two incidents in Asia involving rice oil contaminated by dioxins during manufacture. In Japan in 1968, a substantial batch of rice oil was accidently contaminated by a leaking heat exchanger. The event was not noticed in the processing plant and the oil was sold for human consumption and chicken feed. The first warning was when chickens became breathless and died, but this was followed by health effects on humans. Follow-up to this incident, known as Yusho in Japanese, have shown severe long-term impacts on health, including an increase of liver cancers. In 1979 a similar incident, though less severe, known as Yu-cheng, occurred in Taiwan, Province of China, also with long-term health consequences.

These follow-up studies collectively show a very slow process of elimination from the body and an increase in all cancers, but it must be remembered that they are based on very substantial exposures. Environmental contamination with dioxins and dioxin-like PCBs reaches the food chain through various routes: air, soil and water. It is estimated that today 95–98 percent of human exposure comes from the food supply, particularly products of animal origin - dairy products, seafood and meat. However, there is considerable variation from one country to another on the major source as demonstrated by the figures in Table 3 below. In North America the major contributor is dairy products and in Australia and some European countries it is seafood. In all cases meat and dairy prodcts make a significant contribution. Dioxins are insoluble in water but readily soluble in oil, hence their higher concentration in the fatty tissues of animals.

Dioxins in the air are highly mobile, tending to move towards the poles. Once they reach the water they are taken up into aquatic food chains by unicellular organisms and biomagnify in the same way as the heavy metals. Once again the higher levels are in apical predators, with particularly high concentrations in the fat of marine mammals. Levels of concern are found in pelagic species in the northern hemisphere (high fat content) and in piscivorous species in polluted freshwater environments. Once consumed dioxins are eliminated from the organism only slowly. In species with short life cycles the content that has accumulated during life is returned to the environment where it recycles.

**Table 3. Percentage contribution of total dioxin intake from various food groups in the diets of selected countries**

| Country | Fish | Meat | Dairy products | Eggs | Other foods |
|---|---|---|---|---|---|
| **Australia** | 39 | 11 | 31 | 2 | 8 |
| **Denmark** | 11 | 30 | 39 | 11 | 9 |
| **Finland** | 63 | 6 | 16 | 4 | 11 |
| **France** | 26 | 13 | 33 | 2 | 26 |
| **Italy** | 35 | 32 | 26 | 7 | - |
| **Netherlands** | 2 | 20 | 39 | 4 | 35 |
| **New Zealand** | 7 | 40 | 19 | | 24 |
| **Norway** | 46 | 14 | 22 | 12 | 6 |
| **Sweden** | 34 | 31 | 19 | 2 | 14 |
| **UK** | 6 | 20 | 25 | 4 | 45 |
| **USA** | 7 | 53 | 35 | | 3 |

# 4. RISK-BENEFIT COMPARISON

The previously described principles of risk analysis can be further extended to risk-benefit analysis, based on knowledge of the benefits and potential risks of seafood consumption. The scientific risk-benefit assessment component is a useful tool that food safety agencies can use to inform the management and communication components. This will ensure that seafood makes the maximum nutritional contribution, without risking the harmful effects of contaminants. Knowing how to communicate the benefits and risks, both real and perceived, to the consumer is a continuing challenge. A further complicating issue is that nutritionists and toxicologists think about the risks and benefits in differing ways, due to their diverse backgrounds and experience.

Human nature is risk-averse and publicity about perceived risks always makes better press than stories about the benefits. It is hoped that the cross-disciplinary scientific approach now being developed, will improve consumer confidence. If the general public sense disagreement between scientists their first reaction is avoidance, with potentially serious consequences if the beneficial components of fish are removed from the diet. It is also true that consumer food choice is influenced by the information received, and new dietary advice does not necessarily make consumers change the way they eat. A balance is required as some consumers will make high-risk seafood choices in the hope of gaining high benefits, while others will take a more conservative view.

National and international food safety agencies have developed a variety of different methodologies in recent years. In general a tiered approach has been taken, once the problem has been defined. At the lowest level a qualitative comparison is used and if this satisfies the requirements no further investigations are undertaken, as the amount of data needed for a quantitative assessment is very great. However, if required, the second level is a semi-quantitative assessment, which is conducted without the use of a common measurement to compare the risks and benefits. The third level is fully quantitative with the risks and benefits integrated by a common metric.

The experts participating in the FAO/WHO Expert Consultation developed a methodology to compare the risks of the contaminants: methyl mercury and dioxins with the benefits of the ώ-3 LC-PUFAs - DHA and EPA, derived from seafood. They developed common numerical indices from the data contained in the extensive peer reviewed prospective cohort studies and randomized trials that have been published in recent years. The choice of study, the reasons and the actual numerical indices are given in their Report.

Their first comparison was of the risks and benefits of fish consumption on the neurodevelopment of infants of mothers consuming fish. The common measure was the gain in IQ points of the children from DHA+EPA (benefit) and loss of IQ points from intake of methyl mercury (risk). The data showed an average gain of 4 IQ points per 100mg of DHA per day up to a maximum gain of 5.8 points. The second example compared the effect of seafood (or DHA+EPA) consumption (where reduced mortality from coronary heart disease as the benefit), with the increased cancer risk from intake of dioxins.

The Experts then collected available data to classify the EPA+DHA contents of 96 fish and shellfish species by total mercury content. For 76 of these species, for which information was available, a further classification was made of EPA+DHA by dioxin content.

The following two tables using this data are taken from the Report. The data was drawn from Europe, Japan and North America as there is an absence of reliable data from the southern hemisphere and developing countries Although this is northern hemisphere data, similar tables could be developed for other regions as a tool to provide advice to populations about fish consumption; leading to a call by the experts to improve international data bases on fish composition.

**Table 4. Classifying EPA+DHA content by mercury content**

| | | **EPA + DHA** | | | |
|---|---|---|---|---|---|
| | | $x \leq 3$ mg/g | $3 < x \leq 8$ mg/g | $8 < x \leq 15$ mg/g | $x > 15$ mg/g |
| **Mercury** | $x \leq 0.1$ µg/g | **Fish:** butterfish; catfish; Atlantic cod; Pacific cod; Atlantic croaker; haddock; pike; European plaice; pollock; saithe; sole; tilapia **Shellfish:** clams; cockle; crawfish; cuttlefish; oysters; periwinkle; scallops; scampi; sea urchin; whelk | **Fish:** flatfish; John Dory; perch, ocean and mullet; sweetfish; wolf fish **Shellfish:** mussels; squid | **Fish:** redfish; Atlantic salmon, (wild); Pacific salmon, (wild); smelt **Shellfish:** crab, spider; swimcrab | **Fish:** anchovy; herring; mackerel; rainbow trout; Atlantic salmon, (farmed); sardines; sprat **Fish liver:** Atlantic cod, (liver); saithe (liver) **Shellfish:** crab (brown meat) |
| | $0.1 < x \leq 0.5$ µg/g | **Fish:** anglerfish; catshark; dab; grenadier; grouper; gurnard; hake; ling; lingcod and scorpionfish; Nile perch; pout; skate/ray; snapper, porgy and sheepshead; tuna, yellowfin; tusk; whiting **Shellfish:** lobster; American lobster | **Fish:** bass, freshwater; carp; perch, freshwater; scorpion fish; tuna; tuna, albacore **Shellfish:** crab; lobster, Norway; lobsters, spiny | **Fish:** bass, saltwater; bluefish; goatfish; Atlantic halibut, (farmed); Greenland halibut; mackerel, horse; Spanish mackerel; seabass; seabream; Atlantic tilefish; tuna, skipjack | **Fish:** eel; mackerel, Pacific; sablefish |
| | $0.5 < x \leq 1$ µg/g | **Fish:** marlin; orange roughy; tuna, bigeye | **Fish:** mackerel, king; shark | **Fish:** alfonsino | **Fish:** Pacific tuna, bluefin |
| | $x > 1$ µg/g | | **Fish:** swordfish | | |

**Table 5. Classification of the content of EPA + DHA by dioxin content in 76 fish and shellfish species**

| | | **EPA + DHA** | | | |
|---|---|---|---|---|---|
| | | $x \leq 3$ mg/g | $3 < x \leq 8$ mg/g | $8 < x \leq 15$ mg/g | $x > 15$ mg/g |
| **Dioxins** | $x \leq 0.5$ pg TEQ/g | **Fish:** anglerfish; catshark; Atlantic cod; grenadier; haddock; hake; ling; marlin; orange roughy; pollock; pout; saithe; skate/ray; sole; tilapia; tuna, bigeye; tuna, yellowfin; tusk; whiting<br>**Shellfish:** cockle; clams; crawfish; cuttlefish; periwinkle; scallops; scampi; sea urchin | **Fish:** flatfish; John Dory; perch, ocean and mullet; shark; sweetfish; tuna, albacore | **Fish:** redfish; salmon, Pacific (wild); tuna, skipjack | |
| | $0.5 < x \leq 4$ pg TEQ/g | **Fish:** catfish; dab; gurnard; plaice, European<br>**Shellfish:** lobster; oysters; scallops; whelk | **Fish:** scorpion fish; swordfish; tuna<br>**Shellfish:** mussels; shrimp; squid | **Fish:** alfonsino; goatfish; Atlantic halibut, (farmed); Greenland halibut; mackerel, horse; Atlantic salmon, (wild); seabass; seabream | **Fish:** anchovy; herring; mackerel; Pacific mackerel; rainbow trout, (farmed); Atlantic salmon, (farmed); tuna, Pacific bluefin<br>**Shellfish:** crab (brown meat) |
| | $4 < x \leq 8$ pg TEQ/g | | | **Fish:** emperor<br>**Shellfish:** crab, spider | **Fish:** sardines; sprat |
| | $x > 8$ pg TEQ/g | | | **Fish:** bluefish | **Fish:** eel<br>**Fish liver:** cod, Atlantic (liver); saithe (liver) |

The Experts then developed a matrix for the comparison of children's IQ points lost by methyl mercury ingestion by the mother, or gained by EPA+DHA consumption. A further matrix for dioxins vs EPA+DHA was also constructed. Examples of the overall effects of eating one and seven servings of 100g of seafood per week are shown in Table 6 for IQ points lost from methyl mercury and gained from EPD+DHA, and Table 7 comparing the lives lost from dioxin exposure to those saved by the effect of EPA+DHA on reduction of coronary heart disease. The Group also made calculations for two and four servings per week, which are given in the Expert Consultation report. For those species included in the data base and other species, for which accurate compositional data is available, the numbers can be entered into the matrix to determine net benefit or risk. Where adequate data is not available, an additional step of compositional analysis must be undertaken. It would be most useful if the recommendation of the Consultation, that regional and international compositional data bases should be improved, was actively taken up.

**Table 6. Estimated changes in child IQ resulting from the child's mother having consumed fish with different methyl mercury and EPA plus DHA contents at one and seven servings per week**

**(a) One serving per week**

| | | | **EPA + DHA** | | | |
|---|---|---|---|---|---|---|
| | | | $x \leq 3$ mg/g | $3 < x \leq 8$ mg/g | $8 < x \leq 15$ mg/g | $x > 15$ mg/g |
| | | Median | 2 | 5.5 | 11.5 | 20 |
| **Methylmercury** | $x \leq 0.1$ μg/g | 0.05 | **−0.02, −0.08**<br>*+0.77* | **−0.02, −0.08**<br>*+2.1* | **−0.02, −0.08**<br>*+4.4* | **−0.02, −0.08**<br>*+5.8* |
| | $0.1 < x \leq 0.5$ μg/g | 0.3 | **−0.12, −0.47**<br>*+0.77* | **−0.12, −0.47**<br>*+2.1* | **−0.12, −0.47**<br>*+4.4* | **−0.12, −0.47**<br>*+5.8* |
| | $0.5 < x \leq 1.0$ μg/g | 0.75 | **−0.30, −1.2**<br>*+0.77* | **−0.30, −1.2**<br>*+2.1* | **−0.30, −1.2**<br>*+4.4* | **−0.30, −1.2**<br>*+5.8* |
| | $x > 1.0$ μg/g | 1.5 | **−0.60, −2.3**<br>*+0.77* | **−0.60, −2.3**<br>*+2.1* | **−0.60, −2.3**<br>*+4.4* | **−0.60, −2.3**<br>*+5.8* |

**(b) Seven servings per week**

| | | | **EPA + DHA** | | | |
|---|---|---|---|---|---|---|
| | | | $x \leq 3$ mg/g | $3 < x \leq 8$ mg/g | $8 < x \leq 15$ mg/g | $x > 15$ mg/g |
| | | Median | 2 | 5.5 | 11.5 | 20 |
| **Methylmercury** | $x \leq 0.1$ μg/g | 0.05 | **−0.14, −0.5**<br>*+5.4* | **−0.14, −0.5**<br>*+5.8* | **−0.14, −0.5**<br>*+5.8* | **−0.14, −0.5**<br>*+5.8* |
| | $0.1 < x \leq 0.5$ μg/g | 0.3 | **−0.84, −3.3**<br>*+5.4* | **−0.84, −3.3**<br>*+5.8* | **−0.84, −3.3**<br>*+5.8* | **−0.84, −3.3**<br>*+5.8* |
| | $0.5 < x \leq 1.0$ μg/g | 0.75 | **−2.1, −8.2**<br>*+5.4* | **−2.1, −8.2**<br>+5.8 | **−2.1, −8.2**<br>+5.8 | **−2.1, −8.2**<br>+5.8 |
| | $x > 1.0$ μg/g | 1.5 | **−4.2, −16.3**<br>*+5.4* | **−4.2, −16.3**<br>*+5.8* | **−4.2, −16.3**<br>*+5.8* | **−4.2, −16.3**<br>*+5.8* |

For the construction of these tables, fish serving size was estimated to be 100 g. The ratio of DHA to EPA + DHA was assumed to be 0.67. Maternal body weight was assumed to be 60 kg. The numbers in the upper row in each cell (**bold**) are estimates of the number of IQ points lost as a result of methyl mercury exposure, with the lower of the two values being calculated using the central estimate of −0.18 and the higher value calculated using the upper estimate of all studies of −0.7. The number in the lower row in each cell (*Italics*) is the estimate of IQ points gained from DHA exposure using the coefficient of 4 IQ points for 100 mg of DHA intake. The maximum positive effect from DHA was estimated at 5.8 points, equivalent to 150 mg/day DHA. Grey shaded cells represent the estimates where the net effect on child IQ, using the upper-bound estimate for methyl mercury, is negative. However, if the lower estimate is used even 7 servings per week of all species would remain within limits and the benefits would exceed the risks.

**Table 7. Estimated changes in mortality per million people from consuming fish with different dioxin and EPA plus DHA contents at one and seven 100 g servings per week**

**(a) One serving per week**

| | | | **EPA + DHA** | | | |
|---|---|---|---|---|---|---|
| | | | $x \le 3$ mg/g | $3 < x \le 8$ mg/g | $8 < x \le 15$ mg/g | $x > 15$ mg/g |
| | | Median | 2 | 5.5 | 11.5 | 20 |
| **Dioxins** | $x \le 1.0$ pg/g | 0.2 | **+50** *−4550* | **+50** −12 500 | **+50** *−26 200* | **+50** *−39 800* |
| | $1.0 < x \le 4.0$ pg/g | 2.5 | **+600** *−4550* | **+600** *−12 500* | **+600** *−26 200* | **+600** *−39 800* |
| | $4.0 < x \le 8.0$ pg/g | 6.0 | **+1400** *−4550* | **+1400** *−12 500* | **+1400** *−26 200* | **+1400** *−39 800* |
| | $x > 8.0$ pg/g | 20.0 | **+4800** *−4550* | **+4800** *−12 500* | **+4800** *−26 200* | **+4800** *−39 800* |

**(b) Seven servings per week**

| | | | **EPA + DHA** | | | |
|---|---|---|---|---|---|---|
| | | | $x \le 3$ mg/g | $3 < x \le 8$ mg/g | $8 < x \le 15$ mg/g | $x > 15$ mg/g |
| | | Median | 2 | 5.5 | 11.5 | 20 |
| **Dioxins** | $x \le 1.0$ pg/g | 0.2 | **+330** *−31 900* | **+330** *−39 800* | **+330** *−39 800* | **+330** *−39 800* |
| | $1.0 < x \le 4.0$ pg/g | 2.5 | **+4200** *−31 900* | **+4200** *−39 800* | **+4200** *−39 800* | **+4200** *−39 800* |
| | $4.0 < x \le 8.0$ pg/g | 6.0 | **+10 000** *−31 900* | **+10 000** *−39 800* | **+10 000** *−39 800* | **+10 000** *−39 800* |
| | $x > 8.0$ pg/g | 20.0 | **+33 300** *−31 900* | **+33 300** *−39 800* | **+33 300** *−39 800* | **+33 300** *−39 800* |

The mean body weight of the population was assumed to be 60 kg. The numbers in the upper row in each cell (**bold**) are estimates of the number of lives lost from dioxin exposure calculated using the upper-bound estimates of risk. The numbers in the lower row in each cell (*Italics*) are the estimates of the lives saved due to reduction in coronary heart disease risk as a result of EPA + DHA intake. The maximum positive effect from EPA + DHA was estimated to occur at 250 mg/day. Grey shaded cells indicate where the net effect would be negative – lives lost are greater than lives saved. However, note from Table 4 that no species were identified in this danger zone, that is with 8 pg/g or more of dioxin and an EPA+DHA content below 3mg/g. This does not mean that there are no such species and emphasizes the need for more analytical data.

Although at first glance the above tables appear complicated, an analysis leaves in no doubt the conclusion that the benefits of seafood consumption vastly exceed the risks, except under extreme circumstances involving excessive consumption of a few species. The graphic in Figure 1 below, which the Washington Post developed from the report of the FAO/WHO Expert Consultation, gives a simplified visual presentation of how the level of risk and benefit depends on the composition of the seafood species.

But if seafood is good for you: how much should the average consumer eat? National and international food safety agencies in general encourage the consumption of seafood as part of a healthy lifestyle, but there is some equivocation in their recommendations on weekly intake. However, the generally held view is that eating seafood (at least) twice a week is beneficial.

In the UK the SACN/COT panel recommended that women of reproductive age should eat two servings per week, one of which should be of oily fish, while males and post-reproductive women should eat four servings per week. EFSA for the EU recommends 2 servings per week but that pregnant women should avoid species known to be high in mercury. In the USA the US FDA/US EPA and the American Heart Association (AHA) recommend two servings a week, with FDA/EPA warning against high mercury and AHA stressing oily fish. Health Canada also recommends two servings per week. In Australia and New Zealand: FSANZ and the Australian Heart Foundation have recommended 2-3 servings a week, with FSANZ appending a list of species to avoid. In Japan the MHLW provides specific advice for pregnant women to limit consumption of named species but suggests no restrictions for other consumers.

WHO/FAO in 2003 suggested that 1-2 servings a week would give protection from coronary heart disease. The recommendations need to be interpreted intelligently to eat a sufficient quantity to provide on average the 150mg/day of EPA+DHA that would enable pregnant women to increase their offspring’s IQ by 5.8 points, and for others perhaps to provide the 250mg/day that would give maximum protection from coronary heart disease. Knowledge of the composition of the various species is therefore essential, leading to encouragement of the inclusion of nutritional information on packaging or at point-of-sale. The effect of increasing publicity is that the average consumer is becoming more knowledgeable about a healthy life style and more demanding in their choice. The seafood industry can benefit by playing to this strength.

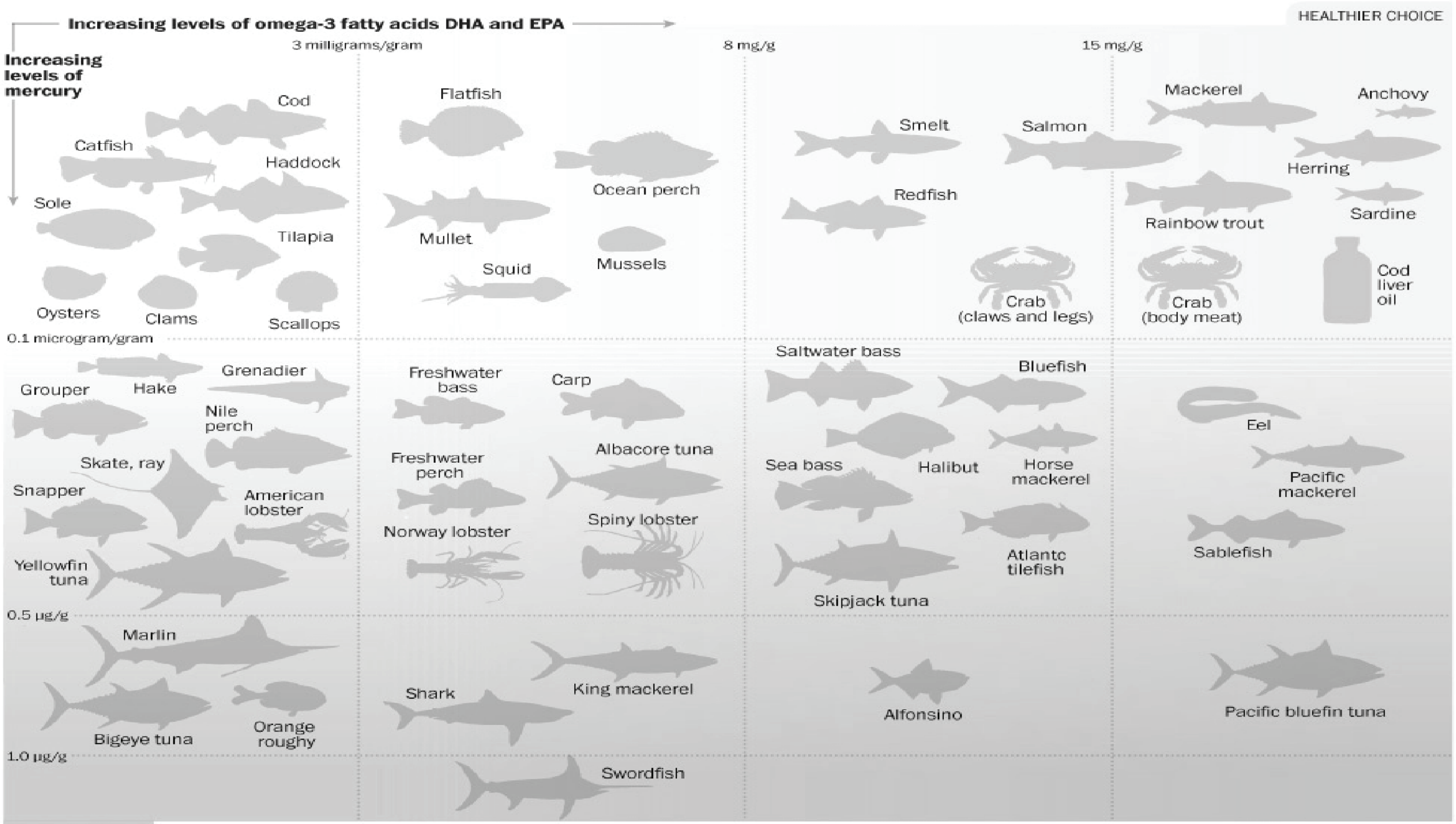
## 5. SUSTAINABILITY

This Research Report has amply demonstrated that under almost all circumstances the benefits of moderate seafood consumption far outweigh the risks. Although there is no association between resource sustainability and human health, should there be a dramatic response to the message it would be necessary to consider the impact on the capacity of the ecosystem to respond and on the sustainability of aquatic resources. Based on FAO preliminary estimates for 2011, produced in early 2012, total world seafood production (capture and aquaculture), excluding aquatic plants, has shown recent new growth, after a period of stagnation, increasing from 143 million tonnes in 2008 to a preliminary estimate of 152 million tonnes for 2011.

The growth has been in aquaculture as capture fisheries have remained at around 90 million tonnes per year for the last 20 years. Even with the widespread failure to manage fishery resources properly, which has resulted in a situation that some 28 percent of stocks are overexploited, there is general scientific agreement that significantly more cannot be produced from wild fish populations. Any future increases, therefore, will have to come from aquaculture. Global per capita consumption has also risen to an estimated 18.8 kg/year, but this hides enormous variations. FAO data show that countries with the highest consumption are in the range of 100 to 200 kg per capita per year, while others have very low consumption in the range of 0.1 to 1 kg per capita per year.

Aquaculturists are optimistic that much more fish could be produced if greatly increased demand results from the perceived health benefits of seafood. However, it would be necessary to use land-based feeds as there would be constraints on the availability of feed from aquatic resources. This raises potential issues of nutritional quality as LC-PUFAs would be low. They would have to be sourced from elsewhere, at competitive prices, for incorporation in the feed, if the health benefits were to be maintained. There is intensive ongoing research on production methods as well as some significant manufacturing. A number of avenues are being followed; including yeast fermentation of hydrocarbons, extraction from algae and the genetic modification of plants to become producers of LC-PUFA.

**Figure 1. The species from the FAO/WHO report data base displayed to show how seafood ranges from a healthier to a riskier choice**




***Source:*** Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption. Patterson Clark/The Washington Post. Published on April 3, 2012.

## 6. CONCLUSIONS

This Globefish Research Report presents convincing evidence that the proven benefits of seafood consumption far outweigh the possible risks. The debate can be summarized by reference to the conclusions of the FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption, which are reproduced below. These represent the most recent scientifically justified commentary on the topic. It is hoped that sufficient explanation is given in this Globefish Report to enable the reader to understand the reasoning behind these conclusions. A list of further reading is included at the end of the report for those who wish for a deeper understanding.

- Consumption of fish provides energy, protein and a range of other important nutrients, including the long-chain ω-3 polyunsaturated fatty acids (LC-PUFAs).
- Eating fish is part of the cultural traditions of many peoples. In some populations, fish is a major source of food and essential nutrients.
- Among the general adult population, consumption of fish, particularly fatty fish, lowers the risk of mortality from coronary heart disease. There is an absence of probable or convincing evidence of risk of coronary heart disease associated with methylmercury. Potential cancer risks associated with dioxins are well below established coronary heart disease benefits from fish consumption.
- When comparing the benefits of LC ω-3 PUFAs with the risks of methylmercury among women of childbearing age, maternal fish consumption lowers the risk of suboptimal neurodevelopment in their offspring compared with the offspring of women not eating fish in most circumstances evaluated.
- At levels of maternal exposure to dioxins (from fish and other dietary sources) that do not exceed the provisional tolerable monthly intake (PTMI) of 70 pg/kg body weight established by JECFA (for PCDDs, PCDFs and coplanar PCBs), neurodevelopmental risk for the foetus is negligible. At levels of maternal exposure to dioxins (from fish and other dietary sources) that exceed the PTMI, neurodevelopmental risk for the foetus may no longer be negligible.
- Among infants, young children and adolescents, the available data are currently insufficient to derive a quantitative framework of the health risks and health benefits of eating fish. However, healthy dietary patterns that include fish consumption and are established early in life influence dietary habits and health during adult life.

## 7. LIST OF FURTHER READING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**ANNEX 1**

## Executive Summary of the Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption

**25–29 January 2010, Rome, Italy**

### Background

The 38th meeting of the Codex Committee on Food Additives and Contaminants (CCFAC) requested the Codex Alimentarius Commission (CAC), at its 29th session in 2006, to seek scientific advice from FAO and WHO on the health benefits of fish consumption comparing those to the health risks associated with the contaminants methylmercury (MeHg) and dioxins and dioxin-like PCBs (DLCs) that may be present in fish. The health risks associated with dietary intake of these compounds have previously been assessed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

The CAC request was driven by growing public concern regarding the presence of chemical contaminants in fish. This concern has become more apparent in recent years, while during the same period the multiple nutritional benefits of including fish in the diet have become increasingly clear.

The evolving science in this field has led to questions about how much fish should be eaten, and by whom, in order to minimize the risks of chemical exposures and maximize the health benefits. National authorities have been faced with the challenge of communicating complicated and nuanced messages to consumers and also with questions on regulating maximum levels of these chemical contaminants in fish and other foods.

FAO and WHO held an Expert Consultation on the Risks and Benefits of Fish Consumption 25 to 29 January 2010 at FAO Headquarters, Rome, Italy. Seventeen experts in nutrition, toxicology, epidemiology, dietary exposure and risk-benefit assessments discussed the risks and the benefits of fish consumption. Their task was to review data on nutrient and specific chemical (MeHg and DLCs) contaminant levels in a range of fish species, as well as recent scientific literature covering the risks and benefits of fish consumption. The review was used to consider risk-benefit assessments for specific end-points of benefits and risks, including for sensitive groups of the population. The output is intended to provide guidance to national food safety authorities and the Codex Alimentarius Commission in their work on managing risks taking into account the existing data on the benefits of eating fish.

**Scope**

- The purpose of the Expert Consultation was to provide a framework for assessing the net health benefits or risks of fish consumption that would assist governments to prepare advice for their own populations.

- Fish was defined as finfish and shellfish, whether of marine or freshwater origin, farmed or wild. Marine mammals and algae, as well as sustainability issues and environmental impacts, although important, were considered to be outside the scope of the Consultation.

- Based on the strength of the evidence, the Consultation examined the benefits of fish consumption on neurodevelopment and prevention of cardiovascular disease. Multiple other possible benefits were reviewed in background papers but not focused upon by the Consultation in their consideration of relative risks and benefits. The Consultation also examined the risks from fish consumption of MeHg and DLCs, including dioxins, furans and dioxin-like PCBs.

- The group was also requested to conduct an analysis of these benefits and associated risks and make a series of recommendations for target populations: including fetuses, infants/young children, women of reproductive age and high fish consumers as well as the general population.

**Conclusions**

- Consumption of fish provides energy, protein, and a range of other important nutrients, including the long-chain n-3 poly unsaturated fatty acids (LC n-3 PUFA).

- Eating fish is part of the cultural traditions of many peoples and in some populations is a major source of food and essential nutrients.

- Among the general adult population, consumption of fish, particularly oily fish, lowers the risk of coronary heart disease (CHD) mortality. There is absence of probable or convincing evidence of CHD risks of MeHg. Potential cancer risks of DLCs are well below established CHD benefits.

- When considering benefits of LC n-3 PUFA vs. risks of MeHg among women of childbearing age: maternal fish consumption lowers the risk of suboptimal neurodevelopment in their offspring compared to women not eating fish in most circumstances evaluated.

- At levels of maternal DLC intake (from fish and other dietary sources) that do not exceed the provisional tolerable monthly intake (PTMI) of 70 picograms/kg bodyweight/month established by JECFA, neurodevelopmental risk is negligible. At levels of maternal DLC intake (from fish and other dietary sources) that exceed the PTMI, neurodevelopmental risk may no longer be negligible.

- Among infants, young children, and adolescents, the available data are currently insufficient to derive a quantitative framework of health risks and benefits of eating fish. However, healthy dietary patterns that include fish and are established early in life influence dietary habits and health during adult life.

**Recommendations**

- To minimize risks in target populations, the Consultation recommended a series of steps that member states should take to better assess and manage the risks and benefits of fish consumption and more effectively communicate with their citizens:

  - Acknowledge fish consumption as an important food source of energy, protein, and a range of essential nutrients and part of the cultural traditions of many peoples.

  - Emphasize the benefits of fish consumption on reducing CHD mortality (and CHD mortality risks of not eating fish) for the general adult population.

  - Emphasize the neurodevelopment benefits to offspring of fish consumption by women of childbearing age, particularly pregnant women and nursing mothers, and the neurodevelopment risks to offspring of such women not consuming fish

  - Develop, maintain, and improve existing databases on specific nutrients and contaminants, particularly MeHg and DLCs, in fish consumed in their region.

  - Develop and evaluate risk management and communication strategies that both minimize risks and maximize benefits from eating fish.

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