The role of seafood in a healthy diet

By Amanda Johnson

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The information included in this report is intended to provide general information only and does not address the specific circumstances or health needs of any particular individual or entity. Medical and dietary advice for individuals should be sought from a qualified health professional.

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Summary

Seafood has played an important role in our evolutionary history, and its consumption should continue to be strongly encouraged today.

Fish and shellfish are a good source of high biological value protein and are low in fat and saturated fatty acids. Key micronutrients in fish include iron, zinc, iodine and selenium. Fish eaten with bones, such as salmon and sardines, are a source of calcium. Fish contains B vitamins. Oily fish, and the liver of white fish, are a source of the fat-soluble vitamins A and D.

There is increasing evidence for the beneficial role of fish in a number of different diseases. Fish is a rich source of the very long chain omega-3 polyunsaturated fatty acids (LC*n-3*PUFA) docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which have been linked to health benefits, particularly in relation to the prevention of cardiovascular disease. The protein in fish may also be helpful in promoting satiety in people on weight-reducing diets. Further, LC*n-3* fatty acids may be helpful for people with diabetes and may be protective against cancer, although there is a need for more research in these areas.

The anti-inflammatory effects of LC*n-3*PUFA have also been investigated, and fish and/or LC*n-3*PUFA supplementation may play a beneficial role in some inflammatory conditions.

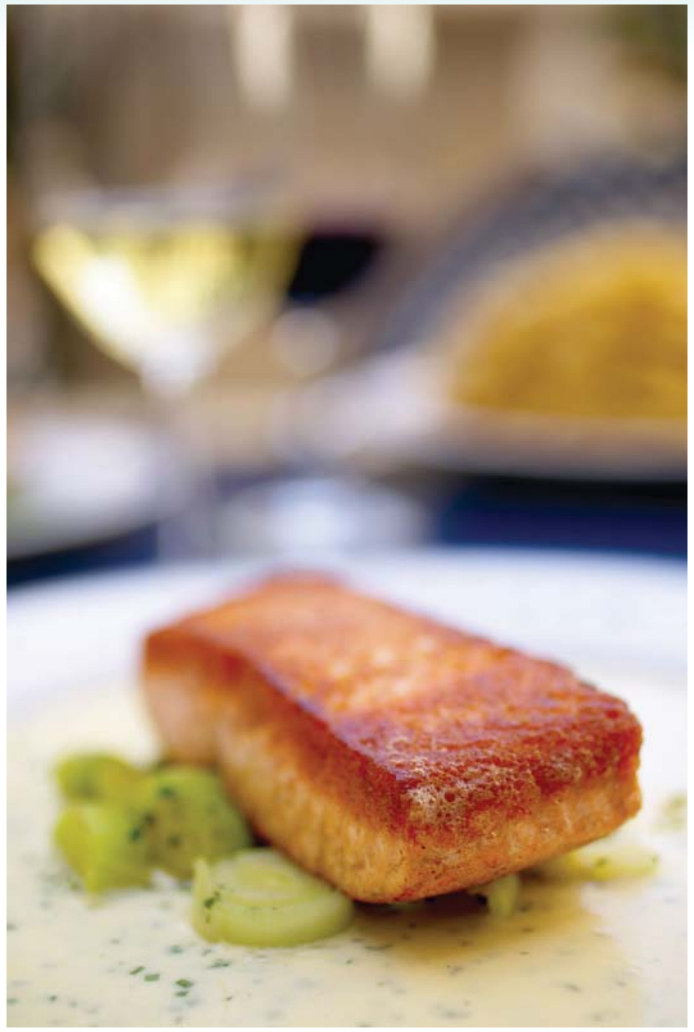
In addition, research seems to indicate that including relatively high intakes of

LC*n-3*PUFA in the diets of pregnant women may be associated with beneficial developmental effects among their babies. There is also some evidence of a positive effect of LC*n-3*PUFA on learning and behaviour in children. And there is a growing body of evidence to suggest that LC*n-3*PUFA might be important for the maintenance of good cognitive function later in life; as such, it has been suggested that older people may benefit from consuming oily fish.

There are limited data on intakes of LC*n-3* fatty acids in the New Zealand population; however, intakes are thought to be modest. Given the evidence for beneficial effects on health, it has been suggested that it would be prudent to increase intakes to 610mg/day for men and 430mg/day for women.

In summary the consumption of fish can make a significant contribution to nutritional intakes, and may be beneficial in helping to prevent some chronic diseases. Fish may also have a role in promoting mental health and wellbeing among some population groups.

This report reviews the key nutrients in seafood, current intakes in New Zealand, and the role of seafood in health and disease.



1. Introduction

Humans have been eating seafood since the beginning of recorded history; ancient Egyptians fished both the River Nile and the Mediterranean Sea, and the ancient Greeks used fish and shellfish extensively (Pigott & Tucker, 1990).

Kai moana, or food of the sea, includes fin fish, shell fish (molluscs and crustaceans), kina (sea eggs) and seaweed. This report is focused primarily on the role of fin fish and shell fish in a healthy New Zealand diet.

Finfish can be divided into two key types: white fish and oily fish. White fish store their fatty reserves in their liver, whereas oil-rich fish, such as salmon, mackerel, pilchards, and sardines, store their fat in their flesh.

Shellfish belong to two invertebrate groups; Mollusca and Arthropoda. Molluscs include the twin-shelled oysters, mussels and scallops, and single shelled creatures such as squid that have an internal rather than an external shell. The edible parts of such species are commonly organs such as digestive glands and gonads as well as muscle. The Anthropoda group of shellfish include Crustacea, and the muscle tissue of these animals constitutes most of the meat consumed, although some internal organs, such as those of crabs, may be eaten. (BNF, 1993).

The freshwater fish lipid profile has a docosahexaenoic acid (DHA): arachiodonic acid (AA) value that is closer to that in our own brain phospholipids than any other known food source. It has been hypothesised that the consistent consumption of fish, crustaceans, molluscs and other species from lake margins provided the means for both initiating and sustaining growth of the cerebral cortex (Broadhurst et al., 1998). Hominids are thought to have scavenged fish and/or fished opportunistically, which helped to increase their intelligence enough for them to fish more often and more successfully (Broadhurst et al., 1998). With respect to modern diets, it is recognised that, for the general population of New Zealand, it is beneficial to include fish in a normal varied diet (National Heart Foundation, 1999).

2 Key nutrients in seafood

Fish is a highly nutritious food; it has a high protein content and is a good source of B vitamins – particularly niacin and vitamin B_{12}. Fish also provides iron, zinc, selenium and iodine, and tinned varieties of fish, such as salmon and sardines, provide calcium, when they are eaten with their bones. Oily fish, and the liver of white fish, contain the fat soluble vitamins A and D.

Fish and shellfish are a good source of the very long chain omega-3 polyunsaturated fatty acids (LC*n-3*PUFA). Oily fish, such as salmon, tuna, mackerel and sardines, which live in icy cold waters, are particularly rich sources, since their PUFA remain liquid at cold temperatures, protecting the fish against the cold (National Heart Foundation, 1999). Other species with a high oil content that are available in New Zealand include kahawai, trevally, kingfish, warehou, dory and eel. Squid, mussels and oysters also have a medium to high fat content (National Heart Foundation, 1999).

Fish contains very little carbohydrate.

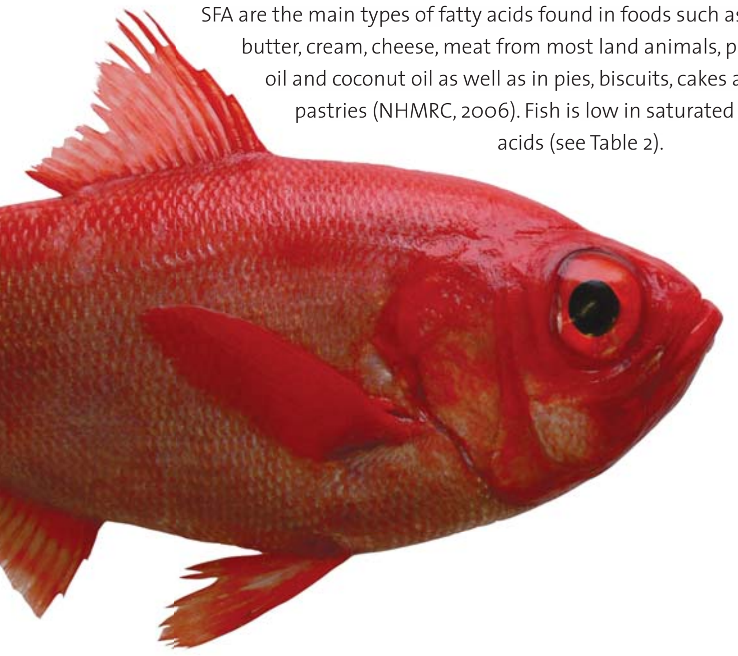
A summary of the nutrients in selected seafood can be found in Table 1.

2.1. Fat

White fish contains very little fat; the fat content of oily fish is slightly higher. Most of the fat present is in the form of the healthy unsaturated fatty acids, in particular the LC*n-3*PUFA. The fat in fish contains a higher proportion of PUFA than chicken or meat, and their cholesterol content is about 40% lower, suggesting fish could be a valuable part of a healthy diet (National Heart Foundation, 1999). The amount of fat per 100g, and the amounts of the different fatty acids in selected seafood, is shown in Table 2.

2.1.1. Saturated fatty acids

Saturated fatty acids (SFA) are fully saturated with hydrogen and contain no double bond. Diets high in SFA increase total and low density lipoprotein (LDL) cholesterol (British Nutrition Foundation, 2005). SFA are the main types of fatty acids found in foods such as milk, butter, cream, cheese, meat from most land animals, palm oil and coconut oil as well as in pies, biscuits, cakes and pastries (NHMRC, 2006). Fish is low in saturated fatty acids (see Table 2).



2.1.2. Monounsaturated fatty acids

Monounsaturated fatty acids (MUFA) have one double bond; the main MUFA is oleic acid (NHMRC, 2006). Monounsaturates have been found to help lower the amount of LDL cholesterol in the blood, while maintaining high density lipoprotein (HDL) blood cholesterol levels. Fish provides some monounsaturated fatty acids (see Table 2).

2.1.3. Polyunsaturated fatty acids

Polyunsaturated fatty acids (PUFA) contain two or more double bonds. There are two distinct families of PUFA: omega-3 and omega-6 (abbreviated as *n-3* and *n-6*). These two families can not be inter-converted. The *n-6* family is derived from linoleic acid, which has two double bonds; the *n-3* family is derived from alpha-linolenic acid (ALA), which has three double bonds. These parent fatty acids can not be made by the human body and have to be provided by the diet; as such they are referred to as essential fatty acids (BNF, 1999).

Provided that the raw materials are available via the diet, the LC*n-3*PUFA can be produced by the body, by introducing double bonds and lengthening the carbon chain (BNF, 1999). This conversion is done slowly and sparingly and neither humans nor plants can easily convert the parent *n-3*PUFA ALA into its longer chain derivatives such as EPA and DHA; the only form of life that can readily make these longer chain fatty acids are algae (BNF, 1993). Since all fish feed on algae, they become rich sources of EPA and DHA. Fish and other seafood are a rich dietary source of LC*n-3*PUFA (Howe et al., 2006).

High intakes of *n-6*PUFA have been linked with a lower risk of coronary heart disease (CHD) and lower LDL cholesterol levels (NHMRC, 2006; BNF, 2005). The LC*n-3*PUFA have little effect on blood cholesterol, but reduce triglyceride levels and have a beneficial effect on blood clotting. DHA plays an important role in structural membrane lipids, particularly in nerve tissue and the retina, and can also act as a precursor to certain eicosanoids (NHMRC, 2006). EPA is the precursor of the 3 series of prostaglandins and the 5 series of leukotrienes (NHMRC, 2006). Experimental studies have shown LC*n-3*PUFA modify inflammatory and immune reactions (Simopoulus, 2002). For more detailed information on the health effects of LC*n-3*PUFA, see section 5. The total PUFA content of selected seafood is shown in Table 2, including a breakdown of *n-3* and *n-6* fatty acids.

2.2. Protein

Fish is a good source of high biological value protein, most finfish providing around 20-25g per 100g portion, as shown in Table 1. The protein content of shellfish is slightly lower, ranging from 8-20g per 100g (Lesperance et al., 2009).

The amount of connective tissue in fish is low (typically 2% or less) and it softens and dissolves on heating in the presence of water more quickly and at a lower temperature than the connective tissue of land animals (BNF, 1993). Cooked fish is, therefore, easy to chew and digest.

Table 1: Nutritional composition of selected seafood (per 100g)

Nutrient	*Snapper flesh, baked (100g)**	*Tarakihi flesh, baked (100g)**	*Salmon, red, canned (100g)**	*Tuna, canned in spring water, drained (100g)**	*Mussel, green, steamed (100g)**	*Adult NZ RDI***
Energy (kJ)	556	461	653	468	498	5,600-18,600
Protein (g)	25.2	24.4	20.3	25.3	18.8	46-81
Fat (g)	3.4	1.3	8.2	1.2	3.1	-
Vitamin A (total vitamin A equivalents) (µg)	35	10	90	trace	57	700-1,100
Thiamin (mg)	0.1	0.02	0.04	0.04	0.02	1.1-1.4
Riboflavin (mg)	0.02	0.02	0.18	0.11	0.18	1.1-1.6
Total niacin equivalents (mg)	8.6	7	10.8	17.9	5.4	14-18
Vitamin B_6 (mg)	0.1	0.1	0.45	2.04	0.08	1.3-2.0
Vitamin B_{12} (µg)	0.63	0.63	4.0	3.29	20.0	2.4-2.8
Total folate (µg)	18	18	12	4	39	400-600
Sodium (mg)	99	97	570	288	553	460-920+
Potassium (mg)	608	531	300	239	399	2,800-3,800+
Calcium (mg)	22	25	93	9	173	1,000-1,300
Iron (mg)	0.7	0.5	1.4	1.2	10.9	8-27
Zinc (mg)	0.6	0.4	0.9	0.9	1.6	8-14
Selenium (µg)	120	40	19.5	47.2	75.6	60-75
Iodine (µg)	56	48.4	27.4	12.7	17.2	150-270

Sources: *Lesperance et al., 2009; **NHMRC, 2006

RDI is the Recommended Dietary Intake (the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage and gender group).

+Adequate Intake (AI), used when an RDI can't be determined.

2.3. Micronutrients

2.3.1. Iron

Iron is needed for the production of a number of proteins in the body, including haemoglobin, myoglobin, cytochromes and enzymes involved in redox (reduction- oxidation) reactions (NHMRC, 2006).

Dietary iron is found in two forms: haem and non-haem. Around 25% of haem iron (found in animal foods such as meat and fish) is absorbed in the body. (Hallberg & Rossander-Hulthen, 1991). Non-haem iron (found in foods such as vegetables and cereals) is less bioavailable and absorption is influenced by other dietary components. Absorption of iron in a vegetarian diet is around 10%, which means that iron requirements for vegetarians are around 80% higher than those of people who consume a mixed diet including animal foods (NHMRC, 2006).

Iron deficiency is the most common nutritional deficiency in industrialised countries, with anaemia affecting just over 1.5 billion people worldwide, equivalent to almost 25% of the world's population (McLean et al., 2008). The adverse effects of iron deficiency include reduced physical

Table 2: Fat and fatty acid content of selected seafood (per 100g)

Type of fish	*Total fat (g)*	*SFA (g)*	*MUFA (g)*	*PUFA (g)*	*n-3 (g)*	*n-6 (g)*
Eel, smoked	11.1	2.5	4.1	3.5	0.4	0.7
Flounder, flesh, baked	3.1	0.7	0.8	0.7	0.5	0.2
Hoki, flesh, baked	1.3	0.3	0.4	0.3	0.3	0
Orange roughy, flesh, baked	10.2	0.5	8.1	0.4	0.2	0.2
Salmon, red, canned	8.2	2.0	3.1	2.1	1.7	0
Snapper, flesh, baked	3.4	0.9	0.8	0.7	0.6	0.1
Tarakihi, flesh, baked	1.3	0.3	0.3	0.5	0.4	0.1
*Tuna in spring water, canned, drained**	1.2	0.4	0.2	0.3	0.2	0.1
Mussel, green, steamed	3.1	0.9	0.6	0.9	0.8	0
Shrimp, canned, drained	1.2	0.2	0.3	0.4	0.1	0

Source: Lesperance et al., 2009

*Although tuna is an oily fish, traditional canning methods usually involve pre-cooking the tuna before canning. As some of the fish oil drains away during this pre-cooking stage, the amount of fat and fatty acids is reduced.

work capacity, delayed psychomotor development in infants, impaired cognitive function, impaired immunity and adverse pregnancy outcomes (NHMRC, 2006). In New Zealand, iron deficiency is prevalent among infants and toddlers (Soh et al., 2004; Grant et al., 2007), adolescent girls (Schaaf et al., 2000) and women of childbearing age (Ferguson et al., 2001).

Red meat is one of the richest sources of dietary haem iron; however, fish can also make a useful contribution to intakes of iron in New Zealand, since the iron is present in the haem form and is well absorbed. The protein in meat, fish and poultry can also help to increase the absorption of non-haem iron from vegetables and cereals when eaten at the same time (NHMRC, 2006).

Fish and shellfish provide 4% of our iron intakes (Russell et al., 1999), although the actual contribution maybe higher than this since the iron is well absorbed. Among seafood, the richest sources of iron are mussels (up to 10.9mg/100g), oysters (9.4mg/100g), cockles (7.9mg/100g) and dark-fleshed fish such as sardines (2.9mg/100g) (Lesperance et al., 2009).

2.3.2. Zinc

Zinc is a component of various enzymes that help maintain the structural integrity of proteins and regulate gene expression. Mild zinc deficiency can result in impaired growth velocity, sub-optimal pregnancy outcomes and impaired immune responses (NHMRC, 2006).

In general, the absorption of zinc will be higher from animal foods such as fish than from plant sources, so vegetarians, particularly strict vegetarians whose major staples are grains and legumes, will require zinc intakes around 50% higher than non-vegetarians (NHMRC, 2006).

Zinc is widely distributed in foods; meat, fish and poultry are the major contributors to the diet, but cereals and dairy food also contribute substantial amounts (NHMRC, 2006). Oysters are a particularly good source of zinc, providing 10.3mg per 100g, and sardines are also a good source, providing 3mg per 100g (Lesperance et al., 2009).

2.3.3. Selenium

Selenium functions as an antioxidant and in redox reactions is a constituent of several selenoproteins (NHMRC, 2006). Selenium is essential for optimal immune function (Arthur et al., 2003) and may also be anti-carcinogenic (Combs, 2005). A selenium intake that is higher than that recommended may have additional health benefits; however, large-scale trials are needed to establish the level of selenium that is protective (Thomson, 2004a). Overt deficiency of selenium in humans is rare but results in Keshan disease, an endemic cardiomyopathy that occurs in adolescent or pre-adolescent years in low selenium areas of China (Yang et al., 1988).

The main sources of selenium in the diet are seafood, poultry and eggs, and to a lesser extent other muscle meats; cereals are also a source of selenium, but their contribution varies depending on the source of the crop (Thomson, 2004b). Fish and seafood are a major contributor to overall selenium intakes in New Zealand, providing 29% of intakes (Ministry of Health, 2003a).

In spite of a recent increase in selenium status, the status of New Zealanders remains low compared with the populations of many other countries, and may be considered marginal, although the clinical consequences of the marginal selenium status are unclear (Thomson, 2004b). An analysis of data from the 2002 *Children's Nutrition Survey* (which looked at children aged 5-15) found that the selenium status of our children falls in the middle of the international range of serum selenium concentrations; however, the selenium status of South Island children is among the lowest values reported, and may be a cause for concern (Thomson et al., 2007). One reason for the regional differences in selenium status is the high fish and poultry intakes of Pacific children, of whom there was a higher proportion in the north of the North Island (60%) compared with the lower North Island (18%) and the South Island (11%). The importation of Australian wheat (which has a higher selenium content) into the upper North Island may also be a factor.

The major contributors to selenium intake in children aged 5-15 in New Zealand are breads and grains (33%), meat (14.8%), poultry (11.2%) and fish/seafood (8.6%). However, when data for fish consumers only were analysed (498 of the total 3,275 children), fish and seafood contributed a much larger proportion of selenium intakes (65%) (Thomson et al., 2007).

A study of younger South Island children (aged 6 to 24 months) and their mothers, found dietary selenium intakes were below recommended levels (McLachlan et al., 2004) with intakes of 7.9 $\pm$ 6.2µg/day in infants (6-11 months); 13.7 $\pm$ 8.4µg/day in toddlers (12-24 months) and 38 $\pm$ 25µg/day in mothers. In this study, meat and fish/seafood combined comprised a significant source of selenium in mothers (32%) but not in the infants and toddlers. The major food source of dietary selenium for both children and mothers were bakery products and cereals.

Older New Zealanders are also at risk of poor selenium status. A study that looked at New Zealand women aged 70-80 years found that 74% were at risk of sub-optimal selenium status (de Jong et al., 2001).

The promotion of foods that provide a good source of selenium should be encouraged, particularly in population groups vulnerable to poor selenium status, such as infants and young children, women of childbearing age and older people. Fish can make a useful contribution to selenium intakes among these groups.

2.3.4. Iodine

Iodine is an integral part of the hormone thyroxine (T_4), which is required for normal growth and metabolism.

Most soils in New Zealand are low in iodine, which results in low concentrations in locally-grown foods; in addition the discontinuation of iodine-containing sanitisers within the dairy industry in New Zealand has resulted in reduced iodine content in milk. Both these factors, along with a reduction in intake of iodised table salt, have meant a decline in iodine intakes in New Zealand (NHMRC, 2006). Research suggests the possible re-emergence of mild iodine deficiency and goitres among New Zealand adults (Thomson et al., 2001). Mild iodine deficiency has also been documented in a sample of New Zealand school children aged 8-10 years (Skeaff et al., 2002).

Iodine deficiency results in a range of disorders; severe deficiency can have major effect on the foetus (such as abortion, still birth or congenital anomalies), and in neonatal life, childhood or adulthood, iodine deficiency can lead to goitre or hypothyroidism, as well as impaired mental and motor development (NHMRC, 1996). The consequences of the decrease in iodine status of New Zealanders is unclear (Thomson, 2004); however, it would seem prudent to increase iodine intakes in New Zealand.

Since September 2009 it has been mandatory for bread manufacturers to replace non-iodised salt in breads with iodised salt (with the exception of organic and unleavened bread). Consuming foods that are naturally rich in iodine will also help to ensure an optimal iodine status; the major food sources of iodine are of marine origin, for example, fish, shellfish and seaweed. Mussels and oysters are particularly good sources, providing 172µg/100g (green steamed mussels) and 100µg/100g (dredge oyster, flesh, raw) respectively. Salmon (red, canned) contains 27.4µg/100g and tarakihi flesh baked 48.4µg/100g (Lesperance et al., 2009). The recommended dietary intake for adults 19 years and over is 150µg/day (NHMRC, 2006). Milk, milk products and eggs also provide iodine. A further dietary source of iodine is iodised table salt. The Ministry of Health does, however, recommend limiting overall salt intake, so if salt is used, it should be iodised (Ministry of Health, 2003a). Women who are pregnant or breastfeeding are advised to take a daily 150µg iodine supplement, which has been available in New Zealand since July 2010.

2.3.5. Calcium

Calcium is required for the normal development and maintenance of the skeleton as well as for proper neuromuscular and cardiac function (NHMRC, 2006).

Calcium is found predominantly in milk and milk products. However, some calcium is also provided by the bones in some tinned fish, such as canned salmon and sardines.

2.3.6. Vitamin A

Vitamin A is a fat-soluble vitamin that helps maintain normal reproduction, vision and immune function (NHMRC, 2006). Fish muscle is generally low in vitamin A as most fish and shellfish are low in fat. The fattier fish do provide some vitamin A, but not in significant amounts (see

Table 1). Other sources of vitamin A include milk, cheese and eggs. Also, beta-carotene (a precursor of vitamin A) is found in yellow and orange fruits and vegetables and green leafy vegetables.

Fish oil supplements may be high in vitamin A and as such are not recommended for pregnant women. It is particularly important that pregnant women do not exceed the upper limit for vitamin A (3,000µg RE/day) because of the serious toxicity of high intakes during pregnancy.

2.3.7. B Vitamins

Vitamin B_{12} is required for the synthesis of fatty acids in myelin and, in conjunction with folate, for DNA synthesis (NHMRC, 2006). An adequate intake of vitamin B_{12} is essential for normal blood and neurological function. Seafood is a rich source of vitamin B_{12}, which is only found naturally in foods of animal origin. A 100g portion of salmon or tuna, or a 30g portion of mussels, for example, provides the entire recommended daily intake of vitamin B_{12} for adults (see Table 1). For strict vegans, who avoid all animal products, fortified foods or supplements will be necessary to provide adequate B_{12} (NHMRC, 2006).

Seafood is also a good source of niacin. One portion (100g) of tuna provides enough niacin to meet the recommended daily intake for an adult (see Table 1). Seafood also provides small amounts of other B vitamins, such as thiamin, riboflavin and vitamin B_6.

2.3.8. Vitamin D

Vitamin D is a fat-soluble vitamin and is an important nutrient for bone health. The main function of vitamin D is to help maintain serum calcium concentrations by enhancing the ability of the small intestine to absorb calcium from the diet (NHMRC, 2006). Vitamin D status is generally maintained by the exposure of the skin to sunlight. Where exposure to sunlight is inadequate, dietary sources of vitamin D become important.

Some vitamin D is provided by oily fish, such as salmon. Vitamin D is present in large amounts in fish liver, and is found in some fish oil supplements. Fortified foods such as milk and yoghurt are also sources of vitamin D.

3 The role of seafood in the diets of different population groups

Fish and shellfish are nutrient-dense foods and can make an important contribution to the nutritional intakes of different population groups.

3.1. Infants and toddlers

From around the time an infant is six months of age, complementary foods make an increasingly important nutritional contribution to the diet. At this time iron and zinc stores are likely to be depleted, so it is particularly important that foods providing these nutrients are supplied. Fish is a good source of these nutrients and can be introduced from six to seven months of age – initially fish should be served cooked and puréed, progressing to mashed, then chopped as the child gets older. Tinned fish should be avoided as a first food and the recommended minimum age for introducing seafood such as sea eggs, crayfish, periwinkles, parengo (a type of seaweed), paua and eels, is 8-12 months (Ministry of Health, 2008a).

Oily fish are an excellent source of the LC*n-3*PUFA, thought to be important for cognitive development in young children (see section 5.7). For toddlers, mashed tinned fish eaten with bones, such as sardines and salmon, can also make a useful contribution to calcium intakes, particularly in those toddlers who do not have cows' milk or milk products. In addition, fish and seafood are an important source of iodine. This may be particularly useful for New Zealand infants who are exclusively breastfed and who may have a low iodine status resulting from a low iodine status in the mother (Skeaff et al., 2005). Fish and seafood also provide a good source of selenium for this age group.

Toddlers should be offered a variety of nutritious foods from the four main food groups each day, including vegetables and fruit, breads and cereals, milk, milk products or suitable alternatives, and lean meat, poultry, seafood, eggs, legumes, nuts or seeds (Ministry of Health, 2008a).

3.2. Children

Children are one of the most vulnerable groups in society with many special dietary needs, which are often quite different from those of healthy adults (Ministry of Health, 1997). Fish can make a useful nutritional contribution to the diets of children, providing high quality protein for growth and development along with a whole package of vitamins and minerals, including iron, zinc, selenium and iodine. Calcium can be provided by fish eaten with bones and oily fish will provide the LC*n-3*PUFA.

3.3. Adolescents

Adolescence is a time of rapid growth associated with hormonal, cognitive and emotional changes. In particular, adolescents are vulnerable to iron deficiency due to high physiological requirements for growth, high losses in menstruating females, and diets which are often low in haem iron (Ministry of Health, 1998). Fish and shellfish can make a useful contribution to intakes of a variety of nutrients (including haem iron, which is easily absorbed) in this age group. The Ministry of Health (1998) recommends 1-2 servings a day from the meat, fish and alternatives food group for adolescents. One portion of cooked fish is around 100g, and one portion of mussels is around 30g (or three medium mussels).

3.4. Healthy adults

The Food and Nutrition Guidelines for Healthy Adults (Ministry of Health, 2003a) recommend eating well by including a variety of nutritious foods from the four major food groups each day (vegetables and fruit, breads and cereals, milk and milk products, and meat, poultry, seafood, eggs or alternatives). Foods should be low in salt with minimal added fat and sugar.

Adults are advised to consume at least one serving a day of lean meat, poultry, seafood, eggs, nuts and seeds, or legumes.

3.5. Pregnant and breastfeeding women

LC*n-3*PUFA are necessary for normal growth and brain development in the foetus and in infants, especially in the last trimester when nerve tissue growth is maximal (Ministry of Health, 2006). Fish oil supplements during pregnancy and breastfeeding are not, however, recommended and pregnant women are advised to obtain their LC*n-3* fatty acids from food sources. Oily fish (for example sardines, salmon, eel, warehou and kahawai) are an excellent source of LC*n-3*PUFA. In addition, fish and seafood contribute to intakes of minerals, trace elements and vitamins, such as iron, zinc, iodine, selenium and vitamin B_{12}.

Iron requirements during pregnancy increase substantially and in order to meet these requirements pregnant women are advised to consume two portions of lean meat, fish, or alternatives per day (Ministry of Health, 2006). In addition to providing haem iron, fish is an excellent source of selenium, providing the main source of this mineral (31%) for New Zealand women aged 25-44 (Ministry of Health, 2006). Foods rich in selenium should be regularly selected by pregnant and breastfeeding women; additional sources of selenium are meat and poultry, eggs, milk and milk products, bread, nuts and seeds (Ministry of Health, 2006). Iodine is also an important nutrient during pregnancy, and fish and seafood can make a useful contribution to intakes of this mineral.

3.5.1. Mercury and fish – advice for pregnant women

Fish and seafood are highly nutritious and provide a range of important nutrients for pregnant women; however, there have been concerns about the mercury content of some fish and the possible impact on the growing foetus. The New Zealand Food Safety Authority (NZFSA), provides advice on fish consumption for pregnant women. For many of the commonly eaten species of fish in New Zealand there is no concern about the mercury content and these species can be eaten freely (for example, farmed salmon, tarakihi, blue cod, hoki, warehou, whitebait, flounder, mussels and pacific oysters). However, consumption of longer-lived fish, which have a higher mercury content, should be limited to 3-4 servings of 150g per week (for example, orange roughy, kahawai, hapuka (groper), red cod, and rock lobster). For a small number of species it would be wise to eat no more than one serving per week or fortnight, and not at all if consuming other species of fish. These include swordfish, marlin, and lake trout caught in geothermal regions. Pregnant women are also advised limit their intake of Bluff oysters and Queen scallops due to high cadmium concentrations.

Breastfeeding women do not need to limit their consumption of any types of fish.

Further up to date information can be found on the NZFSA website at www.nzfsa.govt.nz.

A review into the risks and benefits of fish consumption in adults concluded that for women of childbearing age the benefits of modest fish consumption (excepting a few species) outweighs the risks (Mozaffarian & Rimm, 2006). The authors caution that avoiding fish consumption due to confusion regarding risks and benefits could result in sub-optimal neurodevelopment in children (for more information, see section 5.7.1), and advise consumption of two portions of fish a week among women of childbearing age and nursing mothers, while limiting intake of selected species. A recent commentary on this issue (Stern, 2007) further recommends that as there are easily available fish that offer both high PUFA and low methylmercury, that consumers should choose wisely among the available fish species to maximise the benefits of fish consumption and to minimise the risks.

Further, a recent review of dietary selenium's protective effects against methylmercury toxicity concludes that reducing maternal seafood consumption to less than two fish meals a week may actually be causing harm because of the loss of nutritional benefits (Ralston & Raymond, 2010). Almost all varieties of ocean fish and seafood are rich dietary sources of selenium; as a result, most ocean fish offer abundant natural protection against any methylmercury they may also contain.

Also of note, a recent FAO/WHO expert report (2010), which looked at the risks and benefits of fish consumption, recommended that the neurodevelopmental benefits to offspring of fish consumption by women of childbearing age should be emphasized, particularly for pregnant women and nursing mothers.

3.6. Older people

The number of older people in New Zealand is expected to rise considerably in the coming decade. Nutrition deserves special attention in this age group as it is essential for good health (Ministry of Health, 2010). Good nutrition in older people will help to prevent malnutrition, will support physical function and mental health, will reduce the risk of chronic disease and will help to prevent disability (Ministry of Health, 2010).

In terms of specific nutritional requirements, the need for riboflavin, calcium and vitamin D, are higher for older people (NHMRC, 2006).

The Ministry of Health recommend eating well by including a variety of nutritious foods from each of the four food groups: vegetables and fruit; breads and cereals (preferably wholegrains); lower fat milk and milk products; and lean meat, poultry, fish and legumes, nuts and seeds.

It may be beneficial to include sources of LC*n-3*PUFA (found in oily fish) in the diet. The LC*n-3*PUFA may be beneficial for heart health (see section 5.1) and may also benefit mental health (see section 5.8.2) in this population group.

4 Current intakes of seafood and *n-3* fatty acids in New Zealand

4.1. Types and frequency of fish and seafood consumption

The 1997 survey *NZ Food: NZ People* (Russell et al, 1999) looked at the diets of people aged 15 years and older, and the 2003 survey *NZ Food NZ Children* (Ministry of Health, 2003b) looked at the diets of children aged 5 to 14 years.

The 1997 survey found that among adults in New Zealand, fish and seafood provide 2% of our energy intake, 3% of our total fat intake, and 7% of our protein intake (Russell et al., 1999). In terms of types of fish eaten, at least once a week 15% of adults have canned fish, 15% have battered fish, 13% have steamed, baked, grilled or raw fish, 12% have fried fish, 6% have shellfish, and 2% have other seafood (such as prawns). Results from the next national nutrition survey are expected in 2011.

Among children aged 5 to 14 years, fish and seafood provided 4% of protein intakes and 22% of selenium intakes. Fish and seafood were the most significant source of selenium for New Zealand children, with Pacific children obtaining more selenium from fish and seafood than Māori or New Zealand European Origin children (Ministry of Health, 2003b). Thirty seven percent of children consumed fish weekly. In terms of types of fish consumed once a week, 13% consumed fish cakes, fish fingers or fish pie, 15% consumed canned fish (such as salmon or tuna), and 9% consumed shellfish.

Table 3: Amounts of n-3 fatty acids in fish

Name of fish	*Amount of n-3 fatty acids (mg/100g)*	*Amount of fish consumption required to provide 1g n-3 fatty acids (g)*
Ling	222	450
Southern bluefin tuna	230	435
John dory	315	317
Garfish	327	306
Red snapper	357	280
Squid	584	171
Gemfish	1,360	74
Swordfish	2,571	39

Adapted from Soltan & Gibson, 2008.

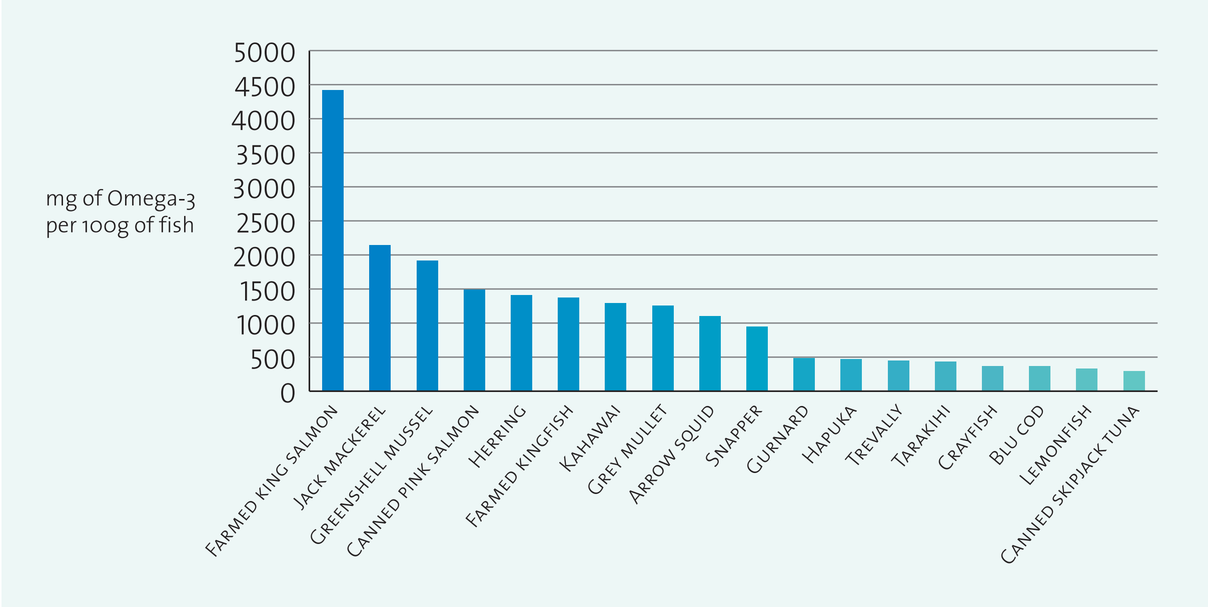
4.2. Intakes of *n-3* fatty acids

There are limited data on intakes of *n-3* fatty acids in the New Zealand population. However, American data show intakes of *n-3* fatty acids in the USA to be 1.6g per day, of which 1.4g is ALA, and 0.1-0.2g is EPA and DHA (Kris-Etherton et al., 2000). The main source of EPA and DHA is fish and fish oils. Attaining the proposed recommended combined intake of EPA and DHA of 650mg per day would require a four-fold increase in fish consumption in the United States.

A recent Canadian study among children aged 4 to 8 found that combined intakes of DHA, EPA and DPA (docosapentaenoic acid) were 55mg per day, which is just 51% of the recommended Australia/New Zealand intake (Madden et al., 2009).

Mean intakes of LC*n-3*PUFA in Australian adults has been estimated to be 246mg/day; women have lower intakes than men proportional to their lower total energy and PUFA intake, and children have substantially lower intakes, even in proportion to their total PUFA intake (Howe et al., 2006). The contribution to LC*n-3*PUFA from fish and seafood was estimated to be 48%.

Figure 1: Omega-3 fatty acids in common varieties of fish



Source: Katvi, 2005. Reproduced with permission.

A recent Australian study found that the fats of Australian fish are rich in *n-3* fatty acids, but because many species that are commonly eaten are low in total fat, a large intake of seafood would be required if consumers were attempting to meet their recommended daily LC*n-3*PUFA intake (Soltan & Gibson, 2008). The amount of *n-3* fatty acids found in selected fish in this study is shown in Table 3 above right. The fish species listed are also found in New Zealand waters.

A New Zealand study in 2005 found that farmed king salmon was a particularly good source of *n-3* fatty acids, as shown in Figure 1 below. Jack mackerel, Greenshell mussels, canned pink salmon, herring, and farmed kingfish were also found to be good sources.

Current intakes of LC*n-3*PUFA in both Australia and New Zealand are thought to be modest; and given the evidence for beneficial effects on health it has been suggested that it would be prudent to increase intakes to 610mg/day for men and 430mg/day for women (NHMRC, 2006).

The Australian Heart Foundation recommends that all adult Australians, to lower their risk of heart disease, consume about 500mg per day of DHA and EPA combined through a mixture of the following: two or three 150g serves of oily fish a week; fish oil capsules or liquid; and/or foods and drinks enriched with marine *n-3*PUFA (National Heart Foundation of Australia, 2008). The American Heart Foundation recommends consuming two servings (around 8oz [225g]) of fish (especially oily) a week (Lichtenstein et al., 2006). In New Zealand, the Heart Foundation recommends that those at high risk of cardiovascular disease aim to eat at least two fish meals a week (200-400g per week), preferably fish and shellfish with high oil content (National Heart Foundation, 1999).

Consumption of concentrated sources of LC*n-3*PUFA, such as farmed king salmon, will help to achieve the recommended intakes of these fatty acids. However, depending on the type of fish consumed, intakes may need to be even higher than that suggested above, to achieve the intake of LC*n-3*PUFA recommended by the NHMRC.

A further consideration is the method of cooking used. One study found, for example, that both the type of fish consumed and the method of cooking used were associated with subsequent plasma levels of EPA and DHA (Chung et al., 2008). In this study, non-fried fish (such as tuna, salmon and sardines) was associated with higher levels of plasma EPA and DHA, even after adjustments for demographic and dietary characteristics. Shellfish and fried fish (such as cod, catfish or shrimp) were not associated with any change in plasma levels of these fatty acids. Often fish used for frying is low in LC*n-3*PUFA and additionally, frying alters the nutrition profile of fish by absorbing fatty acids from cooking oils. This study emphasizes the importance of not only considering levels of consumption of seafood, but also the type of seafood consumed and the cooking methods used.

5 The role of seafood in promoting health and preventing disease

5.1. Coronary heart disease and stroke

In the 1970s, a group of Danish researchers began investigating the diets of Greenland Eskimos, who have a very low rate of heart disease despite a high intake of fat (Bang et al., 1980). They concluded that the rarity of CHD in Greenland Eskimos may in part be explained by the anti-thrombotic effect of the LC*n-3*PUFA, especially the EPA prevalent in diets rich in marine oils. Subsequent research supports the beneficial effect of LC*n-3*PUFA in the prevention and management of cardiovascular disease.

Two significant intervention trials that have investigated the supplementation of LC*n-3*PUFA have shown clinical benefit: the *GISSI-Prevenzione Trial* and the *JELIS Trial*.

The *GISSI-Prevenzione Trial* randomly assigned 11,324 patients surviving recent (ffi3 months) myocardial infarction to receive daily supplements of LC*n-3*PUFA (as a gelatine capsule containing 850 – 882 mg EPA and DHA), 300mg vitamin E, both, or none for 3.5 years (GISSI-Prevenzione Investigators, 1999). Dietary supplementation with *n-3*PUFA led to a clinically important and statistically significant benefit. Vitamin E had no effect. The reduction in risk of sudden death was statistically significant as early as 4 months [RR 0.47; 95% CI 0.219 to 0.995; p= 0.048] (Marchioli et al., 2002).

The *JELIS Trial* randomly assigned 18,645 patients with a total cholesterol of 6.5mmol/l or greater to receive either 1,800mg of EPA/day with statin, or statin only; patients were monitored for an average of 4.6 years (Yokoyama et al., 2007). Sudden cardiac death and coronary death did not differ between the two groups. However, in patients with a history of coronary artery disease who were given EPA, major coronary events were reduced by 19% (8.7% in the EPA group versus 10.7% in the control group [p=0.048]).

These trials confirm the beneficial effects of LC*n-3*PUFA seen in two earlier studies, the *Multiple Risk Factor Intervention Trial* (MRFIT) and the *Diet and Reinfarction Trial* (DART). The MRFIT trial found mortality from CHD, CVD and all causes was 50%, 45% and 27% lower respectively in the highest quintile of intake of fish fatty acids (mean ingestion of 664mg/day) compared with zero intake (Dolecek, 1992). In the DART trial, subjects advised to eat fatty fish had a 29% reduction in 2-year all-cause mortality compared with those not so advised (Burr et al., 1989), although longer-term follow up from this trial did not show any substantial long-term survival benefit (Ness et al., 2002).

The majority of prospective studies have found that increasing fish consumption decreases risk of heart disease. Follow up of the *Health Professionals Study* found that increasing fish intake from 1-2 servings a week to 5-6 servings a week did not substantially reduce the risk of coronary heart disease among men who were initially free of cardiovascular disease (Ascherio et al, 1995). However, a more recent study on the same cohort of men found that modest fish consumption was associated with a lower risk of total cardiovascular disease; compared with a fish intake of <1 serving a month, consumption of one serving and 2-4 servings a week were associated with a lower risk of total CVD of around 15% (Virtanen et al., 2008).

The *Physicians' Health Study* found no evidence that moderate fish consumption reduces risk of myocardial infarction, stroke or cardiovascular death at intakes of less than 100g/day (Morris et al., 1995), although more recently, a strong association has been found in this population between intake of LC*n-3*PUFA found in fish and a reduced risk of sudden death among men without evidence of prior cardiovascular disease (Albert et al., 2002).

The *Nurses' Health Study* also found that, among women, higher consumption of fish and LC*n-3*PUFA was associated with a lower risk of CHD, particularly CHD deaths (Hu et al., 2002).

In relation to long-term fish consumption and risk of sudden CHD death, the Zutphen study examined a cohort of 1,373 men born between 1900 and 1920 repeatedly between 1960 and 2000 (Streppel et al, 2008). Results showed that long-term fish consumption reduced risk of CHD death. There was no clear dose-response relationship, but an average cumulative intake of 1-2 servings of fish per week (an average of 22g per day) was inversely associated with CHD death. The strength of this association decreased with increasing age, and remained statistically significant up to the age of 65 years. Long-term fatty fish consumption (on average 7g per day) lowered the risk of sudden coronary death by 54%.

Various mechanisms have been considered to explain the cardio-protective role of LC*n-3*PUFA. Marine *n-3* fatty acids are effective at lowering elevated plasma triacyglycerol concentrations, although the dose required to achieve these effects is thought to be 3-4g/day (Deckelbaum, 2008). A review of the effect of LC*n-3*PUFA fatty acids on serum markers of cardiovascular disease concluded that most studies of triglycerides found at least a 15% reduction with fish oil consumption; in contrast the net effects on total, LDL and HDL cholesterol levels were small (<5%) (Balk et al., 2006).

It has also been suggested that the reduced risk of sudden death arises from the incorporation of DHA and EPA into myocardial phospholipids during high-dose supplementation with fish oils, at the expense of arachidonic acid (AA) (Metcalf et al., 2007). AA is a precursor of pro-inflammatory eicosanoids, whereas EPA and DHA have been shown to be anti-thrombotic and anti-inflammatory respectively.

LC*n-3*PUFA may also have a small, dose-dependent hypotensive effect, although the extent of the effect seems to be dependent on the degree of hypertension. Given the high dose required (around 3-5g/day), and the proven efficacy of other nutritional factors and of anti-hypertensive medication, overall, the role of *LCn-3*PUFA is limited in the management of hypertension (Kris-Etherton et al., 2002).

The evidence for a beneficial effect on cardiovascular disease of EPA and DHA is strong, but is largely based on epidemiological data and secondary prevention trials (BNF, 2005). A review by Mozaffarian (2008) concludes that modest consumption of fish or fish oil (1-2 servings a week of oily fish or around 250mg EPA + DPA) substantially reduces risk of CHD death and sudden cardiac death. Pooled analysis of prospective cohort studies and randomised controlled trials demonstrates the magnitude and dose-response of this effect, with a 36% lower risk of CHD death with modest consumption, compared to no consumption.

Research into fish consumption and risk of stroke suggests fish may be protective, although research to date is equivocal. The *Health Professional Follow-up Study* found that in men, eating fish once per month reduced the risk of ischemic stroke (He et al, 2002). However, the *Nurses' Health Study* found no association between fish or LC*n-3*PUFA intake and risk of hemorrhagic stroke, though there was a reduced risk of thrombotic infarction, primarily among women who did not take aspirin regularly (Iso et al., 2001).

An eight-and-a-half-year study by Myint et al (2006) found no consistent relationship between total fish consumption and stroke in men and women. The authors suggest that a period of more than 10 years may be needed to show a beneficial effect of fish on the risk of stroke. It is also possible that any protective effect of fish may be an indicator of other dietary patterns or behaviours that may be protective - for example, higher intakes of fruits and vegetables or lower fat intakes. In addition, inconsistencies in the observed health effects of fish in different populations may be a result of different patterns and types of fish consumed and different preparation methods. This suggestion is supported by a study which found that intake of tuna, or other broiled or baked fish, was associated with a reduced risk of ischaemic stroke, while intake of fried fish and fish sandwiches was not (Mozaffarian et al., 2005).

A more recent study also found that although total fish intake did not predict cerebrovascular disease, intake of salted fish increased the risk of intracerebral heamorrhage (Montonen et al., 2009). Further research is needed into the relationship between fish consumption and stroke, particularly into the potential mechanisms that may be involved.

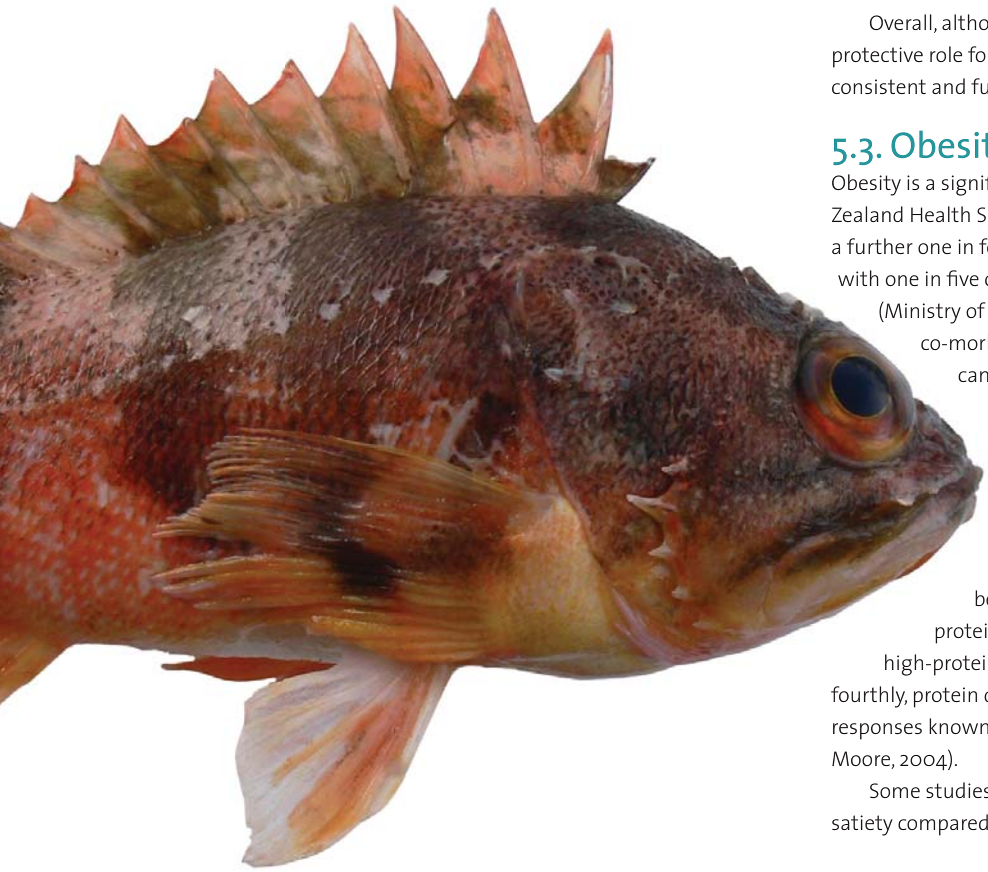
The National Heart Foundation New Zealand recommends that fish should be considered an integral part of the weekly food plan as the regular consumption of one or two fish meals each week has been shown to lower risk factors for CHD as well as reduce the incidence of sudden death post MI (National Heart Foundation, 1999). The recommendation to consume 1-2 fish meals a week was also supported by the evidence-based best practice guideline – *The Assessment and Management of Cardiovascular Risk* by the New Zealand Guidelines Group (NZGG) report (2003a).

According to the NZGG (2003a) it remains to be determined whether fish oil supplements are more beneficial than eating fish, as fish provides other important nutrients along with the fatty acids such as protein, vitamins and minerals that would not be found in a fish oil supplement. Dietary advice from the NZGG (2003a) is to eat 300g/week of oily fish to reduce risk of coronary heart disease.

5.2. Cancer

Experiments in animal models and tissue culture overwhelmingly support a protective effect of LC*n-3*PUFA against colon, prostate and breast cancer; however, human studies have been less consistent (Berquin et al., 2008). Some studies have shown a protective effect of fish (Norat et al., 2005; Hall et al., 2008; Norrish et al., 1999, Braskey et al., 2010), others have shown no effect (Engeset et al., 2006)

The European Prospective Investigation into Cancer and Nutrition (EPIC) found that the association between increased consumption of fish and decreased risk of colorectal cancer was highly statistically significant (Norat et al., 2005). This study population included 478,040 men and women from 10 European countries who were followed up for 4.8 years. The absolute risk of developing colorectal cancer within 10 years for a study subject aged 50 years was 1.86 for subjects in the lowest category of fish intake (<10g/day) and 1.28 for those in the highest category of fish intake (>80g/day). Results from the *Physicians' Health Study*, a large cohort of physicians (21,406 participants) followed for 22 years, also suggest that intakes of fish and LC*n-3*PUFA may decrease the risk of colorectal cancer in men (Hall et al., 2008). In relation to prostate cancer, a study in Auckland suggests a reduced risk of prostate cancer associated with dietary fish oils, possibly acting via inhibition of arachidonic acid-derived eicosanoid biosynthesis (Norrish et al., 1999). A more recent EPIC study found no significant association between fish consumption and breast cancer risk in 310,671 women aged between 25 and 70 years (Engeset et al., 2006). However, a further prospective study, specifically designed to investigate the effects of specialty supplements among female members of the *VITamins And Lifestyle (VITAL)* cohort, found that among postmenopausal women aged 50-76, current fish oil use was associated with reduced risk of breast cancer (Braskey et al., 2010).



Likely mechanisms for the protective effect of fish LC*n-3*PUFA in relation to colon cancer revolve around their role in reduction of *n-6* derived eicosanoid biosynthesis, and direct inhibition of COX-2 (cyclooxigenase-2), an enzyme involved in the production of prostaglandins and implicated in the cancer process (WCRF, 2007). It has also been suggested that the selenium and vitamin D content of fish may be protective (WCRF, 2007).

A meta-analysis of prospective cohort studies into fish consumption and colorectal cancer concludes that fish consumption and possibly *n-3* fatty acids inhibit colorectal carcinogenesis, although results from epidemiological studies do appear to be inconsistent (Geelan et al., 2007). The recent World Cancer Research Fund report, which provides a comprehensive review of diet and cancer, concludes that much of the data in relation to fish and colon cancer is inconsistent, but there is limited evidence suggesting fish may be protective (WCRF, 2007).

Overall, although there are some positive results, the evidence for a protective role for fish and fish oil supplements in relation to cancer is not consistent and further research is needed.

5.3. Obesity

Obesity is a significant problem in New Zealand. The 2006/7 New Zealand Health Survey found that one adult in three is overweight and a further one in four is obese. Among children, body size is also an issue, with one in five children overweight and a further one in twelve obese (Ministry of Health, 2008b). Obesity is associated with a number of co-morbidities including Type 2 diabetes, CHD, some types of cancer, osteoarthritis, gallbladder disease, and sleep apnoea (Ministry of health, 2003a).

It has been suggested that higher amounts of dietary protein may help facilitate weight loss (Halton & Hu, 2004). Several mechanisms have been proposed. Firstly, protein suppresses food intake more than fats and carbohydrates and does so more than can be accounted for by its energy content alone; secondly, proteins make a stronger contribution to satiety; thirdly, high-protein diets support the maintenance of lean body mass; and fourthly, protein digestion stimulates many physiological and metabolic responses known to be involved in food intake regulation (Anderson & Moore, 2004).

Some studies have specifically looked at the effect of fish protein on satiety compared with other types of protein. One study, for example, among six lean male subjects found the level of satiety in subjects was significantly greater after a fish meal compared with that measured after a meal of chicken or beef (Uhe et al., 1992). The satiety produced after the fish meal also declined more slowly than that of the other meals. Other research has found that varying the protein source in a mixed meal does not affect food behaviour in healthy humans (Lang et al., 1998), although this study did not look at fish specifically; protein types measured included egg white (albumin), casein, gelatine, soy protein, pea protein and wheat protein (gluten).

A more recent study compared the effects of fish and beef protein on satiety in 23 normal-weight men (Borzoei et al., 2006). Subjects were served an iso-energetic protein-rich meal with either beef protein or fish protein for lunch, and four hours later, an *ad libitum* evening meal was served, and intake of food was measured. Appetite was rated by visual analogue scales (VAS). Although no significant difference was detected in VAS ratings of satiety or hunger, subjects who had eaten the fish protein lunch displayed an 11% reduction in energy intake at the subsequent evening meal, compared with those who had eaten beef protein.

Further long-term trials are now needed, with larger numbers of subjects, to help reveal whether fish protein helps to control energy intakes and also whether fish-based meals help with weight loss in obese subjects.

5.4. Type 2 diabetes

Diabetes is a metabolic disorder resulting from a lack of the hormone insulin, which is essential for the transfer of glucose from the blood to the tissues. Insulin deficiency may result from reduced production or resistance to its action (Thomas, 2005).

The effect of LC*n-3*PUFA in people with Type 2 diabetes has been studied, but evidence of a beneficial effect of supplementation on glycaemic control is equivocal. A recent Cochrane review identified 23 randomised trials (maximum duration 8 months) including 1,075 people, and found that supplementation with LC*n-3*PUFA did not have a statistically significant effect on glycaemic control or fasting insulin. (Hartweg et al., 2008).

People with diabetes are at increased risk of heart disease. This review also showed that LC*n-3*PUFA supplementation lowers triglycerides and very-low-density lipoprotein cholesterol, but may raise LDL cholesterol. This confirms the guidelines given in earlier reports, such as the evidence based best practice guidelines from the New Zealand Guidelines Group (2003b) *Management of Type 2 Diabetes*, where fish oil supplementation in people with Type 2 diabetes was reported to lower triglycerides, raise LDL cholesterol and have no statistically significant effect on HbA1c or fasting blood glucose.

Although fish oil does not have a significant effect on glycaemic control in Type 2 diabetes, the possible reduction in cardiovascular disease (CVD) risk is important. People with diabetes are at increased risk of CVD, in part due to hyperglycaemia and insulin resistance, but also due to excess weight, hypertension, dyslipidaemia and unvavourable haemostatic changes (De Caterina et al., 2007). Dietary LC*n-3* fatty acids may reduce cardiovascular disease risk in people with Type 2 diabetes, as they are effective in reducing plasma triglycerides and platelet aggregation (McEwen et al., 2010, De Caterina et al., 2007). For example, in a study by Hu et al. (2003) found a higher consumption of fish and LC*n-3* fatty acids was associated with a lower coronary heart disease incidence and total mortality in diabetic women. In this study, after adjusting for age and other cardiovascular risk factors, relative risks (RR) of CHD were 0.7 (0.48-1.02) for fish consumption 1-3 times a month, 0.6 (0.42-0.85) for once a week, 0.65 (0.43 to 0.99) for 2-4 times a week, and 0.38 (0.21-0.68) for ffl5 times a week (p for trend = 0.002). A higher consumption of fish was associated with a significantly lower risk of both fatal and non-fatal myocardial infarction.

In terms of prevention of Type 2 diabetes, a recent study found no evidence that higher consumption of LC*n-3* fatty acids reduces risk of developing the condition (Kaushik et al., 2009). In fact, higher intakes may modestly increase the incidence of Type 2 diabetes. The clinical relevance of this finding requires further investigation.

Further trials of sufficient duration are required to establish the role of *n-3* fatty acids in improving glycaemic control for those with Type 2 diabetes. In the meantime, it is recommended that those with Type 2 diabetes consume at least 1-2 portions a week of fish – preferably the oily varieties (NZGG, 2003b). This may help reduce risk of cardiovascular disease.

5.5. Age-related macular degeneration

LC*n-3*PUFA may operate as protective factors in degenerative retinal diseases (SanGiovanni & Chew, 2005). The most common cause of blindness in Western countries is age-related maculopathy (ARM) and identifying preventable risk factors may be the only way of reducing the burden of this disease, as current treatments are rarely effective in the longer term (Smith et al., 2000). Recent studies have examined the link between macular degeneration and dietary intake of fatty acids.

The *Blue Mountains Eye Study* examined the association between intake of dietary fat and fatty acid components and the 5-year incidence of ARM among a cohort of non-institutionalised residents of Sydney, Australia aged 49 years or older (Chua et al., 2006). Data were collected from 2,895 people at baseline by means of a food frequency questionnaire. Results showed that those who reported eating at least one fish serving a week had a 40% lower risk of 5-year incident early ARM (OR, 0.58; 95% CI, 0.37-0.90). Significant risk reduction for incident late ARM only became apparent, however, for participants who reported consuming at least three servings of fish per week (OR, 0.25; 95% CI, 0.06-1.00). Similar results were found in an earlier study of the same cohort (Smith et al., 2000), where a higher frequency of fish consumption was associated with decreased odds of late ARM (OR for frequency of consumption of more than once per week compared with less than once per month, 0.5).

A further study, by the *Age-Related Eye Disease Study Research Group*, found that dietary total LC*n-3*PUFA intake was inversely associated with neovascular AMD (OR, 0.61; 95% CI, 0.41-0.90), as was intake of DHA, a retinal LC*n-3*PUFA (OR, 0.54; 95% CI, 0.36-0.80) when the highest quintile of intake (> 2 medium servings a week) was compared with the lowest quintile of intakes (< 1 medium serving a month (SanGiovanni et al., 2007).

A recent systematic review and meta-analysis analysed nine studies providing data on a total sample of 88,974 people (Chong et al., 2008). Results showed that a high dietary intake of LC*n-3*PUFA was associated with a 38% reduction in the risk of late AMD (pooled OR, 0.62; 95% CI, 0.48-0.82). Fish intake at least twice a week was associated with a reduced risk of both early and late AMD.

In conclusion, research suggests that a high intake of LC*n-3*PUFA and fish is associated with reduced risk of AMD. However further prospective studies and randomised controlled trials are needed before routine recommendations of LC*n-3*PUFA and of fish can be made (Chong et al., 2008).

5.6. Inflammatory conditions

A group of compounds that provide a link between PUFA, inflammation and immune function are eicosanoids. Eicosanoids are synthesised from PUFA, in particular dihomo-γ-linolenic acid (DGLA; 20:3*n-6*), arachidonic acid (AA; 20:4*n-6*) and eicosapentaenoic acid (EPA; 20:5*n-3*) (Calder, 2001). Eicosanoids include prostaglandins, thromboxanes, leukotrienes, lipoxins, hydroperoxyeicosatetraenoic acids and hydroxyeicosatetraenoic acids. Because the membranes of most immune cells contain large amounts of AA compared with DGLA and EPA, AA is usually the principal precursor for eicosanoid synthesis (Calder, 2001).

Competition between the *n-3* and *n-6* fatty acids occurs in prostaglandin formation, with EPA competing with AA for prostaglandin and leukotriene synthesis (Simopoulos, 2002). In general, eicosanoids produced from EPA are less potent in their ability to cause an inflammatory response than the corresponding ones from *n-6* fatty acids such as AA (BNF, 1999). Metabolism of *n-3* fatty acids results in thromboxane A3 and leukotrien B5, which are much less biologically active than their *n-6* counterparts (Ergas et al., 2002). Competition between *n-3* and *n-6* also affects cell function in the immune system, inhibiting production of pro-inflammatory cytokines, including tumor necrosis factor and interleukins 1 and 6 (Calder, 1998).

Among the fatty acids, it is the *n-3*PUFA that possess the most potent immunomodulatory activities and among the *n-3*PUFA, those from fish oil (EPA and DHA) are more biologically potent than ALNA (α-linolenic acid) (Calder, 2001).

A review of the evidence of the role of fish oils in asthma, Crohn's disease, cystic fibrosis, rheumatoid arthritis and psoriasis is summarised below.

5.6.1. Asthma

Asthma is a chronic inflammatory disease of the respiratory tract and although medication and environmental manipulation remain the cornerstones of treatment, dietary intervention has emerged as a potential therapy (Wong, 2005).

In a small-scale randomised trial among 29 children, subjects were given either fish oil or olive oil (controls) for 10 months in a strictly controlled environment, where food constituents and exposure to inhalant allergens were the same for all subjects. Results showed that dietary supplementation with fish oil was beneficial for children with bronchial asthma (Nagakura et al., 2000).

A large population-based study among adults (16,187 subjects, aged 23-54 years), also found a protective effect of fish and fish oil on asthma (Laerum et al., 2007). In this study, asthma and asthma symptoms were less common in adults eating fish weekly as compared with those eating fish more rarely. Asthma risk was doubled in subjects who had never eaten fish in childhood. Although positive results were achieved in this study, further prospective studies with more detailed information on the amount and type of fish consumed in childhood and adulthood are now needed.

A Cochrane review found that there was no consistent effect on any of the analysable outcomes in relation to asthma, including Forced Expiratory Volume in one second (FEV1), peak flow rate, asthma symptoms, asthma medication use or bronchial hyper reactivity (Thien et al., 2002). The authors concluded that there was little evidence to recommend that people with asthma should modify or supplement their diet with marine LC*n-3*PUFA; however, equally there is no evidence of risk if they do so.

It is possible that LC*n-3*PUFA suppress inflammation by exerting an inhibitory and competitive effect on the biosynthetic pathways of leukotrienes and other pro-inflammatory eicosanoids; however, overall there is currently a lack of evidence supporting the use of LC*n-3*PUFA supplementation in improving the outcomes of asthma (Wong, 2005). Further research is needed into the use of fish oils in the treatment of asthma. In the meantime, it has been recommended that regular fish consumption (at least three times a week) should be highly encouraged as part of a well balanced diet (Wong, 2005).

5.6.2. Crohn's disease

Crohn's disease results in the inflammation of the wall of the bowel, most commonly affecting the small bowel, usually the terminal ileum (Thomas, 2005). Some patients remain chronically active, while others have a clear pattern of exacerbations and remissions. It has been suggested that a diet rich in fish oil may reduce the frequency of relapses, because of its anti-inflammatory effects (Belluzzi et al., 1996).

A double blind placebo controlled study involving 78 patients with Crohn's disease who had a high risk of relapse found that after one year 59% in the fish-oil group remained in remission, compared with 26% in the placebo group (Belluzzi et al., 1996). With regard to indicators of inflammation, there was a significant decrease in all such markers in the fish-oil group compared with the placebo group. In this study, the patients in the fish-oil group received 2.7g per day of LC*n-3*PUFA.

A Cochrane review of four studies into *n-3* fatty acids for maintenance of remission in Crohn's disease found that three of the four studies reviewed reported a significant reduction in the 1-year rate of relapse in comparison with placebo (Turner et al., 2007). The one study that did not show any benefit did not use enteric coated capsules. However, the studies reviewed were small and the authors recommend further larger trials to validate the results of the previous studies.

Two large studies have now been published, the *Epanova Program in Crohn's Study (EPIC) Randomised Controlled Trials* (Feagan et al., 2008). These studies were conducted between 2003 and 2007 at 98 centres in Canada, Europe, Israel and the USA. Data from 363 and 375 patients with quiescent Crohn's disease were evaluated in EPIC-1 and EPIC-2 respectively. Patients were randomly assigned to receive either 4g/day LC*n-3*PUFA or placebo for 58 weeks, with no other treatment for Crohn's permitted. In these trials, treatment with LC*n-3*PUFA was not an effective treatment for Crohn's disease. These findings are very different to those reported in earlier studies. The reason for this may be, firstly, different study designs.

For example, the study by Belluzzi et al. (1996) included only patients at high risk of relapse; secondly, different formulations were used; and thirdly, earlier studies were small and as such may have been subject to bias.

Currently, the use of fish oil supplements as a treatment for Crohn's disease does not look promising.

5.6.3. Cystic fibrosis

Cystic fibrosis is an inherited disorder that results in chronic lung disease and pancreatic insufficiency. The anti-inflammatory effect of LC*n-3*PUFA supplements has been investigated in people with cystic fibrosis. A Cochrane review concluded that regular supplements of LC*n-3*PUFA may benefit people with cystic fibrosis. However there is insufficient evidence to recommend the routine use of such supplements, and larger and longer trials are needed to assess clinical benefits, dosage required and duration of treatment (McKarney et al., 2007).

5.6.4. Rheumatoid arthritis

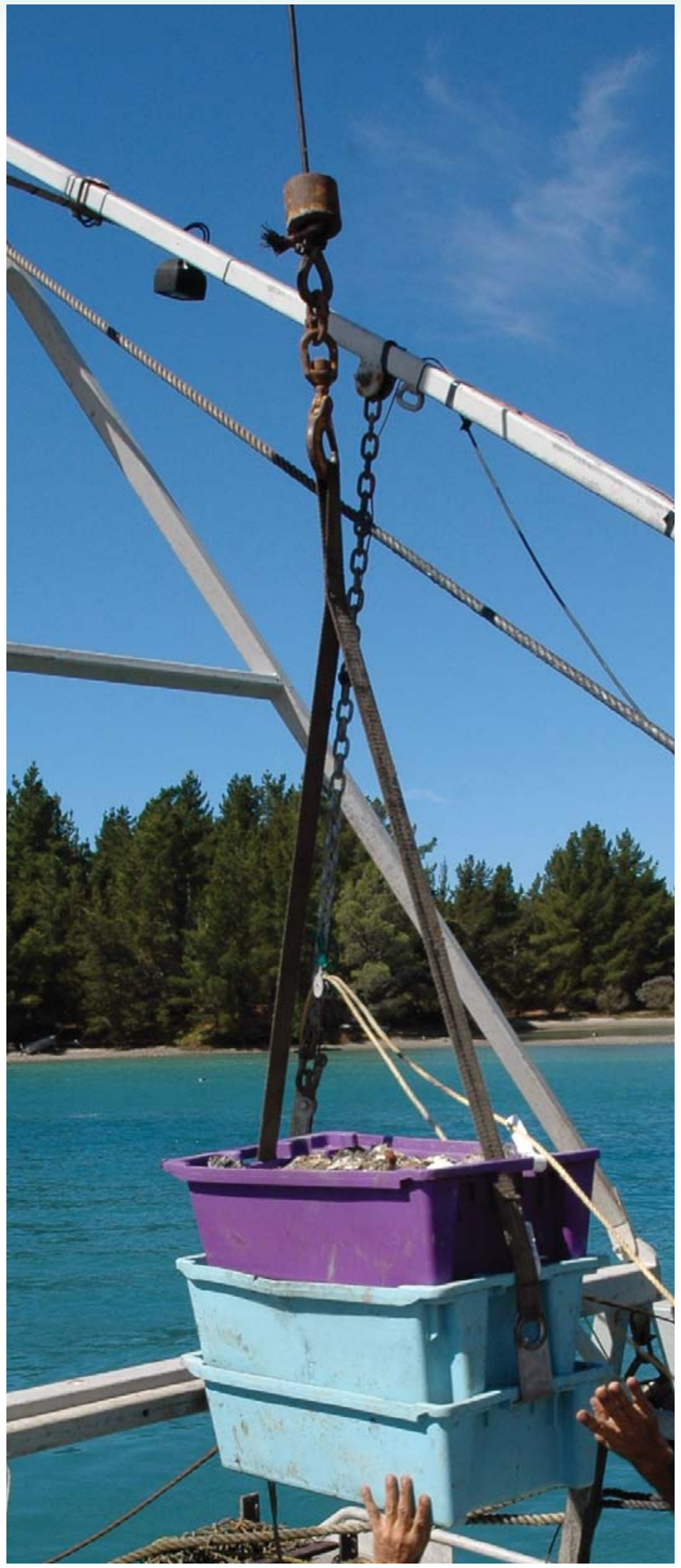
The main long-term problem in rheumatoid arthritis (RA) is progressive erosion of the cartilage in joints leading to irreversible destruction (BNF, 1999). It has been suggested that marine LC*n-3*PUFA somewhat alleviate the symptoms of RA (de Deckere et al., 1998) as they suppress production of pro-inflammatory cytokines and cartilage degradative enzymes (Cleland et al., 2003). The most consistent benefit has been reduced morning stiffness and a decrease in tender joints (Cleland et al., 2003).

In a recent study, 97 patients with RA were randomised to receive either 10g cod liver oil (containing 1.5g EPA and 0.7g DHA), or air-filled identical placebo capsules (Galarraga et al., 2008). At 12 weeks patients were instructed to gradually reduce, or if possible stop, their intake of medication. Relative reduction of daily non-steroidal anti-inflammatory drug sparing agent (NSAID) requirement by > 30% after 9 months was the primary outcome measure. Of the 58 patients who completed the study, 39% of the cod liver oil group and 10% in the placebo group were able to reduce their intake of NSAID by > 30%, suggesting that cod liver oil supplements can be used as NSAID-sparing agents in patients with RA.

A review of the role of fish oil in the treatment of RA suggests that an anti-inflammatory dose of fish oil requires delivery of 2.7g or more of LC*n-3*PUFA daily and that higher doses are also safe and effective (Cleland et al., 2006).

5.6.5. Psoriasis

There are limited data on the LC*n-3*PUFA in psoriasis, a common inflammatory skin disorder. Providing intravenous LC*n-3*PUFA has been found to cause a reduction in psoriasis symptoms (Mayser et al., 2002). However, further research is needed into the possible role of *n-3* supplements or fish intake for the alleviation of this condition.



5.7. Foetal, infant and child development

5.7.1 Fish intake during pregnancy and cognitive development of offspring

DHA is the most abundant LC*n-3*PUFA in the mammalian central nervous system and is specifically concentrated in the membrane lipids of brain grey matter and the visual elements of the retina (Innis, 2008). Studies to date suggest that maternal intake of LC*n-3*PUFA during pregnancy might be important for later cognitive functioning in the offspring (Helland et al., 2003) and that diets poor in LC*n-3*PUFA may contribute to poor central nervous system foetal development and function (Innis, 2008).

The *Avon Longitudinal Study of Parents and Children* (ALSPAC) evaluated the association between maternal fish intake during pregnancy and offsprings' early development of language and communications skills in a cohort of 7,421 British children born in 1991-1992 (Daniels et al., 2004). Fish intake during pregnancy, and by the infant post-natally, was associated with higher mean developmental scores in the child at age 15-18 months. The relationship between fish and neurodevelopment was strongest for those pregnant women eating fish 1-3 times a week. More recent results from the ALSPAC study show benefits of maternal seafood intakes of more than 340g per week as compared to none for child neurodevelopment as reflected by verbal IQ scores at 8 years of age (Hibbeln et al., 2007). There was no evidence in this study to lend support to the recommendation jointly issued in 2004 by US Department of Health and Human Services and US Environmental Protection Agency for pregnant women to limit seafood consumption to 340g (12 oz) per week. In fact, it is suggested that limiting seafood consumption might reduce the intake of nutrients necessary for optimum neurological development (Hibbeln et al., 2007).

The effect of maternal intake of LC*n-3*PUFAs during pregnancy and lactation, as compared to the intake of LC*n-6*PUFAs may also be associated with beneficial effects on child mental development. In a randomised, double-blinded study conducted by Helland and colleagues (2003), mothers received either 10ml/d of cod liver oil (providing 1,183mg/10ml DHA and 803mg/10ml EPA) or 10 ml/d of corn oil from 18 weeks of pregnancy until three months post-partum. Results indicated that the children's mental processing scores at 4 years of age were correlated significantly with maternal intake of DHA and EPA during pregnancy. Using the same cognitive tests, further follow-up of the children at 7 years of age did not reveal any significant difference in overall IQ scores in the two groups (Helland et al., 2008). However, maternal plasma concentrations of LC*n-3*PUFA during pregnancy positively correlated with scores on the sequential processing scale (reflecting the ability to take in, store, process and use information) suggesting that LC*n-3*PUFA intake during pregnancy may be important for later cognitive functioning in this particular area.

A recent Australian study also found beneficial effects of supplementing pregnant women with fish oil (2.2g/day DHA and 1.1g/day EPA) or olive oil from 20 weeks gestation to delivery (Dunstan et al., 2008). This dose was chosen as it is approximately equivalent to consuming around one fatty fish meal a day. Follow-up of children at age 2½ years found that those in the fish oil supplemented group attained a statistically significant higher score for eye and hand coordination than those in the placebo group. This study concluded that maternal fish oil supplementation during pregnancy was safe for the foetus and for the infant. Further studies are now needed to confirm the significance of the findings

Research to date suggests that including relatively high doses of LC*n-3*PUFA in the diets of pregnant women is associated with beneficial effects on the infant post-natally, and there are biologically plausible mechanisms to support this; however, the outcomes of the trials have not been conclusive and are limited by small sample size. Further research is needed to establish the long-term benefits, optimal composition of fatty acid intake, and dose-response relationship of LC*n-3*PUFA intake during pregnancy and lactation. It is currently recommended that pregnant women should not take fish oil supplements during pregnancy and breastfeeding (Ministry of Health, 2006). For more information, see section 2.3.6.

5.7.2. Learning and behaviour in young children

Attention deficit hyperactivity disorder (ADHD) is the most common neurodevelopmental disorder of childhood (Richardson, 2006, Sinn, 2008). Core symptoms of ADHD include developmentally inappropriate levels of hyperactivity, impulsivity and inattention (Sinn, 2008). It has been proposed that LC*n-3*PUFA may play a role in ADHD

and related developmental disorders. This proposition is supported by both theoretical considerations, and some promising, but inconclusive, experimental evidence (Richardson, 2006).

One interesting study, which looked at the role of dietary supplementation with fatty acids in children with developmental coordination disorder (DCD), was the *Oxford-Durham Study* (Richardson & Montgomery, 2005). DCD shows substantial overlap with ADHD, dyslexia and autism spectrum disorder, and in this study 32 of the 102 children (aged 5-12 years) had symptoms of ADHD, although diagnosis was not confirmed. Supplementation with a fatty acid supplement, which contained 80% fish oil (LC*n-3*PUFA: 558mg/day EPA and 174mg/day DHA) and 20% evening primrose oil plus vitamin E (9.6 mg) was compared with placebo treatment of olive oil capsules. It is important to note the composition of this supplement, as DHA only studies have shown no effect. After three months of treatment, there was no effect on motor skills, but significant improvements were found for active treatment versus placebo for reading, spelling and behaviour. However, the magnitude of the difference between the placebo and the supplemented groups is not striking and given that most of the participants (69%) did not have clinically confirmed ADHD, the validity of the authors' observations are unclear (Ross et al., 2007).

LC*n-3*PUFA supplementation in children with autism spectrum disorders may also be efficacious in treating associated symptoms. In a small randomised, double-blind, placebo-controlled, 6-week pilot study Amminger et al. (2007) examined the effect of 1.5g per day LC*n-3*PUFA (0.84g/day EPA and 0.7g/day DHA) among 13 autistic children aged 5 to 17 years. Results of this study indicated a benefit of LC*n-3*PUFA supplementation compared with placebo for hyperactivity and stereotypy, providing preliminary evidence that warrants larger scale, long-term trials.

Overall, the number of studies investigating the therapeutic administration of LC*n-3*PUFAs for the treatment of ADHD and related conditions are limited. Most studies to date have used doses of around 300-700mg of EPA and DHA in varying ratios (Richardson, 2006). Several studies have demonstrated a significant benefit with respect to improvement in clinical symptoms such as hyperactivity and concentration/attention problems associated with ADHD. It should, however, be noted that there are clearly multiple influences on ADHD including genetic and environmental factors (Sinn, 2008). A recent review concludes that LC*n-3*PUFA supplemented children do not perform better than placebo in children with clinically diagnosed ADHD, but may have a modest effect on attention and hyperactivity symptoms in children with DCD (Ross et al., 2007). Large-scale dose-response studies are now needed, to determine whether LC*n-3*PUFA supplementation is beneficial in those with ADHD and to establish the optimal dose and composition of LC*n-3*PUFA intakes.

5.8. Adult mental health

5.8.1 Mood disorders, depression and schizophrenia

A number of studies have investigated the effects of fish consumption, or supplementation with LC*n-3*PUFA, on mood disorders.

A New Zealand study of 4,644 adults aged 15 years and older, found fish consumption was significantly associated with higher self-reported mental health status (Silvers & Scott, 2002). This study was based on a nationally representative sample of New Zealanders aged 15 and over and the authors suggest that the association between self-reported mental health status and fish consumption may be a result of the LC*n-3*PUFA found in relatively high concentrations in fish.

A more recent survey of New Zealanders, which measured fatty acid composition of serum phospholipids in 2,416 subjects, and assessed mental and physical health, suggested a strong and consistent association between EPA in serum phospholipids and self-reported physical wellbeing, but there was no association between EPA and DHA and mental wellbeing (Crowe et al., 2007). This study was also based on the general New Zealand population, and subjects were not diagnosed with depression at the time of the study. The authors of this study question the findings of the earlier study by Silvers & Scott, as only 87 of the 4,644 participants were categorised as non-fish consumers and there was little adjustment for lifestyle and demographic characteristics that could confound the relation.

A further study evaluated the effects of EPA and DHA supplementation (1.5g/day) on mood and cognitive function in mild- to moderately-depressed individuals. Although the primary outcome of depressed mood improved over the 12 weeks of the intervention, there was no significant difference between the supplemented group and the placebo group (Rogers et al., 2008a). The placebo group in this study received olive oil and it has been suggested that olive oil may also have a beneficial effect on mood disorders, which may have been the reason for the lack of difference between the two groups (Zhang & Li, 2008). This suggestion was refuted by the authors of the study (Rogers et al., 2008b).

Schizophrenia is serious mental illness in which the role of LC*n-3*PUFA as a treatment has been investigated. Schizophrenia disrupts a person's normal perception of reality, with patients suffering from hallucinations, paranoia, delusions, and speech and thinking impediments (Lakhan & Vieira, 2008). Studies have found reduced levels of polyunsaturated fatty acids, particularly DHA and AA, in the cell membranes of red blood cells from schizophrenic patients. This has lead to research interest into the possible therapeutic benefits of LC*n-3*PUFA in schizophrenia (Peet, 2008). A Cochrane review concluded, however, that the use of LC*n-3*PUFA for schizophrenia remains experimental, and highlighted the need for large well-designed, -conducted and -reported studies (Joy et al., 2006).

A review of LC*n-3*PUFA for clinical use in the prevention and/or treatment of psychiatric illness concluded that epidemiologic and tissue compositional studies support a protective effect of LC*n-3*PUFA intake, particularly EPA and DHA, in mood disorders, but the evidence for a benefit in schizophrenia is less strong (Freeman et al., 2006). A recent Cochrane review looked at the efficacy of LC*n-3*PUFA, either as a mono-therapy or an adjunctive treatment for bipolar disorder. The authors found that one study showed positive effects of LC*n-3*PUFA fatty acids as an adjunctive therapy for depressive symptoms but not for manic symptoms (Montgomery & Richardson, 2008). Five studies were reviewed; however, methodological quality was highly variable. The authors conclude that there is currently insufficient evidence on which to base clear recommendations in relation to LC*n-3*PUFA fatty acids for bipolar disorder, but there is an acute need for well- designed and -executed randomised controlled trials in this field.

While it is not currently possible to recommend LC*n-3*PUFA as either a mono- or adjunctive-therapy in any mental illness, the available evidence is strong enough to justify further study, especially in relation to attention, anxiety and mood disorders (Ross et al., 2007).

5.8.2. Cognitive function and dementia in older people

Information on the effects of LC*n-3*PUFA on cognitive function in older people is quite scarce (Dangour & Uauy, 2008). A recent systematic review identified only five studies that have investigated the effect of LC*n-3*PUFA on cognitive function (Issa et al., 2006). Four of the studies reviewed found a trend in favour of LC*n-3*PUFA (fish and total LC*n-3*PUFA consumption) toward reducing dementia and improving cognitive function; the other study found no association. A recent Cochrane report aimed to review the evidence that LC*n-3*PUFA supplementation prevents cognitive impairment and dementia in cognitively intact elderly persons. In order to be selected for review, trials needed to be randomised, placebo controlled, double-blinded and with a minimum duration of 6 months involving people aged 60 and over without pre-existing dementia at the study onset and with cognitive endpoints. The authors found no randomised controlled trials that met the inclusion criteria and concluded that although there is a growing body of evidence from biological, observational and epidemiological studies suggesting a protective effect of LC*n-3*PUFA against dementia, until further data from randomised trials become available, there is no good evidence to support the use of dietary or supplemental LC*n-3*PUFA for prevention of cognitive impairment or dementia (Lim et al., 2006).

Since the publication of the Cochrane review, a 5-year follow-up study has been published, which includes data on fish consumption of 210 participants in the population-based *Zutphen Elderly Study* (van Gelder et al., 2007). The *Zutphen Elderly Study* is a prospective cohort study of men born between 1900 and 1920 who live in Zutphen in the Netherlands. The elderly men were examined in 1985 and subsequent follow up examinations were carried out in 1990 and 1995, where information was collected on cognitive functioning. Men were selected without myocardial infarction, stroke, diabetes or cancer at baseline, as poor health status may have influenced both food intake and cognitive function. In this study, fish consumers had significantly less cognitive decline over the 5 years, than non-consumers. The authors conclude that a combined daily intake of ≈400mg LC*n-3*PUFA EPA + DHA (similar to 6 servings of ≈140g lean fish/week or one serving of 140g fatty fish/week) is associated with less subsequent cognitive decline in elderly men.

A more recent randomised controlled trial of 302 independently living individuals were given either a high dose of fish oil (1,800mg/day EPA + DHA), a low dose of fish oil (400mg/day EPA + DHA) or a placebo, for 26 weeks (van de Rest et al., 2008). The subjects were all aged 65 or over and were mainly recruited through an existing database of volunteers, with an interest in participating in studies conducted by the Wagenigen University in the Netherlands. This study, however, observed no significant effect of EPA + DHA supplementation on mental wellbeing in this general, older, non-depressed population, as assessed by depression and anxiety questionnaires. However, when the authors carried out an exploratory post hoc analysis in subjects within the highest tertile for impaired mood, the scores on the depression questionnaires changed more during intervention – although not significantly so. It is suggested that subjects with an impaired mental well-being may benefit from supplementation, however, further research is needed in this area.

Although there is a growing body of evidence to suggest that LC*n-3*PUFA might be important for the maintenance of cognitive function later in life (Dangour & Uauy, 2008), there is clearly a need for more good quality evidence before firm recommendations can be made. Evidence to support the use of LC*n-3*PUFA as an intervention for preventing or reversing further cognitive decline in people with established dementia is scarce. In four studies reviewed by Issa et al (2006) that assessed the effects of LC*n-3*PUFA on incidence and treatment of dementia, a trend in favour of LC*n-3*PUFA reducing risk of dementia and improving cognitive function was reported, although the available data are in sufficient to draw strong LC*n-3*PUFA conclusions and further research is needed.

6 Conclusions

Seafood can make a useful contribution to the nutritional intakes of New Zealanders. In particular, it is an important source of protein, iron, zinc, selenium, iodine, and B vitamins. Fish eaten with the bones provide some calcium. Oily fish and the liver of white fish provide vitamins A and D.

There is significant evidence for a beneficial health effect of eating fish, particularly oily fish, which is a good source of LC*n-3*PUFA. The evidence for a protective effect against cardiovascular disease is strong, and it is recommended that to reduce the risk of heart disease we should consume at least two fish meals per week. There have also been some positive results from studies investigating a protective role for fish and fish oils in relation to cancer, although research in this area is currently inconsistent and further studies are needed. In addition, fish-based meals may be helpful in promoting satiety and in aiding weight loss, and there is a possible role for high intakes of LC*n-3*PUFA in reducing risk of age-related macular degeneration and some inflammatory conditions such as rheumatoid arthritis. More research is, however, needed in these areas.

A possible beneficial effect for LC*n-3*PUFA, when taken by pregnant women, on the cognitive development of their offspring has also been demonstrated. Supplementation of the diet with LC*n-3*PUFA may also be helpful for some children with attention and hyperactivity symptoms. In addition, there is a growing body of evidence that LC*n-3*PUFA might be important for the maintenance of good cognitive function later in life.

Seafood is thought to have been responsible for the very rapid expansion of the human cerebral cortex over the last one to two million years (Broadhurst et al., 1998) and continues to have an important role to play in our diet today. Although many of the health benefits of seafood and LC*n-3*PUFA require further research before firm recommendations can be made, there is a large body of evidence to suggest that it is highly beneficial to include seafood in the diet on a regular basis as part of a healthy, balanced eating regimen. Its consumption should be strongly encouraged.

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