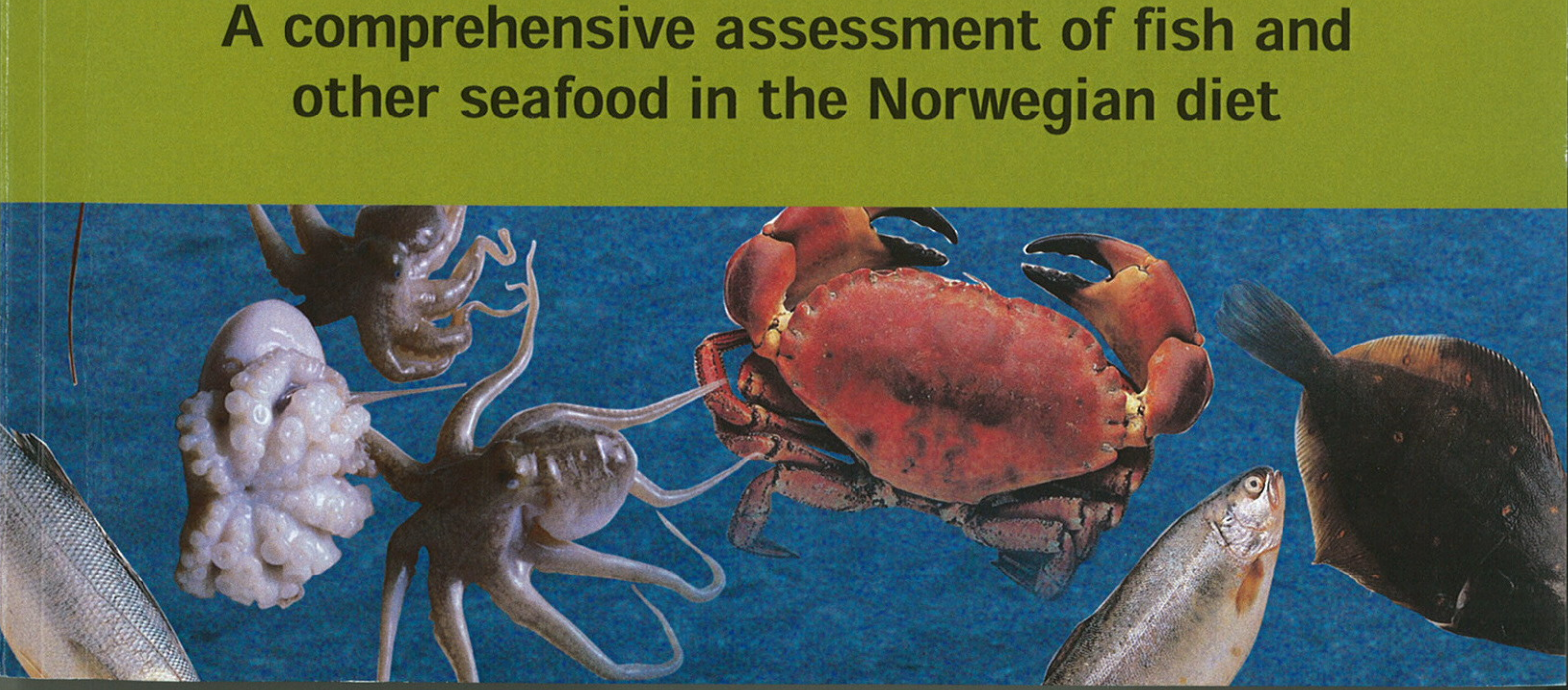
Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

A comprehensive assessment of fish and other seafood in the Norwegian diet



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Preface

At the request of the Norwegian Food Safety Authority, the Norwegian Scientific Committee for Food Safety (VKM) has conducted an assessment of the nutritional benefits of eating fish and other seafood compared with the health risks associated with the intake of contaminants and other undesirable compounds that fish and other seafood may contain.

Under the auspices of VKM, an *ad hoc* group of experts has prepared this report. The *ad hoc* group consisted of Jan Alexander, Livar Frøyland, Gro-Ingunn Hemre, Bjarne Koster Jacobsen, Eiliv Lund, Helle Margrete Meltzer and Janneche Utne Skåre (chair).

Other contributors to the assessment are Tore Aune, Christina Bergsten, Claudette Bethune, Roald Bøe, Helen Engelstad, Anne-Katrine Lundebye Haldorsen, Marc Berntssen, Kari Grave, Kristin Hamre, Margaretha Haugen, Martinus Løvik, Bjørn Munro Jenssen, Arne Levsen, Bjørn Tore Lunestad and Rune Waagbø. VKM thanks Anne Liv Rudjord and Torbjørn Gäfvert of the Norwegian Radiation Protection Authority for their contribution on radioactivity. Åse Borgejordet of the Directorate for Health and Social Affairs has supplied updated data to the Norwegian Food Composition Table (Matvaretabellen). A special thanks to Helle Knutsen for her contribution on the compilation of data and calculation of the exposure estimates for contaminants.

The following VKM scientific panels have reviewed the report during its preparation:

The Panel on Biological Hazards
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The Panel on Contaminants in the Food Chain
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The Panel on Animal Feed
Anne-Katrine Lundebye Haldorsen (chair), Marit Aursand, Aksel Bernhoft, Marc Berntssen Gro-Ingunn Hemre, Bjørn Munro Jenssen, Magny Thommassen, Harald Volden

The Panel on Nutrition, Dietic Products, Novel Foods and Allergies
Margaretha Haugen (chair), Lene Frost Andersen, Livar Frøyland, Ragnhild Halvorsen, Kåre Julshamn, Helle Margrete Meltzer, Judith Narvhus, Jan Erik Paulsen

Anne Finstad has been coordinator at the VKM Secretariat, ably assisted by Tor Øystein Fotland, Bente Mangschou and Marie Louise Wiborg.

The report has been discussed by the National Council of Nutrition.

This report was approved by the members of the Scientific Steering Committee for Food Safety (VKM) on 14 February 2006.

Scientific Steering Committee
Åshild Krogdahl (chair), Bjørn Næss (deputy chair), Hilde Kruse, Erik Dybing, Ingolf Nes, Jan Alexander, Janneche Utne Skåre, Anne-Katrine Lundebye Haldorsen, Margaretha Haugen, Wenche Farstad, Lene Frost Andersen, Georg Kapperud, Øyvind Lie, Judith Narvhus, Leif Sundheim

Background

At the request of the Norwegian Food Safety Authority in 2004, the Norwegian Scientific Committee for Food Safety (VKM) has conducted a comprehensive review of fish and other seafood. Fish and other seafood contain substances that have a positive effect on public health, but they may also contain contaminants and other undesirable compounds. The Norwegian Food Safety Authority saw the need for an evaluation of the pros and cons of fish consumption so that advice could be given to the population based on a comprehensive scientific assessment of fish and other seafood.

An assessment of this nature is extensive and spans the purviews of several of VKM's scientific panels. It was therefore decided that the overall responsibility for the assessment would rest with the Scientific Steering Committee. The members of the Scientific Steering Committee prepared a mandate and appointed an *ad hoc group* which was charged with conducting the assessment.

The *ad hoc*-group has worked according to the following mandate issued by the Scientific Steering Committee:

- The group is to conduct a comprehensive assessment of fish and other seafood. This comprehensive assessment is to address the nutritional benefits of consuming fish and other seafood compared with the health risks associated with the intake of contaminants and other undesirable compounds contained in fish and other seafood.

- Insofar as possible, the group is to weigh the benefits of fish and seafood consumption against the risks. This comprehensive assessment is to be based on relevant Norwegian data, including data on intake, nutritional value and toxicology. In addition, the group is to use information from the comprehensive assessments of fish and other seafood published in reports by the Danish Veterinary and Food Administration, the Food Standard Agency Scientific Advisory Committee in the UK, and any other relevant documentation.

- The group is to assess whether the conclusions drawn on the basis of the comprehensive assessment provide a basis for making changes in the current Norwegian recommendations regarding the consumption of fish and other seafood.

- The group is also requested to report on any other factors relating to fish and other seafood, e.g. hygiene, which may be of concern for public health.

- The group is asked to identify trends in nutrition, toxicology and other factors that may imply a need for reviews of the recommendations in future.

- The group is requested to identify gaps in specific areas of knowledge and the need for new monitoring or research which may be discovered during the course of the assessment.

The *ad hoc* group was comprised of experts from VKM, as well as two further experts, including one person appointed by the National Council of Nutrition. The members of the *ad hoc* group were Jan Alexander, Livar Frøyland, Gro-Ingunn Hemre, Bjarne Koster Jacobsen, Eiliv Lund, Helle Margrete Meltzer, and Janneche Utne Skåre (chair).

The results of the assessment performed by the *ad hoc* group are presented in this report 'A comprehensive assessment of fish and other seafood in the Norwegian diet'. The report has been reviewed by several of the scientific panels in VKM based on their specific spheres of responsibility, and it has been discussed by the National Council of Nutrition. Finally, the report was evaluated and approved by the members of the VKM Scientific Steering Committee.

1 Summary

1.1 Mandate

Fish and other seafood contain nutrients that have a positive effect on public health, but they may also contain contaminants and other undesirable compounds. At the request of the Norwegian Food Safety Authority, the Norwegian Scientific Committee for Food Safety (VKM) has conducted an assessment of the nutritional benefits of consuming fish and other seafood, compared with the health risks associated with the intake of contaminants and other undesirable compounds that fish and other seafood may contain.

An *ad hoc* group of experts has drawn up this report. Several of VKM's scientific panels reviewed the report during its preparation, and the members of the Scientific Steering Committee of the Norwegian Scientific Committee for Food Safety have given their final assessment and approval. The report has also been discussed by the National Council of Nutrition.

In this report, VKM has used Norwegian dietary data to estimate the intake of relevant nutrients and contaminants by children and adults who have consumed fish and other seafood. The various nutrients (proteins, vitamins, minerals and marine n-3 fatty acids) in fish and other seafood have been characterised with regard to their occurrence and their capacity to have health-promoting effects.

Compounds that constitute potential health hazards that may be found in fish and other seafood have been characterised with regard to their occurrence, their capacity to cause negative health effects, and the intake levels at which they may be regarded as safe. Many contaminants and other undesirable compounds have been evaluated, including organic contaminants such as chlorinated pesticides, PCBs, dioxins, brominated flame retardants and perflourinated compounds (PFOS), potentially hazardous metals and trace elements (e.g. mercury, cadmium, lead, arsenic, selenium), marine algal toxins, drug residues, radioactive isotopes, infectious organisms and disinfectants. VKM has also assessed farmed fish, with special emphasis on the impact of feed on the content of nutrients and contaminants in fish.

VKM has conducted a critical review of selected literature in preparation for its assessment of the health effects associated with fish consumption and the way in which these effects have been documented in epidemiological studies. Cardio-vascular disease in relation to fish consumption has been thoroughly investigated by the Scientific Advisory Committee on Nutrition (SCAN) and the Committee for Toxicology (COT) in the UK (SACN/COT, 2004), as well as by the Danish Veterinary and Food Administration (2003). This report summarises their results and also considers other scientific studies that have appeared subsequent to the SACN/COT report. As regards any potential correlation between fish consumption and cancer, a separate evaluation of the existing epidemiological literature has been conducted, since cancer is not discussed to any great detail in any of the reports mentioned above.

1.2 Background

Fish and other seafood provide us with a number of nutrients. They contain high-quality proteins and are rich in vitamin D, vitamin B_{12}, and the minerals iodine and selenium. Fish and other seafood are also a natural source of the marine n-3 fatty acids eicosapentaenoic acid, docosapentaenoic acid and docosahexaenoic acid. Fatty fish and certain fatty seafood products are the most important natural sources of marine n-3 fatty acids and vitamin D in the Norwegian diet.

A large body of documentation shows that consuming fish is beneficial to human health, and there are strong indications that consuming fatty fish in particular prevents and slows down the development of cardio-vascular disease. Eating fish and other seafood is also important for foetal development, not least for foetal growth and neurological development. It is assumed that marine n-3 fatty acids play an especially important role in the health-promoting effects of fish.

However, documentation also shows that high consumption of certain fish species may be associated with a relatively high intake of contaminants and other compounds that are potentially hazardous to human health. The potentially highest risk from contaminants and other undesirable compounds in fish and other seafood is posed by dioxins and dioxin-like PCBs as well as by methyl mercury. These contaminants may cause various adverse health effects and the most sensitive life stage for exposure is during foetal development. Fatty fish appears to be the most important source of dioxins and dioxin-like PCBs for adults. The highest mercury levels are found in large freshwater fish, such as large pike, and in predatory fish, such as large halibut.

A health-based risk-benefit assessment, in which the health benefits of some substances in a food group are weighted quantitatively against the health hazards of other substances in the same food group, is a highly complex task to perform. To date, there is no widely accepted method that can be used to conduct a quantitative risk-benefit assessment. It is the composition of the overall diet, genetic makeup, and other lifestyle factors that are most important for a person's health. Moreover, it is important to note that a food group is not homogeneous in terms of nutrients or contaminants. The type of fish or seafood, season, feed, life stage (developmental or reproductive stage) and age affect the amount of nutrients and contaminants within a single species and between species. It is the respective amounts of nutrients and contaminants consumed by a person over time that determines the extent to which a food group will have positive or negative effects on health.

Recommendations for the daily intake of nutrients are given in the Nordic Nutrition Recommendations (NNR, 2004). The Norwegian recommendations issued by the Directorate of Health and Social Affairs follow the Nordic recommendations. A safety margin is included in the recommended intake levels for nutrients to ensure individual variations in healthy individuals in the population and to cover any possible non-specific increase in the requirements. The safety margin is set to ensure individual differences, variations in the body's storage capacity, utilisation of food, negative effects of a high intake etc. In recent years, 'tolerable upper intake levels' (ULs) have been established for most nutrients and are the levels a person can ingest without risking significant undesirable health effects. There can thus be risk associated with too high as well as too low intake of nutrients. A risk-benefit assessment of the nutrients in fish and other seafood consists of comparing recommended intakes and established upper safe intake levels with national intake estimates for the population in general and for sensitive groups in particular.

The safe intake levels of contaminants and undesirable compounds in food are often determined internationally and stated in terms of tolerable daily or weekly intake (TDI/TWI). The tolerable intake levels are intended to give a high level of protection and are often derived from the toxicological effects triggered at the lowest exposure dose. The tolerable intake levels are not a threshold for toxicity, and it is difficult to quantify the risk caused by intakes above the tolerable intake. Due to the integrated uncertainty factors and the conservative way in which the tolerable intake levels are derived, exceeding the tolerable intake level will initially only represent a reduced safety margin. A toxicological risk assessment of contaminants such as dioxins and dioxin-like PCBs in fish and other seafood consists of comparing the tolerable intake level with national intake estimates for the population in general and for sensitive groups in particular.

1.3 Results and discussion

Consumption of fish and other seafood in the Norwegian diet

The consumption of fish and other seafood in Norway differs from the situation in many other countries in that the amount of fish and other seafood consumed is high and the proportion of lean fish is large. The Norwegian population also eats more fish in the form of cold cuts and spreads since several meals per day consist of open-faced sandwiches. Median fish consumption is approximately 65 grams per day for an adult (equivalent to approximately two fish meals per week), and the median consumption for children varies from 6 to 19 grams per day. Two-thirds of the consumption consists of lean fish and minced fish products (e.g. fish cakes, balls or pudding). Although most adults eat some fish or other seafood, a large number of children and teenagers do not eat fish or other seafood at all. In some age groups approximately half do not eat fish. Young women eat less fish than the adult population in general. Fertile women eat fatty fish in amounts equivalent to less than 1/2 meal per week.

Nutrients in fish and other seafood

It is unlikely that fish consumption in Norway could lead to a harmful high intake of vitamins and minerals or marine n-3 fatty acids for any age group. Therefore, interest is focused on the consequences of low intake, especially the consequences of not eating fish at all and of low consumption of fatty fish. Estimates show that even an average fish consumption, equivalent to two meals per week (2/3 lean and 1/3 fatty fish), only provides approximately 25% of the recommended vitamin D intake. To reach the vitamin D requirements, dietary supplements and/or exposure to sunlight is necessary. A low consumption of fish also leads to a low intake of marine n-3 fatty acids, which in turn results in missing out on the recognised health-promoting effects of these nutrients. In practice, low intake must be compensated by taking a dietary supplement to achieve the same beneficial effects. It is possible to have a diet that meets most of the established nutritional requirements without eating fish, or eating only a limited amount of fish. However, it is difficult to reach the recommended intake of vitamin D and n-3 fatty acids without taking dietary supplements.

Based on ***an assessment of nutrient intake***, especially the marine n-3 fatty acids and vitamin D, VKM is of the opinion that an increase in the consumption of fatty fish is advisable, especially for those who eat a limited amount of fatty fish and for that half of the population which eats the least fish. N-3 fatty acids have a positive effect on cardio-vascular disease as well as on the length of pregnancy and foetal development. Adequate levels of vitamin D are also important. The general recommendation to have a varied diet also applies to fish, i.e. people should eat a variety of different kinds of fish. Based on the assessment of nutrient intake, there is no risk associated with eating fish and other seafood in amounts equivalent to four meals or more per week.

Contaminants and other undesirable compounds, including infectious organisms, in fish and other seafood

The amount of man-made radionuclides in Norwegian fish and other seafood is low, and VKM considers their impact on public health to be very limited. Drugs used in aquaculture are thoroughly assessed with food safety in mind, and national monitoring programmes have not found illegal residues of drugs in Norwegian fish farmed for consumption. It is important to keep the use of antibiotics in aquaculture to an absolute minimum to prevent the development and spread of resistance to antibiotics. This also holds true for the latest species being farmed, e.g. cod. Algal toxins are largely a problem in molluscs. Due to the continual monitoring of algal content in the molluscs put on the market, VKM does not regard algal toxins in molluscs to be a problem.

Listeria monocytogenes pose the greatest ***risk from infectious organisms*** since these bacteria can contaminate fish products, such as smoked salmon during production, and they pose a special risk to pregnant women. Furthermore, homemade *rakefisk*, which is partially fermented trout, represents a risk of botulism.

VKM has found that methyl mercury, dioxins and dioxin-like PCBs are the main contaminants that can constitute a potential risk in connection with the consumption of fish and other seafood in Norway.

On the other hand, estimates show that even for persons with high fish consumption, the intakes of mercury are well below the tolerable intake level. In Norway, however, some lakes contain large predatory fish with very high mercury levels. Individuals who consume large amounts of these types of fish may exceed the TWI. Certain instances of local marine pollution with mercury have also resulted in high mercury levels in fish, and those who consume large amounts of these contaminated fish will exceed the TWI for mercury.

It is important to note that the TWI for mercury is established to protect foetal health. Women who are pregnant or who may become pregnant are therefore the most sensitive group, and special dietary recommendations related to mercury have been issued for pregnant women. People in other life stages are assumed to be less sensitive, although increased exposure to mercury appears to increase the risk of cardio-vascular disease in vulnerable population groups. This effect is not yet quantifiable.

Estimates (scenarios) show that adults with a high fish consumption of fatty fish (equivalent to more than four meals of fatty fish per week) could exceed the TWI for dioxins and dioxin-like PCBs solely by the consumption of fish and other seafood. An additional amount of dioxins and dioxin-like PCBs will come from other foods and any cod liver oil consumed. However, according to dietary studies in Norway, this is an unusually high consumption of fatty fish. Dietary studies show that for at least 85% of the adult population, the intake of dioxins and dioxin-like PCBs from the total diet, including fish and other seafood, will be below the TWI. Estimates for children show that the TWI is exceeded by two- to four-year olds with high fish consumption and who also take cod liver oil. For most children, however, other foods such as meat, dairy products and eggs are more important sources of dioxins and PCBs than fish and other seafood.

Cod liver, cod roe pate and brown crab meat have the highest concentrations of dioxins and dioxin-like PCBs, and those who consume large amounts of these foods may also significantly exceed the TWI. This means that there may be individuals, groups of individuals and certain age groups with an especially high consumption of fish and other seafood that have a reduced safety margin. Nonetheless, it is consumption over time that is important.

The TWI has been established to protect the most sensitive life stage, i.e. the foetal stage. However, dioxins and dioxin-like PCBs have such a long half-life in the body that the body burden during pregnancy is not a result of the diet during pregnancy but of the diet during the many years prior to pregnancy. Women who are pregnant or who will become pregnant, and the foetuses, are therefore the most vulnerable group. It is the total accumulated amount of dioxins and dioxin-like PCBs ingested throughout life and throughout the fertile period that is of significance. Women above fertile age and men are believed to be less sensitive to exposure to dioxins.

VKM does not consider that dioxins and dioxin-like PCBs pose a risk of cancer at dietary intake amounts. Nor does VKM consider that PCBs present a risk of neurotoxic effects, since the PCB blood levels of fertile women are well below the level where long-term neurotoxic effects have been seen.

In general, from ***a toxicological perspective***, it is the opinion of VKM that there is no risk associated with eating fish and other seafood in amounts equivalent to four meals or more per week as long as different fish species are eaten and the consumption of fatty fish, with the current level of dioxins and dioxin-like PCBs, does not exceed two meals per week. This (limitation) is especially important with regard to fertile women. However, the equivalent of over two meals of fatty fish per week must be consumed from childhood and continue throughout the entire fertile period in order for a woman to accumulate and exceed the body burden of dioxins and dioxin-like PCBs against which the TWI is intended to protect. However, dietary studies show that pregnant women on average consume only the equivalent of less than 1/2 meal of fatty fish per week. Even those with high fish consumption (95^{th} percentile) do not eat more than 1.5 meals of fatty fish per week.

Comprehensive assessment of fish and other seafood in the Norwegian diet

Based on our review of the literature, VKM finds that the consumption of fish, lean or fatty, has a beneficial effect on health. Even though there is no widely accepted method of conducting a quantitative risk-benefit comparison today, ***an integration of the nutritional and toxicological assessments*** will clearly show that Norwegians in general should eat more fish and that fish consumption should include both lean and fatty fish. This is particularly true for those who eat very little fish. These estimates are based on the current median fish consumption in Norway, which equals approximately two meals of fish meals per week with a proportion of lean to fatty fish of 2:1. It is also evident that the adult population, especially the group with the highest risk of developing cardio-vascular disease, will gain the greatest health-related benefits from increasing their consumption of fatty fish in particular. The next group to benefit is pregnant women due to the probable beneficial effects on foetal development, including the development of brain function. The consumption of fish and other seafood has not been shown to increase or reduce the risk of any common form of cancer.

There is uncertainty regarding how high the fish consumption must be to take full advantage of the health-related benefits. There is reason to believe that further gains from increasing fish consumption will diminish for the population groups that already have the highest consumption. It is therefore uncertain whether those who already consume large amounts of fish would gain further health benefits by eating even more fish.

The content of dioxins and dioxin-like PCBs in fatty fish is the only potential limiting factor for fish consumption. This is because eating fatty fish in an amount equivalent to more than two meals per week, with the current levels of dioxins and dioxin-like PCBs, will over time lead to the tolerable intake level being exceeded. As mentioned above, the tolerable intake level is intended to prevent the accumulation of a high level of these contaminants in women's bodies before and during pregnancy. The consumption must, however, have been in this range throughout the entire fertile period in order to exceed the concentration of dioxins and dioxin-like PCBs in the body that tolerable intake level is set to protect against. With the present consumption of fatty fish, it is unlikely that a general recommendation to increase the consumption of fish will result in young women exceeding an amount equivalent to two meals of fatty fish or more per week over time. Moreover, the tolerable intake level represents a safety level, not a limit for when adverse health effects will necessarily occur. The desirable safety level will, however, be reduced. Even if the safety level is moderately exceeded, the risk is likely to be modest. There are no quantitative population studies that can show this with certainty since the anticipated effects will be small.

Restrictions on and prohibitions against the use and discharge of PCBs and dioxins have resulted in a significant decline in the levels of these organic contaminants. Due to slow degradation, these undesirable contaminants, especially in wild fatty fish and other seafood with high fat content, will nonetheless constitute a potential health risk for many years to come. A continued reduction in the levels of these contaminants is therefore advisable.

Farmed fish is one source of exposure to dioxins and dioxin-like PCBs that currently can be influenced within a reasonable time frame without reducing fish consumption. This can be achieved by selecting feed ingredients with naturally low levels of organic contaminants or by using purifying processes during feed production. Fish and other seafood should preferably contain the lowest possible levels of contaminants and other undesirable compounds so that the safety margin can be upheld at a high level. If marine fat in fish feed is replaced by vegetable fat, the levels of dioxins and dioxin-like PCBs can be reduced, but the nutritional benefits may change as well.

Two- to four-year olds who eat fish and take cod liver oil may exceed the TWI when the total diet is taken into account. For the average child, however, other foods such as meat, dairy products and eggs are a greater source of dioxins and dioxin-like PCBs than fish and other seafood. This is because many children and young people eat little or no fish at all. Cod liver oil is a very important source of vitamin D and marine n-3 fatty acids for children, but with the amounts given to small children, the intake levels of dioxins and dioxin-like PCBs are relatively high. For infants, purified cod liver oil alone can lead to intakes of up to 50% of the TWI for these compounds. It is therefore important that the levels of dioxins and PCB in cod liver oil/dietary supplements are as low as possible.

The nutrient composition, including the composition of fatty acids, in farmed salmon, trout, cod and halibut will vary according to the raw materials and components found in fish feed. It is important that both the nutrient composition and the contaminant level in feed and fish be monitored closely.

1.4 Conclusions

The consumption of fatty fish in particular provides important nutrients such as vitamin D and marine n-3 fatty acids. The consumption of fish in general and of marine n-3 fatty acids is important for preventing and impeding the development of cardio-vascular disease. Marine n-3 fatty acids are important for pregnancy and foetal development as well.

The general Norwegian recommendation is to eat more fish both for dinner and on sandwiches. Based on a comprehensive assessment of scientific documentation of the positive health benefits and the presence of compounds potentially hazardous to health, as well as on knowledge about fish and other seafood in the Norwegian diet, VKM supports this recommendation. The recommendation applies especially to those who currently eat little or no fish. Apart from people with allergies to fish and with certain metabolic diseases, there are no other health-related circumstances that counter indicate fish in the diet. Those who eat more than two meals of fatty fish per week over a long period of time may moderately exceed the tolerable intake (TWI) for dioxins and dioxin-like PCBs, but this would initially only represent a reduced safety margin. Fertile women are particularly vulnerable, but based on knowledge about young women's consumption of fatty fish, there is little reason to believe that a general recommendation to increase fish consumption would result in fertile women consuming so much fatty fish that the intake of dioxins and dioxin-like PCBs over a long period would exceed the tolerable intake (TWI) and consequently constitute a health risk for the foetus.

Children may exceed the TWI, but for most children (2-13 years), foods other than fish are the predominant source of these contaminants.

A continued reduction in the level of potentially hazardous compounds in fish and other seafood is advisable. Only after an extended period of time will restrictions on the discharge of contaminants have an effect on fish caught in the wild and other seafood. Levels of organic contaminants such as dioxins and dioxin-like PCBs in farmed fish and cod liver oil may, however, be influenced within a reasonable time frame.

2 Introduction

Throughout history, seafood has been an important part of the Norwegian diet. The first humans came to Norway by sea some 10 000 to 11 000 years ago. Findings of the skeletal remains of the 'Søgne woman' from the late Stone Age have given us unique insight into how people lived in Norway more than 9 000 years ago. Studies of carbon isotopes in the skeletal remains show that 86% of the Søgne woman's food came from the sea and included bivalves, fish, crab, seal, small whale and probably seaweed. These resources formed the core of the nutritional base for the first inhabitants who settled along the coast of Norway. Access to seafood has been central to the development of the coastal communities.

Seafood is a broad term, encompassing everything from seaweed and kelp to shellfish, fish and sea mammals. Today the notion of what constitutes seafood depends on geography as well as cultural traditions. Culinary traditions undergo continual development, and traditional as well as new seafood products are readily available in supermarkets and restaurants.

Fish consumption in Norway has traditionally been high and has to a high degree consisted of lean wild fish. Today, farmed fish also comprises a significant part of consumption. Due to the rapid growth in the volume of farmed fish, as well as stagnation in the catch of wild fish, the consumption of farmed fish is expected to increase even more in the future. With the success of the aquaculture industry, salmon and trout have become readily available to Norwegian consumers at low prices. It is also expected that more farmed cod will reach the consumer market, whereas the currently small volume of farmed halibut is not expected to increase significantly. Commercial production of bivalves in Norway is still modest, consisting of only a few thousand tonnes of mussels and even smaller amounts of scallops, oysters and other species.

Fish is an important component of a varied diet for the population-at-large, providing a number of important nutrients that are essential for achieving a balanced diet for children, adults and the elderly.

However, lakes, fjords and the open sea are also subjected to a wide range of natural and anthropogenic (man-made) contaminants. When a chemical contaminant is added to an aquatic environment, the contaminant disseminates and can be found in the water, on particles, in biological material or in the bottom sediment. Chemical conversion may also occur. Depending on their solubility, affinity properties and chemical stability, the substances may be absorbed and accumulated in the tissue of fish and other sea animals that are eaten by humans. Persistent lipophilic compounds (e.g. DDT, PCBs and dioxins) have a strong tendency to bioaccumulate in fatty tissue and will also biomagnify in food chains. The highest concentrations will therefore be found in fatty tissue and in species located at the top of the aquatic food chain. Organic metals (e.g. methyl mercury) accumulate in the food chain, and the amounts increase in proportion to the individual's age and size. If a harbour or fjord region is polluted with PCBs and/or undesirable industrial by-products known as dioxins, one can expect to find high concentrations of these compounds in fatty cod livers, while lean cod fillet will contain only minimal amounts. Similarly, in the same polluted waters, one can expect to find relatively high concentrations of dioxins and PCBs in the fillet of fatty fish such as herring, trout and mackerel. The highest concentrations of mercury are found in older and larger fish (e.g. pike). Meanwhile, it is important to be specific when using the generic term 'fish' because nutritional value and potential contaminant levels vary greatly depending not only on the species of fish, but also on the type of tissue analysed, the season and, as regards farmed fish, the composition of the feed.

In recent years, concerns about the potential health risk associated with exposure to contaminants from food have resulted in a strong focus on chemical management and chemical policy at the national and international levels alike. Stricter controls and restrictions on the use and discharge of chemicals have resulted in a significant reduction in concentrations of many contaminants in the environment, not least in fish and other seafood. A time-trend study of the amount of PCBs in the breast milk of Norwegian women shows a considerable decline in PCBs, i.e. 58% from 1970 to 2000 (Becher *et al.,* 2002). A significant reduction of dioxins and dioxin-like PCBs was also found in human breast milk in Norway as well as abroad (Becher *et al.,* 2002). Time-trend studies of brominated flame retardants in breast milk also show a decline in PBDE levels since the late 1990s (Meironyte *et al.,* 1999, 2001).

In the field of nutrition and food safety, assessments have traditionally dealt with individual food components. This has led to the current situation, in which dietary recommendations and advice are experienced as contradictory as well as confusing for the individual consumer. In consequence, it is a formidable challenge for scientists to assess the health-related advantages and disadvantages of an entire food group (like fish and other seafood). Recommendations on fish consumption should be made on the basis of an assessment of all the available documentation on diet, dietary components and health, and they should take a critical view of the quality and reliability of the studies made.

Effective methods for assessing the risks of individual substances have been developed by Codex Alimentarius which is an UN agency under the direction of the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO). These well-established methods for risk assessment of contaminants are also useful for nutrients since the extensive use of dietary supplements, and vitamins and minerals added to food (fortification) has increased the risk of reaching hazardously high intakes of these nutrients. National bodies (national scientific committees for food safety and health, including the Norwegian Scientific Committee for Food Safety (VKM) and international organisations such as the FAO/WHO's Joint Expert Committee on Food Additives and Contaminants (JECFA), as well as the European Food Safety Authority (EFSA) and other bodies, have conducted health risk assessments of many different chemical contaminants.

The health authorities in Norway and other countries place great emphasis on the nutritional benefits of fish consumption. Norway's Directorate for Health and Social Affairs advises people to eat more fish and to eat fish several times a week. This recommendation is based in part on the fact that fish, especially fatty fish such as salmon, herring and mackerel, is an important natural source of a number of nutrients, including n-3 fatty acids, vitamin D, selenium and iodine. The Norwegian health authorities also recommend a daily supplement of cod liver oil from 4 weeks of age, to ensure an adequate supply of vitamin D and marine n-3 fatty acids.

Since the early 1980s, the Norwegian Food Safety Authority[1] has issued dietary advice recommending that people limit their consumption of certain seafood products which may contain elevated levels of one or more contaminants. Providing dietary advice is one of several measures used to reduce the intake of contaminants by the population. Dietary advice is often provided for food that people catch themselves (e.g. by fishing, gathering bivalves, and hunting game) since alternative measures, such as establishing legal maximum intake levels or prohibiting sales, can only be used to reduce the consumption of food sold on the market. Some harbours and fjords along the Norwegian coast are especially polluted, and the Norwegian Food Safety Authority issues dietary advice specific to those regions prohibiting the sale of fish and bivalves from those areas.[2] The

[1] Before 2004 – The Norwegian Food Control Authority
[2] More information on dietary advice is available in Norwegian at: www.matportalen.no.

number of dietary recommendations has grown, both because more regions have been studied and because our knowledge of health hazards and the potential health risk to humans from exposure has increased over time. Private fishing is relatively important in Norway. In 1999, roughly 60% of the population along the coast said that they obtained more than half of the fish they consumed from private fishing or as a gift, whereas only 25% of the inland population said they had obtained fish for their own consumption in this manner.

The Norwegian Food Safety Authority provides dietary advice based primarily on health risk assessments conducted by VKM. Dietary advice related to contaminants in fish and other seafood is based on documentation about the connection between potential health risks to the population in general and/or especially sensitive groups and the consumption of a given amount of food containing one or more chemical contaminants. VKM bases its assessments on internationally recognised health risk assessments when these are available. Owing to new findings and new ways of understanding and analysing data, the existing dietary advice and recommendations undergo continual reassessment.

In general, Norwegian authorities recommend eating a well-balanced diet in order to achieve positive effects and avoid negative health effects from the diet.

Table 1. Summary of the most important advice and recommendations on the consumption of fish and other seafood (as of November 2005).

Directorate for Health and Social Affairs	
General advice Eat more fish - both on bread and for dinner. Eat fish several times a week.	Specific advice A daily supplement of cod liver oil is recommended for all infants from 4 weeks of age to ensure an adequate supply of vitamin D and long-chained n-3 fatty acids. A gradual introduction of cod liver oil from 2.5 ml to 5 ml is recommended during the first 6 months of life. 5 ml cod liver oil per day is recommended from 6 months of age.
Norwegian Food Safety Authority	
General advice The following freshwater fish should not be eaten more than once a month on average: all pike, perch over 25 cm, trout over one kilo, and Arctic char over one kilo. The consumption of fish liver and spreads made of fish liver should be limited. Fish liver taken from especially polluted harbours, fjords and fresh water should not be eaten.	Specific advice Pregnant and breast-feeding women should not eat: - the following freshwater fish: all pike, perch over 25 cm, trout over one kilo, and Arctic char over one kilo; - brown crabmeat (white crab meat in the claws and tail is safe to eat); - exotic fish: shark, swordfish, skate, fresh tuna (tuna in tins is safe to eat); - whale meat; Children, fertile women and pregnant women should not eat: fish liver or spreads made from fish liver.

Since 2004, many articles in the national and international press and other media have mentioned studies of organic contaminants such as dioxins, PCBs and other chlorinated compounds in wild and farmed salmon. These stories have concluded that people should significantly restrict their consumption of salmon, especially farmed salmon, because the intake of organic contaminants could theoretically increase the risk of developing cancer (Hites *et al.,* 2004, Foran *et al.,* 2005). The risk assessment methods used in these articles are elaborated by the US Environmental Protection Agency (EPA). These methods deviate on several counts from the way in which recognised international (WHO/JECFA), European (EFSA) and Norwegian authorities (VKM) conduct risk assessments, and the conclusions of the EPA are not supported by national and international risk assessment experts on food.

Based on the increased focus on the health effects of consuming fish and other seafood, the Norwegian Food Safety Authority asked VKM to conduct a comprehensive assessment addressing the nutritional benefits of consuming fish and other seafood in relation to the health risks associated with the intake of chemical contaminants in fish and other seafood. In addition, the Norwegian Food Safety Authority requested that VKM weigh the benefits of fish consumption against the risks insofar as possible and to assess whether the conclusions of the comprehensive assessment to be conducted indicate a need to alter the current Norwegian recommendations on the consumption of fish and other seafood.

In this report, Norwegian dietary data has been used to estimate the intake of nutrients and contaminants by children and adults when they consume fish and other seafood. Relevant Norwegian data on nutritional significance, toxicology and hygienic factors have been used, as have international assessments and scientific literature. VKM has also used information from the comprehensive assessments of fish and other seafood published in Denmark (Danish Veterinary and Food Administration, 2003) and in the UK (SACN/COT, 2004), as well as the risk assessment of farmed and wild fish conducted by the European Food Safety Authority (EFSA, 2005a).

This report is organised as follows: First, it provides an overview of the consumption of fish and other seafood in Norway, based on Norwegian dietary studies (cf. Chapter 3 'Fish and other seafood in the Norwegian diet'). This chapter discusses various dietary studies and how these are used as a basis for estimating fish consumption. Next, Chapter 4 provides a description of the most important nutrients in fish and other seafood, and Chapter 5 'Contaminants and other undesirable compounds, including infectious organisms, in fish and other seafood' discusses the relevance and capacity of these substances to have an adverse effect on health and the levels at which they are considered to be safe. Farmed fish and the significance of feed for the levels of nutrients and contaminants in farmed fish are discussed in Chapter 6. Specifically, this chapter addresses the significance of the choice of feed ingredients, how the fish can be fortified with the desired amounts of nutrients, how undesirable compounds in feed can be eliminated, and the consequences of using genetically modified raw materials in fish feed.

Chapter 7 describes the health effects associated with fish consumption and how these have been documented in epidemiological studies. The issue of the presumed health-promoting effects against the risk of developing cardiovascular disease is addressed in-depth in a British report (SACN/COT, 2004). This chapter is based on the research presented in this report as well as on scientific studies published since. As regards the possible correlation between fish consumption and cancer, a separate assessment of the existing epidemiological literature was conducted since cancer is not discussed in the SACN/COT report.

In Chapter 8, data on the content of nutrients and contaminants in fish and other seafood are combined with data from dietary studies to estimate the intake of the various compounds.

As of today, there is no standardised methodology for conducting quantitative risk-benefit assessments of food. This situation is about to change since the demand for new methods that can be used to conduct comprehensive assessments, including of entire food groups, is on the rise. The EFSA called for the development of such a method (EFSA, 2005a) in its recent assessment of fish.

Chapter 9 summarises the work underlying this report, and Chapter 10 provides specific answers to the questions posed by the Norwegian Food Safety Authority.

3 Fish and other seafood in the Norwegian diet

This chapter provides an overview of the consumption of fish and other seafood in Norway. The information on the actual consumption of fish and other seafood presented here forms the basis of later chapters, including estimates of the impact of fish and other seafood for the intake of nutrients and contaminants and for our health.

Over the past 10 years, large-scale, national dietary studies of adults and children in different age groups has generated relatively good knowledge about fish and seafood consumption (cf. Table 2). The findings show that Norwegian fish consumption is different from many other countries in Europe. On average, Norwegians eat more fish than most other Europeans, i.e. more than the equivalent of two meals of fish per week, with roughly 2/3 of this in the form of lean types of fish. Because many Norwegians eat two meals of bread per day, cold cuts and spreads made of fish are an important source of fatty fish in the Norwegian diet. Another special feature of the Norwegian diet is the regular consumption of cod liver oil beginning as early as the first year of life.

3.1 Sources of information about fish and seafood consumption

Until relatively recently, statistics on the amount of the Norwegian fish consumption have been unreliable and inadequate. This is partly due to the traditional Norwegian practice of consuming large amounts of self-caught fish, for which it has been difficult to obtain good data from consumer studies. Since 1996, the database has improved considerably. There are currently three levels of information about food consumption in Norway.

Level 1 - Statistics on the food supply
Statistics on the food supply provide information about the production, export, import and sale of food, and they show the amount of food available to the entire population. Norwegian statistics on the food supply are prepared on an annual basis by the Norwegian Agricultural Economics Research Institute (NILF) at the request of the Directorate for Health and Social Affairs. Before 1995, the food supply figures for fish were prepared by the Directorate of Fisheries. However, there was such great uncertainty surrounding these figures that the Directorate of Fisheries determined that the estimates were not useful for explaining trends over time. In this chapter, food supply figures after 1995 are shown in two figures (Figure 7 and Figure 8).

The amount of food (per person) recorded in the statistics on the food supply will always be higher than comparable figures from other studies, such as consumer studies (level 2) or dietary studies, partly because the figures are expressed in round weight and because waste occurs in the food chain. As a result, there is no point in comparing specific figures from data sets at different levels, e.g. comparing these figures with figures from dietary studies (level 3) (Sosial- og helsedirektoratet, 2004). Based on the 'Food Balance Sheets' prepared by FAO, the Norwegian population eats approximately 55 kg fish and other seafood per person per year, which is equivalent to 150 grams per person per day, but consumption figures per person per day are lower at levels 2 and 3. As mentioned above, this is a natural result of the fact that the information becomes more detailed, corrections are made for waste, etc.

Level 2 - Consumer studies

Consumer studies have been conducted by Statistics Norway (SSB) and commercial companies, including GfK.[3] These studies have different strengths and weaknesses. Consumer studies conducted by SSB show how much food is obtained (through purchase, self-catch, as gifts) in a nationally representative sample of private households during a 14-day period. Food eaten outside the home and the amount of food eaten by individual family members are not recorded. SSB has shown that the amount of fish which households have caught themselves or received as gifts is underreported.

Household data compiled by GfK Norway were collected from a panel of 1 500 households and are representative of Norwegian households with regard to age, household size and product type. Each household usually participates in the panel for three years and keeps a daily log on a continual basis. The questionnaire covers fish and seafood that are purchased, self-caught or received as gifts, but not fish that is purchased/obtained in catering establishments or when eating out. In this report, GfK data has been used when cited in reports by the Directorate of Health and Social Affairs (Directorate of Health and Social Affairs, 2004). GfK estimated that the acquisition of fish and fish products by private households was 33.7 kg/person/year (round weight) in 2003, which equals 92 grams/person/day. These figures are the average for all age groups.

Level 3 - Dietary studies

The data from Norwegian dietary studies are based on the participants (self-recording) of what they eat. Conducted using nationally representative samples of the population and subgroups, these studies provide the most accurate picture of the amount of a particular food that is actually consumed. The data from nationally representative studies are presented in Norkost 1997 (Johansson *et al.,* 1999), Ungkost 2000 (Pollestad *et al.,* 2002, Øverby & Andersen, 2002) and Sped- og småbarnskost 1998-99 (Lande, 2003, Lande & Andersen, 2005 a, b). These reports estimate the actual food consumption by adults (16-79 years), children (4, 9 and 13 years), and small children (1 and 2 years), respectively (cf. Table 2). The Fish and Game Study ('Fisk- og viltundersøkelsen'), Part A, provides detailed information about the consumption of fish and game by a representative sample of 6 000 people (18-79 years) in 1999 (Meltzer *et al.,* 2002) (cf. Table 2).

Because these studies make it possible to estimate the consumption of fish at the individual level, they have been used as the primary source of information about the consumption of fish and other seafood in this report.

[3] GfK stands for Growth from Knowledge, an international company with an office in Oslo. GfK Norway offers most types of market analysis, but it specialises in mapping and analysing the purchasing behaviour of the Norwegian population. The studies are conducted on a nationwide basis.

Table 2. Sources of information about the consumption of fish and other seafood in Norway. The table provides an overview of the nationwide dietary studies (level 3) that provide information about the consumption of fish and other seafood in Norway.

Norkost 1997 (Johansson *et al.,* 1999) Conducted in 1997.

Objective: To describe the diet of the general population and assess the correlations between dietary habits, socio-demographic variables and other health habits, as well as to assess the diet's nutritional composition in relation to health policy objectives.

Number of participants/ages: A nationally representative sample of 2 672 persons. 51% women and 49% men between the age of 16 and 79 were included in the data analysis.

Methodology: Quantitative food frequency questionnaire on diet during the past year. Portion sizes were expressed in slices, glasses, cups, bites, decilitres or spoonfuls.

Questions about fish and other seafood: Questions covered roughly 180 food items and dishes. Six questions were related to different types of cold cuts and spreads made of fish, 12 questions were about fish eaten for dinner, and 3 questions pertained to cod liver oil and fish oil capsules.

Ungkost 2000 4-year-olds (Pollestad *et al.,* 2002). Conducted in 2000-2001.
9-year-olds and 13-year-olds (Øverby & Andersen, 2002)

Objective: To collect data on the diets of children and teenagers as a basis for preventive and health-promoting measures targeted at this group. To describe and assess children's and adolescents' meal patterns, food consumption and intake of energy, nutrients and certain contaminants. To describe and assess children's and adolescents' level of physical activity. To assess the diet of children and adolescents in relation to socio-demographic factors.

Number of participants/ages: A nationally representative sample of 381 4-year-olds, 810 9-year-olds and 1 005 13-year-olds is included in the data analysis.

Methodology: Diet recorded over a 4-day period using a pre-coded daily log book. Amounts expressed per unit, e.g. drinks expressed in number of glasses. A picture book was used to show examples of portion sizes for drinks, meals consisting of bread, and dinner.

Questions about fish and other seafood: Four questions about fish cold cuts and spreads, 17 questions regarding fish/other seafood eaten for dinner, two questions about shellfish in salad, and two about cod liver oil and cod liver oil capsules. The questionnaire also contained blank lines for additional comments.

Spedkost 6 months (Lande, 2003). Conducted in 1998-1999.
12 months (Lande & Andersen, 2005a)

Objective: To increase knowledge about the diet of infants and young children in Norway to obtain a better basis for providing advice on diet and preventing diet-related health problems in this age group. The dietary studies were intended to compile data that would provide a basis for describing dietary habits, assessing nutritional quality, determining whether dietary habits correspond to dietary recommendations, assessing factors that explain differences in diet, obtaining an overview of contaminants in the diet, and promoting the establishment of a system to follow-up dietary trends over time.

Number of participants/ages: A nationally representative sample of 2 382 infants at 6 months of age; 1 932 of these were also studied at 12 months of age.

Methodology: Semi-quantitative food frequency questionnaire. A picture book containing examples of portion sizes was attached to the questionnaire.

Questions about fish and other seafood: One question about fish eaten for dinner and two regarding cod liver oil and other dietary supplements at 6 months of age. Two questions about cold cuts and spreads made of fish, five questions about fish eaten for dinner, and two questions about cod liver oil and other dietary supplements at 12 months of age.

Småbarnkost 1999 (Lande & Andersen, 2005b) Conducted in 1998-1999.

Objective: The same as for Spedkost 1998-1999.

Number of participants/ages: A nationally representative sample of 1720 2-year-old children is included in the data analysis.

Methodology: Semi-quantitative food frequency questionnaire. A picture book was included to show examples of portion sizes.

Questions about fish and other seafood: Two questions about cold cuts and spreads made of fish, five questions regarding fish eaten for dinner, and two questions about cod liver oil and other dietary supplements.

Fish and Game Study, Part A (Meltzer *et al.,* 2002). Conducted in 1999.

Objective: To estimate the consumption of food that may contain considerable amounts of contaminants in a representative sample of the Norwegian population, in order to calculate the intake of mercury, cadmium and PCBs/dioxins.

Number/ages of participants: A nationally representative sample of 6 015 people, ages 18 to 79.

Methodology: Qualitative food frequency study without portion sizes. Portion sizes were added during the processing of the data and are based on the portion sizes presented in Norkost 1997.

Questions about fish and other seafood: One question about cold cuts and spreads made of fish and 26 questions about fish and other seafood.

Fish and Game Study, Part B (Bergsten, 2004). Conducted in 2000.

Objective: The same as for part A, but consisted of large-scale consumers of fish and game.

Number/ages of participants: A sample of 5 502 people between the ages of 18 and 79 in 13 inland municipalities and 14 coastal municipalities in which it was assumed that access to and thus the consumption of fish and game are higher than in other regions of the country.

Methodology: The questionnaire contained the same questions as in the Fish and Game Study, Part A, but included a number of additional questions on how the food was obtained.

Fish and Game Study, Part C. Conducted in 2003.

Objective: To study the dietary intake and biological parameters of large-scale consumers from part B. Assess the correlation between intake and biological parameters.

Number/ages of participants: About 200 people from part B, ages 18 to 80.

Methodology: All participants provided blood and urine samples and answered a 12-page questionnaire on diet. The data is currently undergoing analysis and quality assurance.

Thus far, the findings from this study have only been published in the form of three master's theses.

3.2 Methodological challenges

No methodology currently available for dietary studies can measure the diet of an individual or a group of individuals without errors in the data (Andersen, 2000). Much of the data in this report has been taken from self-administered dietary studies based on data obtained from food frequency questionnaires, i.e. the informant fills out a form which asks 'How often do you eat…' and then answers from a set of alternatives, such as 'never', 'a few times a year', '1-3 times a month' or 'xx times per year'. In the Norkost, Småbarnskost and Spedkost studies, the informants were also asked to give a portion size, while this was not included in the Fish and Game Study, Part A. Questionnaires of this type are complicated to complete and require a good memory, the ability to quantify one's diet, etc. If the informant is not asked to give portion sizes, standard portions are used when the data are processed. This practice represents a source of error in itself, although the difference in portion sizes of children, women and men are taken into account.

To ensure that estimates and insufficient data do not result in erroneous conclusions, it is important to evaluate the quality of the methodology used. This can be done by using reproducibility and validity tests. One of the greatest methodological challenges is related to overestimation or underestimation food consumption. The more questions asked about fish consumption, for instance, the greater the chance that consumption will be over-reported. The opposite is true as well. If only a few questions are asked, consumption will likely be underreported. In Norkost 1997, six questions were asked about cold cuts and spreads made of fish and 26 questions were asked about fish eaten for dinner. In the Fish and Game Study, Part A, one question was asked about cold cuts and spreads made of fish and 26 questions were asked about fish eaten for dinner. In the light of this difference in methodology, it is surprising that the estimated overall consumption of fish is so similar in the two studies. In the subgroups of fish, such as fatty fish, however, the findings show a slightly greater difference. To avoid estimates being influenced by participants who report an unrealistically high consumption, percentiles and median values for consumption are used whenever possible. When this report refers to the 95th percentile for the intake of substances, individual food items or total consumption, the absolute intake is probably overestimated and the actual intake of vitamin D or PCBs, for example, is probably lower than estimated.

The Fish and Game Study, Part A, was conducted in 1999 because very little detailed information was available about the consumption of the foods that contribute most to the dietary intake of mercury, cadmium, PCBs and dioxins. The foods in question are certain fish species, especially freshwater fish, shellfish, the edible internal organs of fish, and game and mushrooms. These foods have little significance for the intake of nutrients by the population in general because they are usually eaten in small amounts, if at all. As a consequence, no priority has been given to compiling data on the consumption of these foods in ordinary dietary studies. Nationwide dietary studies such as Norkost and Statistics Norway's consumer studies do not identify groups that eat significant amounts of these foods, quite simply because the studies did not ask about them specifically.

The Fish and Game Study, Part A, has not yet been validated. Nonetheless, this report uses data from that study, as well as from the other nationwide studies, because it is the only data available which is suitable for drawing conclusions about the consumption of certain high-risk foods and, consequently, about the levels of some contaminants. The Fish and Game Study, Part A, is also the newest and largest study available on the consumption of fish and other seafood in Norway.

3.3 The consumption of fish and other seafood in Norway

The average consumption of fish and other seafood, as estimated by the Fish and Game Study, Part A, Norkost, Ungkost 2000 and Småbarnskost 1999, is shown in Table 3. As there is little difference in fish and other seafood consumption between the genders in the younger age groups, the table does not show separate figures for boys and girls. Meanwhile, the difference between the genders is much greater for adults, so the table shows consumption for men and women separately in the Fish and Game Study, part A, and in Norkost 1997.

Table 3 The consumption of fish and other seafood in the Fish and Game Study (Meltzer *et al.,* 2002), Norkost (Johansson *et al.,* 1999), Ungkost (Øverbye & Andersen, 2002; Pollestad *et al.,* 2002) and Småbarnskost (Lande & Andersen, 2005b). Consumption is expressed as the average edible portion in grams/day.

	Fish and Game Study (ages 18-79)		**Norkost 1997 (ages 16-79)**		**Ungkost 2000 (age 13)**	**Ungkost 2000 (age 9)**	**Ungkost 2000 (age 4)**	**Småbarnskost 1999 (age 2)**
	Men n=3091	Women n=2874	Men (n=1298)	Women (n=1374)	(n=1005)	(n=810)	(n=391)	(n=1720)
Fish, shellfish total	76	65	72	58	25	27	27	20
Fish, lean/ intermediate oily fish	28	25	26	21	5	5	5	3
Fish, fatty*	20	16	11	8	5	3	3	1
Fish products	12	11	14	12	8	11	11	11
Fish, misc.	0	0	5	5	4	4	5	0
Crustaceans, brown flesh	12	11	5	4	1	1	0	0
Fish, cold cut	3	3	12	8	2	2	3	5

*Fatty fish is defined as fish with a fat content of more than 5 grams per 100 grams of fish fillet. The Fish and Game Study does not have values in the miscellaneous category because all the answers could be classified in one of the other groups.

Table 4 shows the amount of fish eaten (g/day) by different age groups based on Ungkost, Småbarnskost and the Fish and Game Study, Part A. These values are used as the basis for the intake estimates presented in Chapter 8. The figures show that if a portion of fish is assumed to weigh about 200 grams for adults, then more than half the participants in the Fish and Game Study eat roughly two meals or more of fish per week, and about 10% of these adults eat four or more meals of fish per week. For children, it appears that 2-year-olds have the most regular consumption of fish, while a large number of children in the older age groups never eat fish.

Table 4 Amount of fish (g/day) eaten by different age groups based on Småbarnskost, Ungkost and the Fish and Game Study, Part A. These values are used as the basis for the intake estimates presented in Chapter 8.

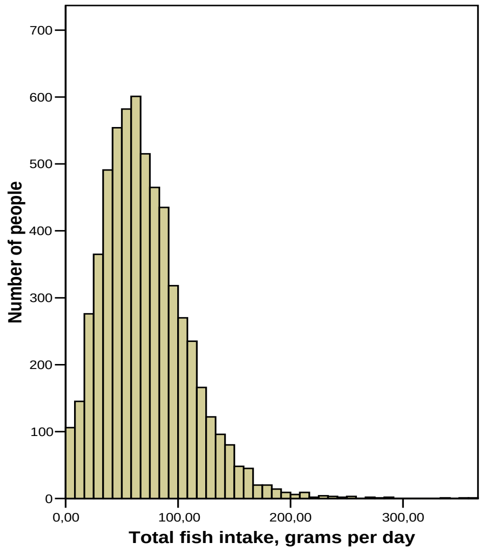
	Age 2	**Age 4**	**Age 9**	**Adults (ages 18-79)**
10th percentile	5,2	0	0	27
25th percentile	9,8	1.3	0	44
50th percentile	16	19	19	65
75th percentile	26	40	38	91
90th percentile	38	63	68	119
95th percentile	46	75	90	139

Based on the Fish and Game Study, Part A, the median consumption of fish in Norway is 65 grams/person/day (figure 1). The average consumption is 70 grams/day, i.e. 65 grams/day for women and 75 grams/day for men, cf. Table 3. The figures include all types of fish and other seafood, including cold cuts and spreads. For minced fish products, the figures are corrected for other ingredients such as flour. There are large differences in the distribution of fish consumption (figure 1). The 95th percentile, with a consumption of 139 grams of fish per day, eats the equivalent to four to five fish meals per week. For most people, this is tantamount to a high consumption of lean fish species.

About 27% report that they eat cold cuts and spreads made of fish at least once per week, while approximately 33% say that they eat processed fish products once or several times per week, and 11% say they eat cod at least once a week. These three product groups are the most frequently consumed ones (Meltzer *et al.,* 2002). The findings show that only 0.5% of the adult population never eats fish. Eleven% report that they never eat cold cuts and spreads made of fish, 4.5% say that they never eat processed fish products[4], and 7% say that they never eat cod.

The median consumption by 2-year-olds is 16 grams/day in contrast to 19 grams/day for 4-year-olds and 9-year-olds. The 13-year-olds have the lowest fish consumption, with a median consumption of 6 grams/day. For 2-year-olds, the 95th percentile for fish consumption is 46 grams/day, for 4-year-olds 75 grams/day, for 9-year-olds 90 grams/day, and for 13-year-olds 96 grams/day. For all age groups, about half or more of the consumption in this percentile consisted of fish products.

[4] Fish products include fish balls, fish cakes, fish pudding and fish gratin



	All particpants (n = 6015)	Consumers only (n = 5983)
10th percentile	27	28
25th percentile	44	44
50th percentile	65	65
75th persentile	91	91
90th persentile	119	119
95th persentile	139	139
Average – SD	70 ± 38	71 ± 38
Min. – maks.	0 - 360	1 - 360

Figure 1. The total fish consumption (grams of fish eaten per day), including shellfish and fish products. Fish and Game Study, Part A.

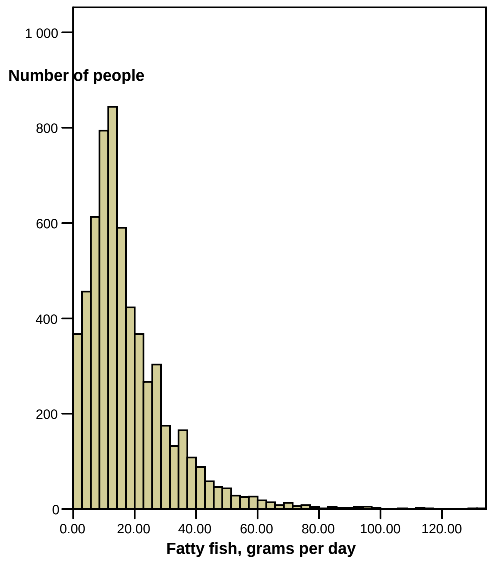
3.3.1 The consumption of fish, categorised by fat content

The Fish and Game Study, Part A, provides a picture of the fish consumption based on different variables, including fat content. The following section describes the consumption of fatty, intermediate oily fish and lean fish from this study. Data from Norkost 1997, Ungkost 2000, Småbarnskost and Spedbarnskost 1998-1999 are also discussed where relevant.

3.3.1.1 The consumption of fatty fish

The median consumption of fatty fish, not including cold cuts and spreads, is 14 grams/day (Figure 2). This accounts for about 25% of the total consumption of fish and other seafood. Assuming that cold cuts and spreads consist primarily of fatty fish species, then fatty fish is about 30% of the total consumption of fish and other seafood by adults. The sum of fatty fish and cold cuts and spreads in Norkost 1997 shows the same result. For 13-year-olds, the same assumption would result in a consumption of fatty fish representing approximately 28% of total consumption. For 9-year-olds and 4-year-olds, this figure is approximately 22%, and for 2-year-olds it is approximately 20%.

A small percentage of the adult population never eats fatty fish (Figure 2). The average consumption of fatty fish is equivalent to about half a meal of fatty fish per week. The consumption of fatty fish by the 95th percentile is 44 grams/day. As stated above, these figures do not include cold cuts and spreads, which consist mostly of fatty fish.



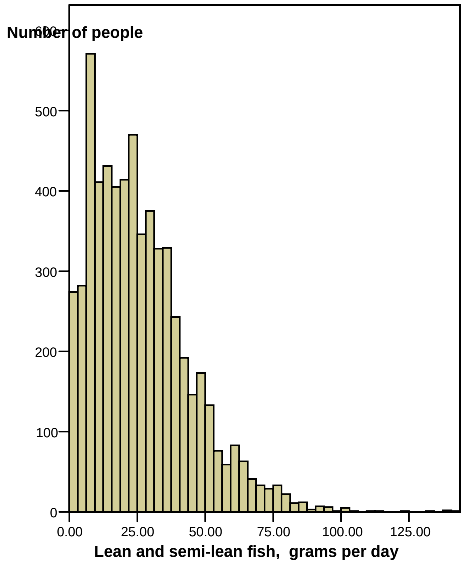
	All participants (n = 6015)	Consumers only (n = 5816)
10th percentile	5	6
25th percentile	9	9
50th percentile	14	15
75th percentile	24	24
90th percentile	36	36
95th percentile	44	45
Average– SD	18 ± 14	19 ± 14
Min. – max.	0 – 134	1 - 134

Figure 2. Consumption of fatty fish in the Fish and Game Study, Part A. Fatty fish is defined as fish with a fat content > 5 grams per 100 grams of fish fillet, i.e. all types of salmon and trout, halibut, mackerel, herring and eel. The figure does not include cold cuts and spreads.

Småbarnskost and Ungkost showed that the 50th percentile for the consumption of fatty fish for dinner was zero, i.e. that at least half of the children never eat fatty fish for dinner. The consumption of fish in the form of cold cuts and spreads was also low. Only 2-year-olds exceeded zero at the 50th percentile, with a median consumption of 1 gram/day. The 95th percentile for consumption of fatty fish by 2-year-olds is 3 grams/day, for 4-year-olds and 9-year-olds it is 29 grams/day, and for 13-year-olds it is 37 grams/day. Fatty fish from cold cuts and spreads is not included in these amounts.

3.3.1.2 The consumption of lean and intermediate oily fish

The median consumption of lean and intermediate oily fish (fish with a fat content < 5 grams per 100g) is 24 grams/day (Figure 3). This accounts for 37% of the total fish consumption in the Norwegian diet. If it is assumed that the fish used in fish products (fish balls, fish cakes, fish pudding, fish gratin) consists primarily of lean and intermediate oily fish, then lean fish species account for 50-55% of the total consumption of fish and other seafood by adults in Norway. For 13-year-olds, the same assumption would result in a consumption of lean and intermediate oily fish representing approximately 56% of the total consumption. For 4-year-olds and 9-year-olds, it would be approximately 59% and for 2-year-olds, it would be approximately 70%.



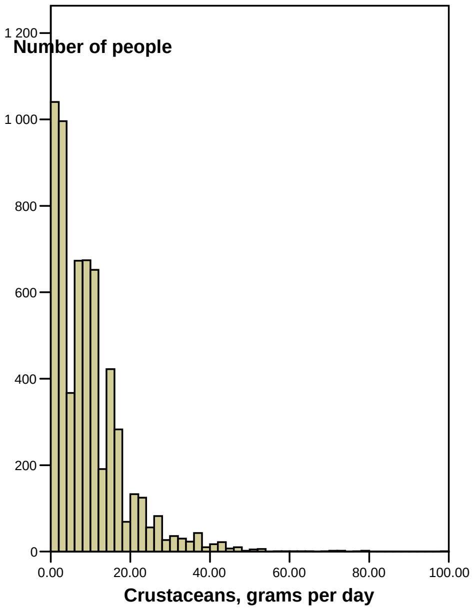
	All participants (n = 6015)	Consumers only (n = 5856)
10th percentile	6	7
25th percentile	12	13
50th percentile	24	24
75th percentile	36	37
90th percentile	50	51
95th percentile	62	62
Average – SD	26 ± 18	27 ± 18
Min. – max.	0 - 144	1 - 144

Figure 3. Consumption of lean and intermediate oily fish in the Fish and Game Study, Part A. Lean and intermediate oily fish is defined as fish with a fat content < 5 grams per 100 grams of fish fillet, i.e. cod, saithe, haddock, plaice, whitefish, wolf fish, red fish, tuna. Lean fish in fish products is not included.

The consumption of lean and intermediate oily fish in the 95th percentile for adults in the Fish and Game Study was 62 grams/day, whereas Småbarnskost and Ungkost showed that the 95th percentile for the consumption of lean and intermediate oily fish by 2-year-olds is 8.8 grams/day. For 4-year-olds, it is 37 grams/day and for 9-year-olds and 13-year-olds, it is 46 grams/day. Lean fish in fish products is not included in these amounts.

3.3.2 The consumption of shellfish

There is great individual and seasonal variation in the consumption of shellfish. Based on the Fish and Game Study, Part A, 33% of the population eats shellfish 1 to 11 times per year, and 2% eats shellfish once or more per month. The median consumption of shellfish (shrimp, crab, bivalves) is 8 grams/day (Figure 4) and accounts for approximately 10% of the total consumption of fish and other seafood in the diet of Norwegian adults. Most of this consumption is shrimp. The 95th percentile for the consumption of shellfish is 27 grams/day, which equals approximately 190 grams/week, i.e. one meal of shellfish per week. The average consumption of shellfish by children and adolescents is insignificant in relation to the total consumption of fish and shellfish, cf. Table 3.



	All participants (n = 6015)	Consumers only (n = 5532)
10th percentile	1.7	1.9
25th percentile	3.3	3.8
50th percentile	8	9
75th percentile	13	14
90th percentile	21	22
95th percentile	27	27
Average – SD	10 ± 9	11 ± 9
Min. – max.	0 – 99	1 – 99

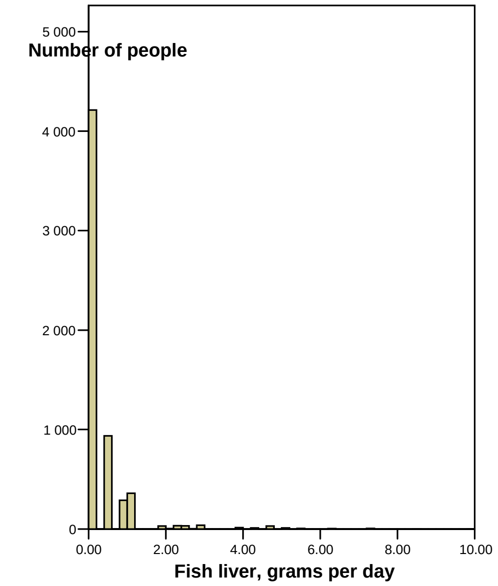
Figure 4. Consumption of shellfish in the Fish and Game Study, Part A. Shellfish refers to shrimp, crabs and bivalves.

Based on the Fish and Game Study, Part A, the median consumption of bivalves in Norway is 0.4 grams/day, whereas the median consumption by those who actually eat bivalves is 1 gram/day. Comparable figures for the 97.5th percentile are 1.1 grams/day total and 5 grams/day for those who eat bivalves. The data show that it is not as common to eat bivalves in Norway as it is in many other European countries.

3.3.3 The consumption of fish liver

The consumption of liver from cod and saithe is very unevenly distributed throughout the population (Figure 5). Seventy per cent never eat fish liver, and the 95th percentile for consumption (among those who eat fish liver) is also low, i.e. approximately 3 grams/day. The figures do not include fish liver used in various types of spreads, such as fish roe and fish liver pâtés. Based on sales figures, it is estimated that fish roe and liver pâtés account for approximately 2% of the fish spreads consumed.

The Fish and Game Study, Part A, also showed that there are considerable regional differences in the consumption of fish liver. In the three northernmost counties of Norway, fish liver is eaten 2-3 times more often than in the rest of the country.

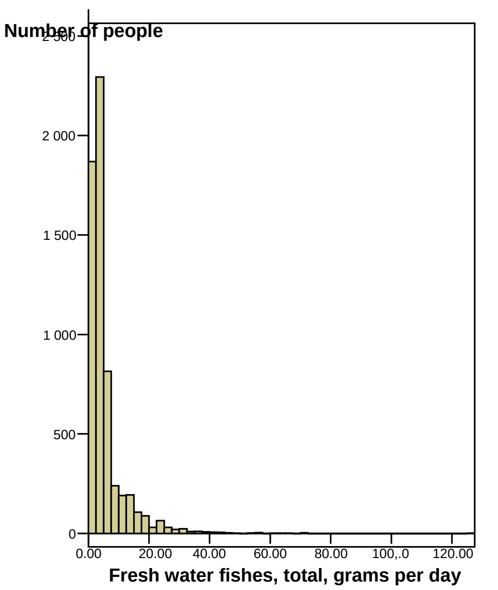


	All participants (n = 6015)	Consumers only (n = 1803)
10th percentile	0	0.45
25th percentile	0	0.45
50th percentile	0	0.53
75th percentile	0.45	1.05
90th percentile	0.9	2.3
95th percentile	1.05	2.8
Average – SD	0.3 ± 0.7	1 ± 1
Min. – Max.	0 – 10	0.45 - 10

Figure 5. Consumption of fish liver in the Fish and Game Study, Part A. Fish liver refers to cod liver and saithe liver.

3.3.4 The consumption of freshwater fish

Figure 6 shows that the consumption of freshwater fish is low in Norway, with a median consumption by those who eat this type of fish of 4.4 grams/day. Most of the consumption is comprised of salmon and trout. Ninety-two per cent of informants report that they never eat pike. Among those who do eat pike, the median consumption is 3 grams/day, and the 95th percentile for consumption is 13 grams/day.



	All participants (n = 6015)	Consumers only (n = 4279)
10th percentile	0	2.6
25th percentile	0	2.6
50th percentile	3.3	4.4
75th percentile	5.6	7
90th percentile	13	15
95th percentile	18	21
Average – SD	5 ± 7	7 ± 7
Min. - Max	0 – 126	1.8 - 126

Figure 6. Consumption of freshwater fish in the Fish and Game Study, Part A. Freshwater fish refers to pike, perch, whitefish, Arctic char, trout, salmon and roach.

3.3.5 The consumption of processed fish products and cold cuts/spreads

3.3.5.1 Processed fish products

Minced fish products, such as fish balls, fish cakes and fish pudding, account for a large percentage of fish consumption in Norway. In the Fish and Game Study, Part A, 1/3 of informants reported that they ate processed fish products once a week or more. Figure 7. Figure 7, based on wholesale figures (level 1), shows that roughly 1/3 of the fish consumption in Norway is comprised of processed products (fish balls, etc. and breaded fish products). Children have the highest consumption of these products, cf. Table 3.

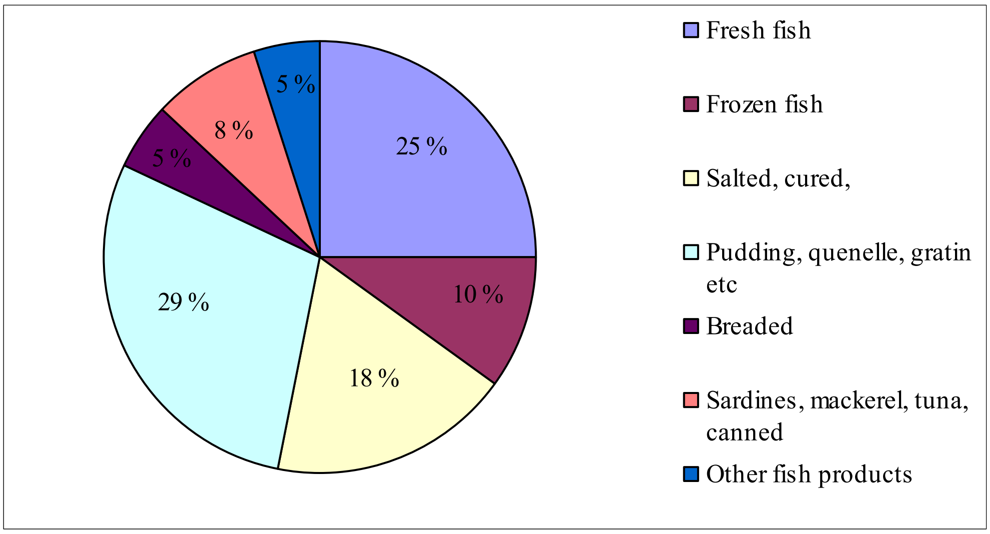


Figure 7. Sales of fish in Norway in 2003 (level 1) based on the degree of processing. Norwegian Seafood Federation, by M. Svennerud (NILF).

3.3.5.2 Cold cuts and spreads

In Norkost 1997 (cf. Table 3), fish in the form of cold cuts and spreads accounted for 17% and 14% of total fish consumption by men and women, respectively. This is the only study of adults at the individual level that asked detailed questions about the various types of cold cuts and spreads. The proportions consumed are as follows: mackerel 47%, sardines and herring 23%, smoked salmon and trout 15%, fish roe spreads 12% and crabsticks 3%. The proportion of shrimp and crab eaten on bread is not included in these estimates.

Sales figures (level 1) also provide a picture of the most common types of cold cuts and spreads and confirm the general impression from Norkost. Figure 8 shows a tentative distribution of different types of cold cuts and spreads. Tuna is probably eaten just as often for dinner and constitutes 20% of this category, whereas tinned mackerel accounts for 70% of this category. Smoked salmon, herring and similar products are not included because it is not possible to distinguish between their use as cold cuts and as dinner food (Norwegian Seafood Federation by M. Svennerud (NILF)). The figures do not indicate who the consumers are (adults or children) because they are wholesale figures. Based on sales figures (level 1), tinned fish comprises the largest percentage of cold cuts and spreads.

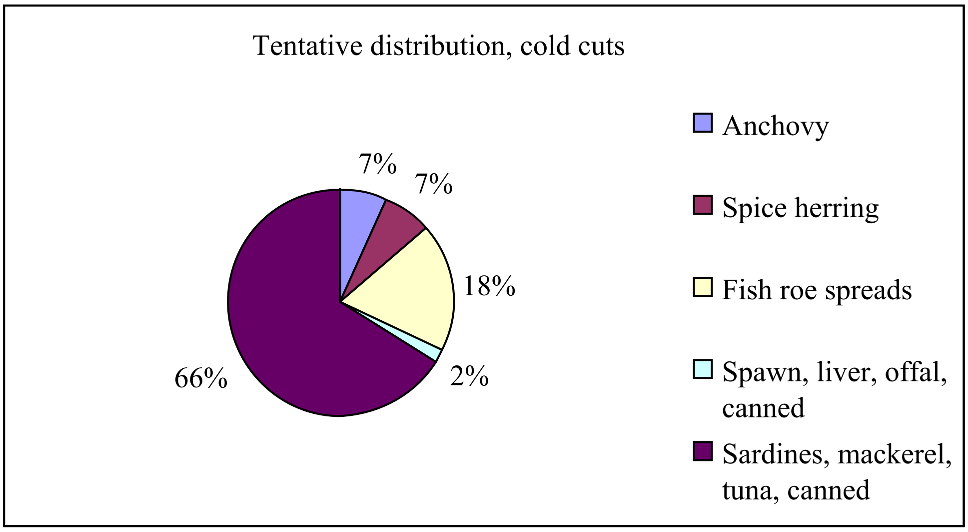


Figure 8. The figure shows a tentative distribution of the consumption of various cold cuts and spreads, level 1. Norwegian Seafood Federation, by M. Svennerud (NILF).

3.3.6 The consumption of fish and other seafood by various groups of the population

3.3.6.1 Saminor[5]

Saminor is a study of health and living conditions conducted in 2003-2004 in regions where Sámi and Norwegians reside. Approximately 13 700 people 30 years of age and ranging from 35 to 79 years of age responded to a food frequency questionnaire about their food consumption, including their consumption of fish. Thirty-five per cent of the participants reported that they were of Sámi descent. Preliminary findings show that 87% ate fish for dinner once a week or more, and 36% ate fish for dinner 3 times or more per week (M. Brustad, personal communication). The types of fish eaten most often for dinner were boiled cod, saithe and fishcakes/balls/pudding. While approximately 70% of the participants in the Fish and Game Study responded that they never eat cod liver, only 20% in the Saminor study said that they never eat cod liver. Ten per cent said that they eat fish liver 10 times or more per year. These preliminary findings suggest that this subgroup of the Norwegian population has a different eating pattern than the population-at-large and that their consumption of fish and other seafood is considerably higher.

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[5] The study was a cooperative project between the Centre for Sámi Health Research and the Norwegian Institute of Public Health, and was carried out in selected municipalities in Finnmark, Troms, Nordland and Trøndelag. The sample consisted of 27,986 people born in 1925-1968 and in 1973 for people who participated in the study in 2003. Those who participated in 2004 were born in 1925-1968 and 1974. More information is available in Norwegian at: http://uit.no/medsamisk/forskning/3.

3.3.6.2 The Norwegian Mother and Child Cohort Study[6]

The Norwegian Mother and Child Cohort Study is still in the inclusion phase (cf. footnote 6), but the first large dietary data file containing preliminary data has been made ready for statistical use. The total average consumption of fish and other seafood by the 19 138 pregnant women included in the study in 2002 and 2003 was 46 grams/day, which is equivalent to 1.6 meals per week. Of this amount, lean fish species accounted for approximately 26%, minced fish products/multi-ingredient products approximately 34%, fatty fish approximately 12%, shellfish approximately 10%, and cold cuts and spreads approximately 18%.

The findings are the same as the nationwide studies, i.e. that younger women eat somewhat less fish than the population as a whole. The distribution between lean and fatty fish, fish products, cold cuts and spreads, and shellfish is the same as for the rest of the population. Only 2.5% report that they have not eaten fish since becoming pregnant, 1.4% have eaten fish liver once a month or more, and 1.2% have eaten perch or pike since becoming pregnant.

The median consumption of fatty fish, including cold cuts and spreads, by pregnant women amounts to about 9 grams per day (Table 6). This is equivalent to a little less than half a meal of fatty fish per week. Roughly half this amount consists of cold cuts and spreads. A high consumption of fatty fish, i.e. the 95th percentile, amounts to a little over 300 grams per week, i.e. 1.6 meals of fatty fish per week, including cold cuts and spreads. Ten to 20% of colds cuts and spreads are probably comprised of shrimp and crab eaten on bread. In other words, the actual consumption of fatty fish is lower than indicated.

Table 5 Consumption of fatty fish before pregnancy (grams per day). The Norwegian Mother and Child Cohort Study. A total of 8 756 women responded to questions about their fish consumption. Norkost questionnaire. Time period: 1999 through February 2002.

	Average	**25th percentile**	**50th percentile**	**75th percentile**	**95th percentile**
Fatty fish	6.4	0	3.3	9	22
Fatty fish+cold cuts/spreads*	16	4.8	12	23	46

*Cold cuts and spreads include all types, including shrimp and crab claws.

Table 6 Consumption of fatty fish during pregnancy, i.e. through weeks 16-17 (grams/day). The questionnaire was designed especially for use in the Norwegian Mother and Child Cohort Study. The responses came from 19 138 women included since March 2003. The questionnaire is currently being validated.

	Average	**25th percentile**	**50th percentile**	**75th percentile**	**95th percentile**
Fatty fish	5.8	0	4.3	8.5	17
Fatty fish+cold cuts/spreads*	14	4	9.4	18	44

*Cold cuts and spreads include all types, including shrimp and crab claws.

[6] **The Norwegian Mother and Child Cohort Study** (www.fhi.no)
Objective: The main objective of this study is to promote better prevention and treatment of serious diseases and greater knowledge about causal connections. The study will form the basis of a number of research projects that aim to understand the significance of various factors in pregnancy for the subsequent development of health and disease in the mother and child. Number of participants/ages: Nationwide study that recruits women in approximately their fourth month of pregnancy. As of 10 March 2005 approximately 40 000 mothers had responded to the questionnaire. The goal is to obtain a total of 100 000 participating mothers. Methodology: Semi-quantitative food frequency questionnaire. Questions about fish and other seafood: There are 10 questions about cold cuts and spreads made of fish, 16 questions about fish eaten for dinner, and four questions about cod liver oil/cod liver oil capsules/fish oil capsules.

3.3.6.3 The Fish and Game Study, Part B (cf. Table 2)

About 5 000 participants from 14 coastal municipalities and 13 inland municipalities responded to a semi-quantitative food frequency questionnaire in spring 2000. The median consumption of fish for men was 67 grams/day for the coastal population and 55 grams/day for the inland population. Corresponding figures for women were 53 grams/day for the coastal population and 47 grams/day for the inland population. The 95th percentile for consumption was considerably higher for the coastal population than for the inland population with 174 grams/day and 149 grams/day for men and 134 grams/day and 118 grams/day for women, respectively. The highest average consumption of fatty fish was found in the inland population and varied from 14-23 grams/day to 38-64 grams/day. The consumption of crab by the coastal population was 6 grams/day on average, while it was 21 grams/day among the high consumers. The highest consumption was equivalent to an annual consumption of approximately 30 medium-sized crabs.

The study also illustrates the reason why it has been difficult to obtain good statistics on fish consumption in Norway. About 60% of the coastal population reported that they obtained more than half of the fish they consume either by catching it themselves or as gifts, compared with only 25% of the inland population who said that they obtained fish in this way for their own consumption (Bergsten, 2004).

3.4 The consumption of cod liver oil and fish oils

3.4.1 Consumption by adults

According to Norkost 1997, 34% of women and 35% of men take cod liver oil. The same study showed that there is a considerable age gradient in the consumption of cod liver oil, cf. table 7. Region, place of residence and smoking habits did not appear to be significant for the consumption of cod liver oil, but it was taken more frequently by people with more than 13 years of education compared with those with less than 13 years of education. More than 45% of women and men who prioritised a healthy diet said that they take cod liver oil.

In the Norwegian section of the EPIC study[7], which included 37 226 Norwegian women ranging from age 41 to age 55, 44.7% reported having taken cod liver oil in 1998 (Brustad *et al.,* 2004). Sixteen per cent took cod liver oil throughout the year, while the remainder took it during parts of the year or occasionally. In this study, the highest consumption was by people with a high level of education, a high level of physical activity, and body weight within the normal range. Consumption also increased with advancing age and with increased consumption of fruits and vegetables.

The consumption of cod liver oil in bottles reached its peak in 1997 (Figure 9). More recent market studies show that the consumption of cod liver oil in bottles has declined in recent years and has been replaced by other forms of cod liver oil, such as capsules (information provided by Peter Möller AS), cf. Figure 10.

[7] EPIC stands for 'The European Prospective Investigation into Cancer and Nutrition'. The EPIC investigates the connections between diet, nutritional status, lifestyle, environmental factors and the incidence of cancer and other chronic diseases, and it encompasses approximately 520 000 people in ten European countries: Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Spain, Sweden and the UK. The Norwegian section of the study includes approximately 37 000 women who were 35-49 years old when they participated.

Table 7 Percentage of the population that takes cod liver oil from 1 to 6-7 times per week.

	Women	**Men**
Norkost 1993	34	37
Norkost 1997	34	35
age 16-29	29	23
age 30-59	33	36
age 60-79	46	49
< 13 years education	32	31
> 13 years education	41	47
Exercise < 1 g/week	28	24
Exercise > 1 g/week	36	39

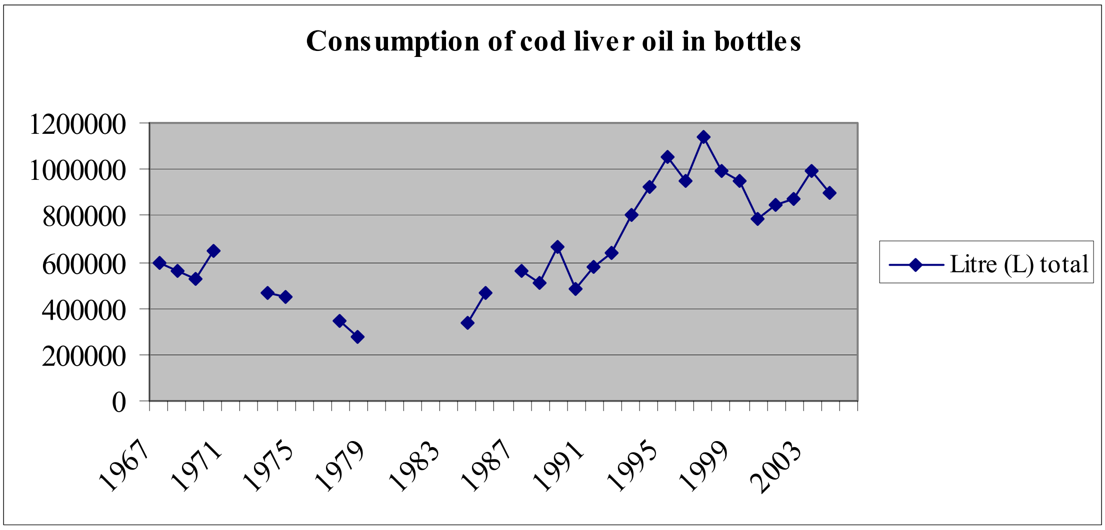

Figure 9. Consumption of cod liver oil in bottles (information provided by Peter Möller AS). Figures prior to 1987 show total annual sales, while figures after 1987 show annual production. 80% of sales are domestic; 20% are exported.

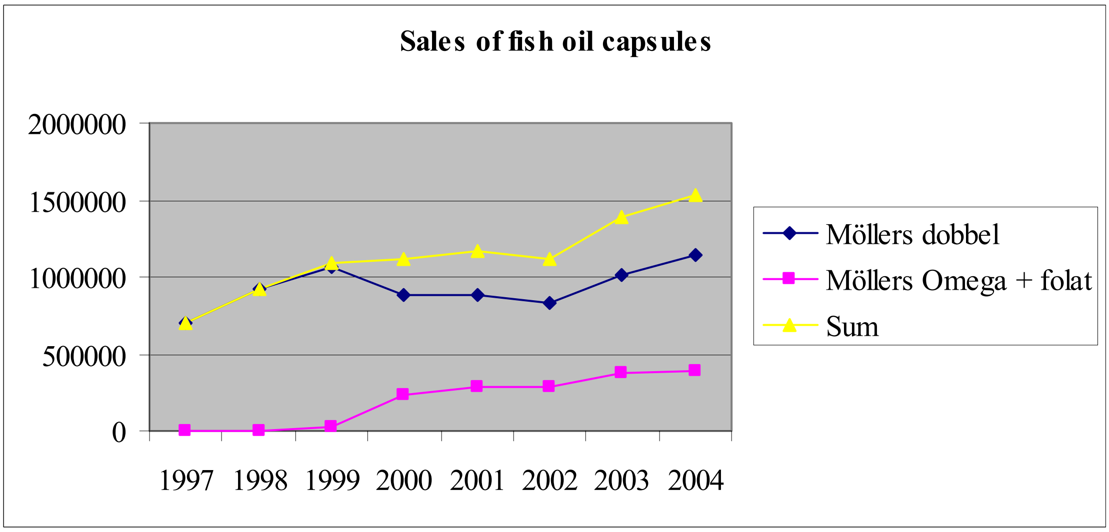

Figure 10. The figure shows the sales of fish oil capsules of one manufacturer, Peter Möller, in the period 1997-2004. One unit is approximately 47 grams and equals the contents of one package.

3.4.2 Consumption by infants and children

The Directorate for Health and Social Affairs recommends a daily supplement of cod liver oil for all infants from four weeks of age to ensure that they receive a sufficient amount of vitamin D (for children given breast milk) and marine n-3 fatty acids (for children fed formula not containing these fatty acids). The recommendation calls for a gradual introduction of cod liver oil from 2.5 ml to 5 ml during the first six months of life. Starting at six months of age, 5 ml of cod liver oil per day is recommended (Recommendations for infant nutrition, 'Anbefalinger for spedbarnsernæring', National Council for Nutrition and Physical Activity, 2000). Five ml of cod liver oil (equivalent to about one dessert spoonful) contains the recommended amount of vitamin D. The percentage of those who take cod liver oil is shown in Table 8.

Table 8. Percentage of those who take cod liver oil in the age group 0-13 years.

Age group	% taking cod liver oil	Reference
6 months (n = 2383)	55	Spedkost 6 months (Lande, 2003)
12 months (n = 1932)	45	Spedkost 12 months (Lande & Andersen, 2005a)
Age 2 (n=1720)	47	Småbarnskost (Lande & Andersen, 2005b).
Age 4 (n=391)	27 (once in a week or more) 1 – 2% took cod liver capsules	Ungkost 2000 (Pollestad *et al.*, 2002)
Age 9 (n = 810)	19[a]	Ungkost 2000 (Øverby & Andersen, 2002)
Age 13 (n = 1004)	8[b]	Ungkost 2000 (Øverby & Andersen, 2002)

a) 4% of the girls reported that they take cod liver oil daily, 6% take it 5-6 times per week, 4% take it 3-4 times per week and 4% take it 1-2 times per week. Eight per cent of the boys take cod liver oil daily, 5% take it 5-6 times per week, 5% take it 3-4 times per week and 4% take it 1-2 times per week.
b) 2% of the girls take cod liver oil daily and 3% of the boys take it daily.

The high consumption of cod liver oil by infants and children in Norway is probably unique in a European and global context. Although the recommendations for the intake of vitamin D are the same in the EU and the Nordic region, the actual dietary advice on how to reach this level of intake varies from country to country. It is primarily the Nordic countries that recommend a vitamin D supplement for infants and children due to the short summers and limited exposure to the sun during the six-month winter season (cf. Chapter 4 on vitamin D). In Denmark, vitamin D drops are recommended for children from two weeks to one year of age. In Sweden, the general recommendation is that 'all children should be given AD drops during the first two years of life'. In Iceland, AD vitamin drops are recommended from four weeks of age and fish oil or fish liver oil from six months of age. Norway is the only country that recommends a vitamin D supplement in the form of cod liver oil for infants and children as young as four weeks old.

3.5 Special features of the Norwegian diet

3.5.1 General

The consumption of fish in the form of cold cuts and spreads is relatively high in Norway (17% for men and 14% for women out of the total consumption of fish and other seafood) as compared with other countries. For 4-year-olds, cold cuts and spreads account for about 11% of total fish consumption and for 2-year-olds this figure is 20%. These figures can be explained by the high bread consumption in Norway, which is a special feature of the Norwegian diet. In the Norbagreen study[8], Norway had the highest consumption of cold cuts and spreads made of fish in the Nordic region

[8] Norbagreen is a study of frequencies of food consumption (i.e. 'How often do you eat…') that encompasses 8,397 people in the Nordic and Baltic countries, 15-74 years old, representative with regard to gender, age and religion in the various countries . There are approximately 1 000 participants from each country.

(Similä *et al.,* 2003). The Fish and Game Study, Part A, showed that 25% of women and 30% of men eat cold cuts and spreads once a week or more.

A consumer study (n=3 536, age>15 years) from 2000 showed that 91% of Norwegians eat bread for breakfast on weekdays, and 93% eat bread for breakfast on weekends. Comparable figures for lunch are 88% and 65%, respectively. Probably about 60% of Norwegians eat a bag lunch consisting of bread, in contrast to 20% who buy their lunch in a cafeteria. When the same study asked about consumption in the past 24 hours, 29% responded that they had eaten fish for dinner the previous weekday, and 11% had eaten fish the previous Sunday. Comparable figures for meat were 41% and 49%, respectively. This shows that meat is still the main ingredient in the Norwegian dinner, even though meat consumption is much lower than in the rest of Europe. Fish is chosen much more often on weekdays than on weekends. In Norkost 1997, the average consumption of meat and meat products was 106 grams/person/day in 1997, whereas fish consumption was 65 grams/person/day. GfK data shows that the consumption of fish is less than half the consumption of meat.

It is difficult to make a definitive statement about the fish consumption trend over time. The acquisition of fish and fish products by private households increased from 1995 to 2004 (Directorate of Health and Social Affairs, 2005a). However, consumer studies show that fish consumption has declined since the early 1990s. In the future, nationally representative dietary studies conducted at the individual level should be able to clarify what is actually happening in terms of the consumption pattern.

The high consumption of cod liver oil, especially by the youngest and oldest people in the population, is also a special feature of the Norwegian diet (Table 7 and Table 8).

3.5.2 Who eats fish?

Due to insufficient data, it is not possible to identify which children eat fish and which do not. In future dietary studies of children, it would be interesting to compile information about the large number of 9-year-olds and 13-year olds who say that they never eat fish or other seafood, cf. Table 4.

Both Norkost 1997 and the Fish and Game Study, Part A, showed that elderly people have the highest fish consumption. In the Fish and Game Study, the median consumption of fish was 51 grams/day in the 18-29 year age group, as opposed to 74 grams/day in the 60-69 year age group. On average, men eat more fish than women in all age groups.

In Norkost, the type of residential area (whether one lives in an area with low population density, high population density or in a city) showed no differences in consumption, indicating that fish is equally available throughout the country, but both Norkost and the Fish and Game Study showed considerable regional differences. Norkost showed that fish consumption was higher in northern and western Norway than in other parts of the country. The Fish and Game Study showed that consumption was highest in the counties of Finnmark and Møre and Romsdal (median 79 grams/day) and lowest in Telemark and Østfold (median 56 grams/day).

Norkost showed a tendency for people with more than 13 years of education to eat more fish than those with less than 13 years of education, while the Fish and Game Study did not show education to be significant. In Norkost, more fish was eaten by people who exercised 4-7 times per week as compared with those who exercised less than that. Norkost also showed that there was considerably higher fish consumption by people who said that they give priority to eating a healthy diet. Men and women who said that they put importance in having a healthy diet ate respectively 30 and 20 grams more fish per day, compared with those who responded that they did not give priority to a healthy diet.

The study Meat, Attitudes and Change 1997-2004 ('Kjøtt, holdninger og endring 1997 – 2004', Lavik, 2005) conducted by the Norwegian National Institute for Consumer Research (SIFO) confirms the trends mentioned above, i.e. that the oldest segment of the population (> 60 years) has the highest fish consumption.

3.5.3 Composition of meals

There is a strong correlation between fish consumption and other aspects of the diet. When the consumption of fish and other seafood is compared within an area, or when a country is compared with another geographic region, the variation in the rest of the diet must also be taken into account. Analyses of the dietary pattern in the EPIC study showed that there are two types of women who eat fish: those with a traditionally high consumption of lean fish who live in the western and northern coastal areas of Norway, and consumers of fatty fish who have a more modern diet. In Norway, lean fish is often eaten with margarine or butter, while in Spain, lean fish is eaten with tomatoes and olive oil. This results in different dietary profiles in different countries and it can distort comparisons of health risks and fish consumption between countries and regions. The type of trimmings varies widely. For example, it was found that higher consumption of fish in Tromsø showed a positive correlation to serum cholesterol, probably due to the use of butter or margarine with lean fish (cod).

3.6 The consumption of fish and other seafood in Norway compared with other countries

The Norbagreen study showed a number of differences in eating habits between the Nordic countries, e.g. that Norwegians and Icelanders have the highest consumption of fish. Norwegians and Icelanders eat fish an average of 2.3 times and 2 times per week, respectively. Swedes eat fish 1.7 times per week, while Finns and Danes eat fish 1.5 and 1.3 times per week, respectively. The frequency of fish consumption in Norway, 2.3 times per week according to the Norbagreen study, corresponds with the findings of Norkost 1997 and the Fish and Game Study, which showed a consumption of 65 grams/day. If this figure is multiplied by 7 to obtain a weekly average, Norwegians eat 455 grams of fish per week, which is equivalent to more than two meals per week.

According to the report by the Danish Veterinary and Food Administration in 2003, a significant percentage of the population in Denmark eats fish rarely or never. The average fish consumption for all Danes is 17 grams of fish/day. Danish children eat an average of 7 grams of fish/day. Norwegian consumption is also considerably higher than the amount reported by the British. Adults in the UK (ages 19-65) eat on average 31 grams fish/day (all adults) and 43 grams/day (consumers only) (SACN/COT 2004).

It is difficult to compare Norwegian fish consumption with consumption in other countries beyond the information presented above. Statistics from FAO provide rough figures regarding the population's access to fish in different countries throughout the world, but the statistics have not been updated for several decades and cannot be used to make any definitive statements about the situation today.

Differences in the fish consumption of European women and men from 21 to 83 years old who participated in the EPIC study showed significant differences in the absolute consumption of fish and other seafood. German, British and Dutch women had the lowest consumption of fish, while Spanish women and men in coastal areas had the highest consumption.

3.7 Summary of fish and other seafood in the Norwegian diet

Regardless of which approach is used, limitations in methodology restrict the ability to estimate the consumption of fish and other seafood among the Norwegian population. In this report, dietary studies have been used as the basis for estimating the consumption of fish and other seafood since this approach allows consumption to be estimated at the individual level. Despite the methodological challenges at this level as well, the various studies are surprisingly consistent in terms of absolute intake, distribution between fatty and lean fish, the proportion of minced fish products, cold cuts and spreads, and distribution by gender and age.

The most recent representative study of adults in Norway is the Fish and Game Study, Part A, conducted in 1999. Intake estimates from the Fish and Game Study will be used in this report as the basis for assessments regarding adults. It will be assumed that the median consumption of fish and other seafood is approximately 65 grams/day for adults, which is equivalent to slightly more than two fish meals per week, and that children consume about 1/3 of this amount. Approximately 2/3 of the consumption consists of lean fish species and minced fish products, and about 1/3 consists of fatty fish species. Shellfish, primarily shrimp, account for approximately 10% of Norwegian fish consumption. Assessments regarding children are based on results from Ungkost 1997 and Småbarnskost 1999. These studies show that although 2-year-olds on average eat some fish, there is a large percentage of 4-year-olds, 9-year-olds and 13-year olds who never eat fish or other seafood. Women of fertile age eat considerably less fish than the population as a whole. According to the Norwegian Mother and Child Cohort Study, their average consumption of fish and other seafood is 46 grams/day, which is equivalent to 1.6 meals per week. The distribution between lean and fatty fish, fish products, cold cuts and spreads, and shellfish is the same as for the rest of the population.

Some population groups eat considerably more fish than the average. This is clearly illustrated in the Saminor study.

The Norwegian consumption of fish and other seafood by adults is different from many other countries in two ways: 1) the total consumption is high and 2) the percentage of lean fish consumed is high. Norwegians eat more fish in the form of cold cuts and spreads due to the custom of eating more than one bread meal per day. Cold cuts and spreads consist primarily of fatty fish. The high consumption of cod liver oil, especially by infants, is unique to the Norwegian diet.

4 Nutrients in fish and other seafood

Fish and other seafood contain high levels of many different nutrients. Based on an assessment of nutritional factors, they are good sources of protein, fat (especially the long, polyunsaturated marine n-3 fatty acids), vitamin D, vitamin B_{12}, selenium and iodine. Fish and other seafood are also good sources of taurine and the co-enzyme Q10 (ubiquinone). Although the two latter substances are not considered nutrients, they contribute to important reactions in the body.

The purpose of this chapter is to discuss the individual nutrients in fish and other seafood and their ability to trigger health-promoting effects. Information on this topic is also included in later chapters, for instance, in estimates of the impact of fish and other seafood on the intake of nutrients and on human health. The sources used are the Norwegian Food Composition Table ('Den store matvaretabellen', 2001), 'Facts about Fish' ('Fakta om fisk', 2005) and international publications.

4.1 Identification and characterisation of nutrients

Nutrients may be defined as substances that occur naturally in foods and that are necessary for achieving normal growth and maintaining good health. Such substances serve known biological functions in the human body. A low intake of such substances leads to symptoms of deficiency or reduced biochemical activity. If such a substance is reintroduced, the signs and symptoms of the deficiency are normalised.

Nutritional requirements depend on factors such as age, gender, pregnancy and breast feeding. It is also known that these needs can vary for genetic reasons (e.g. phenylketonuria, Follings disease) and as a result of more common genetic variations of which the individual is rarely aware. Recommendations for the daily intake of nutrients are given in the Nordic Nutrition Recommendations (NNR, 2004). The Norwegian recommendations issued by the Directorate of Health and Social Affairs follow the Nordic recommendations. According to the Nordic recommendations, the recommended amount of a specific nutrient is defined as follows: 'The amount of a nutrient which, on the basis of existing scientific knowledge, is considered to fulfil the body's nutritional requirements and to maintain good nutritional condition in nearly all individuals.' A safety margin is included in the nutritional recommendations to account for individual variations in the minimum requirement in healthy individuals in the population and there is also a margin to account for an increase in non-specific requirements. The safety margin depends on individual differences, variations in the body's stores, the utilisation of the food consumed, the negative effects of a high intake, and how precisely the minimum requirements can be established. Certain nutrients or dietary components may affect the absorption, metabolism and excretion of other nutrients. Consequently, the composition of the diet can affect the amount of a nutrient required to meet the body's needs.

A correlation exists between the intake of nutrients and the state of health. Although a low intake of nutrients may lead to the development of deficiency symptoms, an excessively high intake may also result in negative health effects or be toxic. For some nutrients, there is a great difference between the recommended intake and a hazardously high intake, while for other nutrients the difference between a too low and a too high intake is small. One example of this is vitamin D. The recommended intake of vitamin D is 10 μg/day for children < 2 years and 7.5 μg/day for children 2 to 9 years of age, while the upper intake level is set at 25 μg/ day for children < 2 years. It is unusual that a normal diet (without dietary supplements and fortified food products) will lead to intake of nutrients that will be hazardly to health.

The EU's Scientific Committee on Food (SCF) has issued 'Guidelines for the development of upper tolerable intake levels for vitamins and minerals' (SCF, 2000a).

4.2 Fat

Fat is not distributed equally in a fish, and the fat content decreases from the head to the tail. In fatty fish, the fat is contained in the muscle (fillet), while in lean fish the fat is located primarily in the liver, which is the source of cod liver oil. The fat content of several different species, e.g. mackerel and herring, varies during the year, with autumn mackerel and summer herring containing up to 20-30 grams of fat per 100 gram of fish. Farmed salmon is fatty, whereas wild salmon contain less fat, in part because wild salmon do not eat while on their journey from the open sea to Norwegian rivers for spawning. During the process of sexual maturation, fat is transferred from the muscle for use in the development of reproductive glands (with the products roe and milt), further reducing the fat content in the fillet. Because sexually mature salmon are not considered to be top quality, the process of fat transfer is avoided in the production of farmed salmon. (cf. Chapter 6). Most fish species are leaner immediately prior to spawning, then they regenerate the fat content in the run-up to the next spawning.

4.2.1 Fish and other seafood categorised by fat content

Different species of fish contain different amounts of fat, and these can be categorised into fatty, intermediate oily and lean types. Fish species containing less than 2 grams of fat per 100 grams are considered lean fish. Fish species containing 2 to 8 grams of fat per 100 grams are considered to be intermediate oily fish, and fish species with an average fat content of more than 8 grams of fat per 100 grams are considered to be fatty fish.[9] In farmed fish, the total amount of fat in the fillet (e.g. halibut, salmon and trout) is regulated largely by the amount of fat in the feed, while the fat content in wild fish varies according to season. Since lean fish, e.g. cod, store excess fat in the liver, the amount of fat in the fillet does not depend on the amount of fat in the feed. However, the composition of fatty acids in the fillet does reflect the fatty acid profile of feed and is reflected in the composition of fatty acids in the blood lipids of those who eat fish and other seafood. This is especially true for fatty fish. A recently published article documents the correlation between the fatty acid profile of salmon feed, the fatty acid composition of salmon fillet, and the blood lipids of those who eat the salmon (Seierstad *et al.,* 2005).

The fat content of shellfish may vary somewhat depending on the season, but shellfish are generally lean. Raw oysters and roe have a fat content of approximately 2 grams per 100 grams of the edible portion. Shellfish are unique in that the content of carbohydrates (primarily glycogen) may account for up to 10% of the wet weight, whereas the content of carbohydrates in fish in general is low (<1% of wet weight).

4.2.2 Fatty acids

Fatty acids can be categorised according to their chemical structure. The different types of fatty acids are found in most types of fat, but the ratios may vary considerably. It is common to divide fatty acids into saturated fats (no double bonds), monosaturated fats (one double bond) and polyunsaturated fats (two or more double bonds). Examples are given in Table 9, which illustrates the structure and nomenclature of fatty acids.

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[9] A different categorisation of lean, intermediate oliy and fatty fish is used in this report. This is because it was not possible to estimate fish consumption according to these categories on the basis of the questionnaire used in the Norkost study.

Table 9. Examples of common fatty acids and abbreviations

Trivial name		Abbreviation
Saturated:		
Palmitoleic acid	16:0	PA
Stearic acid	18:0	SA
Unsaturated		
Oleic acid	18:1 n-9	OA
Polyunsaturated		
Linoleic acid	18:2 n-6	LA
Arachidonic acid	20:4 n-6	AA
α-Linolenic acid*	18:3 n-3	ALA
Eicosapentaenoic acid **	20:5 n-3	EPA
Docosapentaenoic acid **	22:5 n-3	DPA
Docosahexaenoic acid **	22:6 n-3	DHA

* From plants (mainly terrestrial)
** From marine plants (phytoplankton), marine animals and marine algae (protists)

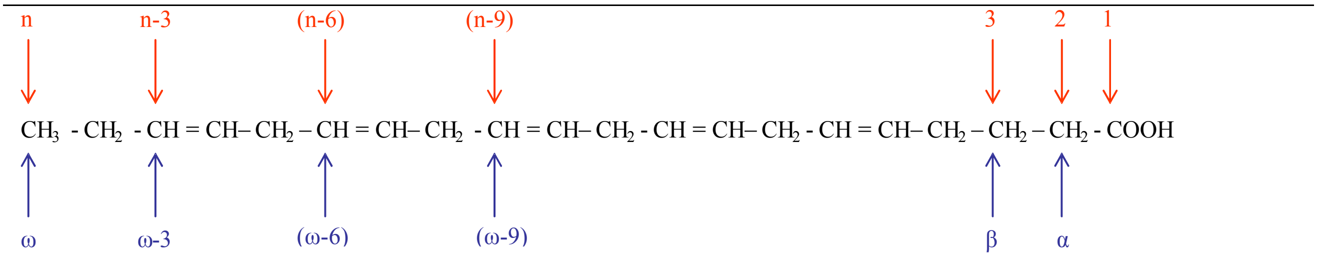

Figure 11. A schematic outline of the structure and nomenclature of the polyunsaturated fatty acid eicosapentaenoic acid, often abbreviated as EPA. The carbon atoms in the fatty acid are numbered (red above) from the carboxyl group (COOH) and the last carbon atom has the designation n. For example, EPA, which has 20 carbon atoms and five double bonds, with the first one located at n-3, can also be written as (20:5n-3). The Greek nomenclature is also often used (blue below). Note that according to the last-mentioned nomenclature, it is carbon atom number two that is α. The two designations (n-3 and omega (ω)-3 fatty acids) are the same and mean that the first double bond counted from n or the ω -end is placed between carbon atoms three and four. If the first double bond had been located between carbon atoms six and seven or nine and ten, we would have an n-6 fatty acid or an n-9 fatty acid, respectively.

People and animals can synthesise most of the fatty acids they need, except for linoleic acid (LA, 18:2 n-6) in the n-6 series and α-linolenic acid (ALA, 18:3 n-3) in the n-3 series. As a result, these two fatty acids are called essential and must be supplied through the diet. Many plant oils, especially soy oil, are rich in LA. Owing to the widespread use of soy oil and soy beans as food and in animal feed, this is the dominant polyunsaturated fatty acid in the Norwegian diet.

Although some plant oils, such as linseed oil and rape seed oil, contain significant amounts of ALA, the Norwegian diet generally contains little ALA. ALA is part of many important metabolic pathways, the most important being the synthesis of the n-3 fatty acids eicosapentaenoic acid (EPA, 20:5 n-3), docosapentaenoic acid (DPA, 22:5 n-3) and docosahexaenoic acid (DHA 22:6 n-3), as a substrate for fatty acid oxidation (energy production) and the recirculation of carbon atoms to *de novo* (new synthesis) of fatty acids (Sinclair *et al.*, 2002).

Fish and other seafood, especially fatty fish and fish oils as well as oils extracted from the blubber of sea mammals, are our main sources of EPA, DPA and DHA. This is because phytoplankton in the sea effectively produces EPA, DPA and DHA from ALA. This marine food chain from phytoplankton via zooplankton to fish causes significant amounts of EPA and DHA to accumulate. EPA and DHA are referred to as marine n-3 fatty acids. Although the amounts of EPA, DPA and DHA obtained from eating lean fish fillet are limited compared with fatty fish, lean fish does contribute to a more balanced intake of fatty acids since close to 50% of the fatty acids in the phospholipids of lean fish, such as cod, are comprised of EPA, DPA and DHA. EPA reduces serum triglycerides because the metabolism of fatty acids increases (Frøyland *et al.,* 1997). EPA also has an anti-inflammatory effect because EPA competes with arachidonic acid (20:4n-6), resulting in decreased production of potent eicosanoids (Calder, 2005). Both EPA and DHA have been associated with enhanced cognitive function (Richardson & Montgomery, 2005). The effect mechanisms are not completely known, but they probably involve signal transfer, increased plasticity and neuroprotection (Mukherjee *et al.,* 2004). DHA has also been shown to reduce arrhythmia (irregular heart beat) by affecting the sodium and calcium channels in the heart muscle and thus stabilising membrane potential (Leaf *et al.,* 2003).

When LA and ALA are metabolised to arachidonic acid (AA), EPA and DHA, respectively, there is competition for the same enzyme system. Conversion from ALA to EPA, and to DHA in particular, is limited in humans (Vermunt *et al.,* 2000, Pawlosky *et al.,* 2001, Hoffman *et al.,* 2001, de Groot *et al.,* 2004). There is also evidence to indicate that the effect of the intake of ALA is not the same as that of EPA and DHA since ALA does not have the same effect mechanisms as EPA and DHA (Sanderson *et al.,* 2002). This highlights the importance of obtaining adequate amounts of EPA, DPA and DHA from the diet.

The amounts of EPA and DHA in our cell membranes are largely determined by the amounts of these fatty acids that we get from our diet or dietary supplements. In Norway, people have a relatively low intake of n-3 fatty acids compared with n-6 fatty acids (especially LA). A moderate to low consumption of fish and other seafood (especially fatty fish), combined with limited conversion of ALA to EPA and DHA in particular, contributes to a relatively high level of n-6 fatty acids in the body compared with the marine n-3 fatty acids. Due to the low conversion of ALA to EPA and DHA, the relationship between n-6 fatty acids and n-3 fatty acids will be affected more by a higher intake of marine n-3 fatty acids than by a higher intake of ALA. By combining a lower intake of n-6 fatty acids with a higher intake of n-3 fatty acids, e.g. through the consumption of fatty fish, a relatively significant effect will be achieved. It is uncertain, however, what the optimal ratio between n-6 fatty acids and n-3 fatty acids is and what effect this might have on our health.

A higher intake of saturated fatty acids (12:0, 14:0 and 16:0) and trans-fatty acids leads to heightened levels of blood lipids, especially LDL cholesterol (low density lipoprotein cholesterol). By replacing saturated fat and trans-fat with monounsaturated fat (primarily in oil acid) and polyunsaturated fat (both vegetable and marine polyunsaturated fatty acids), a reduction occurs in the ratio between the concentrations of LDL cholesterol and HDL cholesterol (high density lipoprotein cholesterol) in serum (LDL/HDL ratio), thereby reducing the risk of developing cardiovascular disease. A high intake of the marine fatty acids may increase bleeding time.

Studies have shown that eating fatty fish results in higher EPA and DHA levels in plasma phospholipids and has health benefits, but that eating lean fish does not have the same results (Mozaffarian *et al.,* 2003, Mozaffarian *et al.,* 2004, Mozaffarian *et al.,* 2005a, Mozaffarian *et al.,* 2005b).

An individual's intake of saturated fatty acids and trans-fat should account for a maximum of 10% of the energy intake (E%), while monounsaturated fat should be approximately 10-15 E% and polyunsaturated fat should account for approximately 5-10 E%, including approximately 1 E% n-3 fatty acids. In the Nordic Nutrient Recommendations (NNR, 2004), the requirement for n-3 fatty acids is estimated at 0.5 E%. In this case, no distinction has been made between vegetable ALA and n-3 fatty acids from marine sources (EPA, DPA and DHA). No quantified recommendations have been issued regarding the intake of marine n-3 fatty acids (EPA, DPA and DHA). An intake of EPA and DHA of > 1.5 E% over a long period of time is not recommended (NNR, 2004) and, according to SCF 1993, an individual's total intake of n-3 fatty acids should not exceed 5% of total energy intake.

Based on figures from Norkost 1997, the average intake of ALA was 1.9 grams/day, and the average total intake of marine n-3 fatty acids (EPA, DHA and DPA) came to 0.9 grams/day. This is equivalent to approximately 0.7 E% from ALA and approximately 0.4 E% from marine n-3 fatty acids.

The intake of marine n-3 fatty acids is discussed in more detail in Chapter 8.

4.3 Protein

Protein is found in all organic material from plant and animal cells. Proteins are built up of 20 different amino acids. Dietary proteins are a source of amino acids, nitrogen and sulphur, and they are a source of energy. Unlike fat, excessive amounts of protein are not stored so the body depends on a constant supply of protein for normal growth and maintenance.

The protein content of fish varies much less than the fat content, and constitutes 15 to 20 grams per 100 grams of fish (Norwegian Food Composition Table, 2001). Fish contains very high quality protein, i.e. it contains all the essential amino acids and is easily digestible. Protein should account for 10 to 20% of energy intake, and the recommended level in the population's diet and for planning purposes is 15 E% (Norwegian Recommendation for Nutrition and Physical Activity, 'Norske anbefalinger for ernæring og fysisk aktivitet', 2005b). According to figures from Norkost 1997, fish and fish products account for an average of approximately 12% of the total protein intake.

4.4 Vitamins

Fish and other seafood, especially fatty fish, are rich sources of many different vitamins, primarily the fat-soluble vitamins (vitamin A to some extent, but especially vitamin D), as well as the water-soluble vitamin B_{12}. In addition, crab is a good source of vitamin E (brown crabmeat may have concentrations >100 mg per kilo of edible meat). Table 10 provides an overview of the recommended intakes of the most important vitamins contained in fish and other seafood and the upper intake levels for vitamin A and vitamin D, where there is little difference between the recommended intake and the upper intake level.

Table 10. Recommended daily intake of vitamin A (expressed here in retinol equivalents (RE)), vitamin D and vitamin B_{12}, (expressed in micrograms (µg)/person) and upper intake levels for vitamin A and vitamin D.

	Vitamin A		**Vitamin D**		**Vitamin B_{12}**
	Recommended intake	**Upper intake levels**	**Recommended intake**	**Upper intake levels**	**Recommended intake**
Children					
6-11 months	300		10	25	0.5
12-23 months	300	800[1]	10	25	0.6
Age 2-5	350	1100[2]	7.5	25	0.8
Age 6-9	400	1500[3]	7.5	25[6]	1.3
Age 10-13	600	2000[4]	7.5	50[7]	2.0
Women					
Age 14-17	700	2600[5]	7.5	50	2.0
Age 18-60 years-old	700	3000	7.5	50	2.0
Age ≥61	700	1500[8]	10	50	2.0
Men					
Age 14-17	900	2600[5]	7.5	50	2.0
Age 18-60	900	3000	7.5	50	2.0
Age ≥61	900	3000	10	50	2.0
Pregnant women	800	3000	10	50	2.0
Breast-feeding women	1100	3000	10	50	2.6

[1]For ages 1-3, [2] For ages 4-6, [3] For ages 7-10, [4] For ages 11-14, [5] For ages 15-17, [6] For ages 3-10, [7] For ages 11-17, [8] For post-menopausal women.

4.4.1 Vitamin A

Vitamin A is a designation for compounds that have the same biological effect as retinol. The term 'retinoids' includes all the natural retinal metabolites, and is often expressed in terms of retinol equivalents (RE): 1 RE = 1 µg retinol = 12 µg β-carotene.

Vitamin A is synthesised by plants and micro-organisms in the form of provitamin A (carotenoids), which are converted to vitamin A in the intestine. Vitamin A is essential for humans and plays a role in a number of important functions, such as eyesight, immune response, growth, development and reproduction. Vitamin A deficiency leads to reduced immune response and increased mortality as a consequence of this. In many developing countries, vitamin A deficiency is a major cause of blindness. The biochemical basis for the role played by vitamin A in eyesight was documented early on. Other functions of vitamin A appear to be mediated through the regulation of gene expression in the various cell types, often in connection with cell growth and differentiation.

It has recently been shown that vitamin A (and vitamin E) can protect against the toxic effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in mice since vitamin A serves as an antioxidant, preventing the formation of reactive oxygen compounds and oxidative damage to DNA (Alsharif & Hassoun, 2004).

Vitamin A was assessed in the Nordic Nutrition Recommendations (NNR, 2004) and by SCF in 2002 (SCF, 2002a). The recommended daily intake of vitamin A for adults is 700 µg/day for women and

900 µg/day for men. An intake of vitamin A (as retinol or retinyl esters) above the upper intake level may lead to deformities in foetuses and probably increase the risk of developing osteoporosis. The upper intake lever (UL) is therefore set at 3000 µg retinol/day for adults and 1500 µg retinol/day for post-menopausal women.

Fatty fish (fillet), liver from cod and cod liver oil contain significant amounts of retinol. Cod liver contains 12-15 mg per 100g, and cod liver oil contains approximately 5 mg per 100 ml (Norwegian Food Composition Table, 2001).

Cod liver oil is an important source of vitamin A in the Norwegian diet as 5 ml of cod liver oil provides 250 µg of retinol. According to figures from Norkost 1997, dietary supplements account for an average of 23% of the total vitamin A intake by adults. Fish and fish products other than cod liver oil are not significant for vitamin A intake in Norway, and figures from Norkost 1997 show that fish and fish products contribute an average of only about 1% of the total vitamin A intake.

4.4.2 Vitamin D

Humans synthesise vitamin D in the skin by means of sunlight, but the amount of time that is necessary to benefit from daylight depends on several factors, including light intensity and the amount of skin exposed to sunlight. Vitamin D is necessary for normal calcium absorption in the intestine, normal bone metabolism and normal cell differentiation (Kato, 2000). Vitamin D deficiency leads to rickets in children and osteomalacy (soft bones) in adults.

Vitamin D was assessed in NNR in 2004 and SCF in 2002 (SCF, 2002b). The recommended daily intake of vitamin D is 10 µg/day for infants and for children under the age of 2, as well as for pregnant and breast-feeding women and adults over 60 years old, and 7.5 µg/day for older children and adults under the age of 60. Large doses of vitamin D are toxic and can lead to elevated levels of calcium in the blood. Deposits of calcium in the kidneys (nephrocalcinosis) may also occur, which can lead to kidney failure. Children are more sensitive than adults. The upper intake level (UL) for children under the age of 10 is 25 µg of vitamin D per day, compared with 50 µg/day for the rest of the population.

In the diet, Vitamin D is found naturally in fish and fish liver. Fatty fish species have a higher vitamin D content than intermediate oily fish. Most of the vitamin D in lean fish is found in the fish liver (100-280 µg of vitamin D per 100 grams of liver).

As a food group, fish and fish products are an important source of vitamin D intake in the Norwegian diet. According to Norkost 1997, fish and fish products account for an average of 22% of the total vitamin D intake. Dietary supplements, including cod liver oil, are nonetheless the most important source of vitamin D. Also, figures from Norkost 1997 show that dietary supplements account for an average of 55% of the total vitamin D intake. Vitamin D intake will be discussed more thoroughly in Chapter 8.

4.4.3 Vitamin B_{12}

B vitamins are important for energy metabolism, and the muscle content of B vitamins varies with activity level and the type of muscle fibre (white or red musculature) in different species of fish (Brækkan, 1959). Vitamin B_{12} is an umbrella term for several bioactive compounds that contain cobalt (corrinoids) and are involved in a number of methylation reactions.

The recommended daily intake of vitamin B_{12} is 2 µg/day for adults. In contrast to many other water-soluble vitamins, it takes a long time before a low intake of B_{12} results in deficiency symptoms. This is largely due to efficient reabsorption from bile. A deficiency results in megaloblastic anaemia and neurological symptoms. The absorption of vitamin B_{12} in the intestine is regulated by a glycoprotein (intrinsic factor) that restricts absorption if large amounts of vitamin B_{12} are available. Toxic effects have not been observed with vitamin B_{12} and there is not established an upper intake level (UL).

Vitamin B_{12} has been assessed in the Nordic Nutrition Recommendation (NNR, 2004) and by SCF (SCF, 2000b).

Vitamin B_{12} is found primarily in animal products. Fish and other seafood are good sources of this vitamin. According to estimates from Norkost 1997, Ungkost 2000 and Småbarnskost 1999, respectively, fish and fish products account for an average of 33% of the total consumption of vitamin B_{12} by adults, 25% by 13-year-olds, 21% by 9-year-olds and 4-year-olds, and 14% by 2-year-olds. The estimates are based on a sample of data from consumers only.

Although seaweed and kelp contain relatively large amounts of vitamin B_{12}, they are not an important source of vitamin B_{12} for the population as a whole. For those who eat seaweed and kelp, however, these foods provide considerable amounts of vitamin B_{12}.

4.5 Minerals

Fish and other seafood are sources of several different minerals, especially iodine and selenium. These are described in more detail below.

Table 11. Recommended intake of and upper intake level for the minerals iodine and selenium expressed in micrograms (µg) per person per day.

	Iodine		**Selenium**	
	Recommended intake	**Upper intake level**	**Recommended intake**	**Upper intake level**
Children				
6-11 months	50		15	
12-23 months	70	200[1]	20	60[1]
2-5 years	90	250[2]	25	90[2]
6-9 years	120	300[3]	30	130[3]
Women				
10-13 years	150	450[4]	40	200[4]
14-17 years	150	500[5]	40	250[5]
18-≥75 years	150	600	40	300
Men				
10-13 years	150	450[4]	40	200[4]
14-17 years	150	500[5]	50	250[5]
18-≥75 years	150	600	50	300
Pregnant women	175	600	55	300
Breast-feeding women	200	600	55	300

[1] For ages 1-3, [2] For ages 4-6, [3] For ages 7-10, [4] For ages 11-14, [5] For ages 15-17

4.5.1 Iodine

Iodine is important for normal functioning of the thyroid gland and production of the hormones thyroxine (T_4) and triiodinethyroxine (T_3). A deficiency of iodine in the diet is associated with enlargement of the thyroid gland (thyroidea), the development of goiter resulting in effects such as arrested growth and mental retardation in children, and low metabolism, reduced blood pressure and weakness of the muscles in adults. In a global context, iodine deficiency is a significant problem; the populations of half the countries in Europe have insufficient iodine intake (Vitti *et al.,* 2003).

The recommended daily intake of iodine for various age groups is shown in Table 11. The recommended daily intake for adults is 150 µg of iodine per day. Based on representative samples of the Norwegian population, the iodine intake for young children and adult men corresponds to nutritional recommendations. Iodine intake for adolescents, especially girls, and adult women is lower than recommended (Dahl *et al.,* 2004). Too much iodine in the diet may lead to reduced functioning of the thyroid gland, resulting in restricted synthesis and excretion of T_4 and T_3. Upper intake levels for various age groups are shown in Table 11. For adults the UL is 600 µg of iodine per day.

Iodine has been assessed in the Nordic Nutrition Recommendations (NNR, 2004) and by SCF in 2002 (SCF, 2002c).

Fish and other seafood are naturally high in iodine. In general, there is about twice as much iodine in lean fish (90 µg per 100 grams of fillet) as in fatty fish (40 µg per 100 grams of fillet), even though there is great variation in the iodine content in some fish, such as cod. (The iodine concentrations are taken from Julshamn *et al.,* 2001 and the Norwegian Food Composition Table, 2001). In Norway, dairy products (due to iodine-fortified feed) and fish and other seafood are the main sources of iodine in the Norwegian diet, while iodised salt is the most important source on an international basis (Dahl *et al.,* 2004).

According to Norkost 1997, fish and fish products account for an average of approximately 23% of the total iodine content in the adult diet. Seaweed and kelp contain high levels of iodine, but these are not important sources of iodine for the population as a whole. For those who do eat seaweed and kelp, these products contribute considerable amounts of iodine to the diet.

4.5.2 Selenium

Selenium is an essential trace element that plays an important role as cofactor for the enzyme glutathione peroxidase. Selenium is also important in the detoxication of various heavy metals (Burk *et al.,* 1977, King & Soares 1978). Selenium deficiency can lead to a weakening of the heart muscle (cardiomyopathy) (Keshan Disease Research Group, 1979) and is related to increased risk of cardiovascular disease (Salonen *et al.,* 1982, Suadicani *et al.,* 1992). The recommended daily intake of selenium for different age groups is shown in Table 11. For adults, the recommended daily intake is 40 µg per day for women and 50 µg per day for men.

Selenium poisoning rarely occurs in humans, but when it does, it results in symptoms such as nausea and vomiting, loss of hair and nails, and damage to the nerves and liver. The upper intake levels for different age groups are shown in Table 11. For adults the UL is 300 µg of selenium per day.

Selenium has been assessed in the Nordic Nutrition Recommendations (NNR, 2004) and by SCF (SCF, 2000c).

The amount of selenium in fish and other seafood varies from 10 to 290 µg per 100 grams of fillet (Norwegian Food Composition Table, 2001). Most species in the Norwegian diet contain from 20 µg to 40 µg per 100 grams of fillets. There are different views on the bioaccessibility of selenium from fish and other seafood (SCF, 2000c, and EFSA, 2005a).

According to estimates from Norkost 1997, Ungkost 2000 and Småbarnskost 1999, respectively, fish and fish products account for an average of 31% of the total intake of selenium for adults, 24% for

13-year-olds, 23% for 9-year-olds, 25% for 4-year-olds, and 14% for 2-year-olds. The estimates are based on consumers only.

4.6 Other substances in fish and other seafood

4.6.1 Taurine and coenzyme Q_{10} (ubiquinone)

Fish and other seafood are rich sources of taurine (Laidlaw *et al.,* 1990). Taurine is an amino acid which is not included in the synthesis of proteins, but which is found in free form or in simple peptides. The estimated intake of taurine from the diet varies from practically nothing among vegetarians, to approximately 20 mg per day among lacto-ovovegetarians, and approximately 60-120 mg per day in people with a normal diet (Rana & Sanders, 1986). No recommended intake level has been established for taurine.

Fish and other seafood are also good sources of ubiquinone (Weber *et al.,* 1994), which is an important cofactor in energy production (the electron transport chain) in mitochondria. Ubiquinone has also been shown to act as an antioxidant. No recommended intake level has been established for ubiquinone.

4.7 Impact of fish and other seafood in the diet

The report 'Trends in the Norwegian Diet 2005' ('Utviklingen i norsk kosthold 2005', Directorate of Health and Social Affairs, 2005a) states that a positive health-related trend can be observed in the Norwegian diet. From the mid-1970s until today, the fat content of the Norwegian diet has decreased from approximately 40 E% to approximately 34 E%. The report also points out that the composition of fatty acids in the diet has changed in a positive direction, with a reduction in the intake of saturated fatty acids and trans-fatty acids over the past 25 years. The relationship between n-6 fatty acids and n-3 fatty acids is not mentioned.

However, there has been a considerable increase in the consumption of meat. In 2004, meat consumption was estimated at 74 kg per person, the highest amount ever recorded in Norway. Although the consumption of fish also has increased, it is still less than half the consumption of meat. (cf. Chapter 3.) The composition of fatty acids in meat is dominated by n-6 fatty acids, not n-3 fatty acids, and the n-6/n-3 ratio has probably not been reduced.

Fish and other seafood contribute a number of important nutrients to the diet, and the positive health effects, especially from fatty fish, are primarily related to the content of the marine n-3 fatty acids EPA, DPA and DHA. Since a large proportion of fish consumption in Norway is in the form of minced fish products, such as fish balls, fish pudding, fish cakes and fish gratin, the fat from these products actually contributes n-6 fatty acids to the diet, not EPA, DPA and DHA. Viewed in relation to the increase in meat consumption and a high consumption of processed fish in the Norwegian diet, there is reason to believe that it is the relatively high intake of fish oil (and other marine oils), in addition to the consumption of cold cuts and spreads (mackerel, sardines, salmon and trout), that contribute the most EPA, DPA and DHA to the Norwegian diet.

4.8 Processing

The processing of fish (boiling, steaming, frying, grilling, etc.) may affect the product's nutritional content. In Norway, there is little scientific documentation on this topic. In particular, water-soluble nutrients may be affected by cooking time (loss of nutrients to the water in which the fish is boiled), whereas steaming will change the nutritional content to a lesser degree.

4.9 Summary of nutrients in fish and other seafood

Fish and other seafood contain high-quality proteins (encompassing all essential amino acids) and are a natural source of the marine n-3 fatty acids EPA, DPA and DHA. Fish and other seafood, especially fatty fish and fish oils as well as oils extracted from the blubber of sea mammals, are the main source of marine n-3 fatty acids in the diet.

Marine n-3 fatty acids have been shown to have a positive effect on blood lipids. EPA has been shown to reduce serum triglycerides and to function as a non-inflammatory agent. Both EPA and DHA have been associated with improved cognitive function. DHA has also been shown to reduce arrhythmia (irregular heart beat).

Linoleic acid is the dominant polyunsaturated fatty acid in the Norwegian diet due to the extensive use of vegetable oils in food and animal feed. In Norway, we have a relatively low intake of n-3 fatty acids in relation to n-6 fatty acids. However, it is not known for certain what the optimal ratio between n-6 and n-3 fatty acids is and how it may affect our health.

Fish and other seafood, especially fatty fish, is a good source of several different vitamins, primarily the fat-soluble vitamins (especially vitamin D) and the water-soluble vitamin B_{12}.

In the diet, vitamin D is found naturally in fish and fish liver. Fatty fish species contain greater amounts of vitamin D than intermediate oily fish. In lean fish, most of the vitamin D is found in the fish liver. As a food group, fish and fish products are an important source of vitamin D in the Norwegian diet, but dietary supplements, including cod liver oil, are the most important source of vitamin D.

Fatty fish (fillet), liver from cod and cod liver oil contain considerable amounts of retinol. Cod liver oil is an important source of vitamin A in the Norwegian diet.

Fish and other seafood are good sources of iodine and selenium. In general, there is about the twice as much iodine in lean fish as in fatty fish, even though there is great variation in the iodine content of fish, such as cod. In Norway, dairy products (due to iodine-fortified feed) and fish and other seafood are the most important sources of iodine in the diet. The amount of selenium varies between fatty and lean fish species.

5 Contaminants and other undesirable compounds, including infectious organisms, in fish and other seafood

Compounds that can be hazardous to health may be present in marine organisms consumed as food. The purpose of this chapter is to discuss the presence of specific groups of substances in fish and other seafood, the ability of these substances to cause adverse health effects, and the levels at which they may be regarded as safe. A brief description of how these assessments have been conducted is provided in Section 5.1

The compounds in this chapter comprise contaminants, marine algal toxins, residues of disinfectants, and radioactivity. Environmental contaminants are either man-made emissions from industry and other activity or they occur naturally. Contaminants are metallic compounds and organic compounds that show persistence to degradation in the environment, bioaccumulate and may cause adverse effects at low intake levels. Radioactive isotopes occur both naturally and as a result of man-made emissions (e.g. waste and nuclear testing) and accidents (e.g. Chernobyl).

Algal toxins are formed by toxin-producing algae, and they can contaminate bivalves and shellfish in particular. This chapter also discusses certain infectious organisms, including bacteria, viruses and parasites. Disinfectants are used on production equipment which comes into contact with fish during processing.

5.1 Identification and characterisation of hazards caused by chemical contaminants

A number of hazardous inorganic and organic compounds are present in fish and other seafood. This section briefly discusses the ability of these compounds to cause toxic effects and describes the tolerable intake levels established in safety assessments performed by international bodies such as SCF, EFSA, and JECFA. The tolerable intake levels are the amounts which can be consumed safely throughout a person's lifetime without appreciable risk of adverse health effects.[10] Tolerable intake levels have been derived from studies in humans where sufficient quantitative data is available. Where that is not the case, data from studies in laboratory animals have been used. In cases in which the tolerable value has been derived from animal studies, data from the most sensitive animal species and the critical effect has been used. Uncertainty factors have been used to account for uncertainty in the extrapolation of the data derived from animals to humans, and to account for variations among humans. Usually, a default uncertainty factor of 10 is used for extrapolation from animals to humans and a factor of 10 is used for variation among humans (100 altogether). Tolerable values derived from large-scale epidemiological studies encompassing the most sensitive segment of the population justify the use of small uncertainty factors. This approach to deriving tolerable intake levels assumes that the adverse health effects are of such a nature that there is a dose threshold for effect, i.e. that a certain amount of exposure must be reached before adverse health effects occur.

Two different methods are used to express dose threshold: 1) the no adverse effect level (NOAEL), which is the highest dose without any adverse effect, or 2) a benchmark dose for the upper

[10] WHO (1994) has defined adverse effect as follows: 'A change in morphology, physiology, growth, development and life span of an organism which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase susceptibility to the adverse effects of other environmental influences. Decisions on whether or not any effect is adverse require expert judgement.'

confidence limit of adverse effects with an occurrence rate in 5% or 10% of the animals, derived from a modelled dose-response curve. The tolerable intake levels is derived by dividing the NOAEL or the benchmark dose by the uncertainty factor (usually 100). It is important to be aware of the fact that the tolerable intake level is not a threshold for toxicity above which adverse or toxic effects will occur. The level is conservative and has, as a general rule, built-in safety margins. Consequently, when the level is moderately exceeded, the safety margin is eroded.

Some chemical compounds are considered to be carcinogenic. In a large-scale programme spanning over many years, the International Agency for Research on Cancer (IARC), an agency of WHO, has assessed the carcinogenic potential of chemicals, work processes and exposures. IARC classifies chemicals and exposures according to the quality of scientific evidence of carcinogenicity. The most solid evidence comes from studies in humans that unambiguously show carcinogenic effects. Chemicals with evidence of carcinogenicity in laboratory animals are generally regarded as possibly or probably carcinogenic to humans, unless the mechanism is not relevant to humans. The ability of a substance to damage genetic material (to be genotoxic) is assessed as part of the basis for the classification. The classification system operates with the following groups:

Group 1: The agent is carcinogenic to humans.
Group 2A: The agent is probably carcinogenic to humans.
Group 2B: The agent is possibly carcinogenic to humans.
Group 3: The agent is not classifiable as to its carcinogeneity to humans.
Group 4: The agent is probably not carcinogenic to humans.

The IARC does not assess carcinogenic potency. For carcinogenic substances that are toxic to genetic material and cause cancer via genotoxic mechanisms, it is not possible to identify a dose-threshold under which there is no risk. In other words, any exposure may result in a theoretical risk down to zero exposure. In such cases, various methods have been used for quantitative extrapolation. In Norway and some other countries such as the USA, linear extrapolation from a dose that causes cancer in a certain percentage of the laboratory animals down to a negligible lifetime risk, e.g. 10^{-5}, has been used. Methods like these most probably result in conservative risk estimates. In recent years, a Margin of Exposure (MOE) approach has been used. The MOE specifies the margin between current human exposure and the upper confidence level of the exposure causing cancer in 10% of the laboratory animals. The assessment of margins considered to be tolerable is comparable to the assessments conducted using linear extrapolation.

Many of the chemicals discussed below accumulate in the body, causing effects only when a certain concentration has been reached. Therefore, variations in daily intake have little significance and, as a result, tolerable intake levels are sometimes expressed on a per month basis (e.g. JECFA's tolerable intake of dioxins (JECFA, 2001)).

5.2 Metals that are potential health hazards

The presence of metals in aquatic environments is a result of natural geological conditions as well as anthropogenic factors, such as industrial emissions. Metals are absorbed by aquatic organisms, and some of these metals may accumulate. Accordingly, metals may be found in high concentrations in organisms high up in the food chain.

5.2.1 Arsenic (As)

Arsenic occurs naturally in larger amounts in marine waters than on land. Arsenic compounds accumulate in fish and other seafood. Arsenic is found primarily in organic form in aquatic organisms. To date, more than 30 different forms of arsenic have been identified in the environment.

The most common of these are arsenobetaine, arsenocholine and arsenosugar, while only a small percentage (usually <1%) is found as inorganic arsenic (Kohlmeyer *et al.,* 2002, Sloth *et al.,* 2005 a,b).

The various forms of arsenic show considerable differences in toxicity. Organic forms of arsenic, insofar as these have been studied, are far less toxic than inorganic arsenic. The extent of conversion of organic arsenic to inorganic arsenic in marine products during storage is not known. In humans, most forms of organic arsenic are not altered prior to excretion from the body (Le *et al.,* 1994, Lai *et al.,* 2004). The sections below discuss inorganic arsenic.

Inorganic arsenic has been classified by IARC as carcinogenic to humans (Group 1) on the basis of sufficient evidence showing an increased risk of cancer in the urinary bladder, lungs and skin (IARC, 1987, IARC, 2004a). Other adverse effects include peripheral vascular disease (blackfoot disease), peripheral neuropathy, and possibly diabetes and reproductive disorders. In 1988, JECFA established a provisional tolerable weekly intake (PTWI) for inorganic arsenic of 15 μg/kg body weight/week (WHO, 1989).

Because the relative amount of inorganic arsenic in fish and other seafood, at least in areas with little contamination, is very small, i.e. <1%, and the concentrations of arsenic are very low, inorganic arsenic in fish and other seafood is not regarded to represent a health risk. As regards organic arsenic, these compounds are excreted in unchanged form, they are not particularly toxic, and neither arsenobetaine nor arsenocholine has been found to be genotoxic in mammalian cells *in vitro*. Therefore, the intake of arsenic from marine organisms is not considered to represent a significant health risk.

5.2.2 Lead (Pb)

Lead accumulates in several tissues and organs of the body, and the intake of lead may result in many different toxic effects, i.e. on the nervous system, blood formation and the kidneys. The most important target following long-term, low level exposure to lead is the nervous system. Small children, and foetuses in particular, are most vulnerable, and exposure to lead may result in impaired development of cognitive functions (learning ability) and motor skills. The effects of lead exposure have been well-documented and have also been found in epidemiological studies (WHO-IPCS, 1995). An inverse association has been shown between intellectual capacity in school age children and lead levels in umbilical cord blood at birth from approximately 60-80 μg/l and lead levels in the blood during the first year of life from approximately 60-400 μg/l. More recent studies indicate that adverse effects may occur even at levels previously regarded as safe (Lanphear *et al.,* 2000, Canfield *et al.,* 2003, Selevan *et al.,* 2003).

The mechanism underlying the neurotoxicity of lead is that lead passes easily through the blood-brain barrier, causing cell death and interference with the transfer of signals between nerve cells and in support cells. Lead is not genotoxic, but it can cause tumours in laboratory animals. Lead has been classified in Group 2A by IARC (IARC, 2004b). Due to the effects of lead on children and foetuses, the provisional tolerable weekly intake (PTWI) was set at 25 μg/kg body weight by JECFA in 1986. The PTWI was based on studies on lead in children and was set with the aim of avoiding the accumulation of lead in the body. In 1993 and 2000 JECFA confirmed this PTWI value and expanded it to include all age groups (WHO 1993, WHO 2000).

In general, fish and other seafood are not significant sources of lead.

5.2.3 Cadmium (Cd)

Cadmium is absorbed in the intestines and accumulates in the kidneys and liver in particular. In individuals with iron deficiency, the intestinal uptake of cadmium may increase considerably. The metal is excreted slowly (the biological half-life is 10-30 years) and is accumulated with age. The largest concentration can be found in the cortex of the kidney. In the cells, cadmium bonds with the protein metallothionein, which it also induces. The toxicity depends on the amount of free cadmium in the cells and is manifested especially when the capacity for detoxification with metallothionein is exceeded (Jin *et al.,* 1998).

The effects of cadmium have been well-documented in a number of experimental and epidemiological studies (WHO-IPCS, 1992). Kidney damage with proteinuria is the primary effect of exposure to cadmium, sometimes accompanied by perturbation of calcium and vitamin D metabolism, which may lead to loss of bone mass and possibly osteoporosis. Long-term effects have also been observed in the liver, in the organs associated with blood formation, the immune system and the cardiovascular system. Cadmium has also been classified as a human carcinogen (Group 1) by IARC, but this applies especially to exposure by inhalation.

The PTWI has been set by JECFA at 7 µg/kg body weight on the basis of studies on humans (WHO, 2001). JECFA re-evaluated cadmium in 2003 (WHO, 2003). Recent epidemiological studies indicate that low exposure, at the PTWI level, is associated with an increased incidence of minor kidney changes. Because the long-term significance of these changes is unknown, JEFCA upheld the previously established PTWI at 7 µg/kg body weight.

The intake of cadmium from fish and other seafood is significant primarily in relation to the consumption of crabs, which may contain high levels of cadmium in the brown meat.

5.2.4 Mercury (Hg)

There are different forms of mercury, both inorganically and organically bound. In fish and other seafood, methyl mercury is most prevalent (75-100% in various fish species) and represents the greatest health risk. Methyl mercury is absorbed in the intestine (95%), crosses the placenta and blood-brain barrier and is also excreted in breast milk. The average half-life is 70 days in adults (JECFA, 2003).

Methyl mercury is neurotoxic. While the peripheral nervous system is most vulnerable in adults, the central nervous system is most vulnerable in the early stages of human development. The foetal brain is especially vulnerable, and increased concentrations of methyl mercury may result in impaired cognitive skills as well as motor skills. The human foetus is believed to be most sensitive in the last six months of pregnancy and in the first period following birth due to the rapid development of the nervous system in this period. Some studies also indicate that methyl mercury may affect blood pressure (Grandjean *et al.,* 2004). Also, a number of studies, including studies from Finland (Landmark & Aursnes, 2004, Virtanen *et al.,* 2005) and a large-scale European study (Guallar *et al.,* 2002), show an association between exposure to methyl mercury and risk of cardiovascular diseases, (cf. Chapter 7.)

In 2003, JECFA revised its earlier assessment of mercury. The previous PTWI value for methyl mercury was reduced from 3.3 to 1.6 µg/kg body weight (JECFA, 2003). In addition to earlier studies from incidents of intoxication in Iraq, Minimata and Niigata, the assessment was based largely on new epidemiological studies from the Faeroe Islands and the Seychelles (JECFA, 2003), with the support of an earlier study from New Zealand that investigated the relationship between exposure of pregnant women to mercury and arrested development of the central nervous system in children

(Kjellstrom *et al.,* 1986, 1989). The tolerable intake level was derived from an average NOAEL/'benchmark dose' in the two studies from the Faeroe Islands and the Seychelles and based on a concentration of 14 mg Hg/kg in the mothers' hair. By using empirical toxicokinetic models and uncertainty factors, this value was converted to a tolerable weekly intake of methyl mercury of 1.6 µg/kg body weight (JECFA, 2003).

In 2004, EFSA assessed the European population's exposure to mercury from fish and gave its support to the PTWI established by JECFA in 2003 (EFSA, 2004a).

Methyl mercury is found in small amounts in many different fish species, but because it accumulates in the food chain, the highest levels are found in various predatory fish. Concentrations increase with age and size of the fish.

5.2.5 Organic tin compounds

Organic tin compounds are fat-soluble compounds that tend to biomagnify through the food chain, especially in marine organisms. EFSA assessed organic tin compounds in 2004 (EFSA, 2004b). The largest amounts found in marine organisms are comprised of tin substituted in three positions, such as tributyltin (TBT) and triphenyltin (TFT). These substances were also used extensively in the past as biocides in impregnation and antifouling agents for wood. Monosubstituted and disubstituted tin compounds include dibutyl and di-n-octyl tin, and have been used as stabilisers in PVC plastics. These organic tin compounds are immunotoxic via similar mechanisms. A group TDI of 0.25 µg/kg body weight (given as tributyltin) was derived from studies on rodents.

Organic tin compounds are found primarily in bivalves and result from pollution, especially in harbours where these compounds have been used as antifouling agents on boats.

In 1990, Norway banned the use of organic tin compounds in antifouling agents on boats under 25 metres and in impregnation agents for fishing nets. Starting in 2003, the ban was expanded to include antifouling agents containing TBT/TFT for use on boats over 25 metres.. From 2008, the use of these antifouling agents on boats will be prohibited. The Norwegian ban complies with the provisions of a convention adopted by the International Maritime Organisation (IMO) in 2001.

5.2.6 Summary of metals that are potential health hazards

In terms of exposure from marine organisms, the compounds that represent the most significant health hazards are methyl mercury, cadmium and organic tin. Methyl mercury is found in small amounts in many fish species. Because it accumulates in the food chain, the highest levels are reached in various predatory fish, with concentrations increasing with age and size. Cadmium may be found in large amounts in the brown meat of crab, while fish is of limited significance for human cadmium intake. Organic tin compounds are found primarily in bivalves as a result of pollution, especially in harbours since in the past tin compounds were used in antifouling agents for boats.

5.3 Organic compounds that are potential health hazards

5.3.1 PAHs and benzo[a]pyrene

The group known as polycyclic aromatic hydrocarbons (PAHs) comprises a large number of compounds consisting of condensed aromatic benzenes. Among the PAHs, there are several mutagenic compounds, and some of them are possible or probable human carcinogens (IARC Group 2A or 2B) (IARC, 1987, SCF, 2002d). Some PAHs bind to the Ah-receptor and may trigger a number of toxicological effects on the immune, reproductive and cardiovascular systems. However, the carcinogenic and genotoxic effect is considered to be the most critical. Exposure to PAHs by inhalation has been associated with an increased risk of lung cancer in humans. Information on the hazards associated with oral exposure to PAHs is available only from studies on laboratory animals.

Benzo[a]pyrene (BaP) has been classified by IARC in Group 2A as one of the most potent carcinogenic PAH compounds. Like several other PAH compounds, when BaP is absorbed, it is metabolised in the liver and other tissues into reactive compounds that can bind to DNA and cause mutations. It is believed that the carcinogenic mechanism occurs primarily by mutations. BaP causes tumours in the stomach and liver, and in combination with other PAHs it causes lung tumours as well as tumours in other organs.

The relative amount of BaP in PAHs found in food varies by a magnitude of 10. SCF concluded that BaP can be used as an indicator of the presence of PAHs and for assessing the risk of the carcinogenic PAH compounds in food (SCF, 2002d).

The former Subcommittee for Environmental Contaminants of the Scientific Committee of the Norwegian Food Control Authority (SNT) has assessed the risk of PAHs in bivalves, most recently in March 2004. A linear extrapolation was performed from the carcinogen dose descriptor T25 (i.e. the lifetime dose that causes tumours at a specific site in 25% of the animals in the experiment after adjusting for tumour frequency in the control animals). The T25 dose is converted to the corresponding human dose (HT25) by accounting for differences in metabolic activity. HT25 is then extrapolated linearly down to an intake comparable to a theoretical cancer risk of 10^{-5}. The committee concluded that an intake of 6.1 ng BaP/kg body weight/day gives a theoretical worst case lifetime risk of 10^{-5} in humans. The risk is estimated on the basis of experiments on mice exposed to BaP only. PAHs that contain BaP are more potent, so an overall uncertainty factor of 5 was used and a negligible risk (lifetime risk of 10^{-5}) was estimated at 1.2 ng BaP in a mixture of PAH/kg body weight/day. This equals an intake of 85 ng BaP/day for an adult weighing 70 kg (Knutsen *et al.,* 2004).

JECFA assessed PAHs in February 2005 (JEFCA, 2005) based on the same study as the one used by the Subcommittee for Environmental Contaminants of SNT's Scientific Committee, Culp *et al.,* 1998, in their risk assessment of BaP in combination with other PAH compounds. JECFA calculated the margin of exposure (MOE) between estimated intakes and the 'benchmark dose lower confidence limit' for 10% incidence (BMDL10) = 100 µg/kg body weight/day for tumours in laboratory animals. At an estimated intake of 4 (average consumption) and 10 (high consumption) ng BaP/kg body weight/day, margins of exposure of 25 000 and 10 000, respectively, were estimated. JECFA concluded that at the estimated intake levels of BaP, there is little cause for concern for human health. Nonetheless, JECFA recommended that measures should be implemented to reduce PAH contamination in food.

Organisms high up in the food chain such as fish, generally detoxify and excrete PAHs. Bivalves, however, are less able to metabolise and excrete PAHs and thus they retain larger amounts of these substances. As a consequence, bivalves grown in locations contaminated with PAHs present a greater risk of exposure than fin-fish.

5.3.2 Halogen-substituted organic compounds

A large number of compounds in the group of chlorine- or bromine-substituted organic compounds can occur as contaminants in marine organisms and thus represent a hazard to human health. This applies to polychlorinated dibenzodioxins and furans (PCDD/Fs), polychlorinated biphenyls (PCBs), campheclor, dichlordiphenyltrichlorethane (DDT) and its metabolites (DDD and DDE), chlordane, dieldrine, aldrin, endrin, heptachlor, hexachlorbenzene, chlorinated cyclohexane and brominated flame retardants such as bromated diphenylamine (PBDE). Some of these compounds occur as by-products of industrial production (PCDD/F), in products (PCB and PBDE) or from past use as pesticides. Most of these compounds are no longer in use. Cleaning of industrial emissions has been implemented, and as a result, the levels in the environment are generally declining. A summary of the features of the health hazards represented by the most relevant compounds is given below.

5.3.2.1 Dioxins, dioxin-like PCBs and non-dioxin-like PCBs

Dioxins and polychlorinated biphenyls (PCBs) are closely related groups of chlorinated organic compounds. The term 'dioxins' usually encompasses both the 75 chlorinated dibenzo-p-dioxins (PCDDs) and 135 chlorinated dibenzofurans (PCDFs). Altogether there are 209 different PCB congeners. The chemical properties and toxicological effects of these individual compounds vary according to the number and position of the chlorine atom on the phenyl rings. Dioxins and PCBs are fat-soluble and persistent to degradation, they bioaccumulate and are biomagnified in the environment. They are found in the highest concentrations in organisms located high up in the food chain. Because they are fat-soluble, the highest concentrations are found in fatty fish such as herring, mackerel, salmon and trout.

As mentioned above, PCBs consists of 209 congeners, 12 of which are included in the group of dioxin-like PCBs. The rest are referred to as non-dioxin-like PCBs. Non-dioxin-like PCBs were recently assessed by EFSA's Scientific Panel on Contaminants in the Food Chain (EFSA, 2005c). As with dioxin-like PCBs, non-dioxin-like PCBs bioaccumulate to varying extents and can cause a number of toxicological effects. More than 90% of the exposure to PCBs in the population occurs via food, and fatty fish is a significant source. The presence of non-dioxin-like PCBs has been expressed as the sum of three PCB congeners (PCB138, 153 and 180) or PCB7, which is the sum of six congeners (PCB28, 52, 101, 138, 153, 180) in addition to PCB118, a dioxin-like PCB. Previously, the PCB content was expressed as total PCBs. Nearly all toxological studies performed on PCBs are conducted using technical mixtures of PCBs containing both dioxin-like and non-dioxin-like PCBs, often in addition to small amounts of dioxins.

Several toxological effects of PCBs have been observed in the thyroid gland, liver, immune system, and the reproductive system, as well as on behaviour and the development of cancer, but it is not possible to distinguish between the effects resulting from dioxins and dioxin-like PCBs and the effects resulting from non-dioxin-like PCBs. IARC has classified PCBs in Group 2A, i.e. probably carcinogenic to humans. There are reasons to belive that it is the dioxin-like PCBs that are responsible for the carcinogenic effect (EFSA, 2005c). In laboratory animals, non-dioxin-like PCBs cause toxicological effects on the thyroid gland, liver, brain, and immune system as well as estrogenic effects. In addition, interference with the development of the central nervous system has been observed in exposed foetuses, but this effect is not specific to non-dioxin-like PCBs. It has not been possible through epidemiological studies to identify the effects specific to non-dioxin-like PCBs. As a result, EFSA's Scientific Panel on Contaminants in the Food Chain concluded that it is not possible to establish a tolerable intake level for non-dioxin-like PCBs (EFSA, 2005c). In epidemiological studies, exposed workers were found to have an increased risk of cancer, but the most important health effects associated with exposure from food and the environment were related to perinatal PCB exposure and the impairment of reproduction, including delayed development of the central nervous system and a reduced immune system. In these studies, exposure to PCBs is expressed in terms of the levels of PCBs in the blood, and not in terms of the intake of PCBs through food. Consequently, any risks to the Norwegian population from these effects have to be assessed using PCB levels in the blood. This will be discussed in more detail in Chapter 7, Section 7.5.3.

The most significant hazardous effects on health resulting from chronic exposure to dioxins and dioxin-like PCBs are impairment of the reproductive system, a weakened immune system, impairment of the endocrine system and neurotoxic and carcinogenic effects. Dioxins have been classified as carcinogenic to humans (Group 1) by IARC (IARC, 1997). Several epidemiological studies have shown that there is an increased risk of cancer associated with dioxin exposure, but these studies do not give consistent results in terms of the specific organs affected. Dioxins are carcinogenic in laboratory animals and cause liver cancer in rats (IARC, 1997). Dioxins are non-genotoxic, and it is believed that the carcinogenic effects occur through non-genotoxic mechanisms (SCF, 2001, JECFA, 2001).

The effects of long-term exposure to small amounts of dioxins appear to be related to the bonding of dioxin-like compounds to a specific receptor protein (the Ah (aryl hydrocarbon) receptor, also known as the TCDD or dioxin receptor). This dioxin/protein complex is transported to the nucleus and affects gene expression and hence a number of fundamental biochemical processes in the cells. The receptor-mediated mechanism for the toxicological effects is considered to have a dose threshold. The different PCDD/Fs and dioxin-like PCBs bond to the dioxin receptor with variable strength and, as a result, their effects also vary in strength. This presumes a dose addition model for PCCD/Fs and dioxin-like PCBs. The toxicity of 17 dioxins and 12 dioxin-like PCBs is expressed in terms of toxic equivalency factors (TEF) in relation to 2,3,7,8-TCDD which is the most potent dioxin-congener. The total amount of toxic equivalents (TE) in a sample is estimated by multiplying the content of each congener with the associated TEF and then adding the contributions from the different congeners. The amount of toxic equivalents in a sample is an estimate of the total dioxin effect, which is a simplified method for making risk assessments of dioxin/PCB-mixtures.

No human data are available for a quantitative risk assessment. Data from animal studies have therefore been used, especially results for reproductive effects in rats, which appear to be the effects triggered at the lowest dose. Expert groups in SCF (SCF, 2001) and JECFA (JEFCA, 2001) have assessed the health hazards associated with the intake of dioxins and dioxin-like PCBs, taking into account the large difference in biological half-life of TCDD between rats and humans (i.e. about one month versus 7.5 years), the insufficiency of the toxicological database, and limited knowledge about the variation in the biological half-lives in different population groups.

The tolerable weekly intake (TWI) established by SCF is 14 pg TE/kg body weight/week (SCF, 2001). JECFA's assessment is comparable with that of SCF, except that JECFA expresses the tolerable intake level on a monthly basis (70 pg TE/kg body weight/month) (JEFCA, 2001).

Fish and other seafood, especially fatty fish and liver, are the most important sources of exposure to dioxins and dioxin-like PCBs in the Norwegian population. The intake of dioxins and dioxin-like PCBs from fish is discussed in more detail in Chapter 8.

5.3.2.2 Polybrominated diphenyl ethers (PBDE)

Polybrominated diphenyl ethers (PBDE) are used as flame-retardants in a number of products, e.g. electrical appliances, electronic circuit boards, textiles and building materials. There are 209 individual PBDE congeners. Three main commercial PBDE-mixtures are produced, with varying degrees of bromination of the aromatic rings. These are decabrominated diphenyl ether (deca-BDE), octabrominated diphenyl ether (octa-BDE) and pentabrominated diphenyl ether (penta-BDE). The mixtures have different compositions and degrees of purity. One or more of these mixtures are used in most of the toxicity studies conducted. The fully brominated PBDE (deca-BDE) is poorly absorbed, rapidly eliminated and bioaccumulates only to a lesser extent. Congeners with lower levels of bromination (tri- to hexa-BDE) are almost completely absorbed, and they are slowly eliminated, bioaccumulate, and more bioactive than deca-BDE. Deca-BDE may be converted to more bioactive forms in the environment. It is not known to what degree the lower brominated forms in the environment originate from the use of low-brominated commercial compounds or from the breakdown of deca-BDE (VKM, 2005).

The use of penta-PBDE and octa-PBDE compounds was banned in the EU and Norway as from 1 July 2004. The Norwegian Pollution Control Authority (SFT) has also proposed a ban on the use of deca-BDE as of 1 July 2006.

Risk assessments of three technical PBDE-mixtures have been presented in three EU reports (penta-BDE (EU, 2000), octa-BDE (EU, 2003) and deca-BDE (EU, 2002)). In addition, the Committee on Toxicity of Chemicals in Food (COT, 2004) conducted a risk assessment of PBDE in 2003 in which recent studies published after the EU assessments were discussed. JECFA also assessed the risk of exposure to PBDE in February 2005 (JEFCA, 2005), and VKM assessed PBDE in June 2005 (VKM, 2005).

In short-term toxicity studies, the effects of PBDE mixtures and single congeners were observed primarily in the liver, kidneys and thyroid gland. Following exposure during the foetal stage, the nervous system was affected in the form of persistent increased behavioural activity. PBDE is not considered genotoxic or carcinogenic. Owing to insufficient data, it is difficult to determine the health risk resulting from the intake of PBDE. The possible contamination of PBDE with polybrominated dioxins and furans, which may result in dioxin-like effects mediated via the Ah receptor, increases uncertainty about how the observed effects should be interpreted. Two studies on rats indicate that the no observed effect level (NOEL) for the most toxic PBDE compound, DE-71, is 1 mg/kg body weight/day. Furthermore, behavioural studies on mice show that single doses of the individual PBDE congeners may have lowest observed effect level (LOEL) or no observed effect level (NOEL) than DE-71, they are however of the same magnitude.

Based on the limited toxicological information about the most toxic PBDEs, JECFA concluded that it is not likely that adverse health effects will occur in rodents exposed to approximately 100 µg/kg body weight/day.

In its assessment, COT chose to provide a margin of exposure and also provided a 'target MOE', i.e. to be on the safe side, COT recommended a particular margin of exposure to the population (COT, 2004). COT established a target margin of exposure of 3 000 to 10 000 (10 for extrapolation between rats and humans, 10 for inter-individual variation, 10 for limitations in the database, and 3 to 10 for LOAEL) between human exposure and the lowest effect level/no effect level in laboratory animals that will give satisfactory protection, especially against liver toxicity and neurotoxicity.

VKM's scientific panel for contaminants, natural toxins and drug residues used a NOEL of 1 mg/kg body weight/day to estimate the margin of exposure and found a MOE > 5 000 for most population groups (VKM, 2005).

In Norway, a significant part of the exposure to PDBE (approximately 75%) comes from fish and fish products, and a smaller percentage (approximately 3%) comes from shellfish (VKM, 2005).

<u>Other brominated flame retardants</u>

Hexabromocyclododecane (HBDC) and tetrabrombisphenol A (TBBPA) are two other brominated flame retardants. Knowledge about the toxicity of these two compounds is limited.

HBCD is a commercial mixture of the three stereoisomers α, β and γ. Toxicological studies have been conducted using this mixture. The α isomer accumulates more than the β and γ isomers, and predominates in food. The degree to which these substances are metabolised is not known. HBCD is toxic to the liver, with a lowest observed adverse effect level (LOAEL) of 100 mg/kg body weight/day. The substance has not been shown to impair development in routine tests, but it has been shown to interfere with the development of the nervous system in newborn mice at a LOAEL of 0.9 mg/kg of body weight/day (COT, 2004). COT considered that the target margin of exposure to HBCD should be in the range from 3 000 to 10 000.

More studies have been conducted on TBBPA than on HBCD. COT evaluated TBBPA in 2004 (FSA, 2004). No significant effects were found following exposure to doses of up to 10 000 mg/kg body weight/day for 90 days. No long-term cancer studies have been conducted. TBBPA is not a mutagen, and there is no evidence to suggest that it poses a cancer risk to humans. TBBPA is weakly estrogenic *in vitro* in some tests, but had no effect in a recently conducted two-generation study on rats with doses up to 1 000 mg/kg body weight/day. There are conflicting results from two neurotoxicity studies in rats. Although no such effects were found in the two-generation study, a study on rats given TBBPA during gestation showed some behavioural effects. COT considered these cases to be coincidental. For TBBPA, COT derived a tolerable daily intake level of 1 mg/kg body weight/day from a no effect dose of 1 000 mg/kg body weight by using an uncertainty factor of 1 000 (FSA, 2004).

5.3.2.3 Chlorinated pesticides

<u>Campheclor</u>
Campheclor is a technical mixture of a large number of chlorinated bornanes with up to 670 congeners after the chlorination of camphene. Campheclor has been used extensively as a contact insecticide, but is now banned in most countries. Campheclor has also spread to the marine environment. Due to the decomposition of this substance in the environment and its congener-specific accumulation in the marine environment, there are relatively high levels of the congeners #26, #50 and #62 (Parlar system). Depending on the type, origin, fat content and methodology used for determining total campheclor, these three congeners account for 8 to 50% of the total amount of campheclor (EFSA, 2005b). Campheclor was evaluated by WHO in 1984 (WHO, 1984), by a Nordic group of experts under the Nordic Council of Ministers in 1996 (Anonymous, 1997), by Brüschweiler *et al.* in 2004 (Brüschweiler *et al*., 2004) and by EFSA in 2005 (EFSA, 2005b).

The EFSA assessment was based on studies of campheclor given to laboratory animals such as mice, rats, guinea pigs, dogs and monkeys, and effects were observed on the liver, thyroid gland, kidneys and immune system. Based on a 33-week monkey study, effects on the immune system occurred at the lowest dose, with a NOAEL of 0.1 mg/kg body weight/day. By using an uncertainty factor of 1 000, Brüschweiler *et al.* established a TDI of 100 ng/kg body weight/day.

Campheclor is found primarily in the marine environment, and the main source of exposure is fatty fish. There is limited knowledge about the amount of campheclor in fatty fish. Based on an average amount of 20 μg/kg (EFSA, 2005b), consuming 65 g/day of fatty fish would lead to a campheclor intake of approximately 21 ng/kg body weight/day, i.e. 20% of TDI.

<u>Other chlorinated pesticides</u>
DDT (and the metabolite DDE) and many other chlorinated and persistent pesticides (HCH, aldrin/dieldrin, endrin, HCB, endosulphane and heptachlor) have been used extensively in the past.

These have now been phased out and are no longer in use. The level of these substances in the environment has declined dramatically, and the levels currently found in marine organisms are consistently low, except in some harbours and fjords for which dietary recommendations have been issued.

These compounds will therefore not be discussed further in this report.

5.3.2.4 Chlorinated paraffins, naphthalenes and styrenes

In recent years, attention has been focused on several other chlorinated organic contaminants that can accumulate in marine food chains. Short-chained chlorinated paraffins (SSCPs) are hydrophobic polychlorinated [C_{10}-C_{13}]-n-alkanes in which chlorine constitutes 50 to 70% of the molecular weight (Tomy *et al.,* 1998), Drouillard *et al.,* 1998 a,b). SSCPs were assessed by the EU's Scientific Committee for Toxicity, Ecotoxicity and the Environment in 1998 (CSTEE, 1998). SCCPs show little acute toxicity. Upon repeated exposure in rodents, SCCPs cause liver damage associated with peroxisome proliferation and tumour development, as well as tumours in the thyroid gland. None of these effects are relevant for humans. Tumours were also found in the kidneys of male rats. This effect is probably not relevant for humans either. CSTEE concluded that current environmental exposure does not constitute a health problem for the population as a whole.

Concentrations of SCCPs at 90 ng/g fat weight in cod liver and 40-300 ng/g fat weight in sand flounder (*Limanda limanda*),both from the North Sea, have been reported (Reth *et al.,* 2005).

Medium-chained chlorinated paraffins (MCCPs) are polychlorinated [C_{14}-C_{17}]-n-alkanes in which chlorine constitutes 40 to 50% of the molecular weight (Tomy *et al.,* 1998). These are also considered to have low water solubility (AMAP, 2004) and can therefore be stored in fatty tissue. In cod liver and sand flounder from the North Sea, concentrations of MCCPs have been reported at 30 and <10-260 ng/g fat, respectively (Reth *et al.,* 2005).

Polychlorinated naphthalenes (PCNs) comprise a group of 75 different chlorinated naphthalenes that were assessed by WHO in 2001 (WHO-IPCS, 2001). PCNs are planar molecules with some structural similarity to dioxins and PCBs (Villeneuve *et al.,* 2000). The toxicological information on PCNs is limited. PCNs bioaccumulate and are found in fatty tissue, liver, blood and breast milk at levels in the order of ng/kg fat in the general population. In animal testing, short-term exposure at the level of mg/kg body weight causes death, liver and kidney damage, and thickening of the cornified layer of the skin (hyperkeratosis). Chloracne was reported in workers who handled PCNs. PCNs show a dioxin-like pattern ofenzyme induction in the liver, but their relative potency is more than 1 000 times less than the most potent dioxin compound, 2,3,7,8-TCDD. There are no long-term studies or enough data available to establish a NOAEL or tolerable intake level. Little is known about the extent to which PCNs bioaccumulate in fish, but PCNs have been documented in cod liver from the west coast of Sweden (Asplund *et al.,* 1994) and in fish from the lakes of North America (Kannan *et al.,* 2000).

Octachlorostyrene (OCS) is a fully chlorinated derivative of styrene considered to be persistent and able to bioaccumulate (AMAP, 2004). Toxicological information about OCS is limited. In rat tests, OCS appears to: cause damage to the thyroid gland, induce enzymes that metabolise xenobiotica in the liver, cause changes in the liver and kidneys, and arrest the development of red blood cells. The excretion of porphyrins is elevated in workers exposed to OCS, which may indicate an effect on the synthesis of haem similar to that caused by hexachlorbenzene. OCS is not genotoxic and does not cause estrogenic effects. In 1998, Health Canada established a Minimum Risk Intake for OCS from food of 0.31 μg/kg body weight/day.

5.3.2.5 Fluorine compounds

Perfluoroalkyl sulfonates and perfluoroalkane sulfonic acids (PFAS) are carbon-chained molecules in which all the hydrogen atoms have been replaced by fluorine. The most well known are perfluorooctane sulfonate (PFOS) and perfluorooctaonoic acid (PFOA). These compounds are both hydrophobic and oleophobic (oil repellent) and therefore surfactants (surface active). As a result, these compounds are not stored in fatty tissue, but in the liver and blood, where they bond with proteins (AMAP, 2004).

The US EPA recently assessed PFOA, one of the most important components in PFOS (US EPA, 2005). A large number of studies on rodents and monkeys show that PFOA may cause liver toxicity, damage during foetal development and impairment of the immune system. There are great differences in the elimination rates both between rats of different genders and between rats, monkeys and humans. Based on a two-generation rat study and levels of PFOA in humans, the EPA has established margins of exposure (MOE). The EPA points out that these must be interpreted with caution. Extensive research is now being conducted, focusing in particular on impaired foetal development.

In the Arctic food web, it has been shown that PFOS is biomagnified to a greater degree than PFOA (Tomy *et al.,* 2004a). The concentrations of PFOS in polar cod (*Boreogadus saida*) and redfish (*Sebastus sp)* were 1.3±0.7 ng/g wet weight (n=6) and 1.4±0.9 ng/g wet weight (n=7), respectively, in whole fish, whereas the corresponding concentrations of PFOA were 0.16±0.06 ng/g wet weight (n=6) and 1.2±0.8 ng/g wet weight (n=7) (Tomy *et al.,* 2004a).

5.3.3 Summary of organic compounds that are potential health hazards

The most significant organic compounds that represent health hazards are dioxins and PCBs, followed by campheclor (toxaphene) and PAHs. In contrast, the exposure to brominated compounds is currently low in relation to the effect level reported for laboratory animals. A number of persistent, chlorinated pesticides are no longer used and have been shown to occur only at very low levels. Dioxins and PCBs show a declining trend. Chlorinated paraffins, polychlorinated naphthalenes (PCNs) and octachlorstyrene (OCS) are of little significance with regard to the consumption of fish and other seafood.

Fat from marine fish is the most important source of the Norwegian population's intake of dioxins and PCBs. PAHs are primarily a problem in lower organisms such as bivalves, which are less able to convert and excrete PAH compounds. PAH concentrations in marine organisms result from local pollution. Research is currently being conducted on the intake and the toxicological significance of perfluorated compounds (PFOS).

5.4 Marine algal toxins

Marine algal toxins include many different toxin groups. Many of them accumulate primarily in bivalves, and may present a threat to the consumers.

5.4.1 Toxicology

Exposure to marine algal toxins occurs sporadically, and most toxicological data is based on acute or short-term exposure. Consequently, acute reference doses (ARfD) have been established. These are an estimate of the amount of toxin, expressed in terms of body weight, which can be consumed during a 24-hour period without significant health risk to the consumers.

Based on figures from a number of countries (FAO/IOC/WHO Expert Consultation 2004), the 97.5th percentile for consumption by people who eat bivalves is 250 grams per portion on an international basis. This is important because up to now the EU and other countries have used 100 grams of bivalve consumption per portion as a basis for establishing limits for algal toxins in bivalves. In 2003, FAO/WHO developed a scientific basis for maximum levels of algal toxins in bivalves based on risk assessments. As a result, the toxins were categorised in a new way, based on their chemical structure. The following section provides a description of the most important groups.

5.4.1.1 The saxotoxin group (STX)

Paralytic shellfish poisoning (PSP) has been known for several hundred years and is caused by toxins in the STX group. The most important producer of STX in Norwegian waters is the algal genus *Alexandrium*, especially *A. tamarense*. The STX toxins accumulate in a number of different species of bivalves, as well as in other shellfish. The toxin is a classic neurotoxin that afflicts both the peripheral and central nervous systems with sensory impairment, paralysis and death. The mortality rate in adults is 5-10% without treatment and higher in children. No deaths from PSP have been recorded in Norway in the past 50 years, but several serious poisoning incidents have been reported. There is great uncertainty regarding the dose/response. Temporary ARfD is set at 0.7 µg STX-eq/kg body weight based on the LOAEL of 2 µg STX-eq/kg body weight and an uncertainty factor of 3.

5.4.1.2 The okadaic acid group (OA)

These toxins are produced primarily by the genus *Dinophysis*, especially *D. acuta,* and accumulate in most types of bivalves, particularly in mussels. The toxins cause effects in the gastro-intestinal tract in the form of diarrhoea and vomiting. Several poisoning incidents caused by these toxins are known to have occurred in Norway since the 1970s, and the number of unreported incidents is probably high. The number of poisoning incidents has declined in recent years due to improved monitoring and control. Temporary ARfD is set at 0.33 µg OA-eq/kg body weight, based on a LOAEL of 1 µg OA-eq/kg body weight and an uncertainty factor of 3.

5.4.1.3 The domioic acid group (DA)

First documented in Canada in 1987, amnesic shellfish poisoning (ASP) was found to be caused by domioic acid (DA). DA and its analogues are produced by the genus *Pseudonitzschia*. DAs tend to accumulate in scallops in particular. The symptoms occur in the gastro-intestinal tract and can at worst result in amnesia and death. No poisoning incidents from ASP have been reported in Norway.

5.4.1.4 The yessotoxin group (YTX)

Since 1987, the toxins in this group have been found together with toxins from the OA group, and until recently they were included in the DSP complex. YTX toxins are produced primarily by the algae *Protoceratium reticulatum*. They accumulate in most bivalves, as do the toxins in the OA group. Temporary ARfD is set at 50 µg/kg body weight. There is not sufficient data for chronic effects to be able to establish TDI values.

5.4.1.5 The azaspiracid group (AZA)

The first case of azaspiracid poisoning (AZP) was reported from bivalves in Ireland in 1995. It is not certain which alga produces the toxin, but it is believed to be *Protoperidinium crassipes*. AZAs accumulate in mussels in particular, and they have also been documented in Norwegian bivalves. Temporary ARfD is set at 0.04 µg/kg body weight, based on a LOAEL of 23 µg/person, body weight 60 kg, and with an uncertainty factor of 10 (few persons and uncertain dose estimates).

Other less relevant toxins are described in appendix A.

5.4.2 Incidence in Norway

The marine algal toxins mentioned above occur primarily in bivalves. The toxins found in Norwegian waters are mainly from the STX, OA, YTX and AZA groups. Small amounts of toxins from the PTX and DA groups and spirolides (the cyclic imine group) have also been documented in Norwegian bivalves. Except for the DA group, which occurs in the highest concentrations in scallops, the highest concentrations of toxins by far occur in mussels. Toxin concentrations vary from year to year, and from place to place along the coast. They also occur during different seasons. The STX group occurs most frequently in the period February/March to May/June, whereas the toxins causing diarrhoea (the OA and AZA groups) predominate in the autumn, and may remain in the bivalves far into the winter. The YTX group occurs most frequently in spring and summer.

Only sporadic analyses of sea urchins and snails have been conducted, and these have shown negative results for the presence of algal toxins. In 2002, Norway had its first incident of algal toxins in edible crabs. The crabs had eaten large amounts of mussels containing high levels of toxins from the OA group. The brown meat in the crabs contained such high levels of toxins that about 200 people reported symptoms of diarrhoea from shellfish poisoning.

Fish death associated with marine algal toxins is often reported, but this is caused by other groups of toxins produced by the algae genuses *Chrysochromulina, Prymnesium, Chattonella* and *Karenia* (previously known as *Gyrodinium*). These toxins kill large numbers of fish, but very little accumulates in muscle tissue, and they are not considered to present a risk to humans.

5.4.3 Summary of algal toxins

Toxicological information about algal toxins is still limited. New toxins are continually being identified, and the number of analogues in each group continues to grow. Even though the effect mechanisms are known for several of the most important groups, there is a great need for more information about toxins such as azaspiracids, spirolides, pectenotoxins and yessotoxins. In Norwegian bivalves today, the main problem is associated with the paralysing toxins and the diarrhoea-producing toxins from the OA and AZA groups. The toxins that cause diarrhoea are not life-threatening, but they cause such great discomfort that it is important to control their levels. It is also important for the bivalve industry that effective control measures are in place to prevent poisoning from bivalves sold on the market.

5.5 Infectious organisms in fish and other seafood

Infectious organisms that can cause food-borne infections are often classified as prions, viruses, bacteria or parasites. Parasites are discussed in Section 5.5.4. Some types of infectious organisms may cause infections in both humans and animals. These organisms are referred to as zoonotic, and there are many instances in which warm-blooded animals act as a reservoir for disease that can be transmitted to humans. Infections can also be transmitted from humans to animals. Under the climatic conditions found in Norway, there are in practice no infectious organisms that cause disease in fish which can also infect humans. In warmer waters the situation is different, and some bacteria that cause disease in fish may also infect humans, but this is not regarded as a significant health problem.

5.5.1 Bacteria

Bacteria comprise a large and important group of microorganisms. Due to the high incidence and activity of bacteria, they are the group of microorganisms that have the greatest negative impact on fish quality. Some bacteria can also cause disease in humans. In general, fish and other seafood from cold waters do not naturally contain human pathogenic microorganisms. When such bacteria are found in processed fish products, it is usually because the product has been contaminated during processing. *Listeria monocytogenes* is the most important bacteria that cause contamination of fish in cold waters.

5.5.1.1 *Listeria*

The genus *Listeria* includes several species, two of which are considered to be human pathogens. Both *L. monocytogenes* and *L. ivanovii* have been shown to cause disease in humans. *L. monocytogenes* has been associated with food-borne disease, and they have the ability grow both with and without access to oxygen and at refrigeration temperatures. Because the bacteria are widespread, they are found in a number of foods, including products made of fish. In international scientific literature, the reported frequency of these bacteria in fish and other seafood ranges from 0 to 75% in the products studied (Ben Embarek, 1994).

L. monocytogenes can cause the disease known as listeriosis, which is primarily a problem for sheep, but humans may also be infected. The bacteria can cause infections in the central nervous system or result in miscarriages. Although the number of cases of listeriosis in humans is usually low, the mortality rate is reported to be potentially higher than 30%. Listeriosis in humans has been associated with the consumption of several different foods, such as lettuce, cheese, meat cold cuts, bivalves, cold smoked fish, and fermented fish and meat products. The first documented case of listeriosis from fish was recorded in 1989 (Facinelli *et al*., 1989).

The number of reported cases of listeriosis in western European countries is 2-4 cases per one million inhabitants. In most of these cases, listeriosis affects people with an underlying illness and thus reduced resistance to infection (weakened elderly people, people with HIV, cancer patients or people using medicines that weaken the immune system). Pregnant women who are infected may show only mild symptoms, but the foetus can be injured or even die. The Food safety authorities in many countries therefore advise pregnant women not to eat high risk products such as certain types of cheese, meat cold cuts, cold-smoked fish or fermented meat or fish products.

The presence of *L. monocytogenes* is monitored on a regular basis by national inspection authorities. Although these inspections show annual variations in the fish products examined, the general tendency is that the occurrence of the bacteria increases with increasing degree of processing. As a result, more *L. monocytogenes* will be found in smoked, vacuum-packed salmon, for instance, than in raw salmon products. This illustrates the bacteria's ability to establish itself in the production facilities and to grow at refrigeration temperatures. In 2003, the frequency of *L. monocytogenes* in smoked salmon produced in Norway was approximately 5% (Zoonoserapporten, 2003).

The amount of *L. monocytogenes* required to cause disease (the infective dose) is generally high. International literature indicates that products with a level of *L. monocytogenes* under 1 000 bacteria per gram of food product will not cause disease in healthy adults. International food safety organisations consider establishing limits for the concentration of *L. monocytogenes* in foods that can be tolerated by different population groups.

In the production of fish and other seafood in cold and temperate regions where the overall incidence of food-related infections is low, *Listeria monocytogenes* represents the greatest microbiological risk since these bacteria can contaminate fish products, such as smoked salmon, during production and poses a particular risk to pregnant women.

5.5.1.2 *Clostridium botulinum*

Fish caught in unpolluted cold waters are generally free of pathogenic microorganisms, with the exception of a few cases in which the presence of the bacteria *Clostridium botulinum* type E has been documented (Hielm *et al.,* 1998, Huss, 1980, Huss & Rye Pedersen, 1980). Under certain conditions, these bacteria can produce potent neurotoxins. The bacteria grow only under anaerobic conditions and not at temperatures below 3.3 ºC or with a salinity above 5% in the water phase of the product (Gram, 2001). Therefore, the bacteria can develop only in sealed packaging, such as tin cans or vacuum-packaging or in fish silos where oxygen is depleted. To avoid problems with the growth of *C. botulinum*, it is important to have good control over factors affecting the growth of these bacteria in fish and fish products throughout the entire food chain from catch to consumption (Huss *et al.,* 2004). It has been reported in international literature that fish and other seafood have caused to botulism (Solomon & Lilly, 2001, Telzak, 1990). No cases of botulism have been documented in Norway as a result of commercially produced fish products, but home made *rakefisk* (partially fermented fish) has resulted in several cases of botulism and does pose a risk of this disease.

5.5.1.3 *Vibrio*

Marine and estuary waters are the main reservoir for bacteria in the genus *Vibrio* (Baumann *et al.,* 1984). This distinguishes them from other bacteria of significance as food-borne pathogens. To date, 12 *Vibrio* species have been shown to cause disease in humans, and eight of these have been reported to infect humans via food products (West, 1989). Of this group, *V. cholerae*, *V. parahaemolyticus* and *V. vulnificus* are the most significant. The presence of these bacteria in sea water is greatly affected by temperature (Baffone *et al.,* 2000, Høi *et al.,* 1998, Oliver & Kaper, 2001, O'Neil *et al.,* 1992, Dalsgaard, 2002). Human pathogenic *Vibrio* species may be observed in fish and other seafood from temperate regions, especially in the summer, but they occur less frequently than in warm-water regions. Consequently, cases of food-borne bacteria from this group are most common in regions with high temperatures (Sutherland & Varnam, 2002).

Infections from *V. cholerae* have been historically significant in relation with the many cholera pandemics (Todar, 2004). *V. parahaemolyticus* cause symptoms typical for a gastro-intestinal infection, with diarrhoea and moderate fever, while *V. vulnificus* may cause serious infections in the dermis in persons disposed to infection. Although some of the pathogenic *Vibrio* species can occasionally be observed in Norwegian seafood, particularly in bivalves, none of them are considered to present serious problems in Norwegian fish.

5.5.1.4 *Salmonella*

Bacteria of the genus *Salmonella* are among the most significant causes of infections from food products. In Norway, *Salmonella* is the second most important cause of bacterial food-related infection after *Camphylobacter.* Seafood products produced in Norway rarely contain *Salmonella*, but fish feed and ingredients used in fish feed may be infected with certain varieties (serotypes) of the bacteria. The most common of these are *Senfetenberg, Agona* and *Montevideo.* These serotypes do not appear to be the cause of a large number of reported infections in humans. *Salmonella* in fish feed has currently been assessed by VKM (VKM, 2006).

5.5.1.5 Other bacteria

Bacteria of the genuses *Camphylobacter*, *Yersinia* and *Shigella* are significant as causes of food-borne infections in general, but they are rarely associated with fish in temperate climatic conditions.

5.5.2 Viruses

Viruses are non-living, microscopic particles consisting of a protein casing that contains genetic material, either in the form of RNA or DNA. Many different types of viruses can be transferred through food products; two examples of this are the hepatitis A virus and the Norovirus. Food-borne viral infections are reported to be among the 10 most common causes of disease in humans, and it is futher believed that many cases are not recorded in any statistics (Cliver, 2001, Koopmans, 2002). Filtering molluscs, such as bivalves, are known to accumulate bacteria or viruses found in water. Thus, when fish and other seafood are involved in virus-borne diseases, most of the cases are caused by bivalves, especially oysters (Lees, 2000). Information has recently been published on the presence of the Norovirus in mussels (*Mytilus edulis*), horse mussels (*Modiolus modiolus*) and oysters (*Ostrea edulis*) collected from locations along the Norwegian coast (Myrmel *et al.,* 2004). Even at locations assumed to be free of contamination, the prevalence was approximately 6%. Therefore, in principle fish could be carriers of viruses found in the environment, and workers who handle these fish could also transfer the viruses. Viral infections from fish in Norwegian waters are however not considered to be common.

5.5.3 Prions

Prions are proteins which can cause infections in mammals, including humans. These infections have been given the generic designation 'transmissible spongiform encephalopathies', abbreviated TSE. TSE infections are characterised by abnormal changes in the brain of infected humans or animals. Typical changes include the development of a cavity in the grey matter, which over time appears in tissue samples under a microscope as sponge-like material – thus, the term 'spongiform'. TSE infections have a long incubation period and are always fatal. In contrast to other known infectious agents, prions do not trigger an immune response in the infected animal or human. Prions may be transmitted from animals to humans through food. Although some TSE diseases have been known for many years, prions attracted increased attention in connection with the outbreak of 'mad cow disease' (BSE), involving many infections in horned cattle and in a few humans (vCJD) (Belay, 1999). It has been shown that fish have DNA which codes for the production of prion proteins, and thus in theory fish could develop prion diseases (Oidtmann *et al.,* 2003). However, the fish prions are so different from those found in mammals that the transmission of TSE in fish to humans is regarded as highly unlikely (Rivera-Milla *et al.,* 2003).

5.5.4 Parasites

5.5.4.1 Encysted nematode larvae

It is well known that both marine and fresh water fish can have parasites. Most of them are not hazardous in terms of food safety, but some fish parasites may represent a health risk if they are eaten alive. The most important group of parasites in this regard comprises encysted nematode larvae, which refers to the larvae of at least four different species of parasitic round worms, or nematodes, found in practically all marine fish species. The most common, and in this connection most important type is *Anisakis,* which appears as small, flat spirals on the outside of the intestines of fish such as herring, mackerel, cod and saithe. The adult larvae live in the stomach/intestines of whales and to a lesser degree in seals, where they produce large amounts of eggs that are deposited into the water along with the excrement. The eggs hatch and the larvae are eaten by various crustaceans such as krill and shrimp, which may be eaten by fish, which in turn are eaten by larger fish. As a result, large predatory fish, such as cod and saithe, may accumulate significant amounts of encysted nematode larvae. Sea mammals that eat infected fish then lay the foundation for new generations of these larvae.

Since most encysted nematode larvae are found on the intestines of fish, they can easily be removed along with the guts. However, some larvae may be found in the muscles, sometimes far into the fillet. From a public health perspective, it is this phenomenon that gives cause for concern. During a meal consisting of raw or partially raw fish, it is possible for a person to eat living encysted nematode larvae. In the worst case, the result can be an acute, painful infection in the stomach and intestines, possibly accompanied by diarrhoea and vomiting or allergic reactions (Levsen & Lunestad, 2002).

Due to the growing popularity of products containing raw or almost raw fish (sushi, matie fillet), infections from living parasites may become more common if the necessary precautions are not taken. In contrast, dead larvae of this type do not present a direct health hazard. In fact, there is no documentation showing that dead encysted nematode larvae can produce allergic reactions in people who have not previously been sensitised to live *Anisakis*.

Provisions in the Norwegian food quality regulations for fish and fish products state that herring, brisling, mackerel and wild salmon to be eaten raw or partially raw must be deep frozen for at least 24 hours prior to use. However, these regulations do not cover typical raw sushi ingredients such as halibut, turbot and shrimp, which also may contain nematodes (Kvalitetsforskrift for fisk og fiskevarer, 2003). A recent, comprehensive study conducted by the National Institute of Nutrition and Seafood Research (NIFES) has shown that farmed salmon does not contain encysted nematode larvae (Lunestad, 2003). The reason for this is that farmed fish are given dry feed and crustaceans infected with encysted nematode are evidently not found in significant amounts in or around net pens.

5.5.4.2 Tapeworm in freshwater fish

Tapeworm (*Diphyllobothrium latum*) may infect humans, for example, through the consumption of fresh or lightly processed/cured perch, pike, grayling, Arctic char or trout in which the larvae of the parasite may occur in the muscle tissue. The tapeworm is most widespread in northern Norway, particularly in Pasvik in the county of Finnmark (Vik, 1957, Vik, 1964, Berland, 1977). In addition to humans, other known end-hosts include dogs, cats and other fish-eating mammals. Symptoms of infection from tapeworm often begin with increased appetite, then develop into fatigue and sometimes anaemia. However, presence of the parasite is easy to detect, and it can be easily treated with medicine.

<u>Deep freezing is important</u>

Even for professionals, it is difficult and time-consuming to detect the presence of parasites in fish fillet (Levsen *et al.,* 2005). When private individuals prepare and consume raw, lightly marinated, cold-smoked or cured fish that they have caught themselves or purchased blood-fresh at the pier, it is easy to overlook a parasite in the meat. This shows the importance of deep-freezing all fish for at least 24 hours before serving it raw or partially raw. It is important to point out, however, that boiling, frying and grilling until well-done, as well as warm-smoking and salting over an extended time period, also will kill the parasites which may be present in the fish.

5.5.5 Summary of infectious organisms in fish and other seafood

In general, fish from cold waters do not naturally contain human pathogenic microorganisms. If these organisms occur in food products, it is usually because the fish has been contaminated during processing. The most important infectious organism in fish is the bacteria *Listeria monocytogenes* which has been shown to cause the disease listeriosis in humans and animals. Homemade *rakefisk* (partially fermented trout) poses a risk of botulism. Some naturally occurring parasites (encysted nematode larvae) in marine fish may also cause infections if they are consumed alive. Conservation methods, such as boiling, frying, freezing and strong salting, kill these parasites. Although fish from Norwegian waters may sometimes cause infectious disease, fish represents a much smaller risk of infectious disease than products made from warm-blooded animals.

5.6 Other (wax esters and histamine)

Some fish species, such as escolar (*Lepidocybium flavobrunneum*) and oil fish (*Ruvettus pretiosus*) belonging to the family *Gempylidae*, contain large amounts of wax esters. Humans cannot digest wax esters, and the consumption of these fish causes diarrhoea. These species also contain a relatively large amount of histamine, and during improper storage conditions and bacteria growth, histamines may be produced, resulting in a variety of symptoms such as nausea, inflammation of the skin and heart palpitations.

5.7 Disinfectants

A large number of chemicals are used as disinfectants in industry. Cleaning agents and disinfectants should be effective, but not present a health hazard to consumers. In some cases, however, by-products or residues of disinfectants on food products may pose a potential health risk. In these cases, an assessment is made based on the substances potentially toxic properties.

5.7.1 Toxicology

Risk assessments should determine whether residues of disinfectants found on food products will represent a risk to consumers. If international intake levels (e.g ADI/TDI) have been established these are applied in the risk assessment.

The amount of a chemical substance present in the residual water after cleaning is uncertain. If it is present, it has to be determined whether it is absorbed or reacts with biological molecules on the surface of the food products. If so, the chemicals can be found on the food products. In any case, the disinfectants *per se* should not present a risk to consumers. It is therefore important that the production facilities are rinsed thoroughly after cleaning agents are used to ensure that residue levels are as low as possible.

An important factor is whether the raw products are rinsed thoroughly with clean drinkingwater as the products go through the production line. Doing so ensures clean, hygienic surfaces of the raw products,|and rinses disinfectant residues off the raw products.

5.7.2 Summary of disinfectants

It is hypothetically possible to be exposed to various disinfectants over time, but it is difficult to assess the actual risk they may present. The risk from exposure to these substances is probably limited.

5.8 Radioactivity

5.8.1 Occurrence

In the marine environment along the Norwegian coast and in Norwegian waters, there are several different sources of anthropogenic radioactivity, including ^{137}Cs, $^{239+240}Pu$, ^{99}Tc and ^{90}Sr. The most significant sources are fallout from nuclear testing in the atmosphere in the 1950s and 1960s, emissions from the recycling facility at Sellafield, and water currents originating in the Baltic Sea that were contaminated by fallout from the Chernobyl accident in 1986. In addition to the anthropogenic radionuclides, there are several natural radionuclides, including those from the uranium and thorium chains in the marine environment, where ^{210}Po is indicated as the most important radionuclide in the marine food chain. Elevated concentrations of ^{226}Ra and ^{228}Ra have been found in emissions of process water from oil and gas production. ^{226}Ra is converted via disintegrations to ^{210}Po (equilibrium after ca. 200 years).

5.8.2 Health hazard from the intake of radionuclides

The intake of radionuclides may result in damage to genetic material. As for carcinogenic genotoxic chemicals, there is probably no safe minimum threshold of exposure. In theory, any exposure presents a risk. For the intake of a radionuclide, the effective dose for adults is integrated over 50 years, resulting in an acquired effective dose. The probability of developing fatal cancer following exposure to ionised radiation has been determined by the International Commission on Radiological Protection (ICRP) to be approximately 5% per Sv per year.

5.8.3 Exposure from the marine environment

The activity concentration (Bq/kg) from the marine environment (cf. Annex B) (Gäfvert *et al.,* 2003, NRPA, 2004) and data from the Fish and Game Study, Part B (Bergsten, 2004) were used to estimate the radiation dose (effective dose) from the consumption of fish and other seafood. With an average consumption and an average activity concentration of radionuclides in fish and other seafood, an annual dose of approximately 0.1 mSv[11]. Using the same assumptions for high consumers, the annual radionuclide intake may reach approximately 0.3 mSv, whereas the most conservative estimates (maximum radionuclide level along with high consumption) show that it is possible to reach a intake of 1 mSv per year by consuming fish and other seafood. In all scenarios, more than 99% of the dose comes from natural radionuclides.

Out of all types of seafood, crab and fish result in the highest doses. For crabs this is due to the relatively high level of ^{210}Po, while the relatively high doses from fish are caused by high consumption of this type of seafood (Table 12). The high proportion of radioactivity from ^{210}Po is due to the generally high uptake of ^{210}Po in marine organisms and its radiotoxic properties. For the most part, ^{210}Po occurs naturally in the environment, although a small amount comes from anthropogenic sources, such as emissions of process water from oil and gas operations in the North Sea.

Table 12. Percentage of dose from fish and other seafood (assumed average consumption and average activity concentration)

	Coast		**Inland**	
	Men	**Women**	**Men**	**Women**
Fish	25	21	28	26
Fish liver	4	4	4	4
Prawns	14	14	15	11
Crabs	42	45	31	33
Molluscs	16	17	23	25

In addition to being the nuclide with the highest activity content in fish and other seafood in general, ^{210}Po is also the most radiotoxic nuclide (by means of oral intake) of the various nuclides included in this dose assessment.

5.8.4 Risk assessment

The estimated risk of developing fatal cancer for the average consumer with an intake of 0.1 mSv per year is approximately 0.0005% per year ($3.5\text{x}10^{-4}$ lifetime risk – 70 years). For high consumers, an intake of 0.3 mSv per year triples this risk, while the most conservative estimate in which the consumer has an intake of about 1 mSv results in a comparable figure of 0.005% per year ($3.5\text{x}10^{-3}$ lifetime risk).

[11] This may be compared with the average dose from natural sources, except for radon in homes in Norway, for one person of approximately 1 mSv per year in which approximately 0.6 mSv comes from natural external radiation in the environment, 0.3 mSv comes from cosmic radiation, and 0.4 mSv comes from natural radiation in the human body (e.g. potassium-40).

5.8.5 Summary of radioactivity

The levels of man-made radionuclides in Norwegian fish and other seafood are low, but naturally occurring radionuclides usually result in doses equal to approximately 10% of the average dose for a Norwegian from all natural sources, except for radon in homes. For high consumers of fish and other seafood, consumption may result in an additional dose of approximately 100% compared with the average dose from natural sources. The levels of man-made nuclides along the Norwegian coast are considered to have little significance for the public health.

5.9 Summary of contaminants and other undesirable compounds, including infectious organisms, in fish and other seafood

In terms of exposure from marine organisms, the metal compounds that present the most significant health hazards are methyl mercury, cadmium and organic tin compounds. Fish and other seafood are the main source of methyl mercury, while cadmium and organic tin compounds are found to be less important. Only methyl mercury will be discussed further in this report.

The most important organic health hazards are dioxins, PCBs and PAHs, while brominated compounds currently occur at relatively low levels. A number of persistent, chlorinated pesticides that are no longer in use, are observed only at very low levels, whereas campheclor is still found in marine fat in amounts that are significant if fish consumption is high. The most important dietary source of dioxins and PCBs is fat from marine fish. Exposure to dioxins and PCBs in the Norwegian population shows a declining trend. This report will mostly focus on dioxins and dioxin-like PCBs in the further assessment.

The greatest problems involving algal toxins are related to their variable occurrence in bivalves and their acute health effects. Bivalves are controlled for algal toxins before they are sold on the market, and dietary advice is issued regarding safe consumption of self-caught bivalves.

The risk of exposure to disinfectants used in the production of fish is very small and is not considered to present a food safety problem. Accordingly, disinfectants will not be discussed further in this report.

Levels of man-made radionuclides in Norwegian fish and other seafood are low. The intake of naturally occurring radionuclides from fish and other seafood by the average consumer results in doses of ionised radiation equalling approximately 10% of the total average dose from all sources. The intake from fish and seafood may be up to approximately 100% for high consumers. Ionised radiation from fish and other seafood will not be discussed further in this report.

Fish from cold waters do not, as a general rule, naturally contain human pathogenic microorganisms. If such microorganisms are found in processed products, it is usually due to contamination during processing. *Listeria monocytogenes* presents the greatest microbiological risk since the bacteria can contaminate fish products, such as smoked salmon, during production, and because they present a particular risk for pregnant women. Homemade *rakefisk* (partially fermented trout) poses a risk of botulism. Infectious organisms from fish will not be discussed further in this report.

6 Farmed fish as food - the significance of feed for nutrients and contaminants

The composition of nutrients and contaminants in farmed salmon, trout, cod and halibut varies according to the raw ingredients and components found in fish feed. This means that from a human health perspective, the end-product may vary considerably depending on the feed eaten by the fish, especially during the last few months before slaughter. Although the feed determines the composition of the fish, the pattern of nutrients and contaminants is not the same in feed as in fish due to differences in bioavailability and retention. As shown in Chapter 4, the nutritional composition of farmed salmon is reflected in the blood of the people who eat this fish, and it may have a great impact on the health effects of the fish that is eaten (Seierstad *et al.,* 2005).

This chapter discusses the significance of the choice of feed ingredients, both oils and protein, for the nutritional composition of fish, and how the end-product (fish fillet) can be fortified with the desired amounts of nutrients, such as vitamins, minerals and fatty acids. The chapter also addresses how the levels of undesirable compounds can be reduced by choosing the best strategies, for instance, by making calculated choices regarding raw ingredients, combining them to achieve the desired results and possibly purifying them before use. Consequently, it is possible to control the level of contaminants in farmed fish, as opposed to what is the case for fish caught in the wild. The chapter also concerns what happens if genetically modified ingredients are used in fish feed.

6.1 Choice of feed ingredients

A few years ago, 3-4 kg of wild fish were needed to produce 1 kg of farmed fish. These figures are based on the fact that fish meal and fish oil comprise the protein and fat components of the feed (Nortvedt, 2003). Because ingredients from plants are included in the feed used today, about 1 kg of wild fish is used to produce 1 kg of farmed fish (Nutreco - unpublished data). Introducing new raw materials into feed requires knowledge about how this will affect the nutritional composition and availability of a number of nutrients. Exposure to contaminants will change as well, and problematic new compounds may be introduced. In sum, this will affect the nutritional composition and the sensory quality of the end-product, in addition to affecting the levels of contaminants.

Today, alternative feed ingredients are being used in an effort to address the anticipated future lack of fish meal and fish oil and to make better use of valuable marine resources.In addition to ingredients from the plant kingdom alternative marine oil and protein sources, such as krill and bioprotein, e.g. gas from the North Sea, converted to protein by means of bacteria are seen as possible future feed ingredients.

6.1.1 Significance of feed for levels of fat and fatty acid profiles in salmon

While the fatty acid profile of salmon fillet reflects the fatty acid profile of the feed oil, the total amount of fat in salmon fillet depends on the amount of fat in the feed (Hemre & Sandnes, 1998), the season and the size of the fish (Nordgarden *et al.,* 2003). In the spring, salmon fillets are leaner than in the autumn, and as a general rule, farmed salmon has a higher fat content than wild salmon. For instance, a 3-4 kg wild salmon may contain 8-10% fat in the muscle, whereas farmed salmon contains approximately 16% fat. If salmon is given feed containing soy oil, this will produce a 'soy oil fatty acid profile' in the salmon muscle (Waagbø *et al.,* 1993). If salmon is fed other oil combinations, such as rape seed oil or olive oil, this will result in a fatty acid profile that reflects the rape seed oil and olive oil profile in the feed. This fact may have an impact on how the consumption of different types of fish fillets affects public health and a strategy has been developed for increasing the amount of marine n-3 fatty acids (EPA and DHA) in the muscle of salmon fed a cost-efficient vegetable feed. During the last five months of the production cycle the desired fatty acid profile is re-established by giving the fish a customised, pre-slaughter feed. Using this method, the marine n-3 fatty acids in the salmon fillet can be re-established.

Results from the EU project (RAFOA) show that it is possible to increase the level of n-3 fatty acids, but it is difficult to reduce the content of n-6 fatty acids. Feed containing 100% vegetable oil (rape seed) did not result in any difference in the fat level in the muscle, but it did change the fatty acid profile in the muscle, resulting in lower levels of marine n-3 fatty acids (EPA and DHA) and more monounsaturated fatty acids, more n-6 fatty acids and shorter n-3 fatty acids. In a final feeding phase intended to re-establish the marine fatty acid profile in salmon given vegetable feed, it has only been possible to partly re-establish the marine profile related to the fatty acids EPA and DHA. While feed made with vegetable oil did not produce changes in the levels of other nutrients, such as astaxathin and vitamin E, it did give the salmon fillet a taste and smell that was less marine-like and more vegetable-like (evaluated by a tasting panel at Matforsk – the Norwegian Food Research Institute). After five months using 100% fish oil feed at the end of the production cycle, there was no difference in the taste or smell between salmon that had previously been given vegetable oil and those that had only been fed marine oil (Torstensen *et al.,* 2004).
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Higher amounts of EPA and DHA have been shown to be incorporated into large salmon (from 3 kg and up) in the transition from feed with marine oil containing little n-3 (smelt) to a feed featuring a South American oil with higher n-3 levels. The curve shown in figure 12 has been published in the textbook *Fish Farming: A Growth Industry for Norway's Districts* ('Fiskeoppdrett. Vekstnæring for distrikts-Norge', Trygve Gjedrem, Landbruksforlaget 1993).

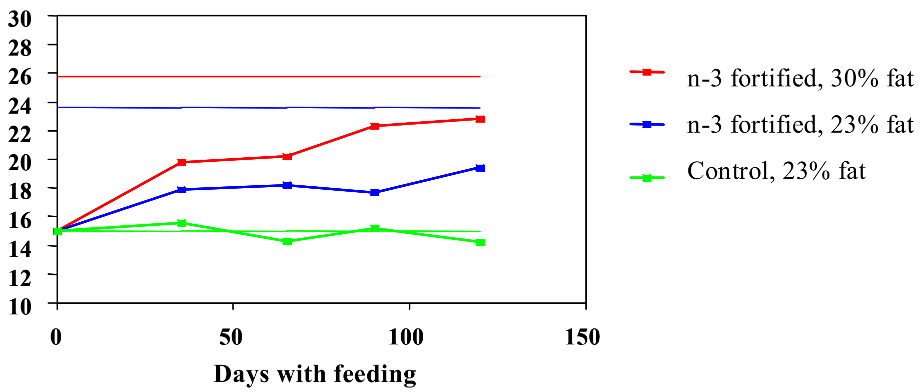


Figure 12. Percentage of long-chain 3-n fatty acid in 'fortified' farmed salmon.

Figure 12 shows the percentage of marine n-3 fatty acids in 'fortified' farmed salmon. Salmon given 15% fat (capelin oil) in the feed (green line) maintain a marine n-3 level in the fillet of approximately 15%, salmon given 23% sardine oil in the feed (blue line) slowly build up the level of marine n-3 fatty acids in the fillet to approximately 19% during a period of 130 days, and salmon given 26% sardine oil in the feed (red line) build up a level of marine n-3 fatty acids in the fillet of approximately 23% during a period of 130 days.

6.1.2 Significance of feed for vitamin content in salmon

Vitamin A is stored primarily in fish liver, and only a small amount is retained in the muscle. In salmon, this constitutes an average of approximately 1.1 ng per 100 grams (R. Ørnsrud - unpublished data, 2005), i.e. a person who eats a 200 gram portion of salmon will consume 0.002 µg of vitamin A.

Muscle tissue is an important organ for the storage of vitamin D in salmon, and the levels of vitamin D are highly dependent on the levels of vitamin D in the feed, i.e. it is possible to enrich salmon with a pre-determined desired amount of vitamin D. If a person eats a 200 gram portion of salmon given feed containing low levels of vitamin D, that person will have an insignificant intake of vitamin D from the fish. If the salmon has received feed with a moderate level of vitamin D intake from 200 gram fish will be 2 µg of vitamin D, whereas a person may have an intake up to 14 µg of vitamin D if the salmon has been given feed fortified with high amounts of vitamin D. No negative effects were measured in salmon given highly fortified feed (Graff *et al.,* 2003).

A 200 gram portion of farmed salmon contains 2 to 14 mg of vitamin E (α-tocopherol), and the level in the fillet depends on the amount of vitamin E in the feed (Hamre, 1995, Hamre & Lie 1997). Although salmon is not a primary source of this vitamin in the Norwegian diet, vitamin E is considered necessary for stabilising fatty acids during storage and possibly when preparing a meal. It is therefore important that the level of vitamin E is high enough to maintain stability during storage and processing.

6.1.2.1 Water-soluble vitamins

The water-soluble vitamins, i.e. vitamins C (ascorbic acid) and B (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folate (folic acid) and cobalamin), are added to feed for farmed fish primarily to prevent vitamin deficiency in the fish. Because they are water-soluble, they must be added to the feed on a regular basis to maintain the vitamin status of the fish. High levels (100 x required amount) of vitamin C are used periodically as a health-promoting element in feed for farmed fish, especially during smoltification, vaccination, periods of handling and stress, disease and sexual maturation.

Vitamin C deficiency was a major problem for the aquaculture industry for a long time until stable, accessible vitamin C compounds were developed and produced (ascorbic acid-phosphate compounds). Ascorbic acid is stored mainly in the liver, kidneys and roe of fish. The amount of ascorbic acid in salmon muscle is relatively small, it is affected by the feed resulting in between 20 to 30 µg/gram of muscle from feed containing from 52 to 1940 µg vitamin C/gram (Waagbø *et al.,* 1998). Except for the roe, vitamin C levels are insignificant in the muscle of other farmed fish species, such as cod and halibut (Norwegian Food Composition Table, 2001). Research on improving egg quality by means of bloodstock feed has shown that the level of vitamin C in roe from all fish species, including trout (Sandnes *et al.,* 1984) and cod (Mangor-Jenssen *et al.,* 1994), can be affected by the vitamin C content of the feed.

Because B vitamins play an important role in nutrient and energy metabolism, the amount of B vitamins in muscle tissue varies according to activity and type of muscle fibre (white or red musculature) in the different fish species (Brækkan, 1959). Due to the nature and function of B vitamins, the possibilities for controlling the levels of B vitamins in the muscle tissue are limited as long as the feed meets the nutritional requirements of the fish. This has been shown in salmon with regard to riboflavin (Brønstad *et al.,* 2002), pyridoxine (Albrektsen *et al.,* 1995), cobalamin and folic acid (Waagbø, 2005 - unpublished data). However, it appears that the amount of biotin in the muscle can be affected through moderate supplements added to the fish feed (10 x required amount), from 0.02 to 0.11 µg/grams (Waagbø R., 2005 - unpublished data). Other variables in fish production, e.g. water temperature, have been shown to result in large variations in B vitamin levels (Waagbø, 2005 -

unpublished data), probably due to changes in the feed availability and metabolism due to changes in temperature.

6.1.3 Significance of feed for the presence of essential trace elements in fish

The accessibility of various trace elements depends on the particular trace element in question and the form in which it is present in fish feed. Only a few trace elements have been studied, but some data shows that salmon can be fortified with zinc (Maage *et al.,* 1991), iron (Bjørnevik & Maage, 1993), copper (Julshamn *et al.,* 1988), and selenium (Lorentzen *et al.,* 1994), if these are added in a bioavailable form.

6.2 Marine and vegetable oil in halibut feed

Fat levels vary greatly in halibut. In a halibut weighing 3 to 4 kg, the abdominal muscle contains 34-44%t fat on a wet weight basis, while the middle of the back and tail contain only approximately 2% fat. The fillet just behind the head contains approximately 5% fat. If halibut is given a feed based on capelin oil, the muscle's fatty acid profile as a result will show approximately 9 to 10% EPA and 19 to 21% DHA of the total fat content.

A 200 gram portion of back or tail fillet will consequently give 1.2 grams of EPA and DHA, while a neck or head piece will give 3 grams of EPA and DHA.

6.3 Marine and vegetable ingredients in cod feed

Research projects conducted in the 1980s and early 1990s have shown that cod can successfully be given a feed made of fish meal and fish oil and that cod require a much leaner feed than salmon. Because cod stores all its excess fat in the liver, the fat content in muscle only accounts for approximately 1% of wet weight. As in salmon muscle, the fat in cod muscle reflects the fatty acid profile of the feed (Lie, 1991), which has been shown to be significant for sensory quality and storage stability (rancidity).

A 200 gram portion of cod gives about 2 grams of fat and can meet a person's daily requirement for n-3 fatty acids if the fish fat has a marine profile in which the marine n-3 fatty acids account for at least 50% of the total fat in the muscle, i.e. up to 0.6 grams of EPA and DHA per 100 grams of fillet.

To achieve cost-efficiency in cod farming one must use the least expensive raw ingredients, at the same time taking into account that negative effects for fish welfare or the quality of the end-product must be avoided. Feeds are currently being tested in which almost 100% of the marine protein is replaced with vegetable protein. This has been shown to cause some changes in the composition of the water-soluble protein fraction in muscle, but it has limited effects on the retention of other nutrients such as fatty acids, minerals and vitamins (Hemre *et al.,* 2004).

200 grams of farmed cod provides several important amino acids, e.g 5 g arginine, 2 g histidine, 4 g isoleucine, 7 g leucine, 9 g lysine, 3 g methionine, 4 g phenylalanine, 4 g threonine, 1 g tryptophan and 4 g valine. If cod is fed only marine oil, the fatty acid profile in the muscle will be as shown in table 13.

Table 13. Percentage of fat and amounts of the different fatty acids in the muscle of a 'typical farmed cod'

Fatty acids	% of total fat in cod muscle
Saturated	22
Monoenes	18
n-3 fatty acids	54
n-6 fatty acids	3
% fat in total muscle (w.w)	0.5 – 1.5

The volume of farmed cod is increasing. If, in future, it becomes possible to use the liver from farmed cod in products such as cod liver oil, it is important to be aware that the content of vitamins will reflect the vitamin A and D content of the feed.

6.4 Cage feeding of mackerel for delivery to the market off season

Cage feeding wild mackerel so they can be delivered to the market throughout the year and not only during the short season in the autumn shows great promise in terms of value creation. Methods have been developed for catching mackerel, bringing them ashore and feeding them, and some feeds have been tested to study how the nutritional composition of mackerel muscle is affected by feed and feeding regimens as well as how shelf-life and nutrient content are affected if the mackerel are frozen and stored for up to 6 months. Feeding small mackerel caught in early autumn (pir), the fat content of the mackerel muscle increases steadily from 6.5% at catch in September to 22% in June the following year. In large mackerel, fat can account for as much as 30%of the muscle wet weight.

The fat in cage fed mackerel reflected the fatty acid profile in the feed and showed an EPA content of approximately 7% and a DHA content of approximately 15% of the total fat in the muscle. That is, a portion (200 grams) of lean (6.5% fat) mackerel provides 2.9 grams of EPA and DHA fatty acids, whereas a portion of cage fed mackerel (22% fat) provides 9.7 grams of EPA and DHA fatty acids. The mackerel showed a storage resiliency at -30°C for 6 months without the fish turning rancid. (The TBARs were 6.1 µmol/kg at the start and 5.4 µmol/kg after 6 months of storage.) The vitamin E content can be increased in the muscle of mackerel by increasing the level of vitamin E in the feed (Hemre *et al.,* 1997).

6.5 The effect of starving fish on the nutritional composition

Before farmed fish is slaughtered for sale, regulations require that the fish be starved for a maximum of one to two weeks in order to empty the intestines. Prior to the introduction of feed quotas in 1996, the entire aquaculture industry was required to implement a longer starvation period to reduce the biomass in the net pens. During that period, a group of researchers from NIFES and the Institute of Marine Research monitored the salmon and arrived at the following conclusion: The composition of primary nutrients showed a lower fat content (and a higher water content) in the muscle of fish that had been starved. The fat loss equalled approximately 2% when the starvation period lasted 78 days (Lie & Huse, 1992), but the fatty acid composition in the muscle did not change. The vitamin status (riboflavin, folic acid, vitamins C, A and E in the muscle) was not significantly affected after after 12 weeks of starvation.

6.6 Use of genetically modified raw materials

Due to the high price and reduced availability of fish meal and fish oil that are the classic ingredients in feed for farmed fish, higher amounts of vegetable protein and vegetable oil sources are being used today. The most commonly used vegetable protein sources are soy, corn and rape seed. A large portion of the volume of these plants sold on the marked has been genetically modified (GM). What happens if genetically modified raw ingredients are added to salmon feed? Some consumer studies show that fish that have eaten genetically modified feed are perceived to be the same as transgenic fish. But will fish that have eaten GM feed contain the transgenic sequences or will the GM feed in any way alter the final edible product?

Genetically modified ingredients are not currently used in fish feed in Norway because their effects on the fish or on the consumers who might eat GM-fed fish are not known. Recent monitoring programmes indicate that Norwegian fish feed does not contain intentionally added transgenic sequences nor does it contain the nationally banned antibiotic-resistant marker genes.

Research has shown that after the feed production process, rather large, intact transgenic sequences may be found if genetically modified raw ingredients have been used. Fairly large, intact transgenic sequences are also found throughout the entire intestinal tract in salmon that have eaten GM feed (Sanden, 2004). Trout that have eaten transgenic soy absorb fragments of transgenetic sequences in the intestinal cells, but the fragments disappear from the cells within 24 hours. Other organs were not investigated in the studies on trout (Chainark *et al.,* 2004). Recently published data show that salmon absorbs feed-DNA in the blood, liver and kidneys. The highest levels were measured eight hours after feeding, and the organs were not free of the feed-DNA even 64 hours after feeding (Nielsen *et al.,* 2005). The study did not analyse muscle or conduct tests beyond 64 hours. Consequently, there is no guarantee that a person who eats this salmon will not consume transgenic sequences. More studies are needed to clarify this. Salmon is readily able to utilise or grow on feed containing GM ingredients, even though certain changes have been documented in their immune response and in the intenstine.

6.7 Genetically modified fish species

Genetically modified fish and bivalves are not produced in Norway. Only small amouts of GM species are sold today. These are to be found in markets far from Norway, and are therefore not regarded as significant for the health of the Norwegian seafood consumer.

6.8 Contaminants in feed for farmed fish

Feed is the main source of a number of contaminants in farmed fish that are relevant for human health (cf. Chapter 5). As a general rule, the water is a much less important source of these substances. As a result of several food scandals, all of which have arisen from feed sources, e.g. BSE in cattle and dioxins in chicken, increasing focus is now placed on feed and the contaminants feed may contain. Risk assessments of undesirable compounds in feed have recently been conducted for some compounds, and many others are currently being assessed (EFSA 2004c,d,e,f and EFSA 2005b,c).

6.8.1 Metallic compounds (Cd, Hg, Pb, As) representing potential health hazards

The transfer of metals to the edible portion of fish depends on the chemical form in which the metals are found. Contamination of feed with cadmium or lead is most likely to occur in an inorganic salt form.

A monitoring programme in 2004 showed that the concentration of cadmium in salmon feed was more than 100 times the cadmium content in salmon fillet (Måge *et al.,* 2005). The concentration of cadmium in feed varied from 0.04 to 0.36 mg/kg in 2002, from 0.09 to 0.60 mg/kg in 2003, and from 0.1 to 0.54 with a mean value of 0.21 mg/kg in 2004 (Måge *et al.,* 2005, Julshamn *et al.,* 2004a). The EU's upper limit for cadmium in feed is 0.5 mg/kg. Research has shown that the uptake of cadmium in feed by salmon is low (2 to 6%) in muscle. Few studies have been conducted of the effects of lead in fish feed, but it has been shown that the transfer of lead from feed to fish muscle is also low. The level of lead in fish feed varied between 0.04 and 0.13 mg/kg in 2003 (Julshamn *et al.,* 2004a), and between <0.04 and 0.3 mg/kg in 2004, with an average of 0.06 mg/kg (Måge *et al.,* 2005).

Industrial fish (e.g. blue whiting and Norway pout) used as marine feed ingredients are naturally high in mercury and arsenic in particular. Both mercury and arsenic are found primarily in organic form (75 to 95%), specifically methyl mercury and arsenic betaine. Although arsenic betaine poses little health risk (Amlund *et al.,* 2004, Sloth *et al.,* 2005a), methyl mercury is a potential health hazard (see Chapter 5). The assimilation of methyl mercury and arsenic betaine from feed to salmon is relatively high (23 to 41%), and the muscle is an important organ for storage (Berntssen *et al.,* 2004a, Amlund *et al.,* 2004). The total mercury content in commercial fish feed varied from 0.04 mg/kg to 0.1 mg/kg in 2003 (Julshamn *et al.,* 2004a) and from 0.04 mg/kg to 0.15 mg/kg in 2004 (Måge *et al.,* 2005). The upper limit for mercury in feed is 0.1 mg/kg. The total arsenic content in fish feed varied from approximately 3 mg/kg to approximately 8 mg/kg in 2003 (Julshamn *et al.,* 2004a) and from approximately 4 mg/kg to 11 mg/kg in 2004 (Måge *et al.,* 2005), whereas the upper limit for total arsenic in fish feed is 6 mg/kg (88% dry matter). It is the inorganic arsenic in fish feed and seafood that is of concern for human health (EFSA, 2005a). The levels of inorganic arsenic have been shown to be low in marine feed ingredients (Sloth *et al.,* 2005a).

6.8.2 Fluoride in the marine food chain - possible raw ingredients for use in fish feed

There is limited information in the scientific literature on the tolerance of fish to the intake of high concentrations of fluoride, but studies on rainbow trout (*Onchorynchus mykiss*) show a relatively high tolerance to high fluoride concentrations in feed (> 2 500 mg/kg for 82 days) (Tiews *et al.,* 1982).

It is possible to use krill as a raw ingredient in Norwegian fish feed, but krill may have fluoride concentrations that limit its potential. Julshamn et al. gave salmon (*Salmo salar*) a feed containing up to 40% krill meal (i.e. fluoride concentrations up to 360 mg/kg) and found no negative effects on growth, feed utilisation, health or the retention of fluoride in the bones, muscle or entire body of the salmon. Unpublished results from a study in which salmon, cod and halibut were given feed containing different proportions of protein in the form of krill meal (from 0 to 100%) confirmed the results from Julshamn et al., 2004, even with very high supplements of krill (Olsen & Moren, 2005 - unpublished data). The fluoride content is high in several marine nektons that have the potential for use as raw ingredients in fish feed. These species constitute an important part of the natural diet of wild fish (Grønvik & Klemetsen, 1987).

6.8.3 Organic compounds that are potential health hazards

6.8.3.1 Dioxins and dioxin-like PCBs

Concentrations of dioxins and dioxin-like PCBs in fish feed are shown in Table 14. The levels in feed depend mostly on the amounts of different fat sources used and the level of PCBs and dioxins in these oils. Data published by the EU (SCAN, 2000) show that fish meal and fish oil produced in Europe contain higher levels of PCDD/Fs and dioxin-like PCBs than fish meal and fish oil from the southern Pacific regions. In feed for omnivorous fish, marine feed ingredients accounted for about 55% of the total of PCDD/Fs and dioxin-like PCBs, while marine feed ingredients accounted for as much as 98% of these substances in the feed for carnivorous fish. Salmon, cod and halibut are all considered carnivorous fish.

Table 14. Overall content of PCDD/Fs, dioxin-like PCBs and total TE (pg TE/g wet weight) in fish feed and fish oil in 2004.

Product	Σ PCDD/F (pg TE/g)	Σ dl-PCB (pg TE/g)	Total Σ (pg TE/g)
Fish oil (n=6) (2004)			
Average	2.7	4.6	7.3
Min.-max.	0.26 – 5.2	1.7-6.7	2.0-12
Vegetable oil (n=5) 2004			
Average	0.17	0.17	0.34
Min.-max.	0.09-0.43	0.02-0.63	0.12-1.1
Fish feed (n=48) (2004)			
Average	0.74	1.9	2.6
Min.-max.	0.16-2.1	0.32-5.1	0.46-7.2

For both salmon and trout, the transfer of dioxin-like PCBs from feed is higher (80 to 90%) than the transfer of PCDD/Fs (40-65%) (Isosaari *et al.,* 2002, 2004, Lundebye *et al.,* 2004, Berntssen *et al.,* 2005). Tetrachlorinated and pentachlorinated congeners are accumulated more effectively than heptachlorinated and octachlorinated dibenzo-p-dioxins. The selective transfer of PCDD/Fs and dioxin-like PCB congeners results in a congener pattern in fish that is different from the feed. An estimate based on different assumed transfer models shows that even with a transfer rate of 80% the, total PCDD/F level are expected to be approximately 50% of the current upper limit established by the EU for fish, i.e. 4 pg TE/g (Commission Regulation (EC) No. 466/2001).

6.8.3.2 Brominated flame retardants (polybrominated diphenyls)

Little information is available on brominated flame retardants (PBDEs) contamination of fish feed. Table 15 shows PBDEs in fish feed and fish oil. The average level of PBDEs was higher in fish oil than in compound feed, and fish oil is the most important source of PBDEs in feed. Vegetable oils had very low PBDE concentrations (data not shown) (Måge *et al.,* 2005).

Table 15. Content of *PBDE (µg/kg) in feed samples from 2003 and 2004 and fish oil samples from 2004 (Måge *et al.,* 2005).

PBDE	Feed (2004) (n=10)	Feed (2003) (n=22)	Fish oil (2004) (n=6)
µg/kg			
Average*	3.0	2.7	5.1
Min.-max.	0.55 – 9.0	0.64-7.9	1.1 – 8.5

*Average of the sum of 6 PBDE congeners (28, 47, 99, 100, 153, 154)

The PBDE concentration in fish organs reflects the concentration of these substances in the feed (Isosaari *et al.,* 2005). The retention efficiency for PBDEs has been documented in studies of Atlantic salmon (Isosaari *et al.,* 2005), zebra fish (Andersson *et al.,* 1999), carp (Stapleton *et al.,* 2002, 2004a,b), pike (Burreau *et al.,* 1977, 2000), rainbow trout (Kierkegaard *et al.,* 1999) and mountain trout (Tomy *et al.,* 2004b). The studies show a variation in the retention efficiency from less than 0.02 to 5.2% for BDE 209 (Kierkegaard *et al.,* 1999, Stapleton *et al.,* 2002) to over 90% for BDE 47 (Burreau *et al.,* 1997, 2000, Stapleton *et al.,* 2004b). Atlantic salmon were found to accumulate PBDEs from the feed just as effectively as non-ortho PCBs and more effectively than other PCB forms and PCDD/Fs (Isosaari *et al.,* 2004). The selective transfer of certain PBDE congeners results in a congener pattern in fish that is different from the feed (Isosaari *et al.,* 2005).

6.8.3.3 Other organic contaminants

In recent years, information has become available about numerous other organic contaminants that may accumulate in the marine food chains (see Sections 5.3.2.4 and 5.3.2.5). Because these compounds have only recently been identified in marine organisms, however, their potential to bioaccumulate is not known. There is little data on the levels of these compounds in fish feed and farmed fish, but if the substances are present in fish feed, it may be expected that they will also be transferred to farmed fish due to their physical and chemical properties.

6.8.3.4 Reducing persistent organic contaminants in farmed salmon

For the species of fish farmed in Norway that are given energy dense feed (such as salmon), fish oil is the main source of the fat-soluble persistent organic contaminants (Isosaari *et al.,* 2002, 2004, Lundebye *et al.,* 2004). There are three strategies that can be used separately or in combination to reduce and control the present levels of dioxins and dioxin-like PCBs (and other persistent organic contaminants) in fish feed and thus in farmed salmon:

a) Selective use of marine ingredients with relatively low levels of organic contaminants in the feed;
b) Use of alternative, non-marine ingredients with naturally low levels of organic contaminants in the feed;
c) Elimination of undesirable compounds from marine ingredients.

Selective use of fish oil containing naturally low concentrations of dioxins can reduce the level of dioxins in feed as well as in fish fillet, but has less effect on the level of dioxin-like PCBs (Lundebye *et al.,* 2004, Isosaari *et al.,* 2004). The use of plant oils instead of marine oils reduces the levels of dioxins, dioxin-like PCBs and PBDEs in feed and fish (Bell *et al.,* 2004, Berntssen *et al.,* 2005), but this also reduces the level of health-promoting nutrients, such as marine n-3 fatty acids, in salmon fillet (Berntssen *et al.,* 2005). A number of physical-chemical refining methods can be used to remove fat-soluble contaminants such as dioxins, dioxin-like PCBs and brominated flame retardants from marine oils. Several methods exist that can potentially be used for this purpose (e.g. activated carbon, steam distillation and short path distillation) (Breivik & Thorstad, 2004, deKock *et al.,* 2004). Activated carbon effectively removes dioxins from fish oil, but is less effective in removing dioxin-like PCBs. Activated carbon does not remove PBDEs from fish oil. Short path distillation is, however, an effective method of removing dioxins, dioxin-like PCBs and PBDEs from oils. This process does not significantly reduce the level of vitamins in the oil unless extreme processing conditions are used (Berntssen *et al.,* 2004b, Otherhals *et al.,* 2005). When oil is refined for direct human consumption, techniques (e.g. molecular distillation) are used that affect the level of fat-soluble vitamins and the fatty acid profile. Removal of the contaminants mentioned here from fish meal requires totally different methods, which are based primarily on the removal of fat. These methods do not affect the fatty acid profile or vitamin content of the oils.

Table 16. Level of dioxins, dioxin-like PCBs (pg TE/g wet weight) and PBDEs (pg/g) in feed and in the muscle of salmon given feed based on oil from fish from the Pacific Ocean, oil from fish from the Baltic Sea, vegetable oil (VO) or fish oil (FO) for a 30-week feeding period or throughout the entire life cycle (Lundebye *et al.,* 2004, Isosaari *et al.,* 2005, Berntssen *et al.,* 2005 - unpublished data).

	Pacific fish oil	Baltic fish oil	100% VO	100% FO
Feed				
Dioxins	0.7	4.9	0.3	2.2
Dioxin-like PCBs	2.8	5.4	0.1	2.7
PBDE	190	16000	320	6417
Fish muscle				
Dioxin	0.5	1.9	0.1	0.7
Dioxin-like PCBs	1.8	3.2	0.2	1.2
PBDE	3020	4620	460	4100

PBDE congeners measured in salmon given feed based on Pacific and Baltic fish oil are the sum of PBDE 28, 47, 66, 71, 75, 77, 85, 99, 100, 119, 138, 153, 154, 183 and 190; congeners measured in salmon feed with 100% VO and100% FO are the sum of PBDE 28, 47, 99, 100, 153 and 154.

6.8.4 Pesticides

Pesticides are a large, heterogeneous group of chemical substances used to prevent molds, weeds, insects and other pests. The pesticides found in animal feed and food that receive most attention are those with a long decomposition time, especially the ones that are chlorinated. Many of these substances went out of use several decades ago, but can still be found in the environment. As a general rule, they are relatively fat-soluble and therefore pose a particular problem in fish feed containing high amounts of fat. The substances are also retained in the fat deposits of fish. Upper limits have been established for aldrin, dieldrin, toxaphen, chlordane, DDT, endosulphane, endrin, heptachlor, hexachlorobenzene (HCB), and hexachlorocyclohexan (HCH) in feed.

In general, there is not sufficient data to assess the transfer of pesticides from feed to fish, but some data are available from samples taken in monitoring programmes. Levels of hexachlorobenzene (HCB) in salmon fillet have been measured for several years. The values have varied from 0.7 to 4.8 µg/kg wet weight with an average of 2.1 µg/kg in 2003 and from 0.8 to 3.4 µg/kg with an average of 1.9 µg/kg wet weight in 2002. DDT has also been measured in salmon muscle in monitoring programmes for several years.

6.8.5 Pharmaceuticals

The two most important groups of pharmaceuticals used to combat disease in farmed fish are antibacterial agents and agents to prevent salmon lice. Pharmaceuticals are also used to prevent intestinal worm and fungus, and anaesthetics are used, especially when vaccinating fish and in other situations to ensure good animal welfare.

6.8.5.1 Monitoring the use of pharmaceuticals - residue control

Since 1 January 1989, veterinarians have been required to send copies of all prescriptions for pharmaceuticals used on farmed fish to the control authorities (Bangen *et al.,* 1994). Information from the prescriptions, such as the type of pharmaceutical and the amount, is entered into a database, which is used to prepare prescription-based statistics on consumption. Sales of pharmaceuticals used on farmed fish have been recorded since the mid-1980s (Grave *et al.,* 1991, 1996, 2002, Lunestad & Grave 2005). The prescription data have continuously been validated in relation to sales data, and there is good correlation between them (Bangen *et al.,* 1994, Grave *et al.,* 2002, Lunestad & Grave, 2005). Monitoring data also show that only legal veterinary preparations are used on farmed fish.

This means that the substances have been assessed by the European Medicinal Evaluation Agency (EMEA) with regard to risk to human health, including potential allergenic effects. This assessment also includes vaccines given to fish.

Since 1989, the inspection authorities have used data from the prescription database to conduct risk-based residue controls of farmed fish (Bangen *et al.,* 1994, Lunestad og Grave, 2005). Prohibited substances have also been investigated in accordance with Directive 96/23 EF. Residues of pharmaceuticals exceeding the limits allowed for legal substances (Maximum Residue Limit = MRL) or residues of prohibited substances in Norwegian farmed fish have not been found (Lunestad & Grave, 2005).

6.8.5.2 Use of pharmaceuticals in aquaculture

Since the mid-1990s, the annual use of antibacterial agents for farmed fish has been equivalent to a 10-day regimen of antibiotics administered to approximately 1% of the biomass of farmed fish (Grave *et al.,* 2004). In 2004, sales figures for agents used to combat intestinal worms were equivalent to a regimen of anthelminticum administered to approximately 7-8% of the biomass of farmed salmon and trout (Kari Grave - unpublished data). This indicates that the transfer of pharmaceuticals from aquaculture facilities to the surrounding environment will be limited.

6.8.5.3 Pharmaceuticals in the environment

Pharmaceuticals are administered either by immersion treatment or through feed. Substances given via the feed, will in metabolised or unmetabolised form, find its way to the sea water or bottom sediment through urine and excrement. Feed not eaten by the fish will either sink to the bottom or be eaten by wild fish. During immersion treatments, a tarp or bag is used around the nets so that the concentration of pharmaceuticals is maintained throughout the treatment period. After the treatment is completed, the pharmaceuticals will be drained into the water around the nets and be diluted. The current requirements regarding the location of aquaculture facilities, including requirements related to water flow, contribute to the dilution of pharmaceutical residues in the environment which occurs from treating fish with pharmaceuticals.

Most antibacterial agents that have been used, or are currently in use, by the aquaculture industry show little or no chemical or microbiological decomposition in marine sediments (Samuelsen *et al.,* 1994). The pharmaceuticals 'disappear' from the sediment through diffusion to the water mass (Smith & Samuelsen 1996). Since the early 1990s, the type of location chosen for aquaculture facilities has changed, with preference now being given to areas with deeper water and faster water replacement. This change, along with the decreased use of antibacterial agents on farmed fish, means that it is less likely that documentable amounts of these agents will be found in the sediment and water mass around the facilities, in contrast to the situation in the mid-1980s and early 1990s when use of antibacterial agents was considerably higher than today.

It has been shown that residues of antibacterial agents in sediment beneath the aquaculture facilities can lead to the development of resistance in the bacteria found there (Hansen *et al.,* 1992). The bacteria may be transferred to farmed fish or wild fish, and in theory these bacteria may be seen to present a health risk to the public, either directly or by the bacteria exchanging genetic material that codes for resistance to antibiotics. Since it is not currently likely that detectable amounts of antibacterial agents will be found beneath the facilities, the risk of increased frequency of resistant bacteria is also limited.

6.8.5.4 Residues of pharmaceuticals in wild fish

Due to the risk of an increase in antibiotic-resistant bacteria and resistance genes, and the health risk related to residues of antibacterial agents in fish used for consumption, special focus has been directed toward the use of antibacterial agents in aquaculture and the presence of these substances in wild fish. Several studies have documented residues of antibacterial agents in wild fish, crustaceans and bivalves near aquaculture facilities where antibacterial treatments are conducted. Ervik et al. (1994) found residues of oxolin acid and flumequin in the musculature of fish caught in the vicinity of six different aquaculture facilities immediately following the completion of an antibiotic treatment. From 74 to 100% of the fish contained pharmaceutical residues, and the mean value varied from 0.95 to 4.89 µg/grams. Samuelsen et al. (1992) studied the concentration of oxolin acid in the muscle and liver of wild fish, including saithe and mackerel caught near two aquaculture facilities on the last day of the treatment. The mean value of oxilin acid in all positive tests from the muscle was 4.38 µg/grams and 0.42 µg/grams, respectively.

Coyne et al. (1997) tested 15 samples of mussels gathered beneath an aquaculture facility and 20 metres away from the facility during and after farmed salmon were treated with oxytetracycline. In mussels taken directly beneath the facility, 10.2 µg/grams of oxytetracycline were found, but in mussels taken 20 metres from the facilities no residues of oxytetracycline were found. Capone et al. (1996) found only traces of oxytetracycline (0.1 µg/grams) in oysters and one species of crab gathered beneath an aquaculture facility during and after treatment of the fish, but half of the samples of a different species of crab were found to have levels of oxytetracycline between 0.8 and 3.8 µg/grams.

Farmed fish which escape while being treated with pharmaceuticals via feed could represent a residue problem for consumers. If these fish are eaten, residues of antibacterial agents above the MRL values might be found in the food. Since pharmaceuticals are administered to farmed fish only sporadically, it is however, unlikely that escaped farmed fish treated with pharmaceuticals and containing residues of antibacterial agents over the upper MRL values would be caught.

Very few antibacterial agents are used by the Norwegian aquaculture industry today. Moreover, pursuant to §15 of Act No. 68 of 14 June 1985 relating to aquaculture, it is prohibited to fish closer than 100 metres from an aquaculture facility or to come closer than 20 metres. As a result, it is unlikely that the use of antibacterial agents in farmed fish presents a risk to human health in terms of antibiotic residues or resistant bacteria in wild fish. However, any use of antibiotic agents in the treatment of farmed fish constitutes a risk associated with the development of resistant bacteria in these fish, and these bacteria may in turn become a source of resistance genes to human bacteria. It is therefore important to keep the use of antibacterial agents, including use on farmed fish, at an absolute minimum. There are indications that the use of antibacterial agents on farmed cod is increasing, and this is a trend that must be reversed.

6.8.5.5 Summary of pharmaceuticals

In Norway, only approved pharmaceuticals are prescribed for farmed fish. Residues of pharmaceuticals exceeding the MRLs and residues of banned pharmaceuticals have so far not been documented in Norwegian farmed fish sold for consumption.

It is also unlikely that wild fish will contain pharmaceutical residues above MRLs since pharmaceuticals are only used in limited quantities by aquaculture facilities and those that are used are diluted in the water mass. For the same reason, the risk is small that antibiotic-resistant bacteria will develop as a result of the use of antibacterial agents on farmed fish. It is important to keep the use of antibacterial agents for farmed fish at an absolute minimum. This is also the case for newer types of production, such as cod farming. Farmed fish which escapes during treatment and which is caught before potential pharmaceutical residues fall below the MRLs could present a residue problem for consumers. However, since pharmaceuticals are only sporadically used on farmed fish, it is unlikely that escaped farmed fish treated with pharmaceuticals and containing residues of antibacterial agents over the upper MRL values would be caught.

6.8.6 Mycotoxins (mould toxins)

Mould is able to grow with only limited access to open water, and some moulds can grow in conditions with a water potential (a_w) as low as 0.60. This means that mould can grow in relatively dry products and in products with added salt. Mycotoxins can be produced by mould on plants in the field, in raw ingredients for feed and food production, and in feed and food that is improperly stored. The stability of mycotoxins varies, but many are unaffected by boiling and other normal heat treatments. It has been documented that vegetable ingredients, especially maize, present a greater problem than comparable animal ingredients (Moss, 2002).

Three genuses of mould are of special interest as producers of mycotoxins in animal feed and food. These are the storage moulds *Aspergillus* and *Penicillium* and the field mould *Fusarium.* Within the genus *Aspergillus*, there are several species that produce aflatoxins which are among the most widely studied mycotoxins and have been documented in several varieties. Aflatoxins are known to be the cause of large-scale outbreaks of disease in livestock and humans following the intake of contaminated feed or food (Jay, 1992, Moss, 2002, Magan & Olsen, 2004). The toxin-producing species in the genus *Aspergillus* have a wide geographic distribution, but because they achieve optimal growth at 35 to 37 ºC, they create problems primarily in warm climatic conditions. Afloxtin is regarded as one of the most important contaminants in dry vegetable products but there are a number of other toxins that can be considered significant for fish, livestock and humans.

Mycotoxins from the genus *Penicillium* are produced under climatic conditions prevalent in Norway, and improperly stored food and feed products may constitute a considerable health risk. Fusarium mycotoxins, such as trichothecenes in grain and fumonisins in maize, may also have negative health effects on humans and animals. Little is known about the presence of mycotoxins in fish feed or about the effects of mycotoxins and their potential for accumulating in fish and being transferred to humans. Also, very little documentation is available about how these factors may affect food safety. Compared with animal feed, fish feed contains a small proportion of vegetable ingredients. For this reason, fish are probably less vulnerable to exposure to some classes of mycotoxins. Due to limited availability of marine ingredients for feed, it will be necessary to use a larger proportion of vegetable ingredients in fish feed. This may present new challenges related to mycotoxins in farmed fish.

6.9 Summary of farmed fish as food - the significance of feed for nutrients and contaminants

Research shows that the levels of nutrients and contaminants in salmon can be controlled through selection of raw ingredients for feed and the composition of feed. Differences in retention result in different nutritional and contaminant patterns fish from what is found in feed with regard to nutrients. It is possible to influence the fatty acid profiles of fish fillet and salmon can be fortified with fat-soluble vitamins (vitamins D and E) and some minerals, depending on their bioavailability from the feed. Fish can be a good source of water-soluble vitamins (vitamin B_{12}) and trace elements (selenium and iodine). The amounts of these nutrients found in farmed fish depend on the level and the form in which they are present in the feed.

Feed for farmed fish is also a source of undesirable compounds in the fillet, but the absorption and retention vary a great deal depending on the type of contaminant. This results in different contaminant patterns for feed and fish. As regards organic contaminants, several strategies are available for controlling and reducing the levels of compounds potentially hazardous to health in farmed salmon. When choosing a strategy, it is important to ensure that the nutritional properties of the fish are maintained. It is possible to control the level of contaminants in farmed fish, but not in wild fish. Pharmaceuticals used as in aquaculture are well-regulated and controlled, and they do not represent a problem for food safety.

7 Health effects associated with fish consumption – epidemiological studies

Traditionally, fish has been regarded a healthy food. Nutritional authorities have promoted increased consumption, particularly of fatty fish due to the content of n-3 fatty acids, based on the assumed beneficial effect on the risk of contracting cardiovascular disease. In the past two years, this issue has been thoroughly investigated by the Scientific Advisory Committee on Nutrition (SCAN) and the committee on Toxicology (COT) in the UK (SACN/COT, 2004) as well as by the Danish Veterinary and Food Administration (2003). This chapter is based on these reports and summarises them in addition to this other scientific studies that have appeared after the SACN/COT report are considered. As regards a potential correlation between fish consumption and cancer, a separate study of the existing epidemiological literature has been conducted since cancer has not been discussed in any great detail in any of the reports mentioned above.

The following section covers cardiovascular disease, cancer, conditions during pregnancy and infancy as well as allergies.

7.1 Epidemiological studies –comments on methodology

Since fish constitutes a considerable proportion of the Norwegian diet, this chapter provides an overview of the studies that have been conducted on humans and the relationship of fish consumption and health. The chapter is based mainly on epidemiological studies, i.e. observational studies that assess the correlation between consumption of fish and state of health. The studies are based either on questionnaire data, on measurements of blood samples using long-chained n-3 fatty acids as a biomarker, or on clinical studies with fish or, more commonly, purified fish oils. The following section will primarily discuss the results of prospective studies. Prospective studies (also called cohort studies) are studies in which the behaviour of healthy persons (here, as regards the consumption of fish) is recorded. The same individuals are followed up with respect to the occurrence of new diseases to determine whether there is any correlation between behaviour and the frequency of the disease. In cohort studies, information on fish consumption is compiled before it is known whether the subjects will contract the disease or not. The dietary data from the subjects included in the study will therefore not be influenced by any subsequent illness. This type of study possesses good internal validity, and systematic errors (bias) are less likely to occur concerning the individuals included in the study or in the information provided (selection bias and information bias).

Case-control studies are epidemiological studies in which patients who have a disease ('cases') are questioned about their habits. The frequency of a certain habit in the group having the disease is compared with the habits in a group of individuals without the disease ('controls'). Although there are numerous case-control studies, they are largely constrained by possible systematic errors. The most frequently mentioned is 'recall bias', which occurs when patients recall their diet differently from the controls.

The epidemiological study design that ensures the greatest degree of reliability is the controlled clinical study. In some fields, controlled clinical studies are conducted in which subjects are given various types of treatment by randomisation, i.e. by drawing lots, without their knowing whether they have received any special kind of treatment. Randomisation safeguards the study to a greater degree against possible sources of errors. Controlled clinical studies are therefore often designated as 'the gold standard' that other studies are measured against. It is difficult to conduct controlled studies in which changes in diet constitute the treatment. Normally, the experiments are based on the consumption of fish oils as compared with other oils.

Both in prospective studies and in case-control studies, the results may be affected by confounding. Confounding arises when the result observed is wholly or partly a consequence of one or several variables not connected with the exposure (e.g. fish consumption) and the disease (e.g. coronary heart disease). An example of this may be a prospective study of more than 40 000 women in the US who were followed up over a period of 15 years. No correlation was found between how often the women ate fish and overall mortality, cardiovascular mortality or coronary heart disease mortality when adjusted for a number of possibly confounding variables such as the level of education, physical activity, alcohol and smoking habits, use of oestrogen, body mass index, high blood pressure and diet (Folsom & Demissie, 2004). However, when adjusted for age and energy intake alone, there were significant inverse relationships for all three endpoints. This may indicate that the correlation between consumption and fish was confounded, i.e. that women who ate a lot of fish generally had healthy, heart-friendly habits.

Nonetheless, the fact that no correlation between fish consumption and coronary heart disease was established in this study does not mean that such a correlation does not exist. Epidemiological studies are far more complicated than studies of cells or animals in which experimental conditions can be strictly controlled. Confounding can also weaken a relationship between the intake of n-3-fatty acids and disease so that it appears to be weaker than it is in reality. In one study, the relationship between the DHA content of the fatty tissues (reflecting the intake of n-3 fatty acids) and the risk of coronary heart disease was strengthened when adjusted for the content of mercury in the toe nails (which may also reflect fish consumption) (Guallar, *et al.,* 2002). There may also be interactions which lead to the result that the relationship between the exposure and the disease is detected only if the level of other risk factors is high or low. For example, a Finnish study established that a high intake of fish fat (reflected in a relatively high concentration of DHA and DPA in serum) gave protection against coronary heart disease only among subjects (in this study) who had a relatively small amount of mercury in their hair (Virtanen *et al.,* 2005).

Furthermore, the result may be caused by, for example, random, statistical variation. Even if there should be a 50% higher risk of disease if fish consumption is low, some studies will conclude that there is no significant relationship. Another explanation for why the correlations do not appear to be stronger may be linked to the difficulty of measuring fish consumption accurately (cf. Section 7.2), thus weakening the statistical correlations.

It must also be taken into account that the correlation between fish consumption and disease is not necessarily linear. With regard to fish, the most likely explanation is that there is a threshold over which increased intake is not accompanied by enhanced health benefits. For example, high fish consumption did not affect overall mortality and cardiovascular mortality in a Japanese cohort study (Nakamura, *et al*., 2005). The explanation given by the authors is that the consumption was so high (only 3% ate fish less than once a week) that the majority had a sufficiently high intake.

In addition, it may be that only one type of fish (such as the fish that is the source of the n-3 fatty acids) or a sub-group of diseases (e.g. fatal coronary heart disease) are relevant with respect to exposure and disease group, respectively (cf. Section 7.3.1). Only in large studies and meta-analyses can such relatively weak correlations be shown as statistically significant. Therefore, conclusions as to whether high fish consumption gives protection against e.g. coronary heart disease or cancer can only be reached after many studies with different designs have been assessed (cf. Sections 7.3 and 7.4).

As regards the application of the epidemiological results in preventive medicine, it should also be taken into account that since cardiovascular disease and cancer are common diseases, a moderate increase in fish consumption may result in a considerable reduction in the number of new cases even if the relationship between fish consumption and disease may be weak from an epidemiological standpoint. If only 4% of the coronary heart disease mortality in Norway could be prevented by increasing fish consumption by one meal of fish per week, this would represent a reduction of 300 deaths per year.

7.2 Fish as exposure – difficult to measure?

The majority of studies are characterised by an oversimplified use of fish consumption as a measure of exposure, perhaps because most studies are conducted in countries where fish consumption is low, such as the USA and the UK. In most cohort studies, the analyses are carried out on the basis of 'grams of fish per time unit'. The distinction between fatty and lean fish is not always made, even though doing so is absolutely essential. In general, different fish species contain different types of nutrients – n-3 fatty acids, fat-soluble vitamins (A, D, E), trace elements (selenium, iodine etc.) as well as other biologically active substances such as free amino acids (taurine). For many years, the focus of research was directed at the possible protective effect of n-3 fatty acids on cardiovascular disease, and this has meant that other potentially significant vitamins and minerals have been overshadowed.

It is difficult to compare studies from different countries because fish consumption in most countries is largely characterised by locally produced fish. The relationship between lean and fatty fish will therefore vary from country to country as well as within a country (Welsch *et al.,* 2002). The latter is true of Norway in that the coastal population have a high consumption of lean fish, while the consumption of fatty fish is almost the same throughout the country (Engeset *et al.,* 2005). Many studies have only asked about the frequency (how often fish is eaten) and a standard portion is assumed. Along with the low fish consumption by many populations, this results in an appreciable lack of variation in exposure. This is considered to be one of the main methodological problems in all dietary research.

The exposure to white meat, i.e. fish and chicken, is combined in a number of studies. To some extent fish and chicken have a very different nutritional content. At best, such analyses can only consider the effect of certain amino acids or proteins. Moreover, it is evident that an effect found to be associated with increased fish consumption may be due to the same individuals eating less of other types of food. Someone who has eaten fish for dinner four times in the course of the week cannot have eaten meat for dinner five times a week. The mutual dependence among dietary components is difficult to analyse because it requires stratification of the analyses, further reducing the statistical strength. One method of solving such problems is to establish a ratio for the consumption of red meat in relation to the consumption of white meat (fish and chicken).

Storage and preparation are factors not usually taken into consideration. In Norway, fish is normally prepared by boiling, while the methods used to prepare fish vary in other countries. This applies in particular to fatty fish. Many countries have strong traditions of salting and smoking fatty fish.

Little is known about the effect of processing fish on the nutritional content. Some research indicates that the nutritional content is somewhat reduced by modern production methods. In addition, seasonal variations are included in only a few studies. The fat content can vary considerably throughout the year, e.g. in herring, and to some extent a considerable amount of fish is only eaten in certain seasons of the year. This makes it more difficult to estimate the intake correctly.

Finally, it can be difficult to distinguish between the effect of contaminants such as organic contaminants and mercury, and the effects of the fish consumption itself.

7.3 Cardiovascular disease

Cardiovascular disease encompasses several disease groups, the largest of which are coronary heart disease and stroke with 7 300 and 4 000 deaths, respectively, in Norway in 2003. For several decades, mortality due to stroke has shown a declining trend while mortality due to coronary heart disease reached a peak in the 1970s and has fallen sharply since. According to Statistics Norway, such a low mortality rate for cardiovascular disease among Norwegian men under the age of 70 and Norwegian women under the age of 80 has not been recorded in the past hundred years. The figures for the oldest age groups in 2003 are the lowest since World War II. Nonetheless, cardiovascular diseases remain the leading cause of death in Norway - with a total of 16 600 deaths in 2003 (approximately 40% of the deaths).

The term stroke includes several kinds of diseases that affect the blood vessels in the brain and that can resemble each other clinically. The two most important are cerebral infarction and cerebral haemorrhage, and the great majority of strokes recorded in Norway are cerebral infarctions. The risk factors for these are similar to coronary heart disease (high blood cholesterol, high blood pressure and smoking), while cerebral haemorrhages are more often caused by high blood pressure. In this connection an increased tendency toward haemorrhaging is detrimental as well.

7.3.1 Fish consumption and the risk of cardiovascular disease

Recently, He et al. (2004b) summarised prospective studies of the correlation between fish consumption and coronary heart disease mortality. Their conclusion, based on the 13 cohort studies included, is that individuals who eat fish often (more than four times per week) have a 38% lower rate of coronary heart disease mortality than those who eat fish less than once a month; for each 20 grams increase in daily fish consumption, coronary heart disease mortality was reduced by 7%. König et al. (2005) recently conducted a quantitative analysis of the correlation between fish consumption and coronary mortality, with particular focus on whether there was a dose-response relationship. Small amounts of fish in the diet (the mere fact of eating fish) lowered the risk of coronary mortality by 17% compared with not eating fish. A further increase in consumption of one meal of fish per week diminished the risk by an additional 4%. The strength of the correlation is similar to that reported by He et al. (2004b). Whelton et al. (2004) carried out a similar meta-analysis that also incorporated case-control studies and concluded similarly.

It is noteworthy that no significant correlation was found between fish consumption and non-fatal coronary heart disease in studies that had provided data about this (He *et al.,* 2004b). For non-fatal coronary heart disease, the regression analysis carried out by König et al. (2005) suggested that there was not a simple dose-response curve. Eating fish was associated with a 25% reduction in the risk of non-fatal coronary heart disease, compared with those who did not eat fish, but increasing consumption did not necessarily result in greater protection. However, these findings may be interpreted as showing that increased consumption gives increased protection, at least at realistic intake levels.

However, the overall picture is not clear. In some studies, i.e. from the USA (Ascherio *et al.,*1995, (Folsom & Demissie, 2004), Finland (Salonen *et al.,* 1995) and Japan (Nakamura *et al.,* 2005), the findings do not show that increased fish consumption is correlated with a reduction in cardiovascular mortality and morbidity. Nor does a Norwegian follow-up study of 11 000 Norwegian men, 967 of whom died of coronary heart disease, reveal any relationship between fish consumption and coronary heart disease mortality, with the exception of in the group of young males (< 45 years old) in which an inverse correlation is suggested (Vollset *et al.,* 1985).

Less research has been conducted on the relationship between fish consumption and stroke than on the corresponding relationship with coronary heart disease. Recently, He et al. (2004a) conducted a meta-analysis of eight relevant cohort studies. All in all, people who ate fish every week or more often had a significantly lower risk of stroke than those who ate fish less than once a month; the risk was reduced by approximately 20% in individuals who ate fish 2 to 4 times a week. The analysis may give grounds for concluding that the protective effect is only present in the case of ischemic strokes. The same conclusion was reached in a prospective study of 626 incidents of stroke published in 2005 (Mozaffarian *et al.,* 2005a) in which a protective effect was only detected for the consumption of fish containing n-3 fatty acids. Bouzan et al. (2005) recently carried out a quantitative analysis of the correlation between fish consumption and the risk of a stroke with particular focus on whether there was a dose-response relationship. Small amounts of fish in the diet (the mere fact of eating fish) reduced the risk of stroke (both ischemic strokes and haemorrhages) by 12% compared with not eating fish. An additional increase in consumption did not diminish the risk further.

Data are also available from prospective studies which indicate that eating fish has a beneficial effect on the risk of sudden death (Albert *et al.,* 1998), as well as on atrial fibrillation (Mozaffarian *et al.,* 2004) and heart failure (Mozaffarian *et al.,* 2005b).

Several randomised clinical studies have been conducted in order to examine whether increased consumption of fish oils affects the risk of contracting a disease, in particular coronary heart disease (cf. Sestion 7.3.3). However, only one randomised clinical study referred to as the DART study (Burr *et al.,* 1989) has examined whether increased fish consumption affected the risk of contracting a coronary heart disease. This study found that increased fish consumption among men who had experienced a heart attack (the men were recommended to eat at least two weekly portions of fatty fish) reduced total mortality by about 30% during the first two years. Coronary heart disease mortality also declined, but the total number of heart attacks (fatal and non-fatal) was not significantly lowered. However, a long-term follow-up of the study population indicates that the effect of eating more fish was not maintained after the first two years (Ness *et al.,* 2002).

7.3.2 How fish consumption can affect the risk of cardiovascular disease

Consuming increased amounts of fish can affect the risk of developing cardiovascular disease in a number of ways. Two of them are discussed below – the content of n-3 fatty acids and of mercury.

7.3.2.1 n-3 fatty acids

One beneficial effect in particular has been associated with an increased intake of n-3 fatty acids. This is the most probable reason that a US study found beneficial effects only for tuna and other grilled and baked fish (i.e. mainly fatty fish, where consumption was significantly correlated with the EPA and DHA content in plasma phospholipids). But not for fried fish/fish sandwiches (mainly lean fish in which consumption was not correlated to the EPA and DHA content in plasma phospholipids) (Mozaffarian *et al.,* 2003, Mozaffarian *et al.,* 2004, Mozaffarian *et al.,* 2005a, Mozaffarian *et al.,* 2005b). Several explanations have been put forward as to why n-3 fatty acids can decrease the risk of contracting coronary heart disease. They affect the level of blood lipids (in particular by reducing triglyceride levels), and they can lower blood pressure and affect the coagulation system positively, thus reducing the tendency to form blood clots.

A large-scale meta-analysis of the results of clinical trials showed a significant reduction in triglycerides and a significant increase in LDL cholesterol, but there was no effect on blood pressure (Hooper *et al.,* 2004). However, it has been pointed out that in order to produce effects on blood pressure, blood lipids and the coagulation system, doses of n-3 fatty acids must be fairly large (generally several grams per day) (Geelen *et al.,* 2004). The most common explanation for the beneficial effect fish has on the risk of developing coronary heart disease, and perhaps on sudden death in particular, has been that fish n-3 fatty acids reduce the risk of fatal arrhythmia. This is in accordance with the findings of prospective studies that demonstrated a protective effect of fish on cardiovascular mortality, but a lesser effect on non-fatal cardiac infarct (He *et al.,* 2004b; Whelton *et al.,* 2004). It also corresponds well with the findings that the effect was only found for fatal coronary heart disease in the DART study (Burr *et al.,* 1989), that fish had a beneficial effect on the risk of sudden death (Albert *et al.,* 1998) and the risk of atrial fibrillation (Mozaffarian *et al.,* 2004). In addition, a randomised clinical study of the effect of n-3 fatty acids on coronary disease and mortality found that the effect appeared fairly quickly after randomisation which also supports these findings (GISSI study, discussed in more detail below) (Marchioli *et al.,* 2002). However, a recently published clinical study involving n-3 fatty acids among patients with arrhythmia did not reveal that supplements of such fatty acids had any beneficial effect (Raitt *et al.,* 2005).

7.3.2.2 Mercury

In recent years, epidemiological studies have demonstrated that mercury (methyl mercury) from fish can increase the risk of developing cardiovascular diseases. Mercury in fish and its relationship to the risk of cardiovascular diseases have been discussed recently by Landmark and Aursnes (2004), and the findings vary considerably (Chan & Egeland 2004, Landmark & Aursnes, 2004). A 14-year follow-up of Finnish material published in 2005 confirms the relationship between the intake of mercury and cardiovascular risk and overall mortality. It also shows that this effect appears to depend on the concurrent intake of fish oils (Virtanen *et al.,* 2005). Therefore, it is possible that the consumption of fish with a high mercury content (especially predatory fish and large freshwater fish) may increase the risk of developing cardiovascular disease and/or neutralise the positive effect of fish oils and n-3 fatty acids. No quantitative data are available on the relationship between mercury intake and increased risk.

7.3.3 Supplement of n-3 fatty acids and the risk of cardiovascular disease

It is also of interest to examine whether an increased intake of n-3 fatty acids (not only from fish but also from plants or food supplements) affects the risk of coronary disease and mortality. The best-known relevant randomised clinical study in this connection is the GISSI study (GISSI, 1999), although it included only subjects who had suffered coronary heart disease (secondary prevention). The study, which included more than 11 000 patients, shows that a supplement of n-3 fatty acids reduces the frequency of coronary death. A significant reduction was shown for overall mortality and for coronary heart disease among persons who received 850 mg n-3 fatty acids per day as a food supplement, corresponding to approximately 30 grams of salmon per day. The effect on fatal cardiovascular events appears to have been greater than in the case of non-fatal events (GISSI, 1999). A small-scale study from India (Singh *et al.,* 1997) also showed a significant effect on heart failure, while a small Norwegian study with supplements of ethyl esters of n-3 fatty acids did not demonstrate any effect (Nilsen *et al.,* 2001).

The overall results from randomised clinical experiments published up to 2003 indicate that an increased intake of n-3 fatty acids reduces overall mortality, fatal coronary heart disease and sudden death (Bucher, 2002, Hooper *et al.,* 2004). However, a large secondary prevention study published in 2003 (DART-II study) did not reveal any protective effect of n-3 fatty acids, mainly ingested in the form of fish oil capsules (Burr *et al.,* 2003). The DART-II study has been criticised, and no great importance is ascribed to it in various reviews of the research field. It should be noted that in clinical experiments the effect of n-3 fatty acids on total and coronary fatality, as opposed to a placebo, is equal to the effect of statins (Studer *et al.,* 2005). However, it must be kept in mind that the findings for people who already have heart disease (this applies to all large randomised experiments, including the trial in which fish consumption was increased (DART-I)) are not necessarily applicable to healthy men and women.

7.3.4 Knowledge base in relation to recent reviews

The UK Scientific Advisory Committee on Nutrition and the UK Committee on Toxicity (SACN/COT, 2004), as well as the Danish Veterinary and Food Administration (Danish Veterinary and Food Administration, 2003) conclude that fish in the diet reduces the risk of contracting cardiovascular disease. As mentioned above, a number of recent review articles (e.g. Hooper *et al.,* 2004, He, 2004b, Whelton *et al.,* 2004, He *et al.,* 2004a, Bouzan *et al.,* 2005, König *et al.,* 2005) as well as a number of recent single studies (e.g. Folsom & Demissie, 2004, Mozaffarian *et al.,* 2005a, Virtanen *et al.,* 2005) have been published since the Danish Veterinary and Food Administration and SACN/COT produced their summaries. Although the picture is not uniform, it appears that no new knowledge has been acquired that affects their conclusions to any appreciable degree.

7.3.5 Summary of the correlation between fish consumption and the risk of cardiovascular disease

In 2002, the American Heart Association concluded that the diet of the general population should include fish from various sources (preferably fatty fish) at least twice a week (Kris-Etherton *et al.,* 2002). For the most part, the results of more recent studies appear to reinforce this conclusion. It seems probable that the main effect is on fatal events. Increased fish consumption, which can realistically be achieved, for example, by a modest adjustment to our dinner habits, can significantly affect mortality from cardiovascular disease in the population.

7.4 Cancer

Epidemiological knowledge of possible correlations between fish consumption and cancer is relatively limited (WCRF, 1997). There may be many reasons for this, but part of the explanation is that a considerable amount of research on diet and cancer has been conducted in countries with relatively low fish consumption, e.g. the USA and the UK. In the SACN report (SACN/COT, 2004), the decision not to discuss cancer due to limited data reflects this.

Cancer is a general term for tumours that may occur in many different organs. The causes vary considerably depending on the localisation. In 2003, a total of 23 307 people developed cancer in Norway, and 10 500 Norwegians died of cancer. The main forms of cancer in men and women will be discussed here: breast cancer (2 694 new cases, 700 deaths), colon and rectal cancer (3 366 new cases, 1 600 deaths) and prostate cancer (3 327 new cases, 1 070 deaths). In addition, cancer of the thyroid will be discussed briefly (180 new cases, 35 deaths).

7.4.1 Fish and the risk of breast cancer

An overview of ten published cohort studies is provided in Appendix C. There is no clear correlation between fish consumption and breast cancer. Nor do the majority of studies reveal a statistical correlation. Two studies show an increased risk when consumption is increased (Mills *et al.,*1989, Stripp *et al.,* 2003). The latter is a Danish study which provides detailed data on fish consumption.

Fish consumption in Denmark is characterised by a high consumption of pickled herring. However, analyses do not indicate any difference between lean and fatty fish as regards the risk of developing breast cancer. A corresponding Norwegian study found no greater risk related to the consumption of fatty fish (Lund *et al.,* 2004). This is the only study that has investigated farmed fish, i.e. salmon and trout. The only study that suggests a protective effect is a Norwegian study (Vatten *et al.,* 1990).

A number of case-control studies have revealed a negative correlation between fish consumption and the risk of breast cancer, i.e. a preventive effect, but not all (Hjartåker, 2003). Most studies in which a protective effect has been found are from the USA or southern Europe, while studies from the Far East have not shown this effect.

7.4.2 Fish and the risk of colon and rectal cancer

There are seven cohort studies that include both genders, two studies that include only women and three include only men, altogether 12 studies (Appendix C). The findings differ considerably. Two of the studies show a reduced risk of colon and rectal cancer for women (Kato *et al.,* 1997, Tiemersma *et al.,* 2002), while none of the studies show an increased risk. Four studies analysed only fish and chicken together, and no correlation was found between consumption and the risk of cancer (Thun *et al.,* 1992, Singh & Fraser, 1998, Flood *et al.,* 2003, Chao *et al.,* 2005). In spring 2005, a large multi-centre study was published by EPIC in which a statistically significant protective effect was found for both genders. An increase in fish consumption of 100 grams per day reduced the risk of contracting colon and rectal cancer by 54% (Norat, 2005). Many case-control studies have been conducted, but there was no clear correlation found between fish consumption and the risk of cancer in any of them.

7.4.3 Fish and the risk of prostate cancer

A total of 10 prospective studies of prostate cancer have been published (Appendix C). Although the majority showed no correlation between fish consumption and prostate cancer, a Swedish study (Terry *et al.,* 2001) showed a protective effect in contrast to a Japanese study that found an increased risk when consumption increased (Allen *et al.,* 2004). Most studies are small and lack statistical power (too few cancer cases) to detect changes in risk of 20 to 30%, and case-control studies do not show clear results (Hjartåker, 2003).

7.4.4 Fish and the risk of thyroid cancer

A pooled analysis has been conducted on the majority of studies containing data on fish consumption and thyroid cancer using both case-control and cohort studies (Bosetti *et al.,* 2001). The main conclusion is that there is no correlation.

7.4.5 The knowledge base in relation to recent reviews

The SACN/COT report does not assess possible correlations between fish consumption and the development of cancer. After a brief discussion, the Danish Veterinary and Food Administration (2003) concluded that no reliable information was available on changes in the risk of cancer due to fish consumption. The summary report prepared by World Cancer Research Found and American Institute for Cancer Research in 1997 (WCRF, 1997) reached the same conclusion.

7.4.6 Summary of the correlation between fish consumption and the risk of cancer

Fish consumption shows no reliable correlation with the development of cancer.

7.5 Intake of various nutrients and contaminants from fish and their effects on the growth and development of the foetus and infants – epidemiological studies

7.5.1 n-3 fatty acids

A good deal of research, including experimental studies, has been conducted on the possible effects of n-3 fatty acids on growth *in utero* (during pregnancy) and after birth. This has been fully summarised in the SACN/COT report, in part because the report stresses that this is the most sensitive health outcome. The reason for this is the need for a number of fatty acids, DHA and arachidonic acid, which are essential for the development of the central nervous system in humans. There is a growth spurt during the last stage of pregnancy and in the first months of life.

Based on studies of birth weight on the Faeroe Islands and in Denmark, it was suggested as early as in 1986 that increased fish consumption could prolong the pregnancy somewhat, thereby increasing birth weight (Olsen *et al.,* 1986). This finding was later confirmed in a prospective study in Denmark in which almost 9 000 children were included (Olsen & Secher, 2002).

Supplements of n-3 fatty acids taken by pregnant women have led to a variety of results. Few studies have been conducted on the intake of n-3 fatty acids during pregnancy and the neurological development of the child. The SACN/COT report gives an account of two studies. Following their report, another study has been published in which no effect was shown (Malcolm, 2003). The effect of n-3 fatty acids supplementation on the duration of pregnancy is uncertain.

Many observational studies have been conducted to determine the significance of dietary supplements of n-3 fatty acids taken by nursing mothers and the addition of n-3 fatty acids to infant formula, but the studies have been difficult to interpret because the development of children's visual and cognitive functions is affected by many different factors. Preterm infants with a birth weight of <1500 grams have limited fat stores and therefore less n-3 fatty acids, in addition they lower the ability to synthesise them. Overall, randomised controlled trials have demonstrated an improvement of visual function by giving n-3 fatty acid supplements to breast-feeding mothers or by adding such supplements to infant formula. These are mainly small studies with 10 to 34 participants, apart from one trial with 140 children. Controlled trials conducted later show the same results (Fewtrell, 2004). Similar studies on term infants have not revealed a clear positive effect, and the nine studies in question are also small with the exception of one study. A recently published Danish study shows a potentially positive effect of fish oil supplements taken by breast-feeding mothers on the development of the child's visual function (Lauritzen, 2004).

The effect on neurological development of n-3 fatty acid supplements given to the child after birth is unclear both for preterm infants (four studies) and for term infants (ten studies). A Norwegian study showed that the children of mothers who had taken cod liver oil during pregnancy and three months after the birth had better neuro-psychological development at age four (Helland *et al.,* 2003).

7.5.2 Mercury

Methyl mercury may cause damage to several different organs (cf. Section 5.2.4). However, the brain is the most sensitive organ, which is affected at the lowest exposure. The nervous system is most susceptible during development, i.e. during the foetal and infant stages. Studies from Iraq where people ate seed treated with methyl mercury (Bakir *et al.,* 1973) and from the extensive mercury contamination in Minamata showed that foetal exposure to organic mercury could damage the foetal brain. Studies from New Zealand and Canada, where exposure to methyl mercury took place mainly via fish consumption, demonstrated that low exposure to methyl mercury at the foetal stage could also result in damage to the nervous system (Kjellstrom *et al.,* 1986, 1989, McKeown-Eysson *et al.,* 1983). The two most recent study as well as the most comprehensive epidemiological studies of fish conspumption and methyl mercury are from the Faeroe Islands and the Seychelles. Both these studies are based on measuring different neuropsychological changes in children resulting from the maternal intake of methyl mercury during pregnancy.

A cohort study of 1 022 births between 1986 and 1987 on the Faeroe Islands foetuses were exposed to methyl mercury via the mother's consumption of pilot whale. Increased methyl mercury exposure to mothers who ate whale meat was demonstrated by the analysis of mercury concentrations in umbilical cord blood and maternal hair analyses. At age seven, 917 children underwent detailed neuro-psychological and neurological tests that showed a dose-dependent reduction in fine motor skills, memory and learning ability (Grandjean *et al.,* 1997). In contrast, studies from the Seychelles, where mercury exposure derived from a large proportion of fish in the diet, do not demonstrate such a correlation. This was a cohort study of 799 children born in 1989 in which the mothers ate fish 12 times a week on average. Developmental tests appropriate for the different age-groups were carried out at ages 6 months, 19 months, 29 months and 66 months. The exposure was measured by the total mercury concentration in maternal hair during pregnancy and in the children's hair at age 66 months. At 66 months no serious effects were observed that could be associated with either prenatal or postnatal exposure to methyl mercury (Davidson *et al.,* 1998). This study was followed up by various tests on adaptability, learning ability and motor development when the children were nine years of age. The results showed nothing to indicate that methyl mercury exposure had any negative effects on the development of the nervous system (Myers *et al.,* 2003).

The mercury exposure levels in the two cohort studies from the Seychelles and the Faeroe Islands are similar, but exposure on the Faeroe Islands is somewhat higher. The reasons why measurable effects were found in the one study but not the other are unknown, but it may be due to differences in the type of seafood consumed (Davidson *et al.,* 2004). The lowest effect level measured in the Faeroe Islands study correlates relatively well with the highest exposure not producing an effect in the Seychelles study. Norwegian fish consumption has a closer resemblance to that on the Seychelles than to that on the Faeroe Islands.

Among other smaller studies carried out is one conducted in an Inuit community on Greenland in which methyl mercury concentrations in umbilical blood and maternal hair were analysed in connection with births. Forty-three children ages 7 to 12 were tested using various behavioural and developmental tests. No clinical deviations were documented, but neuro-psychological tests showed possible exposure-associated deficits. Only a few cases reached statistical significance (Weihe *et al.,* 2002). Another study of 149 7-year-olds in a fishing village in Madeira showed delays in the auditory brainstem after sound stimulation. It was suggested that this might be due to increased exposure to methyl mercury during the embryonic period (Murata *et al.,* 1999). This was corroborated by a prospective study of a birth cohort on the Faeroe Islands in which 878 children were examined at age 14. In this study, delays in the auditory brainstem that were significantly correlated with mercury exposure were also observed (Murata *et al.,* 2004). JECFA's assessment of methyl mercury and the establishment of a tolerable intake are based on the studies from the Faeroe Islands and the Seychelles and supported by the New Zealand study, all of which agree on a threshold level for effect of the same magnitude (cf. Section 5.2.4).

7.5.3 PCBs

Numerous cohort studies have been published on the correlation between dioxin and PCB exposure *in utero* and during infancy. Effects have been observed on perinatal growth and early development, on developmental disturbances of the central nervous system and on the thyroid gland and immune system (summarised in EFSA, 2005c). The effects on anthropometric measurements and the thyroid gland are variable. The immune function has been studied with regard to vaccination response as well as resistance to infection, among other factors. In a study from the Faeroe Islands, the benchmark dose for 5% response among those studied for immune toxicity was found to be 2.3 to 9.0 μg/g fat (Grandjean, 2003). The effects on neuropsychological development and IQ have been examined in several studies (summarised in Schantz *et al.,* 2003 and EFSA, 2005c). Three of the six most important studies are from the USA: North Carolina (Rogan *et al.,* 1986), Michigan (Jacobson & Jacobson, 1996) and New York (Darvill *et al.,* 2000), and three are from Europe: the Netherlands (Patandin *et al.,* 1999), Germany (Walkowiak *et al.,* 2001) and the Faeroe Islands (Steuerwald *et al.,* 2000). The North Carolina study revealed a negative correlation between the mother's prenatal PCB body burden and motor parameters (Rogan *et al.,* 1986). With the exception of this study, which showed no relationship to mental development at any age (Rogan *et al.,* 1986), most studies reveal a negative correlation between the PCB level *in utero* measured in the mother or in blood from the umbilical cord, and the development of cognitive functions. The studies are not completely consistent in terms of the tests that show an outcome. Studies from Michigan and the Netherlands may indicate that infants who are not breast-fed are more affected. There are no clear correlations between the level measured after birth and neuro-psychological development. First, older studies do not specify the type of chemicals accurately enough (congeners); secondly, breast-feeding and postnatal psycho-social care will be key confounding variables; and third, it is difficult to distinguish the effects of PCBs from methyl mercury (Kimbrough, 2003, Grandjean *et al.,* 2001, Stewart *et al.,* 2003). In the Michigan study (Jacobson & Jacobson, 1996, Jacobson & Jacobson, 2002, Jacobson & Jacobson, 2003), a benchmark dose (BMD) for 5% effect was calcultated for four cognitive outcomes at between 0.94 and 1.05 μg total PCB/g fat and a lower 95% confidence interval for BMD (BMDL) between 0.63 and 0.71 μg/g fat. The children were 4 and 11 years old when the study was done. In studies from the Netherlands (Patandin *et al.,* 1999) and Germany (Walkowiak *et al.,* 2001), the exposure was at approximately the same level as in the Michigan study, while exposure in a study from the Faeroe Islands was considerably higher. In the German and Dutch studies, the negative correlation disappeared on retesting at age 72 to 77 months. In an ongoing New York study (Darvill *et al.,* 2000) the exposure level was lower. This study found a negative correlation with perinatal PCB level and the development of the nervous system at age 6 months, 12 months and 38 months, but it disappeared at age 54 months. The Collaborative Perinatal Project (Gray *et al.,* 2005), recruited women from 12 American centres during the period from 1959 to 1965. No significant correlation was established between the maternal PCB level in the first trimester and the result of an intelligence test at age seven. Although congener-specific analyses of PCBs have been carried out in recent studies, it has not been possible to ascribe individual congeners to any particular neuro-psychological outcome because the different congeners are intercorrelated.

PCB exposure has shown a declining trend. Recent Norwegian results on total level of PCB7 in blood are available from a study of 200 subjects selected in accordance with a presumed high and low intake of dioxins and PCBs (Kvalem *et al.,* 2005, Kvalem, 2005). The highest level of PCB7 for women up to age 40 was 0.181 μg/g fat, and from age 40 to 60 the level it was 0.362 μg/g fat. By assuming that PCB7 constitutes 60 to 70% of total PCBs (EFSA, 2005c), these values can be converted to 0.3 and 0.6 μg/g fat, respectively, which is considerably less than the BMD and BMDL for neurotoxicity derived from the Michigan study. These values were confirmed by a recent examination of PCB levels in the breast milk of 55 Norwegian women (Eggesbø, personal statement). Therefore, there is good reason to presume that the PCB exposure level (which is most relevant for women up to age 40) in Norway is below the exposure level where impairment of the development of the foetal central nervous system can be anticipated. Effects on the immune system are expected to occur at a higher exposure level than in the case of developmental impairment of the central nervous system.

One study revealed that impairment of memory and learning could also arise among adults exposed to elevated PCB levels in fish from Lake Michigan (Schantz *et al.,* 2001), while studies of US veterans exposed to dioxn during spraying in Vietnam found only small changes that were of uncertain clinical significance (Barret *et al.,* 2001). The majority of studies are conducted in areas where there is a high or very high intake of contaminated fish or blubber, or in the wake of accidents. All in all, these studies cannot be used as a basis for determining a tolerable intake level.

7.5.4 Summary of the effects of various nutrients and contaminants on growth and development of the foetus and infants – epidemiological studies

No negative effects were found after the use of n-3 fatty acids as a food supplement during pregnancy or as an addition to breast milk during the post-natal period. The increased intake of n-3 fatty acids seems to exercise a positive effect on the visual function of premature babies. PCBs may have a negative impact on the development of the central nervous system at the foetal stage, but the exposure level in Norway is below the level where permanent effects can be expected. The exposure level at which mercury from fish affects the development of the central nervous system of the foetus and newborn babies is disputed. Some experts believe that the effects first occur at a higher exposure than the level on which the tolerable intake is based. The exposure to mercury and other contaminants from fish and seafood, as well as whether these represents a health risk, will be discussed in Chapter 8.

7.6 Allergy to fish and other seafood

Allergy to fish and other seafood is one of the most common food allergies caused by immune globulin-E (IgE), and all these allergies may result in life-threatening reactions. Even though more or less species-specific allergens exist, there is extensive cross-reaction to different kinds of fish. The same applies to crustaceans such as lobster, crawfish, prawns and crabs, i.e allergy to one kind of shellfish entails a considerable risk of allergy to other types as well. Allergies to molluscs such as oysters and scallops, as well as allergy to squid, are not uncommon.

Fish allergy

The main allergen in fish is the calcium-binding muscle protein, parvalbumin. Parvalbumin does not to any appreciable extent lose its ability to bring about an allergic reaction when fish is boiled or fried, but some individuals react either only to raw fish or to boiled fish due to other allergens. The lowest dose of fish reported to cause an allergic reaction is 5 mg.

Shellfish allergy

The main allergen in shellfish is tropomyosin, which is one of the causes of cross-reaction with molluscs (including octopus and squid) and with mites and edible snails, but shellfish also have different, more species-specific allergens. Tropomyosin tolerates heat without losing the ability to cause allergic reaction. Shellfish allergen in sauces or as a contaminant in fish products may result in serious reactions.

Mollusc allergy (bivalves and octopi)

Bivalves, snails and octopi (molluscs) are also allergenic in foods and EU bodies are currently in the process of evaluating whether molluscs should be included in the list of important food allergens that must be specially labelled in line with fish and shellfish. For example, squid contain an important allergen in some parts of Europe, as do oysters, mussels, scallops and edible snails. These contain a major allergen – tropomyosin – that cross-reacts with tropomyosin in crustaceans. In addition several other allergens may contribute to cross-reacions, e.g. house-dust mites. Snails in particular, but also mussels, can trigger serious reactions in the form of asthmatic attacks in individuals who are allergic to mites, and dust mite allergy is one of the most common respiratory allergies.

7.6.1 Symptoms of allergic reaction to fish and other seafood

The symptoms of allergic reaction to fish and other seafood are no different from the reaction to other types of food (Lopata & Jeebhay, 2001). People who are allergic to fish may experience an asthma attack when the fish allergen is airborne because of fumes from boiling or industrial processing of fish, as well as at fish markets. Shellfish and mollusc allergens may also cause asthma when airborne, and fish, crustacean and mollusc allergens may cause anaphylactic shock upon inhalation (Patel & Cockroft, 1992, Jeebhay *et al.,* 2000, Lopata & Jeebhay, 2001, Taylor *et al.,* 2000).

7.6.2 Prevalence

Fish allergy often begins in the first year of life, generally appearing later than egg and milk allergies (Pascual, 1992). The situation is very similar for shellfish and molluscs. In contrast to egg, milk, wheat and soy allergies that typically disappear quickly with age, fish, shellfish and mollusc allergies often last a lifetime (Sampson 1989, Eigenmann *et al.,* 1998, Bock, 1982, Hill, 1989).

It is generally believed that fish allergy is very common in Norway and in other countries where a great deal of fish is consumed, e.g. Portugal and Japan. In the Nordic countries, there are no large-scale studies of the variation in the prevalence of fish allergy, but a study in Reykjavik (high fish consumption) and in Uppsala (low fish consumption) gave only a 0.2% positive result in both cases despite differences in consumption in the order of two to three times (Gislason *et al.,* 1999). Therefore, there is some uncertainty as to how closely the development of fish allergy correlates with fish consumption. The prevalence of fish allergy in the Reykjavik and Uppsala studies corresponds with the findings in a Danish study (Mortz, 2003) and in a Swedish study (Björnsson, 1996). A recent Danish study of an unselected birth cohort and the families of the children in which allergy was verified using a double-blind, placebo-controlled food challenge (DBPCFC) did not find seafood allergy among the children, while 0.2% of the adults were allergic to cod and 0.3% were allergic to shrimp. There are no prevalence figures from the Nordic countries in the case of mollusc allergy, but a number of cases have been reported to the Norwegian Food Allergy Register (see below). A realistic estimate of all seafood allergies in Norway, based on the Danish study and in conformity with a US study, may be calculated at perhaps as much as 1% of the population – approximately 40 000 individuals.

Norway has a Food Allergy Register, which is a reporting system for allergic reactions to food. The register was established in 2000 and provides information on the relative distribution of positive test results to different allergens in individuals with strong allergic reactions. The shrimp allergen is one of the most common food allergens, while allergies to cod and salmon are much less common. However, it is important to note that subjectively experienced food allergy is often five to ten times more common than that diagnosed using sound medical techniques. This may be because the ailments experienced stem from psychological causes or have other mechanisms than the ordinary IgE-mediated food allergy.

7.6.3 Allergy threshold values

It is uncertain whether there is a lower threshold for the minimum amount required to cause a serious allergic food reaction. It may be possible to arrive at a threshold value for labelling that will protect most people but not the individuals who are the most sensitive. In the current EU regulations, based on risk assessments from EFSA, no threshold values for food allergens are accepted (EFSA, 2004).

7.6.4 Summary of allergies to fish and other seafood

The prevalence of fish and shellfish allergy in the Norwegian population is relatively low (estimated at up to 1%), but for people who are allergic, the consumption of fish and other seafood can lead to strong, or even life-threatening, allergic reactions. A family member with allergy affects the whole family through their choice of foods, poses problems with the preparation of fish and their quality of life. From a public health perspective, this is a fairly important problem that concerns a variety of other staple foods. Improved labelling and increased knowledge will reduce the problems experienced by people with fish allergies.

7.7 Summary of health effects associated with fish consumption – epidemiological studies

Epidemiological studies are the only type of study that can show how fish consumption is correlated with the risk of disease in humans. However, in this type of study, fish consumption and health outcome will be registered with errors resulting in the underestimation of the actual correlations between fish consumption and disease frequency. Owing to statistical power, epidemiological studies cannot detect relationships between fish consumption and disease if these are very weak. Furthermore, confounding factors can mar the studies, either because of false correlations or because true correlations do not come to light.

The consumption of fish and other seafood may be associated with both disease-promoting exposures (e.g. mercury) and preventive exposures (e.g. n-3 fatty acids). Increased fish consumption is associated with a reduced risk of cardiovascular disease, but not with the risk of cancer. It appears that n-3 fatty acids have a positive effect on visual function in premature babies, whereas mercury may damage the development of the foetus and the child. Less than 1% of the population is allergic to fish.

This summary of the health effects associated with fish consumption is based on a qualitative assessment of the existing literature. There is no quantitative data available, i.e. individual studies that have concurrently assessed the negative effects of contaminants (mercury, organic contaminants) in relation to the positive effects of different nutrients (n-3 fatty acids, D vitamins, A vitamins, proteins) in fish. Large prospective studies of this kind are in progress.

Based on a review of the scientific literature, it appears to be well documented that from a public health perspective, the consumption of fish, lean or fatty, has a positive health effect overall. This is mainly due to the effects of fish consumption on cardiovascular disease and mortality. Although studies of fish consumption have not shown that marine n-3 fatty acids have a positive effect on the development of the central nervous system of foetuses and newborn babies, this has been shown to be the case in other studies involving supplements of marine n-3 fatty acids. However, the intake of marine n-3 fatty acids from fish appears to have a positive impact on pregnancy.

Some researchers in the US have claimed that it is theoretically possible that there is an increased risk of cancer due to the intake of contaminants (Hites *et al.,* 2004). It is not possible for epidemiological studies to detect a risk of this order of magnitude (approximately one cancer death in 100 000 by the age of 70). In any event, this theoretic increase in the number of cancer deaths is much lower than the benefit gained because of fewer deaths due to cardiovascular disease (Rembold, 2004, Tuomisto *et al.,* 2004).

It may be difficult to assess the significance of the health-promoting aspects of increased fish consumption as opposed to the detrimental aspects that may be due to mercury and organic contaminants. How can the significance of a reduced risk of cardiovascular disease among the middle-aged and elderly be compared with possible foetal damage? One common way of making such comparisons is to calculate the effect of a measure such as the quality-adjusted life year (QALY). Expected remaining life years (a child lives much longer than a 60-year-old man) as well as quality of life (the extent to which quality of life is reduced by a disease/condition) are then considered. Cohen et al. (2005) conducted an analysis of fish consumption which takes into account the effects on cardiovascular disease and cognitive development (due to the intake of marine n-3 fatty acids) on the positive side and effects on cognitive development (due to mercury contamination) on the negative side. Effects of organic contaminants were not included in the analysis because they would only influence the result to a very small degree. The analysis of Cohen et al. demonstrates that with a general increase in fish consumption, the positive health effects dominate completely. No similar analysis has been conducted in Norway.

8 The impact of fish on the intake of nutrients and compounds that are potential health hazards

In order to estimate the dietary intake of substances, occurrence data from analyses of foods are required as well as data from dietary studies that show how much the population eats of the foods in question. This chapter provides an overview of the content and intake of marine n-3 fatty acids and other significant nutrients in fish and other seafood. In addition, it contains values for the content and intake of contaminants from fish and other seafood. The marine n-3 fatty acids (EPA, DPA, DHA), the vitamins B_{12} and D, the minerals iodine and selenium, and the contaminants mercury, dioxins and dioxin-like PCBs appear to be most significant for health at the current levels in fish and other seafood

Nationwide dietary studies of Norwegian adults have been conducted to estimate the intake of nutrients, but none of these studies are suited to estimate the intake of contaminants in the *entire* diet. The Fish and Game Study, Part A, (Meltzer *et al.,* 2002) can, however, be used to calculate the intake of contaminants from fish and other seafood. In addition, models (scenarios) using various fish consumption patterns have been prepared in order to study exposure.

The scenarios are based on the estimated median consumption of 65 grams of fish per person per day (corresponding to two meals per week), 2/3 of which consists of lean fish (cf. Chapter 3). In addition, we have studied the impact on the intake of marine n-3 fatty acids, nutrients and contaminants if all fish consumed is lean, and if all fish consumed is fatty. Furthermore, intakes among persons with a low consumption of fish (10^{th} percentile, i.e. 27 g/day, corresponding to one meal per week) and persons with a high consumption of fish (90^{th} percentile, i.e. 119 g/day, corresponding to four meals per week) have been studied. For some nutrients (e.g. selenium), it makes no difference whether the fish is lean or fatty, while for others, e.g. vitamin D, the fat content affects the intake levels significantly. The same applies to contaminants – some are found in fish fat and others in muscle tissue.

The estimated intake of nutrients and contaminants at ages 2, 4, 9 and 13 is based on data from the Norwegian dietary studies Småbarnskost 1999 (Lande & Andersen, 2005b) and Ungkost 2000 (Øverby *et al.,* 2002, Pollestad *et al.,* 2002), cf. Table 2 in Chapter 3. The participants in these studies recorded their food intake over four consecutive days, and the questionnaire had a blank space where species of fish that were not directly referred to in the questionnaire could be noted. This made it possible to calculate detailed intake estimates for these age groups.

8.1 Content of nutrients in fish and other seafood

The content of nutrients in foods is published in the latest version of the Norwegian Food Composition Table ('Matvaretabellen'), revised edition 2001. Data on nutrients in fish and other seafood were also compiled in the 2005 edition of 'Facts about Fish' ('Fakta om fisk'), which is the result of a joint project between the Norwegian Seafood Export Council, the Directorate of Fisheries and the National Institute of Nutrition and Seafood Research. The sample material was mostly collected in the 1980s and 1990s and, unfortunately, neither locality nor season can be traced for these data. The fish analysed were of normal size and only the edible parts of the different species were included. However, more recent data, e.g. data on iodine, are traceable (Julshamn *et al.,* 2001). These data are based on results from at least 25 fish of each species, and the locality, size and catch date are known. An overview of the nutritional content of over 30 different species of fish can be found in the Norwegian Food Composition Table (2001).

Table 17 provides an overview of n-3 fatty acids, marine n-3 fatty acids (EPA, DPA and DHA) and nutrients in the fish species that are predominant in the Norwegian diet. With the exception of protein, only substances for which fish is a significant source to the intake are included.

Table 17 Content of the key nutrients in fish and other seafood, including cold cuts and spreads made of fish. The nutrient content is stated per 100 grams of edible product.

	Fat	Sum n-6	Sum n-3	Sum n-3 from fish (EPA, DPA, DHA)	Retinol	Vit. D	Vit. B12	Selenium	Iodine
	g	g	g	g	µg	µg	µg	µg	µg
Lean fish									
Haddock	0,20	0,01	0,07	0,07	2,0	0,7	2	30	60-920
Saithe	0,30	0,01	0,09	0,09	2,0	0,8	4	30	20-270
Cod	0,30	0,01	0,11	0,11	2,0	1,4	1	30	30-1270
Partially fatty fish/fatty fish									
Sprat (brisling)	18	0,25	3,8	3,1	60	19	7	10	ia
Halibut	10	0,20	0,72	0,58		18	1	40	ia
Salmon (farmed)	13	0,52	3,2	2,7	11	8	6,9	30	6-34
Salmon (wild)	12	0,22	2,2	1,9		8	6,9	50	ia
Mackerel, july-sept	20	0,45	4,6	3,8	14	13	12	30	14-120
Mackerel, may-june	5,4	0,12	1,2	1,0	14	6	12	30	14-120
Herring, fat herring/ summer herring	25	0,38	5,6	4,5	6,0	12	12	50	14-160
Herring, winter herring	14	0,21	3,1	2,5	6,0	12	12	50	14-160
Scorpaenid/ redfish	2,8	0,06	0,61	0,51	3,0	0	1	50	10-33
Brown trout (farmed)	10	0,42	2,1	1,8	10	10	5	30	
Sea trout	3,3	ia	ia	ia	12	9	5	26	50
Freshwater fish									
Perch	1,3	ia	ia	ia	9,0	0,8	5	28	ia
Pike	0,70	ia	ia	ia	9,0	0,9	24	22	ia
Trout	ia	ia	ia	ia	ia	ia	ia	ia	ia
Crustaceans									
Blue mussel, raw	1,4	0,04	0,32	0,29	14	0	0,8	51	na
Crab, cooked	1,8	0,05	0,46	0,40	4,0	0	1,2	200	na
Prawns, cooked	0,80	0,03	0,26	0,25	2,0	3,5	5,3	30	na
Innards and fish oils									
Cod liver	60	1,7	29	28	12000	100	20	30	ia
Cod Roe Spawn	1,7	0,05	0,83	0,80	79	12	10	20	ia
Cod liver oil	100	2,0	23	21	5400	216	0	0	ia
Sandwich spreads from fish									
Cod roe patè	35	17	3	0,60	0	0	6,7	41	85
Tinned mackrel fillet in tomato sauce	23	2,0	4,5	3,1	64	5,0	8,0	28	75
Roe and liver patè	34	0,52	8,5	8	3000	30	6,6	15	ia

Explanation of the table: The values are derived partly from the database of the National Institute of Nutrition and Seafood Research, and partly from the Norwegian Food Composition Table, 2001. The data for iodine are derived from Julshamn *et al.*, 2001 and give a range for content. 'Total n-3 from fish' gives the total of all n-3 fatty acids in fish, while 'Fatty acids EPA, DPA, DHA' gives the amount of the specific long-chain n-3 fatty acids incorporated in 'Total n-3 from fish'. na = not analysed.

8.2 Intake of nutrients from fish and other seafood

As described in Chapter 4, fish is the only food in Norway that contributes significantly to the intake of marine n-3 fatty acids (EPA, DPA and DHA). Fatty fish is also a unique natural food source of vitamin D, while all fish, especially lean fish, are a naturally good iodine source[12]. In addition, fish are a good source of vitamin B_{12}. Selenium is the most important mineral in fish in addition to iodine. In the following section, the intake of vitamin D and marine n-3 fatty acids from fish and other seafood is described based on estimates from the dietary studies. The authorities primarily wish to promote the intake of these two nutrients. In addition, the significance of different levels of fish consumption for the intake of these nutrients is discussed in scenarios. Estimates from these scenarios also describe the intake of retinol, selenium, iodine and the total of n-6 fatty acids from fish.

8.2.1 Intake of vitamin D and n-3 fatty acids from fish and other seafood, estimated using dietary studies

The average intake of vitamin D in the Norwegian population is lower than recommended (the Directorate for Health and Social Affairs, 2004). The intake of n-3 fatty acids is also lower than advisable among those who do not eat fish at all or eat little fatty fish. Based on these facts, the general population has been officially advised to supplement their diet with cod liver oil, and vitamin D is added to butter and margarine. Since 2000, vitamin D has also been added to extra low fat milk. The content of vitamin D in the diet has increased somewhat since the 1980s (the Directorate for Health and Social Affairs, 2004). If the consumption of fatty fish was higher, these fortification measures would play a more limited role. For those children and adolescents in particular, who do not eat fish at all and who do not take food supplements with vitamin D, it is especially difficult to reach the recommended daily intake of this vitamin during the winter months.

Norkost 1997 showed that fish and other seafood (excluding cod liver oil and other food supplements) contributed an average of 22% of the total vitamin D intake in the diet (Johansson *et al.,* 1990). Only about 5% of those who participated in Norkost and the Fish and Game Study, Part A, were able to reach the recommended daily intake of vitamin D from fish alone.

Småbarnskost 1999 and Ungkost 2000 showed that fish alone met just below 50% of the recommended daily intake of vitamin D among the 4- to 13-year-olds with the highest contribution from fish. For 2-year-olds, fish alone contributed up to 25% of the recommended daily intake of vitamin D. The median and average contribution from fish to D vitamin intake was low because many of the children did not eat fish, as discussed in Chapter 3.

The recommended daily dose of cod liver oil for adults (5 ml/day) gives 10 µg of vitamin D/day. Food supplements other than cod liver oil, e.g. Sana-sol and fish oil capsules, also contain vitamin D. Almost half the participants in Norkost took food supplements, thereby ingesting sufficient vitamin D. None of the participants in the study ingested more vitamin D than the maximum amount advisable. See Appendix E for further details.

Although marine n-3 fatty acids are not essential for humans, regular intake is associated with health benefits, cf. Chapters 4 and 7. The Nordic Nutritional Recommendations (NNR, 2004) do not make specific recommendations for marine n-3 fatty acids, but state that the total intake of n-3 fatty acids should be approximately 1 E% (corresponding to 2.6 grams of n-3 fatty acids per day if the total energy intake is 10 MJ). This is in accordance with the Norwegian recommendations from 2005 (the

[12] The main source of iodine in the Norwegian population is milk and milk products

Directorate for Health and Social Affairs, 2005b). A diet that includes weekly consumption of fatty fish will contribute considerably to the general intake of n-3 fatty acids.

As mentioned in Chapter 4, the intake of ALA averaged 1.9 g/day and total marine n-3 fatty acids (EPA, DHA and DPA) averaged 0.9 g/day in Norkost 1997. This represents approximately 0.7 E% from ALA and approximately 0.4 E% from the marine n-3 fatty acids.

Intake estimates based on Ungkost (ages 4, 9 and 13), Småbarnskost (age 2) and Spedkost (age 12 months) showed that the intake of marine n-3 fatty acids from fish and other seafood (without cod liver oil/food supplements) was between 0.6 and 0.9 g/day for the 95th percentile of children. Corresponding estimates from Norkost and the Fish and Game Study, Part A, showed an intake of marine n-3 fatty acids of 1.3 g/day and 1.5 g/day for the 95th percentile of adult participants.

The recommended dose of cod liver oil (5 ml/day) gives 1.2 grams of marine n-3 fatty acids, while two capsules of fish oil[13] give 0.7 grams of marine n-3 fatty acids. Consequently, fish contributes to the intake of marine n-3 fatty acids for those who eat fatty fish, but cod liver oil and other fish oil supplements are an equally important source for children and adolescents who eat little fish. This is particularly pronounced in the case of the youngest children (cf. Appendix E for further details).

A very high intake of polyunsaturates may have adverse effects, cf. Chapter 4. Owing to the potential increased haemorrhagic tendency, an intake of EPA, DPA and DHA that exceeds 1.5 E% is not beneficial in the long term (NNR, 2004). According to SCF 1993, the total intake of n-3 fatty acids (not only the marine n-3 fatty acids) should not exceed 5% of the total energy intake.

Even among young children (ages 1 to 2), a concurrent high intake of vegetable n-3 fatty acids and marine n-3 fatty acids will not result in a total intake of n-3 fatty acids that exceeds 2.4 E%. This is far below the maximum recommended level mentioned above.

8.2.2 Intake of nutrients from fish estimated with chosen scenarios

Table 18 shows the intake of different nutrients ingested at a low (about one meal per week), median (about two meals per week) or high consumption of fish (about four meals per week), and if only lean fish or only fatty fish is eaten, or if 2/3 lean fish and 1/3 fatty fish is eaten. The last-mentioned estimate is based on the average distribution of the fish consumptionin the Norwegian population; cf. Chapter 3.

[13] Example of a recommended dose by one manufacturer; other manufacturers may have other recommendation.

Table 18 Amount of different nutrients provided by fish if the fish consumption is low, medium or high. The estimates are compared with Norwegian recommendations for the intake of the respective nutrients. The percentiles are based on the Fish and Game Study, Part A, Chapter 3.

Intake scenarios		**Low intake 10-percentile 27 g/day**		**Average intake 50-percentile 65 g/day**		**High intake 90-percentile 119 g/day**	
		per day	%RI NNR	per day	%RI NNR	per day	%RI NNR
Retinol (µg/day)	Lean fish	1	0,1	1	0,1	2	0,3
	2/3 lean and 1/3 fatty fish	3	0,3	7	0,8	13	1
	Fatty fish	8	0,9	19	2	34	4
Vitamin D (µg/day)	Lean fish	0	4	1	10	1	18
	2/3 lean and 1/3 fatty fish	1	14	2	27	4	53
	Fatty fish	2	27	6	83	10	133
Vitamin B12 (µg/day)	Lean fish	1	28	1	66	2	122
	2/3 lean and 1/3 fatty fish	1	58	3	140	5	256
	Fatty fish	2	120	6	290	10	500
Selenium (µg/day)	Lean fish	8	16	20	39	36	71
	2/3 lean and 1/3 fatty fish	9	18	22	44	41	82
	Fatty fish	9	19	23	45	42	84
Iodine (µg/day)	Lean fish	120	80	290	193	530	353
	2/3 lean and 1/3 fatty fish	76	51	180	120	340	227
	Fatty fish	14	9	34	23	63	42
Sum n-3-fatty acids (g/day)	Lean fish	0,0	1	0,1	2	0,1	4
	2/3 lean and 1/3 fatty fish	0,3	12	0,7	29	1,4	53
	Fatty fish	0,9	34	2,2	85	4,0	154
Sum n-6-fatty acids (g/day)	Lean fish	0,0	-	0,0	-	0,0	-
	2/3 lean and 1/3 fatty fish	0,2	-	0,4	-	0,7	-
	Fatty fish	0,4	-	1,0	-	1,9	-

Explanation of the table: % RI NNR is the percentage of the recommended daily intake in the Nordic Nutrient Recommendations (NNR, 2004)

Table 18 illustrates that fish is of major importance for the intake of vitamins D and B_{12}, the trace elements selenium and iodine and the n-3-fatty acids. In these model estimates, the average Norwegian consumption of fish and other seafood in Norway (65 grams/day where 2/3 consist of lean fish) provides 27% of the total recommended intake of vitamin D, more than 100% of the recommended intake of vitamin B_{12} and iodine, and 44% of the recommended intake of selenium. If the proportion of fatty fish increases, the intake of vitamin D and n-3 fatty acids will also increase. As the table illustrates, lean fish is most important for iodine intake.

If the consumption of fatty fish is very high (90th percentile, i.e. 119 g/day or more, corresponding to four meals per week) the intake of vitamin B_{12} might be five times higher than the recommendations. In the Nordic Nutrient Recommendations (NNR, 2004) no upper tolerable intake level for vitamin B_{12} has been determined because there are no reasons for assuming that even a very high intake can lead to negative health effects. This implies that although a high consumption of fish may result in a considerably higher intake of vitamin B_{12} than recommended, the intake level will nevertheless remain unproblematic.

When consumption of lean fish is very high (90th percentile, i.e. 119 g/day or more), the intake of iodine might be 3.5 times higher than recommended. The Nordic Nutrient Recommendations (NNR, 2004) set an upper tolerable intake level for iodine of 600µg/day. Even with a very high consumption of lean fish, this level will not be exceeded.

The intake of n-3 fatty acids when the consumption of fatty fish is very high may also exceed the recommended levels by about 50%. The Scientific Committee on Foods (SCF, 1993) has proposed an upper tolerable intake of 5 E% for n-3 fatty acids. Even with a very high consumption of fatty fish, this intake level will not be exceeded by fish alone.

8.3 The content of metals and organic compounds that are potential health hazards in fish and other seafood

There is great variation in the levels of the individual contaminants in fish, depending for example on the species, the fat content, age and the availability of different substances in the habitat. A relatively stationary fish (e.g. flounder) that remains in a polluted fjord during its entire lifetime will have totally different levels of PCBs than pelagic fish caught in the North Atlantic. Freshwater fish, such as pike, may have different mercury levels from one lake to another, independent of age and length, because of the different availability of nutrients in the lakes, and different drainage basins supplying varying amounts of pollution.

A relatively large number of analyses of fish and other seafood from polluted areas have been conducted in Norway, particularly of seafood from marine environments. Such analyses are not representative of ordinary levels in fish sold for normal consumption, and these results are therefore not included as occurrence data in this chapter.

The food control authorities monitor the content of undesirable components in food sold on the Norwegian market. In recent decades there have been a number of different monitoring programmes in which various institutions have participated. At present the Norwegian Food Safety Authority has the main responsibility for monitoring undesirable components in food, and results from a number of monitoring programmes are to be reported to the EU. The National Institute of Nutrition and Seafood Research (NIFES) has its own monitoring programmes for undesirable components in fish and other seafood in addition to carrying out analyses for the Norwegian Food Safety Authority and other actors in the market. At present there is no joint database containing results from these different monitoring programmes, and this makes it difficult to acquire a complete overview of Norwegian occurrence data on undesirable components in food, including fish and other seafood. The levels of undesirable components presented in this report represent average values for the contaminants present in the fish species listed, and they are derived from databases compiled in connection with projects at the Norwegian Institute of Public Health. These largely incorporate analytical data from both the National Institute of Nutrition and Seafood Research and the Norwegian Food Safety Authority's monitoring programmes.

The most recent analytical data available are used in all intake estimates. It is particularly important that the most recent values for dioxins and dioxin-like PCBs are used because data in food are reported to be declining in recent years. In Norway there is not enough data for individual foods to document that the level of dioxins and dioxin-like PCBs in food has declined. The level in breast milk however reflects the exposure via food. The level of dioxins and dioxin-like PCBs in breast milk has declined by about 60% in the last 20 years (Becher *et al.,* 2002).

No such declining trends have been demonstrated for mercury, and the occurrence data for mercury includes several results from the 1990s in order to incorporate the large variation in mercury levels that occurs in individual fish species such as pike and freshwater trout.

The costs of analyszing organic contaminants are high, particularly in the case of dioxins and dioxin-like PCBs. The analyses are time-consuming and extensive technical equipment and expertise is required. The number of samples analysed for is therefore much lower than what is the case of many other contaminants in food.

Table 19 shows the average content of cadmium, mercury, dioxins and dioxin-like PCBs in fish and other seafood. Although the levels of contaminants in the samples may vary widely, the consumer's intake over time will more closely reflect an average level as it is unlikely that all the fish eaten will come from the same area. As previously mentioned, Table 19 does not include analytical results from polluted areas. For a few species or fish products, no analytical values are available. In lack of such results, Table 19 includes some estimates based on fat proportion and level in species with a comparable lifestyle.

Analytical data available after the calculations in this report were made show that the levels in farmed fish are on average 1.5 pg TE/g fresh weight (58 samples, variation 0.7-2.8 pg TE/g fresh weight).

New analytical data for tinned mackerel in tomato sauce show that the levels of the total amount of dioxins and dioxin-like PCBs are somewhat lower than those used in our calculations (1.7 TE/g fresh weight) with an average of 1.2 pg TE/g fresh weight (5 samples, variation: 0.5-2.3 pg TE/g fresh weight). Smoked salmon is not included in Table 19, but more recent analyses show that the levels are somewhat lower than for farmed salmon with an average of 1.0 pg TE/g fresh weight (4 samples, variation: 0.8-1.3 pg TE/g fresh weight).

Table 19 Average content of a number of organic and inorganic contaminants in different species of fish, other seafood, and cold cuts and spreads made of fish, expressed per gram of edible product. For all fish the fillet has been analysed with the exception of brisling, where the entire fish has been analysed. If other data sources than the monitoring programmes of the Norwegian Food Authority and the National Institute of Nutrition and Seafood Research have been used, this is indicated in the footnotes.

Species	Cadmium (Cd)	Mercury (Hg)	Fat%	Number of	dl PCB[f]	Dioksin	Total TE[g]
	µg/g	µg/g	v/analyse[e]	samples	pg TE (upper bound*)/g fresh weight		
Lean fish							
Haddock	<0,002	0,08	i.a.	1	0,03	0,02	0,05
Saithe	<0,001	0,05[b]	1,3	10	0,14	0,02	0,16
Cod	<0,002	0,05	0,9	25	0,02	0,02	0,05
Partially fatty fish/fatty fish							
Sprat (brisling)	0,02	0,01	18	2	2,2	0,8	3
Halibut		0,1	13	9	1,2	0,3	1,5
Salmon (farmed)	<0,001	0,03	13	79	1,2	0,5	1,7
Salmon (wild)		0,03	i.a.	3	0,9	0,4	1,3
Mackerel	0,006	0,03	23	23	0,56	0,19	0,75
Herring	0,005	0,04	12	19	1,1	0,8	1,9
Scorpaenid/ redfish	0,007	0,04	3,5	12	0,52	0,24	0,76
Trout, sea trout and farmed	<0,001	0,05	19	3	1,70	0,6	2,3
Freshwater fish							
Perch		0,3					
Pike		0,6					
Trout	<0,001	0,3	1,4	14	0,36	0,35	0,71
Crustacean							
Blue mussel, raw	0,14	0,02	2,9	1	0,38	0,04	0,42
Crab, cooked	0,12/3,2	0,2	13	18	1,6	1,7	3,3
Prawns, cooked	0,07	0,02	0,8	4[h]	0,1	0,01	0,11
Innards and fish oils							
Liver, cod	0,07b	0,01	62	23	29	3	32
Spawn, cod	<1[a]	0,01	-	e	0,40[c]	0,36[c]	0,76
Cod liver oil			100	12	1,8[d]	0,2[d]	2,0[d]
Cold cuts from fish							
Cod roe patè			36	2	0,2	0,18	0,38
Tinned mackrel fillet in tomato sauce			22	2	1	0,7	1,7
Roe and liver patè		0,03	-	e	4,3[c]	0,7[c]	5,0[c]

a: Solberg, SNT-report 4, 1997
b: Like cod
c: Estimated value
d: From the surveillance program of the Norwegian Food Safety Authority and information from producers
e: Fat % is analyzed in the same sample as the contaminant is analyzed
f: dl PCB = dioksin like PCB
g: Sum TE = sum toksiske ekvivalenter from dioxins and dioksin like PCB
h: Based on collected samples
i.a = not analyzed or not given
* Upper bound = lower bound i all species/products except cod since all congeners are detected in other species
If non-detected is zero, it is called the 'lower bound' value.

8.4 Intake of compounds that are potential health hazards

When seen in relation to international tolerable intake levels the intake of lead and cadmium from fish and other seafood in Norway are of little or no significance for in Norway, with the exception of brown crabmeat, which will contribute to the intake of cadmium if consumption is high. On the other hand, fish is the main dietary source of arsenic and mercury. As stated in Chapter 5, the arsenic content of fish is not considered to be a problem because it exists in forms that are not particularly toxic for humans. In contrast, there are some concerns regarding mercury in fish because the form methyl mercury found in fish is hazardous to health even at low levels. The levels of mercury are independent of the fat content of the fish.

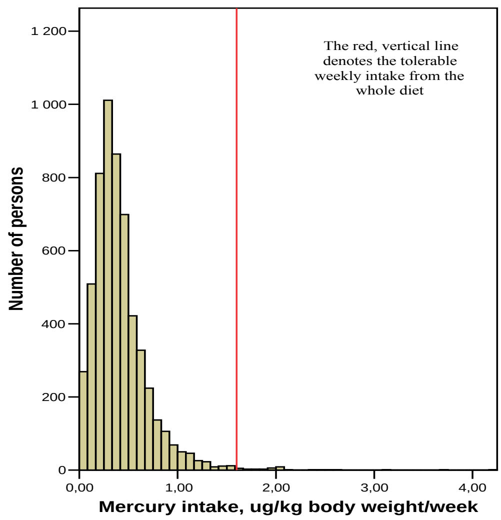
The greatest concern due to organic contamination in relation to exposure from fish and other seafood is dioxins and dioxin-like PCBs –particularly in fatty fish and fish products that contain marine fat. The intake of dioxins and dioxin-like PCBs will therefore be examined in detail in this chapter.

PBDE is another group of fat-soluble organic contaminants that have been found in increasing levels in fish and other seafood recently. Norwegian and international risk assessments of PBDEs have concluded that there is a considerable gap between exposure from food and the effect level reported (VKM, 2005, JECFA, 2005). PBDE exposure from fish and other seafood has therefore not been assessed in this report.

8.4.1 Intake of mercury

8.4.1.1 Estimated intake of mercury based on adult dietary studies

Figure 13 shows the average, median and 5th, 10th, 25th, 75th, 90th and 95th percentiles for estimated intake of mercury (expressed as µg/kg body weight/week) among participants in the Fish and Game Study, Part A. Values from Table 19 are used in the calculations. Both average and median intake among women < 45 years (n = 1 565) are the same per kg body weight as for the entire group of participants. The average intake of mercury from fish and other seafood was 0.4 µg/kg body weight/week. Only 0.6% of the participants exceeded the PTWI value for methyl mercury of 1.6 µg/kg body weight /week. A large proportion of them had a high consumption of pike.



Mercury-intake µg/kg bodyweight/week	
N	5663
Average	0,4
SD	0,3
Minimum	0
Maximum	1,2
5th percentile	0,1
10th percentile	0,1
25th percentile	0,2
50th percentile	0,4
75th percentile	0,5
90th percentile	0,7
95th percentile	0,9

Figure 13. The total intake of mercury (µg/kg body weight/week) from fish and other seafood in the Fish and Game Study, Part A. PTWI for methyl mercury is 1.6 µg/kg body weight/week.

Figure 14 shows the intake of mercury (µg/kg body weight/week) differentiated in accordance with the different types of fish. Mercury follows the proteins in fish, not the fat. Since mostly lean fish is eaten, this is the main source of mercury in the Norwegian diet, while fatty fish plays a lesser role.

Fresh water fish has a mercury content significantly higher than saltwater fish, but freshwater fish contributes relatively little to the mercury level in the Norwegian population because 30% of the general population never eats this kind of fish.

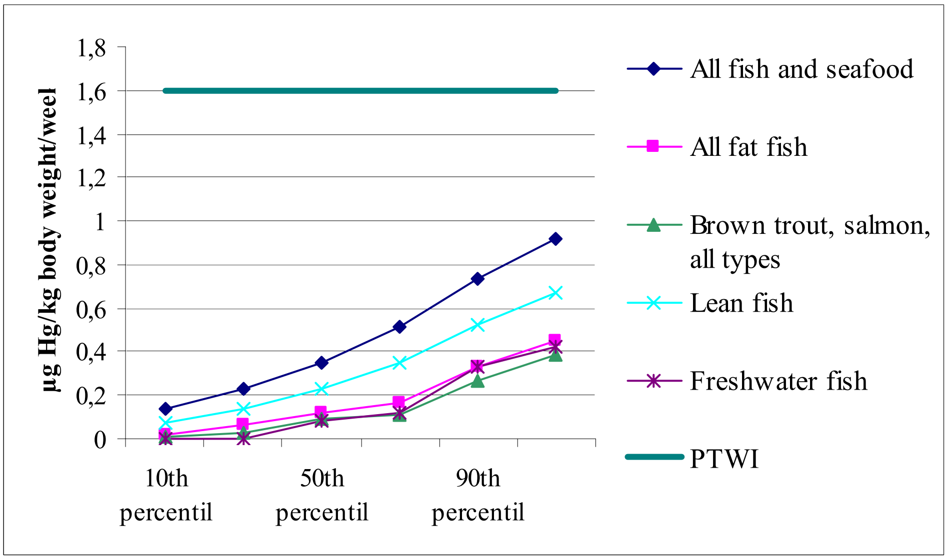


Figure 14. Mercury intake from fish and other seafood (µg/kg body weight/week) in the Fish and Game Study, Part A, in total and when distributed among the different categories of fish. Note that the percentiles cannot be added because the selection in each category (food source) is not identical.

8.4.1.2 Calculated intake of mercury based on dietary studies of children

Based on data from the dietary studies Småbarnskost and Ungkost, estimates have been made of the amount of mercury children get from fish and other seafood. Figure 15 shows that although some 4-year-olds eat a large amount of fish and therefore have the highest intake of mercury, the exposure remains well below the PTWI value of 1.6 µg/kg body weight/week.

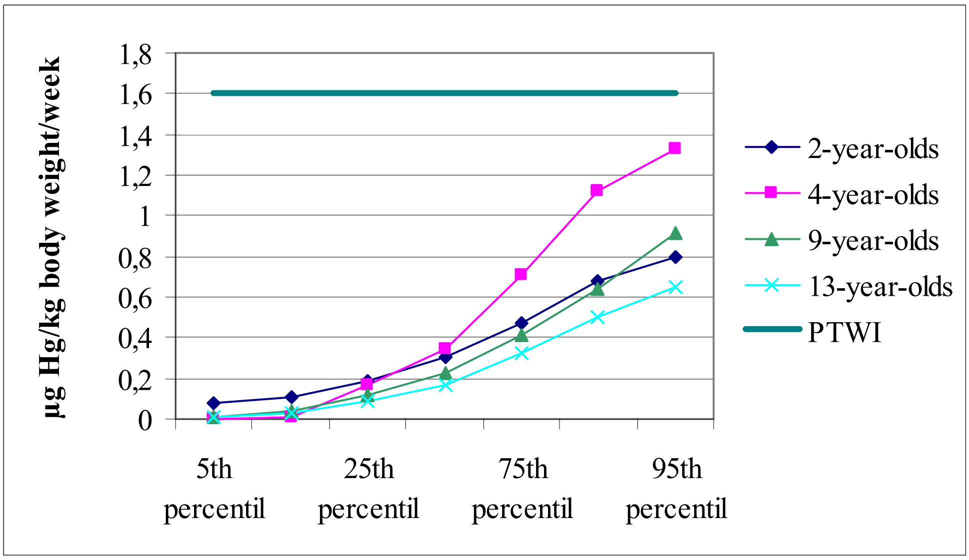


Figure 15. The mercury intake (µg/kg body weight/week) from fish among children of different ages distributed across percentiles for mercury intake based on Småbarnskost and Ungkost. Note that the percentiles cannot be added because the selection in each category (food source) is not identical.

8.4.1.3 Mercury exposure from consumption of fish with a particularly high mercury level

The estimates above are based on the average values for mercury found in fish and other seafood from areas with no known sources of pollution (background levels). However, the mercury content in some species varies considerably with the size of the fish and the trophic level in the food chain, among other factors. In Norway it is not unusual for the mercury content of some common freshwater fish such as pike, large perch (over 25 cm), large trout and Arctic char (over 1 kg) to lie between 1-3 mg/kg, although this is much higher than the average value for these species.

Estimates from the Fish and Game Study, Part A, show that a high consumption of fish with a mercury content greater than 1 mg/kg will lead to an intake of mercury from the overall diet exceeding the PTWI. High consumption in this context amounts to 6 to 24 meals per year.

In addition to freshwater fish, a number of imported fish species available on the Norwegian market may contain high mercury concentrations. The most common among them are fresh tuna (not tinned tuna), swordfish, whale, shark, skate, etc. The consumption of such fish is assumed to be low, but it cannot be ruled out that some groups of the population eat this type of fish on a regular basis.

Common to these imported species and to some species of freshwater fish is that when eaten regularly, the mercury intake may exceed PTWI

8.4.2 Intake of dioxins and dioxin-like PCBs

8.4.2.1 Dioxins and dioxin-like PCBs in cod liver oil

Raw cod liver oil, i.e. unrefined oil from the liver of cod and haddock, contains substantial amounts of PCBs and dioxins. The use of refining techniques ensures that the cod liver oil sold commercially has a considerably lower level of these contaminants.

Analyses conducted by the Norwegian Food Safety Authority as recently as 2004 and 2005 show a variation in total dioxin-like PCBs and dioxins from 1.0 – 2.9 pg TE/g cod liver oil. An average content of 2.0 pg TE/g rinsed cod liver oil is used in the intake estimates. In fish oil capsules, measurements showed an average of 0.74 pg TE/g oil. While cod liver oil is produced from the liver of cod and haddock, the capsules may contain fish fat from other sources. Table 20 shows the exposure to dioxins and dioxin-like PCBs from cod liver oil if the recommended dose is followed. In addition, the table shows the intake from fish oil capsules based on the recommended dosage on the product.

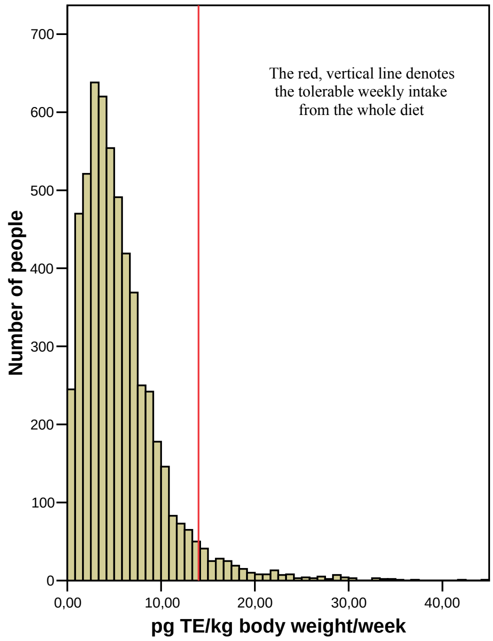
Table 20 Theoretical exposure to dioxins and dioxin-like PCBs (pg TE/kg body weight/week) from cod liver oil and fish oil among adults and children in different age groups. The amount of cod liver oil is set in accordance with the Norwegian recommendations (5 ml, approximately 5 g/day from 6 months and 2.5 ml from 4 weeks to 6 months), while the amount of fish oil in a capsule is set at the amount recommended for one type of product (2 capsules, 1.2 g oil/day). For other products, the recommended daily dosage may differ.

	Adults, age 18-79 74 kg pg TE/kg b.w./week	**Age 13 49 kg** pg TE/kg b.w./ week	**Age 9 32 kg** pg TE/kg b.w./ week	**Age 4 18 kg** pg TE/kg b.w./ week	**Age 2 13 kg** pg TE/kg b.w./ week	**Age 12 months 10 kg** pg TE/kg b.w./ week	**Age 4 weeks 5 kg** pg TE/kg b.w./ week
Cod liver oil (2,0 pg TE/g)	0.95	1.4	2.2	3.9	5.4	7.0	7.0
Fish oil capsules (0.74 pg TE/g)	0.07	0.11	0.16	0.29	0.40	-	-

Table 20 illustrates that the intake of dioxins and dioxin-like PCBs from purified cod liver oil alone may constitute up to 50% of the tolerable weekly intake (TWI) for dioxins and dioxin-like PCBs (14 pg TE/kg body weight/week). The intake in relation to the body weight is highest among the youngest children because the recommended amount of cod liver oil is the same for adults and children, with the exception of children age 4 weeks to 6 months for whom the recommended dosage is 2.5 ml/day.

8.4.2.2 Estimated intake of dioxins and dioxin-like PCBs based on dietary studies of adults

The intake of dioxin-like PCBs and dioxins in the Norwegian population has been estimated on the basis of the Fish and Game Study, Part A. Figure 16 shows that there is a wide range and skewed distribution of the intake. The concentration level used for fish and other seafood is shown in Table 19.



pg TE/kg body weight/week	
N	5663
Average	5.6
SD	4.4
Minimum	0
Maximum	44.2
5th percentile	0.9
10th percentile	1.5
25th percentile	2.7
50th percentile	4.7
75th percentile	7.3
90th percentile	10.5
95th percentile	13.6

Figure 16. Total intake of dioxins and dioxin-like PCBs, pg TE/kg body weight/week from fish and other seafood, Fish and Game Study, Part A. Six per cent of the participants did not state their body weight, and as a result, the number of participants is correspondingly lower than stated in Chapter 3.

The median intake of dioxins and dioxin-like PCBs from fish and other seafood is 4.7 pg TE/kg body weight/week, corresponding to about 30% of the TWI. 4% has an intake of dioxins and dioxin-like PCBs from fish and other seafood alone that exceeds the tolerable weekly intake of 14 pg TE/kg body weight/week (figure 16).

Fatty fish is an important source of dioxins and dioxin-like PCBs, while lean fish contributes little to the exposure (Figure 17). Relatively few people eat cod liver, but among those who do, this alone may contribute up to 3.5 pg TE/kg body weight/week. The remaining foods in the Norwegian diet (all food except fish and other seafood) contribute approximately 4 pg TE/kg body weight/week (median value, data based on Norkost 1997, personal statement Christina Bergsten). When the contribution from other foods is added to the intake from fish and other seafood, a higher proportion of participants in the Fish and Game Study, Part A, will exceed the TWI for dioxins and dioxin-like

PCBs than the 4% who ingest more than the the TWI from fish and seafood alone. An estimate of exposure from all foods is also illustrated in Figure 17. This shows that some 85% of the Norwegian population has an intake of dioxins and dioxin-like PCBs which is estimated to be below the TWI.

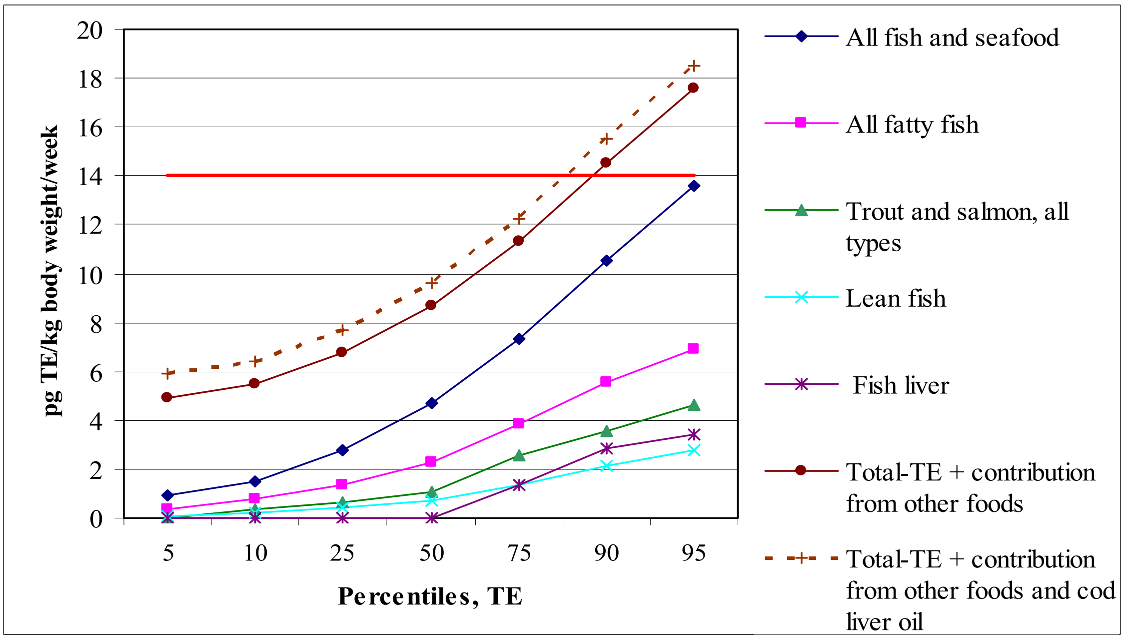


Figure 17 Contribution to the exposure to dioxins and dioxin-like PCBs from various fish groups. Fish consumption is based on all participants in the Fish and Game Study, Part A. Included in the fatty fish category are herring, mackerel, eel and all kinds of salmon and trout. An indication of the total intake from the diet is obtained by adding 4 pg TE/kg body weight/week to the total intake from fish to express the contribution from all other groups of foods. The broken line indicates the total intake from all foods if the recommended dose of cod liver oil is also taken. The tolerable weekly intake (14 pg TE/kg body weight/week) is indicated by a horizontal red line. Note that the percentiles cannot be added because the sample of participants is not identical in each category.

8.4.2.3 Estimated intake of dioxins and dioxin-like PCBs from fish liver

Cod liver is one of the foods that show the greatest variation in the content of dioxins and PCBs. A number of analyses suggest that cod from the Bering Sea contain lower levels of dioxins and dioxin-like PCBs than cod that live in fjords or near the coast. The range is from below 10 pg TE/g liver to over 200 pg TE/g liver (Bergfald & Co AS, 2006). For those who eat cod liver, cod liver contributes substantially to the total exposure to dioxins and dioxin-like PCBs from fish and other seafood. Estimates from the Fish and Game Study, Part A, indicate that if cod liver contains 10 pg TE/g, only those with a high consumption of liver (more than two meals of 30 g per month) will exceed the TWI when this comes in addition to the intake from fish and seafood and other food. If the cod liver contains more than 60 pg TE/g, also the median consumer of fish liver (six meals of 30 g per year) will be exposed to levels close to the TWI.

8.4.2.4 Estimated intake of dioxins and dioxin-like PCBs based on dietary studies of children

The dietary studies Småbarnskost 1999 and Ungkost 2000 (cf. Table 2, Chapter 3) make it possible to calculate intake estimates of dioxins and dioxin-like PCBs, both from the total diet and from fish alone, for the age groups 2, 4, 9 and 13. It must be emphasised that there are uncertainties linked to these estimates; among other factors, they have not been validated by biomarkers. In particular, uncertainty is associated with the contribution from foods that do not belong to the seafood group because the estimates are based on preliminary data from uncompleted projects.

Figure 18 indicates that the intake of dioxins and dioxin-like PCBs from the total diet exceeds the TWI for a high proportion of the youngest children in particular. This is because children eat more food in relation to their body weight than adults, which in turn affects the intake of dioxins and dioxin-like PCBs when the burden is calculated by per kilo body weight. The contribution from cod liver oil is not included in the estimated exposure from all foods. Instead, calculations have been made, based on a hypothetical situation in which all children take a recommended daily dosage of cod liver oil, and the contribution from this cod liver oil has been added to the total exposure (illustrated in the figures). It is clear that consumption of cod liver oil will add considerably to the exposure to dioxin and dioxin-like PCBs to children of all ages, and especially to the youngest children.

It is important to remember that the burden of dioxin and dioxin-like PCBs will increase in the bodies of children at a slower rate than in adults because of dilution due to increased body weight during growth. It is the concentration in the body that causes the toxicological effects. Since the foetus is the most sensitive, the TWI has been set primarily to avoid an elevated concentration in the mother's blood during pregnancy and is meant to protect against excessive accumulation (over a lifetime) up to the time of a pregnancy.

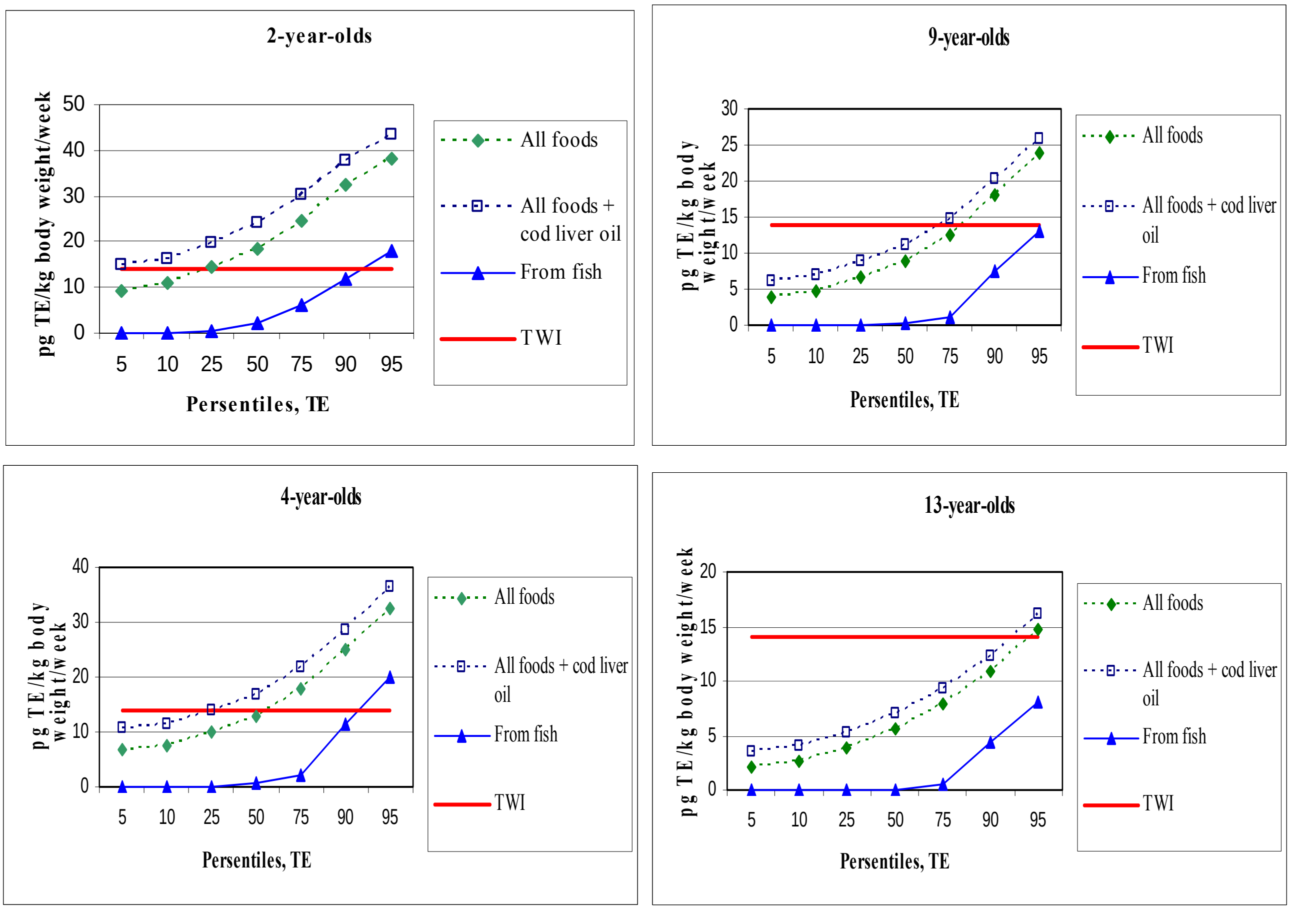


Figure 18 The children's exposure to dioxins and dioxin-like PCBs from fish alone, from the total diet and from the total diet with the addition of cod liver oil. The estimates are made using data from Småbarnskost and Ungkost. The TWI (14 pg TE/kg body weight/week) is indicated by a horizontal red line.

Figure 18 also shows that the youngest children who do not eat fish at all, but take cod liver oil, may exceed the TWI. The figures illustrate that there are many other sources of dioxins and dioxin-like

PCBs in the diet than fish and seafood. Meat is the largest contributor among these other sources, while milk, butter and margarine also contribute to the total intake (VKM, 2004).

As shown in Chapter 3, Table 4, fish consumption among children is very unevenly distributed, and many of the older children in particular do not eat fish. Fish accounts for only 11-18% of the total exposure to dioxins and dioxin-like PCBs for an average child. Nonetheless, fish contributes to a substantial intake of dioxins and dioxin-like PCBs among the children who do eat fish – up to 60% of the total intake. Among the children age 2-4 with the highest exposure from fish, the contribution from fish alone results in exceeding the the TWI (Figure 18). A high proportion of exposure to dioxins and dioxin-like PCBs from fish and other seafood in children are attributed to a high consumption of cold cuts and spreads, which mostly consist of fatty fish.

8.4.3 Scenarios for exposure from contaminants in fish

Table 21 illustrates the intake of different contaminants at a median consumption of fish (65 g/per day), if only lean fish, only fatty fish or if 2/3 lean fish and1/3 fatty fish is eaten. The latter estimate reflects the average distribution of the fish consumption in the Norwegian population; cf. Chapter 3. The scenarios do not include fish liver or freshwater fish.

Table 21 The table shows the contribution from fish to the intake of various contaminants if the consumption of fish is low (27 grams per day), median (65 g/day) or high (119 g/d). Furthermore, the table shows the significance of the proportion of lean or fatty fish for intake. The scenarios do not include fish liver or freshwater fish.

	Intake scenarios	**Low intake 10-percentil 1 serving/week (27 g/dag) kg body weight/week**	**Average intake 50-percentil 2 servings/week (65 g/dag) kg body weight/week**	**High intake 90-percentil 4 servings/week (119 g/dag) kg body weight/week**
Mercury (µg)	Lean fish	0,1	0,2	0,4
	2/3 lean and 1/3 fatty fish	0,1	0,2	0,4
	Fatty fish	0,1	0,2	0,4
dl-PCB (pgTE)	Lean fish	0,1	0,5	0,6
	2/3 lean and 1/3 fatty fish	0,8	1,8	3,4
	Fatty fish	2,6	6,3	12
Dioxin (pgTE)	Lean fish	0,1	0,3	0,6
	2/3 lean and 1/3 fatty fish	0,4	0,9	1,6
	Fatty fish	1,3	3,1	5,6
Dioxin+PCB (pgTE)	Lean fish	0,3	0,9	1,2
	2/3 lean and 1/3 fatty fish	1,1	2,7	5,0
	Fatty fish	3,9	9,3	17

PTWI for methyl mercury is 1.6 µg/kg body weight/week (JECFA, 2003). In fish 75-100% of the mercury is methyl mercury. As can been seen in table 21 the mercury burden will be much lower than the tolerable intake level even with a large consumption of fish. Fish with a high mercury content, such as pike and perch, is not included in the model. Since overall consumption of these fish in the general population is low, it is assumed that this will not affect the results. However, on an individual level the consumption of this type of fish may lead to exceeding the PTWI for methyl mercury (cf. Section 8.4.1.3).

TWI for dioxin and dioxin-like PCBs (SCF, 2001) is 14 pg TE/kg body weight/week. In the scenarios above it is clear that the TWI may be exceeded by consuming large amounts of fatty fish. Fish liver is not included in the model because the overall consumption is low. However, on an individual basis the consumption of fish liver may lead to exceeding the the TWI for dioxins and dioxin-like PCBs (cf. Section 8.4.2.3).

Intake estimates of dioxins and dioxin-like PCBs based on the Fish and Game Study, Part A, show a median intake of 4.7 pg TE/kg body weight/week. From what is known it is reasonable to assume that fish and other seafood accounts for 60-80% of the total intake of dioxins and dioxin-like PCBs in the average Norwegian diet.

8.4.3.1 Farmed fish

Exposure to organic contaminants by consumption of farmed fish has attracted considerable attention in recent years. Table 19 shows that the level of dioxins and dioxin-like PCBs in farmed fish is not particularly high compared with the level in wild fatty fish. In 2004 the average and median concentration of dioxins and dioxin-like PCBs in farmed salmon was 1.7 pg TE/g fresh weight in 2004 (28 samples analysed), with the lowest and highest values being 0.9 and 2.7 pg TE/g fresh weight, respectively. New analyses from 2005 demonstrate an average concentration of 1.5 pg TE/g fresh weight (lowest and highest values 0.7 and 2.8 respectively pg TE/g fresh weight). A total of 58 samples were analysed (National Institute of Nutrition and Seafood Research).

Because the majority of Norwegians eat farmed fish the level of these contaminants in farmed fish will affect the total exposure to dioxin and dioxin-like PCB from fish and other seafood. This is illustrated in Figure 19, which presents how different levels of contaminants in farmed fish affect the total intake of dioxins and dioxin-like PCBs. The estimates are based on fish consumption data from the Fish and Game Study, Part A, for all participants. Due to the fact that many people are unaware whether the fish they eat is wild or farmed, different levels of dioxins and dioxin-like PCBs (0.5 pg TE/g fish, 1 pg TE/g fish, 1.5 pg TE/g fish, 2 pg TE/g fish and 2.5 pg TE/g fish) have been used for all salmon and sea trout, and not simply for farmed fish. These estimates show that a reduction of dioxins and dioxin-like PCBs from 2 pg TE/g fish to 0.5 pg TE/g fish will reduce the average exposure from all fish and other seafood by roughly 25%. In the Fish and Game Study, Part A, high consumption (95th percentile) of fish and sea trout is about one meal of fish per week.

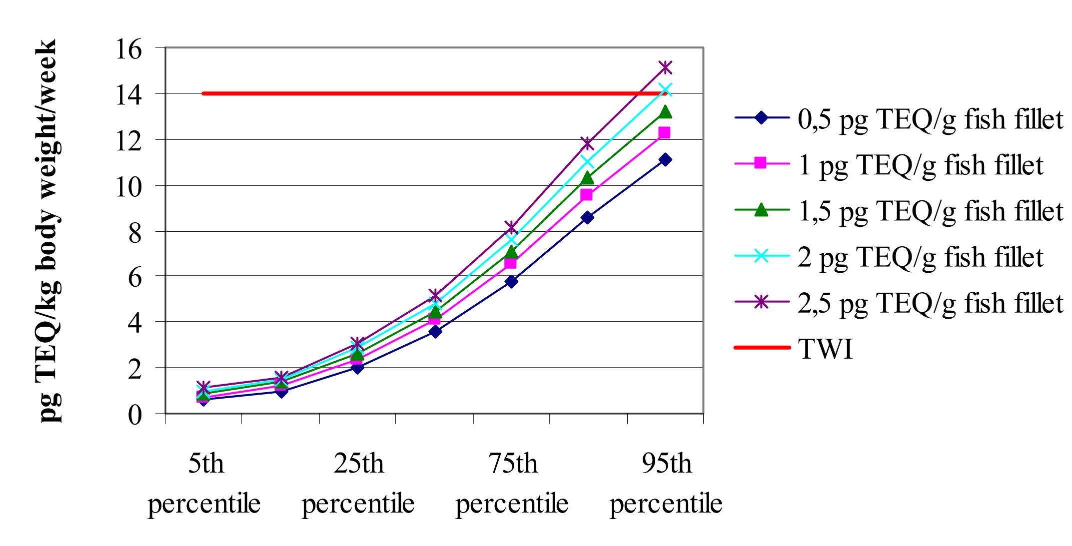


Figure 19 The significance of different contamination levels of dioxins and dioxin-like PCBs in salmon and trout for dietary intake. The estimates include all participants in the Fish and Game Study, Part A. The median exposure from other food (4 pg TE/kg/week) plus potential cod liver oil consumption (0.95 pg TE/kg body weight/week) come in addition to this. The horizontal unbroken red line shows the TWI for dioxins and dioxin-like PCBs (14 pg TE/kg body weight/week). Average, consumption of salmon and trout is 8.7 g/day with an average among consumers of 9.5 g/day, corresponding to 1.4 meals of 200 g fish per month. High consumption (95th percentile) of salmon and sea-trout corresponds to about four meals per month.

Sales figures reveal that the purchase of farmed fish by Norwegian households is increasing (Directorate for Health and Social Affairs, 2004). Since both the Fish and Game Study, Part A, and Norkost were published several years ago (1999 and 1997, respectively), the consumption of farmed fish in these studies give an underestimation of the present situation. Theoretical estimates have therefore been made of the exposure to dioxins and dioxin-like PCBs in adults based on a varying number of portions of farmed fish and with different degrees of contamination in the fish (Figure 20). Estimates have been made for farmed fish using the 2004 average level 1.7 pg TE/g salmon and for salmon with higher (2.5 pg TE/g) and lower (1.0 pg TE/g) values to take into account the variation in content in farmed salmon measured in 2004 and to give an impression of what effect a higher or lower degree of contamination in salmon may have for exposure.

The calculations show that the total exposure to dioxins and dioxin-like PCBs from all foods will reach the TWI level with a consumption of between 1.5 and 2 weekly meals of farmed fish containing 1.7 pg TE/g, If the average level in salmon were 1 pg TE/g, it would be possible to eat three weekly meals of salmon before the total exposure from all food would reach the TWI. If the average level were 2.5 pg TE/g, only one weekly meal of salmon could be eaten before the total exposure from all foods reached the TWI. This must be regarded as a highly simplified approach. The consumption of a number of other foods will also play an important role, e.g. consumption of seagull's eggs and/or brown crabmeat will also greatly increase the exposure. Exposure from other seafood is not included in the estimates, but for the most part it may be assumed that this would be small with a high consumption of fatty fish. Based on the dietary studies (cf. Chapter 3), few people eat more fatty fish (including cold cuts and spreads made of fish) than the equivalent of two meals per week (400 g which represents 57 g/day).

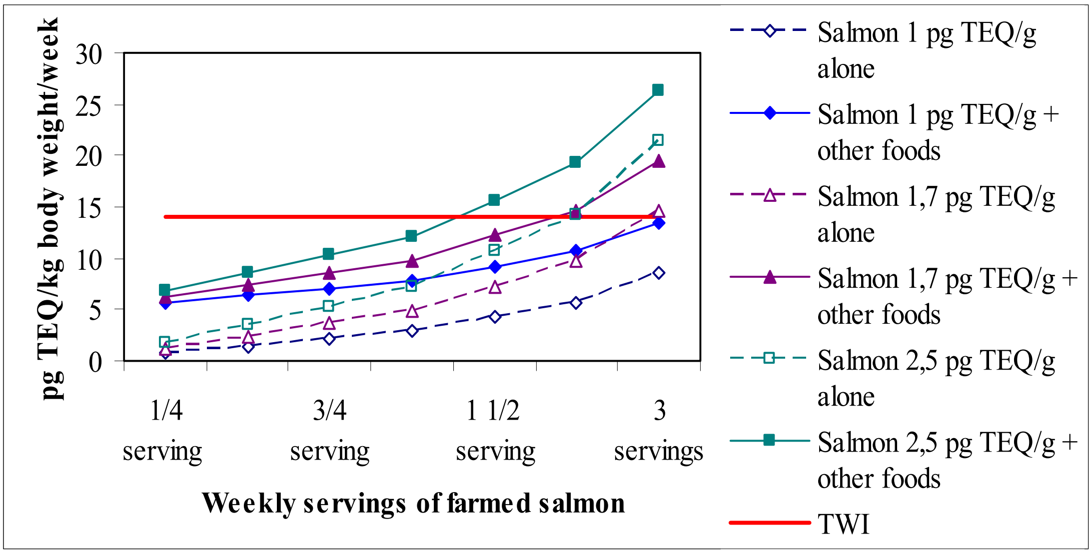


Figure 20 Simple model estimates of weekly intake of dioxins and dioxin-like PCBs for different patterns of consumption of farmed salmon with varying contamination levels. A meal is equivalent to 200g salmon. The category 'other foods' (4.95 pg TE/kg/week) includes the median intake (4 pg TE/kg body weight/week) from food other than fish and other seafood given in Norkost 1997 plus the recommended daily intake of cod liver oil (0.95 pg TE/kg body weight/week). The horizontal unbroken red line represents the TWI for dioxins and dioxin-like PCBs (14 pg TE/kg body weight/week).

8.5 Summary – the impact of fish and other seafood for the intake of nutrients and compounds that are potential health hazards

The summary of the intake of nutrients from fish and other seafood shows that this group of food is a good source of protein, the vitamins D and B_{12}, and the minerals iodine and selenium. In addition, the consumption of fatty fish contributes considerably to the intake of n-3 fatty acids through its high content of marine n-3 fatty acids.

However, intake estimates based on national dietary studies show that the consumption of fish and other seafood is lower than desired in terms of meeting the recommended intake of vitamin D and n-3 fatty acids. At the same time, cod liver oil and several other types of food supplements contain vitamin D so the recommended daily intake is met for people who take this kind of supplement, even among the large group of children who never eat fish.

The recommended daily intake of vitamin D is fairly well met by eating two meals of fatty fish per week, and the intake of n-3 fatty acids is also close to the recommended intake. One to two meals of lean fish per week meets the recommended daily intake of iodine. The normal consumption of fish in Norway meets the requirement for vitamin B_{12}.

Even a high fish consumption (corresponding to four meals per week), whether it be lean or fatty fish, will not result in hazardous intakes of any nutrient or marine n-3 fatty acids.

The intake estimates show that even a high consumption of fish with an average mercury level does not present a risk of exceeding PTWI, neither for children nor adults. Large fish of some fish species such as pike, perch, freshwater trout, swordfish and tuna (different species than tinned tuna), may have a higher mercury level, and consumers of such fish may risk exceeding the PTWI.

Median intake of dioxins and dioxin-like PCBs from fish and other seafood is estimated to be 4.7 pg TE/kg body weight/week, corresponding to approximately 30% of the TWI. When the intake from the total diet is calculated, at least 85% of the adult population is found to have an intake below the TWI (figure 16).

Many children, especially the youngest, exceed the TWI for dioxins and dioxin-like PCBs when considering the total diet. This is because children eat more food in relation to their body weight than adults, which in turn affects the intake of dioxins and dioxin-like PCBs when the burden is calculated by per kilo body weight. For the majority of children age 2-13, fish and other seafood contribute little to exposure to dioxins and dioxin-like PCBs because many children do not eat fish at all. However, fish contribute substantially to the intake of dioxins and dioxin-like PCBs among children who eat fish, and for the 2-year-olds and 4-year-olds who eat most fish, the consumption of fish alone may lead to exceeding the the TWI.

Intake of dioxins and dioxin-like PCBs from purified cod liver oil alone may constitute up to 50% of the tolerable daily intake (TWI) for dioxins and dioxin-like PCBs in the youngest children. Since the recommended amount of cod liver oil is the same for adults and children, the intake is highest among children. The youngest children who eat fish and take cod liver oil will have a total intake of dioxins and dioxin-like PCBs that shows a considerable exceeding of the TWI.

Cod liver is one of the foods that shows the greatest variation in the content of dioxins and PCBs. Estimates from the Fish and Game Study, Part A indicate that if cod liver contains 10 pg TE/g, only those with a high consumption of liver (more than two meals of 30 g per month) will exceed the TWI when this is added to the intake from fish and seafood as well as other foods. If cod liver contains more than 60 pg TE/g, the median consumer among those who eat fish liver (six meals of 30 g per year) will also be exposed to levels close to the TWI.

The calculations show that by eating about two weekly meals of farmed fish with an average dioxin and dioxin-like PCB content of 1.7 pg TE/g, the total exposure to dioxins and dioxin-like PCBs from the total diet will reach the same level as the TWI. The total dietary exposure can be reduced by an average of 25% if the levels in farmed salmon are reduced from 2 to 0.5 pg TE/g fish.

9 A comprehensive assessment of fish and other seafood in the Norwegian diet

Seafood has been an important part of the diet throughout Norway's history. Fish consumption has been and is still among the highest in Europe. Norwegian consumption of seafood is characterised by a high proportion of lean fish and the fact that the consumption of fish in the form of cold cuts and spreads (mainly from fatty fish) is greater than in other countries. Also unique is the high consumption of cod liver oil, particularly by infants and children. However, a number of children and adolescents never eat fish – in some age groups half of them never it fish at all.

There is an extensive body of documentation which indicates that eating fish is generally beneficial to health, and there are strong grounds for concluding that the consumption of fatty fish in particular slows and prevents cardiovascular diseases. The consumption of fish and other seafood is also important for foetal development, e.g. growth and neurological development. The marine n-3 fatty acids in particular are assumed to play an important role in terms of health-promoting effects. In addition, a high consumption of fish may be associated with a lower intake of animal fat, and this is considered beneficial to health. The Directorate for Health and Social Affairs recommends a general increase in fish consumption because of the nutritional benefits, but no specific recommendations are given.

The beneficial effects of high fish consumption are balanced by documentation showing that a high consumption of some fish species may be associated with a high intake of contaminants and other substances that are potential health hazards. The Norwegian Food Safety Authority has issued dietary advice in cases where analytical data or intake estimates show high levels of contaminants. Ideally, dietary advice should take into account both the positive effects and potentially hazardous effects on health, but the focus in the mass media is most often on the significance of possible negative effects of the intake of chemical contaminants. In Norway dietary advice on avoiding or reducing consumption of fish and other seafood has mainly been limited to specific fjords and harbours with known pollution sources and where monitoring programmes have shown that fish and bivalves contain elevated levels of particular contaminants. In addition, dietary advice is provided for specific groups, e.g. those who are pregnant and breast-feeding mothers. The prime objective of the dietary advice issued by the Norwegian Food Safety Authority is to prevent high consumption of contaminated fish and other seafood.

In recent years, a number of scientific publications, as well as the national and international press, have repeatedly focused on the issue of the potential health risk from the intake of contaminants in fish. The discussions have mainly focused on the assessment of the chemical contaminants and the possible health risks posed by the consumption of wild fish and farmed fish. Less attention has been paid to the nutritional value of fish consumption. Based on this, the Norwegian Scientific Committee for Food Safety was asked to conduct an overall assessment incorporating both the nutritional benefits of the consumption of fish and other seafood and the possible health risk associated with the intake of chemical and microbiological contaminants in fish and other seafood.

A health-based risk-benefit assessment, in which the health benefits of some substances in a group of foods are balanced quantitatively against the health hazards of other substances in the same group of foods, is a very complex task. At present, there is no established methodology that can be employed to conduct a quantitative risk-benefit assessment. Many factors make an overall assessment of a food group difficult. A general problem is that risks and benefits are not necessarily comparable in size. Another factor is that there will always be considerable difficulties in assessing one isolated food group. The composition of the diet as a whole, along with the consumers' genetic constitution and other life style factors, has most impact for health. Furthermore, it must be emphasised that a food group is not homogenous with regard to nutrients or contaminants, and it is the amount of nutrients and/or contamination, respectively, ingested over time, that determines whether a food group will give positive or negative effects.

Regarding risk assessment of contaminants and undesirable compounds in food, methods have been established to determine safe intake levels of individual substances or substance groups, i.e levels that do not present a health risk for the general population. Safe intake levels are determined internationally and are expressed as the tolerable daily or weekly intake (TDI/TWI). If there is solid human data, TDI/TWI is derived from such studies (e.g. methyl mercury) while in many other cases the data is derived from animal studies (e.g. dioxins). The tolerable intake levels are intended to provide a high level of protection and are often derived from the toxological effects that are triggered at the lowest exposure dose (e.g. the TWIs for dioxins and methyl mercury are set in order to protect the foetus because the foetus is most sensitive to these substances). For dioxins, the tolerable level for weekly intake is estimated to prevent women to accumulate so much dioxin in the body that the foetus will be at risk. This implies that it is the total amount of dioxin accumulated over time that is significant. For practical reasons, the EU's Scientific Committee on Food has established a weekly intake level. In the Joint FAO/WHO Expert Committee on Food Additives (JECFA) a monthly intake is given. It would also be possible to estimate annual intake, but for practical reasons this would be difficult to relate to. In addition, the tolerable intake levels include a considerable safety margin (cf. Section 5.1). Consequently, tolerable intake levels established in order to protect the most sensitive individuals/population groups. This implies that other individuals/population groups are less sensitive and can probably tolerate considerable exceeding of the TWI with a minimal health risk. Thus, the tolerable intake levels are not a threshold for toxicity, and no quantitative risk is indicated when the tolerable intake is exceeded. Due to both the conservative manner in which the tolerable intake levels are derived and the safety margins applied, exceeding a tolerable intake level will first only represent a reduced safety margin.

A risk assessment consists of collating the tolerable intake levels with national intake estimates for the general population and/or sensitive groups in particular. The authorities base their regulation and dietary advice on a comparison between actual intake and TDI/TWI.

The recommended intake levels of nutrients also include a safety margin which ensures that the entire population will reach an adequate intake. In recent years, safe upper intake levels ('tolerable upper intake levels') have been established for most nutrients. In this manner, there may be health risk associated with a nutrient intake, both when it is too high and if it is too low.

The most reliable basis for concluding that there is a correlation between diet and health is established when observational (epidemiological) population studies are confirmed by clinical controlled studies, and at the same time, there is a plausible biological explanation. Consequently, an assessment will be based on the consistency, strength and quality in a collection of individual studies collocated with the total body of knowledge on the subject.

9.1 Intake estimates

When estimating the intake of nutrients and contaminants, analytical data for the respective substances in fish and other seafood are linked with data on the consumption of individual foods and food groups in the population.

Compared with many other countries, the knowledge used for estimating the consumption of fish and other seafood in Norway is good. The available data on people with the highest fish consumption and those with the lowest is more uncertain than the available data on people whose fish consumption is closer to the average. In Chapter 3 ('Nutrients in fish and other seafood') the consumption of fish and other seafood by the population is estimated based on data from the Fish and Game Study, Part A. Consumption by children is estimated based on Ungkost 2000 and Småbarnskost 1999. The median consumption of fish and other seafood (including fish and other seafood in the form of cold cuts and spreads) is determined to be about 65 grams per day for adults. About 2/3 of fish consumption consists of lean fish species and minced fish, and roughly 1/3 fatty fish species. Estimates from the Fish and Game Study, Part A, correspond well with Norkost 1997. The median consumption for children varies between 6-19 g/day, and the oldest age group (age 13) has the lowest consumption.

Chapter 8 presents intake estimates of nutrients and compounds that are potential health hazards from fish and other seafood. In order to obtain a representative picture of fish consumption, the population is grouped as follows: low consumption (10^{th} percentile), median consumption (50^{th} percentile) and high consumption (90^{th} percentile) with a consumption of 27, 65 and 119 grams of fish per person per day, respectively. This corresponds to one meal, almost two meals and more than four meals of fish per week, respectively. Furthermore, scenarios have been prepared in which fish consumption consists of only 'lean' fish', 2/3 'lean' fish and 1/3 'fatty' fish, or only 'fatty' fish. Therefore, there are nine possible combinations, with four meals of fatty fish per week the most unlikely because lean fish is more common in the diet than fatty fish. The Fish and Game Study, Part A, shows that the 50^{th} percentile for the consumption of lean and fatty fish (excluding cold cuts/spreads and shellfish) is 50 and 36 grams/day, respectively. Consequently, a consumption of 27 grams of lean fish per day (corresponding to about one meal per week) is not uncommon, whereas a consumption of 119 grams of fatty fish per day (corresponding to about four meals per week) would be very unusual. Dietary studies have not revealed any significant groups that eat the equivalent of four or more meals of fatty fish per week over time.

9.2 Risk-benefit characterisation of nutrients from fish and other seafood

Fish and other seafood contribute to a range of different nutrients to the diet. They contain high-quality proteins (covering all the essential amino acids), several vitamins (fat-soluble vitamin D in particular, but also water-soluble vitamin B_{12}), and not least the minerals iodine and selenium. Fish and other seafood are also a natural source of the marine n-3 fatty acids eicosapentaenoic acid (20:5n-3; EPA), docosapentaenoic acid (22:5n-3; DPA,) and docosahexaenoic acid (22:6n-3; DHA).

The intake of the most relevant nutrients and the marine n-3 fatty acids depending on how much fish a person consumes is summarised in Table 18, Chapter 8.

Scenario estimates show that low fish consumption (27 grams/day, equivalent of one meal of fish per week), especially consumption of lean fish, results in such a low intake of vitamin D that food supplements must be taken in order to reach the recommended intake of vitamin D. The recommended daily intake of vitamin D is 7.5 μg per day. A high consumption of fatty fish (119 g/day, equivalent of more than four meals per week) results in an intake of 10 μg/day. This still leaves a good margin before reaching the established upper intake level for vitamin D (25 μg for children and 50 μg for adults). An increased intake of Vitamin D is preferable in several population groups, and since fatty fish is a good source of vitamin D, an increased intake of fatty fish is advisable for various population groups based on an assessment of the intake of vitamin D.

Fish liver has a high content of vitamin D. The intake will however not exceed 13 μg/day which is far lower than the upper intake limit (50 μg) even if liver consumption is combined with high consumption of fatty fish, When 5 ml of cod liver oil per day is taken in addition, this will still not result in exceeding the upper limit for vitamin D. This is a theoretical pattern of consumption. The 95th percentile for the total intake of vitamin D among Norwegians is below 1/5 of the upper intake level (Fish and Game Study, Part A). In fact this intake is lower than recommended for those over 60 and pregnant women/breast-feeding mothers (10 μg/day).

Fish, especially lean fish, is a significant source of iodine in Norway. A high consumption of lean fish can give an intake of up to four times the recommended intake (150 μg/person/day), but the upper intake level for an adult (600 μg/person/day) will not be exceeded.

A high consumption of fish can also be a considerable source of vitamin B_{12} and selenium. Nonetheless, fish and other seafood are less important as a source of these nutrients because there are several other good sources of these nutrients in the diet. No upper intake level has been established for vitamin B_{12}. None of the scenarios results in an intake of selenium that is too high.

The intake of retinol (vitamin A) from fish and other seafood (with the exception of fish liver) is not substantial, irrespective of the consumption pattern, but if fish liver is eaten, the intake may be high. Seventy per cent of Norwegians do not eat fish liver, and the 95th percentile for intake among those who do eat fish liver is estimated in the Fish and Game Study to be about 3 grams/day, corresponding to 360 μg of retinol. Even if this is combined with the highest consumption of fatty fish (approx. 4 meals per week), given 34 μg retinol/day, there is an adequate margin before the upper intake limit of 3000 μg/day is reached. Moreover, a high consumption of fatty fish and fish liver is a very uncommon combination in Norway since a high consumption of cod liver is usually combined with lean fish. Even if 5 ml of cod liver oil (with 270 μg retinol) per day is taken in addition to a high consumption of fatty fish and and fish liver, this will not lead to exceeding the upper limit for the intake of vitamin A.

A low consumption of fish will result in a low intake of the marine n-3 fatty acids (EPA, DPA, DHA), and this in turn may lead to a loss of the health-promoting effects. In practice, a low intake must be compensated for by supplements in order to secure the beneficial effects. The recommended total intake of n-3 fatty acids is 1% of the total energy intake, corresponding to 2.6 grams/day, while the estimated minimum requirement is 0.5 E%, i.e. 1.3 g. For the majority of the population vegetable oils contribute more to the total intake of n-3 fatty acids than fish, i.e. in the range of 1.5 to 1.8 grams α-linolenic acid/day, an amount that meets the minimum requirement. However, to reach a recommended total intake of 2.6 g of n-3 fatty acids, the marine n-3 fatty acids must contribute from 0.8 to 1.1 g/day. This corresponds to a consumption of fatty fish of about 25 to 40 grams/day which is equivalent to one meal of fatty fish per week.

A very high consumption of fatty fish (approx. four meals per week) would result in 1.5 E% coming from marine n-3 fatty acids. This scenario is considered unlikely since a fish consumption equivalent to more than four meals of fatty fish per week far exceeds the norm in Norway. However, if this is combined with a high consumption (3 grams/day) of fish liver as well as 5 ml of cod liver oil per day, the intake will be in the range of 6 grams marine n-3 fatty acids per day, or a little over 2 E%. This intake may affect the coagulation capacity of the blood, but it probably cannot be regarded as harmful.

There is no realistic consumption of fish in Norway that can lead to a harmfully high intake of nutrients (vitamins and minerals), and this applies to children as well. Therefore, interest is focused on the consequences of low consumption, and on the consequences of not eating fish in particular, as well as on a low consumption of fatty fish. It is possible to compose a diet that meets the defined nutritional needs with only a little fish or no fish in the diet, but it is then difficult to reach the recommended intake of n-3 fatty acids and the requirement for vitamin D without resorting to food supplements.

Based on an assessment of the intake of nutrients – in particular the marine n-3 fatty acids and vitamin D – an increased consumption of fatty fish species is advisable, especially in the case of those who eat little fatty fish and for that half of the population who eats the least amount of fish. General advice on the adventages a varied diet also applies to fish; different kinds of fish should be eaten. Based on the assessment of intake of nutrients, there are no reasons why people should not eat fish and other seafood equivalent to four meals or more per week.

9.3 Risk characterisation of contaminants and other undesired compounds, including infectious organisms in fish and other seafood

Listeria monocytogenes represent the greatest microbiological risk in that the bacteria may contaminate fish products, e.g. smoked salmon, during production, thus posing a special hazard to pregnant women in particular. Furthermore, homemade *rakefisk* (partially fermented trout) presents a risk of botulism.

As regards contaminants and other undesirable compounds in fish and other seafood, it is dioxins and dioxin-like PCBs, as well as methyl mercury that represent the potentially greatest risk to health. Fish appears to be the most important source of these contaminants in adults, and the intake by some population groups is close to, or exceeds, the established TWI values. Other foods (meat, dairy products and eggs) are the main source of the contaminants in children and adolescents who eat little fish. Recently, brominated flame retardants (PBDEs) have received considerable attention, mostly because of their increasing concentration in the environment. However, the levels of PBDE in food remain low in relation to the level that is potentially hazardous to health.

The intake of contaminants is estimated by linking the consumption of individual fish species/fish products (Fish and Game Study, Part A) with the analytical data from unpolluted areas (background areas). The most important sources of dioxins and PCBs are fatty fish and fatty liver from lean fish species. Large predatory fish is the most important source of methyl mercury.

Concentrations of contaminants in fish vary according to fish species, age, time of sampling, nutritional basis, etc. Organic contaminants such as dioxins, dioxin-like PCBs and brominated flame retardants are fat-soluble and accumulate in fatty tissue. The fat content and the distribution of fat in fish is significant for the intake of these contaminants.

Table 21 shows the contribution from fish to the adult intake of different contaminants if fish consumption is low (equivalent to one meal per week), median (equivalent to two meals per week) and high (equivalent to four meals or more per week). Furthermore, the significance of the proportion of lean and fatty fish for the intake of mercury, dioxins and dioxin-like PCBs is illustrated.

The highest values of mercury are found in large pike, large trout, large Arctic char, and large perch in freshwater. High mercury values may also be found in top predators such as halibut, tuna and swordfish.

It is evident from the scenarios that none of the estimated intakes of mercury pose a problem compared with the current PTWI (1.6 µg/kg body weight) (Figure 13). This also applies to children.

Even for high consumers of fish (90th percentile), the contribution from fish is well below the tolerable value (approximately 25% of the PTWI). Fish such as pike and perch are not included in the model since they can contain large amounts of mercury. It is assumed that this will not affect the result since the consumption of these fish species in the population as a whole is low. However, for some individuals a high consumption of these fish species may result in exceeding the PTWI.

Less than 1% of the persons in the Fish and Game Study, Part A, exceeded PTWI for mercury; the majority of them through consuming consumed large quantities of pike.

It is important to keep in mind that PTWI for mercury has been set to protect the most sensitive life stage, i.e. the foetus. Thus, pregnant women or women who intend to become pregnant must be careful and special dietary advice is issued for them. People at other life stages are assumed to be less sensitive, although mercury exposure appears to give an increased risk of cardiovascular disease in susceptible population groups. However, this effect is not yet quantifiable.

Fatty fish is considered to be the most important source of dioxin exposure, but other types of fish and seafood can also contribute significantly to the total TE exposure. Figure 17 (Chapter 8) shows that the contribution from fish and other seafood alone almost amounts to the tolerable weekly intake in those with the highest intake of dioxins and dioxin-like PCBs. However, more than 85% of Norwegians have an intake of dioxin and dioxin-like PCBs below the TWI, also when foods other than fish and seafood are included.

Scenario calculations of dioxin and dioxin-like PCB exposure show that high consumers of fatty fish (equivalent to more than four meals of fatty fish per week) could exceed the TWI of 14 pg TE/kg body weight by about 20%. This is however an unusually high consumption of fatty fish according to dietary studies. In addition, there is a contribution from other food groups and possibly cod liver oil estimated to 4+1 pg TE/kg body weight per week in the average diet of adult Norwegians.

The majority of children eat little or no fish and other seafood. Therefore, fish and other seafood contribute little (11-18% depending on the age group) to exposure to dioxins and dioxin-like PCBs for the majority of children from 2-13-years-old. The most important source of dioxins and PCBs for these children is not fish and seafood but meat, dairy products and eggs. For 2-year-olds and 4-year-olds who eat fish, fish and other seafood may contribute substantially to the intake of dioxins and dioxin-like PCBs, constituting some 60% of the intake for those with the highest consumption of fish and other seafood. For those 2-year-olds and 4-year-olds eating most fish, fish consumption alone may lead to an exceeding the TWI. For the youngest children, the intake of dioxins and dioxin-like PCBs from refined cod liver oil may constitute up to 50% of the TWI for dioxins and dioxin-like PCBs. Since the recommended dose of cod liver oil is the same for children and adults, the intake in relation to body weight is greatest for children. The total intake of dioxins and dioxin-like PCBs from cod liver oil for younger children who eat fish shows considerable exceeding of the TWI.

High consumption of foods with the highest concentrations of dioxin and dioxin-like PCB such as cod liver, roe and liver pâté and brown crabmeat will also lead to considerable exceeding of the TWI. This indicates that there may be individuals, groups of individuals and special age groups that have a reduced safety margin in relation to tolerable weekly intake. The most important consideration is consumption over time.

TWI is established to protect the most sensitive life stage – for dioxin this is the foetal stage. However, dioxins and dioxin-like PCBs have such a long half-life in the body that the body burden during pregnancy is not a result of the diet during pregnancy but of the diet over many years prior to pregnancy. Women who are not intended to have more children and men are assumed to be less sensitive to dioxin exposure.

Based on an assessment of toxological conditions, people in general can eat fish and other seafood equivalent to four meals or more per week. They should eat different kinds of fish because a weekly consumption equivalent to more than two meals of fatty fish with today's levels of dioxin and dioxin-like PCBs might lead to a moderate exceeding of the TWI. For some children, the dietary intake from fish might result in exceeding the TWI, but for most children (2-13 years) the contribution from other foods will dominate.

9.4 Health effects associated with fish consumption – epidemiological studies

Epidemiological studies show how fish consumption is associated with the risk of disease in the population. The consumption of fish and other seafood can be linked to both pathogenic exposures (e.g. intake of methyl mercury in the foetus and infants) and preventive exposures (e.g. marine n-3 fatty acids in the adult population in particular). An increasing consumption of fish is associated with a reduced risk of cardiovascular disease. A reduction in risk is documented best for coronary heart disease and for fatal infarctions in particular. Data from clinical trials also show that supplements of marine n-3 fatty acids reduce the risk of total mortality and coronary heart disease mortality among patients who have suffered a coronary infarction. Data available indicate that intake of methyl mercury from fish may result in an increased risk of cardiovascular disease. At present the risk is difficult to quantify.

Some US researchers have claimed that there is a theoretically increased risk of cancer due to intake of contaminants (Hites *et al.,* 2004). Epidemiological studies are unable to detect a risk of this order of magnitude (about one cancer death out of 100 000 in the course of a lifetime of 70 years). This theoretically increased number of cancer deaths is in any case much lower than the benefit gained because of fewer deaths due to cardiovascular disease (Rembold, 2004, Tuomisto *et al.,* 2004). Based on an assessment of the relevant literature, it is clear that fish consumption shows no reliable correlation with the development of cancer.

High fish consumption has been associated with a somewhat longer pregnancy and a higher birth weight, and marine n-3 fatty acids appear to have a positive effect on the visual function of preterm babies. There are epidemiological reasons for concluding that PCB exposure at the foetal stage may have detrimental effects, particularly on cognitive development, but the PCB exposure level among Norwegian women of reproductive age remains below the level of exposure at which foetal effects might be expected.

It is well documented in population studies that consumption of fish, whether lean or fatty, has overall positive health effects. Looking only at fatal coronary infarct and increased fish consumption, it may be estimated from quantitative analyses based on prospective investigations (König, 2005) that the number of coronary hearth disease mortalities (about 7 000 per year) could be reduced by 4% or by approximately 300 deaths per year if the average Norwegian increased their fish consumption by one meal per week.

9.5 A comprehensive assessment of fish and other seafood in the Norwegian diet

A comprehensive assessment of fish and other seafood in the Norwegian diet requires that the benefits of consuming fish and other seafood be weighed against the disadvantages. This includes a risk-benefit assessment of important nutrients from fish, a risk assessment of the main hazardous compounds found in fish, and an assessment of epidemiological studies describing correlations between the consumption of fish and human health. However, there is no established methodology for implementing a quantitative risk-benefit comparison.

Based on an assessment of the intake of nutrients as well as public health studies, increased consumption of fish is advisable, particularly for that half of the population with the lowest fish consumption. This applies to all kinds of fish, but particularly to fatty fish for those who eat little fish. The significance of increased consumption is linked first and foremost to a reduced risk of cardiovascular disease. There are also probable beneficial effects on pregnancy and foetal development. An increased intake of marine n-3 fatty acids is assumed to constitute an important underlying factor for such beneficial effects, but there may also be other significant considerations, such as lower consumption of other foods when fish is eaten. The recommended total intake of n-3 fatty acids is almost fully met by the consumption of about two meals of fatty fish per week. In the case of the recommended vitamin D intake, an average consumption of fish will not be enough to compensate for little sunlight, but two meals of fatty fish per week will nonetheless make a significant contribution. It is uncertain how much fish must be consumed in order to derive the full health benefits from marine n-3 fatty acids, etc. There is reason to believe that the benefits diminish for those with the highest intake. Therefore, there is some uncertainty as to whether people who already have a high consumption of fish and other seafood can obtain further health benefits from eating even more fish.

A limiting factor for fish consumption might be the dioxins and dioxin-like PCBs found in fatty fish in particular. At present levels of dioxins and dioxin-like PCBs, the consumption of fatty fish in amounts equivalent to more than two meals per week over time will lead to intakes exceeding the tolerable intake level. As mentioned above, the tolerable intake level is aimed at preventing a high level of accumulation of dioxins and dioxin-like PCBs in women up to and during pregnancy. It should be noted that consumption must have been at this order of magnitude throughout a woman's reproductive years in order to exceed the accumulated amount that the tolerable intake level is meant to protect against. With today's consumption of fatty fish, it is highly improbable that a general recommendation to increase fish consumption will result in young women exceeding a consumption equivalent to two meals of fatty fish or more per week over time. It must be stressed, however, that the tolerable intake level represents a level of safety, not a limit at which hazardous effects on health will occur. Even if the recommended safety margin were to be reduced, moderate excesses would in all likelihood entail little risk. There are no demographic studies that have elucidated this empirically, taking into account that the expected effects will be small.

The recommended intake of n-3 fatty acids will almost be met by two meals of fatty fish per week. Therefore, the question is whether there is a risk if fertile women were to increase their regular consumption of fatty fish beyond two meals per week. Dietary studies show that pregnant women have an average consumption of fatty fish corresponding to just less than half a meal per week. As a result, it appears unlikely that the majority of Norwegian women would increase their consumption of fatty fish to levels that would cause them to exceed the TWI, but there is good reason to recommend a varied diet of different kinds of fish and other foods.

9.6 Developmental features of nutritional, toxological or other conditions that could result in future need for reassessments of the recommendations

Norwegian fish consumption has traditionally been high and has included a large proportion of lean wild fish. Fish farming is growing in volume, while there is stagnation and/or decline in the catch of wild fish. Accordingly, it is anticipated that farmed fish will generally constitute an ever-increasing proportion of fish consumption. Due to favourable price developments, particularly for fatty farmed fish, the proportion of fatty fish in the diet is expected to rise.

Restrictions and a ban on the use and emission of PCBs and dioxins have led to a significant declining trend in the level of these contaminants. Nonetheless, due to slow degradation, these undesirable compounds, especially in fatty fish and other seafood with a high fat content, may constitute a potential health risk for many years to come. In the long term, however, the potential risk associated with exposure to these organic contaminants is expected to decline significantly.

Until recently, pollution from brominated flame retardants was on the increase. New restrictions and a ban on the use of a number of flame retardants have already stopped this trend, and even reversed it for some brominated flame retardants. Consequently, brominated flame retardants (especially of the PBDE type) are not expected to pose a food safety problem.

Information on PFAS in the environment is limited, so it is not possible to comment on development trends for PFAS or on whether PFAS constitutes a potential food safety problem.

Farmed fish is also a source of undesirable compounds. These are found in fish fillet in concentrations that to a certain extent reflect the amounts found in the feed, although absorption and retention vary depending on the type of contaminant. In farmed fish, organic contaminants such as dioxins and dioxin-like PCBs are among the few exposure sources that can be influenced within a reasonable time frame. This can be accomplished by choosing feed ingredients with a low content of organic contaminants or by implementing purification processes in feed production. It is well-known that fish oil contains the largest amounts of organic contaminants such as dioxins and dioxin-like PCBs. Fish oil with low levels of contaminants is found in the southern hemisphere in particular, but this is a limited resource. Fish oil can be replaced with vegetable oil but the amount of marine n-3 fatty acids in fish will then be reduced, and the health-promoting effects will be altered.

The nutritional composition of farmed salmon, trout, cod and halibut varies depending on the raw ingredients and components in the feed. The result is that the nutritional value of the final product may vary considerably, depending on the feed eaten by the fish. It has been demonstrated that salmon can be 'customised' in terms of the profile of fatty acids in the fillet, and that the content of fat-soluble vitamins and some minerals can be enhanced through the feed. Fish can be a good source of water-soluble vitamins, but the level and type of vitamins in the feed will only determine the content in some farmed fish.

While the maximum content of contaminants and additives in fish feed is regulated (Feed Regulations), there are no regulations that applly to the nutrient content in the feed. It is therefore the responsibility of the aquaculture industry to blend the feed components to achieve good health and growth of the fish, which will in turn have a decisive impact on the nutritional value of the fish.

9.7 Summary of the overall assessment of fish and other seafood in the Norwegian diet

VKM has carried out an assessment that incorporates both the nutritional benefits of consuming fish and other seafood and the health risk associated with the intake of contaminants and other undesirable compounds that may be present in fish and other seafood. The overall assessment has been based on relevant Norwegian intake data. Insofar as possible, the benefits have been compared against the risks – nutritional significance and toxicology. In addition, the assessment is based on information from the overall assessment of fish and other seafood published in reports from the Danish Veterinary and Food Administration, the Food Standard Agency Scientific Advisory Committee in the UK, the assessment of the European Food Safety Authority (EFSA) of farmed fish and wild fish, and other relevant documentation.

Fish consumption in Norway deviates from the patterns seen in many other countries. Consumption is high, the proportion of lean fish is high, and Norwegians eat substantial amounts of fish in the form of cold cuts and spreads because they generally eat several bread meals daily. The median fish consumption is about 65 grams per day for adults (the equivalent of two meals of fish per week). Two-thirds of the consumption consists of lean fish species and minced fish, and about 1/3 of fatty fish. The median consumption for children varies from 6 to 19 grams per day. While most adults eat some fish and other seafood, there are a large number of children and adolescents who do not eat fish or other seafood at all. Young females eat less fish than the adult population in general. Women of reproductive age (the median) eat fatty fish corresponding to just less than half a meal per week.

The type of seafood and fish species, season, feed, life stage (developmental and reproductive stage) and age affect the content of nutrients and contaminants alike. There is large variation both in levels of contamination and individual nutrients in the same fish species and among different fish species, as well as in other seafood.

Assessment of nutritional factors

- Fish and other seafood are an important source of high-quality proteins (covering all the essential amino acids), the marine n-3 fatty acids eicosapentaenoic acid (20:5n-3; EPA), docosapentaenoic acid (22:5n-3; DPA,) and docosahexaenoic acid (22:6n-3; DHA), certain vitamins (particularly fat-soluble vitamin D but also water-soluble vitamin B_{12}) and some minerals (especially iodine and selenium).

- No realistic level on consumption of fish and other seafood in Norway can lead to a harmful intake of nutrients (vitamins and minerals, especially vitamin D and n-3 fatty acids). This also applies to children. Interest is therefore focused on the consequences of a low intake, and in particular on the consequences of not eating fish at all and of a low consumption of fatty fish.

- Even an average consumption of fish (equivalent to about two meals of fish per week) results in such a low intake of vitamin D (roughly 25% of the RDA) that people must either depend on sunlight as a source of vitamin D or take food supplements.

- A low consumption of fish results in a low intake of the marine n-3 fatty acids (EPA, DPA, DHA). This may in turn lead to the loss of acknowledged health-promoting effects. In practice, supplements must compensate for such a low intake if the beneficial effects are to be achieved.

- It is possible to compose a diet that meets most of the defined nutritional requirements without including fish, or including only a little fish. However, it is difficult to reach the recommended intake of vitamin D and n-3 fatty acids without resorting to food supplements.

- Based on an assessment of the intake of nutrients, in particular the marine n-3 fatty acids and vitamin D, it is advisable to eat more fatty fish, especially for those who eat little fatty fish and for that half of the population who eats the least amount of fish.

- There are solid grounds for concluding that the consumption of fish and other seafood, in particular fatty fish, has a health-promoting (beneficial) effect by slowing down and preventing the development of cardiovascular diseases. The consumption of fish and other seafood, especially fatty fish, can also be beneficial for pregnancy and foetal development, including the development of cerebral functions.

- Studies show that among those who eat little fish, an average increase of one meal of fish per week might reduce the risk of fatal coronary heart disease by 4%.

- Apart from those who are allergic to fish or have special metabolic diseases, there are no other health-related considerations to counter-indicate eating fish.

- On the basis of an assessment of the intake of nutrients, there is no risk linked to eating fish and other seafood equivalent to four meals or more per week. The general advice on a balanced diet also applies to fish, i.e. people should eat different types of fish.

Assessment of toxological factors

- Fish can be a source of contaminants and other undesirable compounds. The most significant among them are the organic dioxins and PCBs that endanger health. Of the hazardous metallic compounds, methyl mercury is the most significant.

- The average content of organic mercury is low, and even when fish consumption is high, neither children nor adults will exceed the PTWI. For some species of fish (pike, perch, freshwater trout, swordfish and tuna (different species than tinned tuna), large fish often have higher mercury levels and their consumption may lead to exceeding the PTWI.

- Levels of man-made radionuclides in Norwegian fish and other seafood are low, and these substances are considered to be of no significance for health. Pharmaceuticals used in fish farming are monitored closely, and illegal residues of pharmaceuticals in Norwegian farmed fish intended for consumption have not been observed in national monitoring programmes. Algal toxins primarily pose a problem in shellfish. Continuous monitoring of shellfish before they are put on the market ensures that algal toxins in shellfish are not regarded as a problem.

- Fish, particularly fatty fish, and other seafood with a high fat content (cod liver, roe and liver pâté and brown crabmeat) are the main sources of dioxins and PCBs in Norway. The levels of brominated flame retardants are low.

- Due to national and international restrictions and prohibitions on use, levels of brominated flame retardants (e.g. PBDEs), dioxins and PCBs are on the decline in the environment and in humans.

- People who, over a long period of time, have a high consumption of cod liver, roe and liver pâté and brown crabmeat containing relatively high levels of dioxins and dioxin-like PCBs may exceed the tolerable intake level considerably.

- Foetuses and young children are most sensitive to dioxins, dioxin-like PCBs and organic mercury. For methyl mercury, it is possible to reduce the mother's body burden by reducing exposure prior to and during pregnancy. The same is not possible for dioxins and PCBs due to their very long half-time in the body.

- The total intake of dioxins and dioxin-like PCBs in at least 85% of the adult Norwegian population is estimated to be under the TWI.

- At present, the exposure level to PCBs in Norway is well under the level at which permanent neurotoxic effects have been observed.

- 2-year-olds and 4-year-olds who eat fish and take cod liver oil may exceed the TWI on the basis of their overall diet.

- For the majority of children, the main sources of dioxins and dioxin-like PCBs are meat, dairy products and eggs. This is because many children and adolescents do not eat fish or only eat very little fish.

- For the youngest children, the intake of dioxins and dioxin-like PCBs from refined cod liver oil alone may constitute up to 50% of the tolerable weekly intake (TWI) of dioxins and dioxin-like PCBs.

- ***From a toxological perspective,*** adults can eat fish and other seafood corresponding to four meals or more per week when consumption is varied and when the consumption of fatty fish, at current levels of dioxins and dioxin-like PCBs, does not exceed two meals per week. This limitation applies particularly to women of reproductive age. However, to accumulate and exceed a body burden of dioxins and dioxin-like PCBs that the TWI is intended to protect against, a consumption equivalent to more than two meals of fatty fish per week must start in childhood and last throughout a woman's reproductive years. However, dietary studies show that pregnant women consume an average of just less than half a meal per week. Even high consumers (95th percentile) in the group do not eat more than 1.5 meals of fatty fish per week. For some children, intake through food may lead to exceeding the TWI, but for most children (ages 2 to 13), contributions from other foods will dominate.

Assessment of infectious organisms

- *Listeria monocytogenes* represents the greatest microbiological risk since the bacteria can contaminate fish products such as smoked salmon during production, thereby constituting a special danger to pregnant women. Furthermore, homemade *rakefisk* (partially fermented trout) presents a risk of botulism.

Special circumstances related to farmed fish

- Contamination levels in wild fish can only be reduced by lower emissions of contaminants to the natural environment. Farmed fish on the other hand is greatly influenced by the composition of the feed used.

- Exposure to organic contaminants, such a dioxins and dioxin-like PCBs, from farmed fish and cod liver oil/food supplements can now be influenced within a reasonable time frame without reducing the consumption of the product. This may be done by choosing feed ingredients with a naturally low content of organic contaminants or by carrying out purification processes.

- The nutrient content of farmed fish and its nutritional value may also be affected by the choice of feed. Salmon fillet can be 'customised' with regard to the fat profile and the content of fat-soluble vitamins and some minerals.

- Fish oil and fish meal feed are important sources of marine n-3 fatty acids as well as contaminants in farmed fish. If marine fat is replaced by vegetable fat, levels of dioxins and dioxin-like PCBs will be lowered, but the nutritional benefits may also be altered.

- It is important to minimise the use of anti-bacterial agents in order to prevent the development and spread of resistance to antibiotics. This also applies to more recent types of production, such as cod farming.

Overall view of fish and other seafood in the Norwegian diet – Conclusion

- Based on the current median consumption of fish in Norway, i.e. two meals of fish per week with a 2:1 distribution of lean and fatty fish, an overall assessment of the nutritional and toxological factors shows that Norwegians in general should eat more fish and that their fish consumption should include both lean and fatty fish.

- Based on the assessment of health benefits associated with fish consumption, it is also evident that the adult population, especially the group at the greatest risk of developing cardiovascular disease, will gain the greatest health benefits from increasing their consumption of fatty fish in particular. The next group to benefit consists of pregnant women and breast-feeding mothers due to the potential beneficial effects on pregnancy and foetal development.

- Available literature indicates that the consumption of fish neither increases nor reduces the risk of any common form of cancer.

- The exposure level to PCBs in Norway is now well below the level at which permanent neurotoxic effects have been observed.

- At least 85% of the adult population in Norway has a calculated total intake of dioxins and dioxin-like PCBs below the TWI.

- The potential health risk from exposure to contaminants in fish (dioxins and dioxin-like PCBs in fatty fish and mercury in large predatory fish) of the highest concern at the foetal stage and in infants. Consequently, it is vital that the maternal body burden be as low as possible. It is possible to reduce the maternal body burden in the case of methyl mercury by reducing exposure during pregnancy (i.e. avoid fish with a high concentration of mercury during pregnancy). However, the same does not apply to dioxins and dioxin-like PCBs owing to their very long half-life in the body.

- At present levels of dioxins and PCBs in fatty fish, an adult consumption corresponding to more than two meals of fatty fish per week might lead to the person moderately exceeding the tolerable intake (TWI) for dioxins and dioxin-like PCBs. This is a vital consideration for women during their reproductive years. However, from what is known of young women's consumption of fatty fish, there is little reason to assume that a general recommendation to eat more fish might result in fertile women reaching such a high consumption of fish that the intake of dioxins and dioxin-like PCBs will exceed the tolerable intake (TWI) and pose a health risk to the foetus.

- For some children the intake of dioxins and dioxin-like PCBs from food exceed the TWI, but for most children (ages 2 to 13), the contribution from foods other than fish will predominate. Although small children may exceed the TWI during the first years of life by eating fish and taking cod liver oil, the positive effects of a varied diet that includes fish will counterbalance any negative effects. The body concentration of dioxins and dioxin-like PCBs will be diluted in children undergoing a period of rapid growth.

- The level of exposure in the population to organic contaminants, such as dioxins and dioxin-like PCBs, from farmed fish and cod liver oil/food supplements can be influenced within a reasonable time frame without reducing consumption of the product.

- As of today, it is not possible to conduct a quantitative risk-benefit comparison based on existing data because there is no established methodology available. Based on a comprehensive assessment of scientific documentation on the positive health benefits seen in relation to the levels of compounds that are potential health hazards, and when combined with knowledge of the consumption of fish and other seafood in the Norwegian diet, it may be concluded that the consumption of fish, whether lean or fatty, results in a positive overall effect on health.

Response to questions posed in the mandate for the comprehensive assessment of fish and other seafood in the Norwegian diet

- **VKM is requested to assess whether the conclusions in the comprehensive assessment being prepared provide grounds for changes in the current Norwegian recommendations regarding the consumption of fish and other seafood.**

The general Norwegian recommendation is to eat more fish for dinner and on bread (Directorate for Health and Social Affairs). Based on a comprehensive assessment of scientific documentation of the positive health benefits and presence of compounds that are potentially hazardous to health, as well as on knowledge about fish and other seafood in the Norwegian diet, VKM supports the general Norwegian recommendation to eat more fish both on bread and for dinner. The general public should eat a variety of different types of fish and seafood. Over a long period of time, eating more than 2 meals of fatty fish per week at current levels of dioxins and PCBs may result in the tolerable intake (TWI) for dioxins and dioxin-like PCBs being moderately exceeded. This is especially important in respect of fertile women. Based on knowledge about young women's consumption of fatty fish, however, there is little reason to believe that a general recommendation to increase fish consumption would result in fertile women consuming so much fatty fish that the intake of dioxins and dioxin-like PCBs over a long period would exceed the tolerable intake (TWI) and consequently constitute a health risk for the foetus.

The Directorate for Health and Social Affairs recommends that all infants from 4 weeks of age be given a daily supplement of cod liver oil to ensure that they receive sufficient amounts of vitamin D and n-3 fatty acids. Although cod liver oil is purified and contains reduced levels of dioxins and dioxin-like PCBs, cod liver oil is the source of a relatively high level of exposure in the smallest children. The level of organic contaminants in cod liver oil should be monitored closely, and manufacturers should be encouraged to ensure that their products contain the lowest possible level of organic contaminants.

Although children (especially at age 2) may exceed the TWI by eating fish and taking cod liver oil, the positive effects of a varied diet, which includes fish and fish products, counterbalances any negative effects. The dietary recommendations issued for the public at large can therefore continue to apply to children.

The Norwegian Food Safety Authority has issued general, nationwide dietary recommendations for certain types of freshwater fish with a high mercury content. These recommendations are based on risk assessments and should be maintained and periodically re-assessed. Since the foetus is most sensitive to mercury, it is also important that pregnant women limit their consumption of saltwater fish with high mercury levels (e.g. large wild halibut, fresh tuna and swordfish).

VKM recommends a re-assessment of the general recommendation issued by the Norwegian Food Safety Authority which states that children, fertile women and pregnant women should not eat fish liver or sandwich spread made with fish liver and that consumption of these foods in general should be limited. VKM is of the opinion that a re-assessment is called for since the level of organic contaminants in fish liver can vary greatly depending on the location where the fish is caught and the time of year.

The Norwegian Food Safety Authority has issued special dietary recommendations for the consumption of fish and other seafood from polluted fjords and harbours. VKM recommends that these recommendations be maintained and periodically re-assessed.

The Norwegian Food Safety Authority has also issued special dietary recommendations for certain other foods. These foods should be monitored periodically for levels of organic contaminants, and the recommendations should be re-assessed if the levels change.

The Norwegian Food Safety Authority has also issued a dietary recommendation stating that pregnant women should avoid eating fermented fish, and that cured or smoke fish, such as smoked salmon, should be as fresh as possible when eaten. VKM recommends that this recommendation be maintained.

- **VKM has been asked to provide a statement on any other circumstances relating to fish and other seafood, such as hygiene, that might be of importance to public health.**

Listeria monocytogenes presents the greatest microbiological risk since these bacteria can contaminate fish products, such as smoked salmon, during production and pose a special danger to pregnant women. Furthermore, homemade *rakefisk*, partially fermented trout, represents a risk of botulism.

Allergy is an issue of great consequence to a small portion of the population. It is particularly important that the presence of fish in various food products be declared and that the authorities ensure that this is done.

Pharmaceuticals are an input factor in aquaculture. Their use is well regulated and monitored, and VKM does not consider them to present a problem for food safety. VKM is of that opinion that the use of pharmaceuticals in the Norwegian aquaculture industry is not a matter of concern for public health. Since it is not currently likely that documentable amounts of antibiotics will be found in aquaculture facilities, the risk of increased occurrence of resistant bacteria is also limited.

The dosage of radioactivity from fish is not considered a problem.

Algal toxins are primarily a problem in shellfish. Continual monitoring should be performed to prevent food poisoning.

- **VMS has been asked to identify trends in nutritional, toxicological or other conditions that may result in a need to re-assess the recommendations in future.**

Generally speaking, farmed fish is expected to account for an increasingly larger portion of the fish that is consumed. Due to favourable price trends, especially for fatty farmed fish, the share of fatty fish in the diet is also expected to increase. The farming of lean fish will likely increase as well.

The aquaculture industry has the ability to produce fish with low levels of organic contaminants so that the safety margin for the overall consumption of fatty fish can be held at a high enough level to reap the health benefits. This may be achieved by selecting feed ingredients with low levels of these contaminants and/or by implementing purifying processes during feed production. Nutritional composition can also be changed by altering the composition of the feed. It is therefore important that both the nutritional composition and the contamination level be monitored. Due to restrictions on and bans against the use and discharge of PCBs and dioxins, a reduction of these contaminants in fish and other seafood is expected. However, this is a slow process that should be monitored.

As regards the 'new' organic contaminants (e.g. PFAS), there is not yet adequate documentation available to be able to determine the degree to which these constitute, or may come to constitute, a problem for food safety.

Increased mobility and internationalisation could lead to a change in dietary habits. The selection of fish and other seafood will be larger, and the use of fish and other seafood in the diet will change.

- **VKM has been asked to identify gaps in knowledge or need for new monitoring or research that may come to light during the course of the comprehensive assessment.**

Dietary studies should be conducted on a regular basis to reveal changes in the population's diet. Dietary studies should include foods that are important sources of contaminants. The task of mapping the population's actual diet poses significant methodological challenges. It is important that validated methods is developed and applied. Better knowledge about the diet, combined with biomarkers related to consumption, would be desirable.

The monitoring of contaminants in fish and other seafood is inadequate in some areas and covers only a few species that are important commercially. Monitoring and surveillance should be of an adequate size and include all of the most important species sold on the market. Analyses of contaminants, which are extremely resource-intensive, are conducted by different research institutes. The data should be compiled in a national database.

The current database for nutrients in fish and other seafood, including cod liver oil/dietary supplements, must be futher developed and enhanced.

There is a need to study the health-related significance of fish and other seafood in the Norwegian diet. Both observational and experimental, could include studies on the significance of specific nutrients, marine n-3 fatty acids, the ratio between n-6 fatty acids from plants and n-3 fatty acids from fish and other seafood, contaminants and interactions between these.

It would be useful to have more knowledge about body concentrations of dioxins and dioxin-like PCBs in children of various ages.

References

Albert, C.M., Hennekens, C.H., O'Donnell, C.J., Ajani, U.A., Carey, V.J., Willett, W.C., Ruskin, J.N. & Manson, J.E. (1998). Fish consumption and risk of sudden cardiac death. JAMA., 279, 23-28.

Albrektsen, S., Sandnes, K., Glette, J. & Waagbø, R. (1995). Influence of dietary vitamin B6 on tissue vitamin B6 contents and immunity in Atlantic salmon, Salmo salar L. Aquaculture Research. 26, 331-339.

Allen, N.E., Sauvaget, C., Roddam, A.W., Appleby, P., Nagano, J., Suzuki, G., Key, T.J. & Koyama, K.A., (2004). Prospective study of diet and prostate cancer in Japanese men. Cancer Causes Control. 15, 911-920.

Alsharif, N.Z. & Hassoun, E.A. (2004). Protective effects of Vitamin A and Vitamin E succinate against 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)-induced body wasting, hepatomegaly, thymic atrophy, production of reactive oxygen species and DNA damage in C57BL/6J mice. Basic Clin Pharm Toxicol. 95, 131-138.

AMAP, 2004. AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Oslo, Norway: Arctic Monitoring and Assessment Programme (AMAP).

Amlund, H., Berntssen, M.H.G., Lundebye Haldorsen, A.-K. & Julshamn, K. (2004) Arsen i fiskefôr – er det et problem? Norsk Fiskeoppdrett. 9, 62-64.

Andersen, L.F. (2000). Kriterier ved validering av en metode for kostholdsundersøkelser - Når er validiteten til en metode tilfredsstillende? *Norsk Epidemiologi.* 10, 17-24.

Andersson, P.L., Wågman. N., Berg, H.A., Olsson, P.E. & Tysklind, M. (1999). Biomagnification of structurally matched polychlorinated and polybrominated diphenylethers (PCDE/PBDE) in Zebrafish (Danio rerio). Organohalogen Compounds. 43, 9-12.

Anonymous (1997). Nordic risk assessment of toxaphene exposure. TemaNord 1997:540, ISBN 92 893-0041-8.

Ascherio, A., Rimm, E.B., Stampfer, M.J., Giovannucci, E.L. & Willett, W.C. (1995). Dietary intake of marine n-3 fatty acids, fish intake, and the risk of coronary disease among men. N.Engl.J.Med. 332, 977-982.

Asplund, L., Jakobsson, E., Haglund, P. & Bergman, A. (1994). 1,2,3,5,6,7 hexachlornaphtalene and 1,2,3,4,6,7-hexachloronapthalene - selective retention in rat-liver and appearance in wildlife. Chemosphere. 28, 2075-2086.

Baffone, W., Pianetti, A., Bruscolini, F., Barbieri, E. & Citterio, B. (2000). Occurrence and expression of virulence-related properties of Vibrio species isolated from widely consumed seafood products. Int. J. Food Microb. 54, 9-18.

Bakir, F., Damluji, S.F., Amin-Zaki, L., Murtadha, M., Khalidi, A., al-Rawi, N.Y., Tikriti, S., Dahahir, H.I., Clarkson, T.W., Smith, J.C. & Doherty, R.A. (1973). Methylmercury poisoning in Iraq. Science. 20;181(96),230-41.

Bangen, M., Grave, K., Nordmo, R. & Søli, N.E. (1994). Description and evaluation of a new surveillance programme for drug use in fish farming in Norway. Aquaculture.119, 109-118.

Barrett, D.H., Morris, R.D., Akhtar, F.Z. & Michalek, J.E. (2001). Serum dioxin and cognitive functioning among veterans of Operation Ranch Hand. Neurotoxicology. 22(4), 491-502.

Baumann, P., Furniss, A.L. & Lee, J.V. (1984). Facultatively anaerobic Gram-negative rods. Genus I *Vibrio* Pacini 1854, 411 AL. In: Bergey's Manual of Systematic Bacteriology Vol. 1, N.Krieg and J.G.Holt, Williams and Williams, Baltimore, USA, p. 518-538.

Becher, G., Haug, L.S., Nicolaysen, T., Polder, A. & Skaare, J.U. (2002). Temporal and spatial trends of PCDDs/PCDFs and PCBs in Norwegian breast milk – results from three rounds of WHO co-ordinated studies. Organohalogen Compounds. 56, 325-328.

Belay, E.D. (1999). Transmissible spongiform encephalopathias in humans. Annu. Rev. Microbiol. 53, 283-314.

Bell, J.G., McGhee, F., Tocher, D.R. & Dick, J.R. (2004). Dioxin and dioxin-like PCB content of farmed salmon flesh, the effect of feeding diets containing marine fish oil or vegetable oils. Proc. 11th ISNFF, Phuket, Thailand: 52.

Ben Embarek, P.K. (1994). Microbial safety and spoilage of *sous vide* fish products. 1994. Technological Laboratory of the Danish Ministry of Agriculture and Fisheries & the Royal Veterinary and Agricultural University, Denmark. Ref Type: Thesis/Dissertation.

Bergfald & Co as, 2006. Nivåer av PCB og dioksiner i torskelever. En sammenstilling av data for dioksiner, dioksinlignende PCB og PCB i lever av torsk fra norske farvann. Februar 2006.

Bergsten, C. (2004). Fish- and game study. The consumption of foods that may be important when assessing the dietary intake of mercury, cadmium and PCB/dioxins, with a focus on population groups living on the coast and in the inland of Norway.

Berland, B. (1977). Fiskeparasitter med næringsmiddelhygienisk betydning. Pp. 122-134 in B. Aalvik (red.), *Kontroll med fisk og fiskeprodukter*. Den norske veterinærforening. Veterinærhygienisk forenings årlige etterutdanningskurs. Os ved Bergen, 15-18 mars 1977.

Berntssen, M.H.G., Hemre, G.I. & Lie, Ø. (2004b). Biotechnology and quality of "Fish as Food"-Food Safety, Key note lecture. Aquaculture Europe. 20-23 October 2004, Barcelona, Spain.

Berntssen, M.H.G., Lundebye, A.K., Julshamn, K., Solli, B., Hylland, K. & Waagbø, R. (2004a). Maximum limits of organic and inorganic mercury in fish feed. Aquaculture Nutrition. 10(2), 83-97.

Berntssen, M.H.G., Lundebye, A.K. & Torstensen, B.E. (2005). Reducing the levels of dioxins and dioxin-like PCB's in farmed Atlantic salmon by substitution of fish oil with vegetable oil in the feed. Aquaculture Nutrition, *in press*.

Bjørnevik, M. & Maage, A. (1993). Effects of dietary iron supplementation on tissue iron concentration and haematology in Atlantic salmon (Salmo salar). Fisk. Dir. Skr., Ser. Ernæring. 6, 35-45.

Björnsson, E., Janson, C., Plaschke, P., Norrman, E. & Sjöberg, O. (1996). Prevalence of sensitization to food allergens in adult Swedes. Ann Allergy Asthma Immunol. 77, 327-332.

Bock, S.A. (1982). The natural history of food sensitivity. J Allergy Clin Immunol. 69, 173-177.

Bosetti, C., Kolonel, L., Negri, E., Ron, E., Franceschi, S., Dal Maso, L., Galanti, M.R., Mark, S.D., Preston-Martin, S., McTiernan, A., Land, C., Jin, F., Wingren, G., Hallquist, A., Glattre, E., Lund, E., Levi, F., Linos, D. & Vecchia, C.L. (2001). A pooled analysis of case-control studies of thyroid cancer. VI. Fish and shellfish consumption. Cancer Causes Control. 12, 383-6.

Bouzan, C., Cohen, J.T., Connor, W.E., Kris-Etherton, P.M., Gray, G.M., Konig, A., Lawrence, R.S., Savitz, D.A. & Teutsch, S.M. (2005). A quantitative analysis of fish consumption and stroke risk. Am.J.Prev.Med. 29, 347-352.

Breivik, H. & Thorstad, O. (2004) Removal of organic environmental pollutants from fish oil by short path distilation. The effect of a working fluid. EuroFed Lipid conference, 5-8, September. Edinburgh, U.K.

Brüschweiler, B.J., Spriano, D. & Schlatter, J. (2004). Gesundheitliche Risikobewertung der Toxaphen-Rückstände in Lebensmitteln. Mitt. Lebensm. Hyg. 95, 162-189.

Brustad, M., Braaten, T. & Lund, E. (2004). Predictors for cod-liver oil supplement use--the Norwegian Women and Cancer Study. Eur.J Clin.Nutr. 58, 128-136.

Brækkan, O.R. (1959). A Comparative Study of Vitamins in the Trunk Muscles of Fishes Fisk. Dir. Skr., Ser. Tekn. Unders. 3 (8), 5-42.

Brønstad, I., Bjerkås, I. & Waagbø, R. (2002). The need for riboflavin supplementation in high and low energy diets for Atlantic salmon *Salmo salar* L. parr. Aquaculture Nutrition. 8, 209-220.

Bucher, H.C., Hengstler, P., Schindler, C. & Meier, G. (2002). N-3 polyunsaturated fatty acids in coronary heart disease: a meta-analysis of randomized controlled trials. Am.J.Med., 112, 298-304.

Bugge, A. & Døving, R. (2000). Det norske måltidsmønsteret - ideal og praksis. Statens institutt for forbruksforskning.

Burk, R.F., Jordan, H.E. Jr. & Kiker, K.W. (1977). Some effects of selenium status on inorganic mercury in the rat. Toxicology & Applied Pharmacology 40, 71-82.

Burr, M.L., Fehily, A.M., Gilbert, J.F., Rogers, S., Holliday, R.M., Sweetnam, P.M., Elwood, P.C., & Deadman, N.M. (1989). Effects of changes in fat, fish, and fibre intakes on death and myocardial reinfarction: diet and reinfarction trial (DART). Lancet. 2, 757-761.

Burr, M.L., Ashfield-Watt, P.A., Dunstan, F.D., Fehily, A.M., Breay, P., Ashton, T., Zotos, P.C., Haboubi, N.A. & Elwood, P.C. (2003). Lack of benefit of dietary advice to men with angina: results of a controlled trial. Eur.J.Clin.Nutr., 57, 193-200.

Burreau, S., Axelman, J., Broman, D. & Jakobsson, E. (1997). Dietary uptake in pike (Esox lucius) of some polychlorinated biphenyls, polychlorinated naphthalenes and polybrominated diphenyl ethers administered in natural diet. Environmental Toxicology and Chemistry. 16, 2508-2513.

Burreau, S., Broman, D. & Örn, U. (2000) Tissue distribution of 2, 2', 4, 4'-tetrabromo[14C]diphenyl ether ([14C]-PBDE 47) in pike (Esox lucius) after dietary exposure – a time series study using whole body autoradiography. Chemosphere. 40, 977-985.

Calder, P.C. (2005). Polyunsaturated fatty acids and inflammation. Biochem Soc Trans. 33, 423-427.

Canfield, R.L., Kreher, D.A., Cornwell, C. & Henderson, C.R.Jr. (2003). Low-level lead exposure, executive functioning, and learning in early childhood. Neuropsychol Dev Cogn C Child Neuropsychol. 9(1), 35-53.

Capone, D.G., Weston, D.P., Miller, V. & Shoemaker, C. (1996). Antibacterial residues in marine sediments and invertebrates following chemotherapy in aquaculture. Aquaculture. 145, 55-75.

Chainark P., Satoh, S., Kiron, V., Hirono, I. & Aoki, T. (2004). Suitability of genetically modified soybean meal in rainbow trout diets. 11th International Symposium on Nutrition and Feeding in Fish, Phuket 2-7 May, Thailand.

Chan, H.M. & Egeland, G.M. (2004). Fish consumption, mercury exposure, and heart diseases. Nutr.Rev. 62, 68-72.

Chao, A., Thun, M.J., Connell, C.J., McCullough, M.L., Jacobs, E.J., Flanders, W.D., Rodriguez, C., Sinha, R. & Calle, E.E. (2005). Meat Consumption and Risk of Colorectal Cancer. JAMA. 293, 172-182.

Cliver, D.O. (2001). Foodborne viruses, p. 501-511, in: Doyle, M.P., Beuchat , L.R., Montville, T.J. (eds.). Food Microbiology, fundamentals and frontiers, ASM Press, Washington.

Cohen, J.T., Bellinger, D.C., Connor, W.E., Kris-Etherton, P.M., Lawrence, R.S., Savitz, D.A., Shaywitz, B.A., Teutsch, S.M. & Gray, G.M. (2005). A quantitative risk-benefit analysis of changes in population fish consumption. Am J Prev Med. 29, 325-34.

COT, 2004. COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD CONSUMERPRODUCTS AND THE ENVIRONMENT. COT statement on brominated flame retardants in fish from the Skerne-Tees rivers system. 2004. http://www.food.gov.uk/multimedia/pdfs/bfrstatement.pdf

Coyne, R., Hiney, M. & Smith, P. (1997). Transient presence of oxytetracycline in blue mussels (Mytilis edulis) following its therapeutic use at a marine Atlantic salmon farm. Aquaculture. 149, 175-181.

CSTEE, 1998. Opinion on the results of the Risk Assessment of : Alkanes, C10-13, chloro {SCCP} carried out in the framework of Council Regulation (EEC)793/93 on the evaluation and control of the risks of existing substances - Opinion expressed at the 6th CSTEE plenary meeting, Brussels, 27 November 1998. http://europa.eu.int/comm/health/ph_risk/committees/sct/docshtml/sct_out23_en.htm

Culp, S.J., Gaylor, D.W., Sheldon, W.G., Goldstein, L.S. & Beland, F.A. (1998). A comparison of the tumors induced by coal tar and benzo[a]pyrene in a 2-year bioassay. Carcinogenesis. 19, 117-124.

Dahl, L., Johansson, L., Julshamn, K. & Meltzer, H.M. (2004). The iodine content of Norwegian foods and diets. Public Health Nutrition. 7(4), 569-76.

Dalsgaard, A. (2002). *Vibrio vulnificus*, Culture. 23 (2), 5-8.

Darvill, T., Lonky, E., Reihman, J., Stewart, P. & Pagano, J. (2000). Prenatal exposure to PCBs and infant performance on the fagan test of infant intelligence. Neurotoxicology. 21(6):1029-38.

Davidson, P.W., Myers, G.J., Cox, C., Axtell, C., Shamlaye, C., Sloane-Reeves, J., Cernichiari, E., Needham, L., Choi, A., Wang, Y., Berlin, M. & Clarkson, T.W. (1998). Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment: outcomes at 66 months of age in the Seychelles Child Development Study. JAMA. 280(8), 701-7).

Davidson, P.W., Myers, G.J. & Weiss, B. (2004). Mercury exposure and child development outcomes. Pediatrics. 113(4 Suppl), 1023-9. Review.

de Groot, R.H., Hornstra, G., van Houwelingen, A.C. & Roumen, F. (2004). Effect of alpha-linolenic acid supplementation during pregnancy on maternal and neonatal polyunsaturated fatty acid status and pregnancy outcome. Am J Clin Nutr. 79(2), 251-60.

deKock, J., DeGryt, W., Ayala, V., Vanheerswynghels, P. & Kellens, M. (2004) Removal of dioxins and PCB's from marine oils: current status and future developments. 11^{th} international symposium on nutrition and feeding in fish. 2-7 May. Phuket Island, Thailand. p.53.

Den store matvaretabellen, 2001. Statens Råd for Ernæring og fysisk aktivitet, Statens næringsmiddeltilsyn, Institutt for ernæringsforskning (UIO). Gyldendal norsk forlag. 2001.

Drouillard, K.G., Hiebert, T., Tran, P., Muir, D.C.G., Tomy, G.T. & Friesen, K.J. (1998a). Estimating Aqeous solubilities of chlorinated n-alkanes (C10-C12) from simple mixtures. Environ Toxicol Chem.17, 1261-1267.

Drouillard, K.G., Muir, D.C.G., Tomy, G.T. & Friesen ,K.J. (1998b). Volatility of chlorinated alkenes (C10-C12): vapor pressures and Henry's law constants. Environ Toxicol Chem. 17, 1252-1260.

EFSA, 2004a. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to mercury and methylmercury in food, The EFSA Journal (2004) 34, 1-14. http://www.efsa.eu.int/science/contam/contam_opinions/259/opinion_contam_01_en1.pdf

EFSA, 2004b. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission to assess the health risks to consumers associated with exposure to organotins in foodstuffs. The EFSA Journal (2004) 102, 1-119.
http://www.efsa.eu.int/science/contam/contam_opinions/658/contam_opinion10_ej102_organotins_v2_en1.pdf

EFSA, 2004c. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to arsenic as undesirable substances in animal feed. The EFSA Journal (2004) 34, 1-14. http://www.efsa.eu.int/science/contam/contam_opinions/825/opinion_arsenic1.pdf

EFSA, 2004d. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to lead as undesirable substances in animal feed. The EFSA Journal (2004) 71, 1-20. http://www.efsa.eu.int/science/contam/contam_opinions/474/opinion03_contam_ej71_lead_en1.pdf

EFSA, 2004e. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to cadmium as undesirable substances in animal feed. The EFSA Journal (2004) 72, 1-24. http://www.efsa.eu.int/science/contam/contam_opinions/475/op04_contam_ej72_cadmium_en1.pdf

EFSA, 2004f. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to Fluorine as undesirable substance in animal feed. The EFSA Journal (2004) 100, 1-22. http://www.efsa.eu.int/science/contam/contam_opinions/644/opinion_contam08_ej100_fluorine_en1.pdf

EFSA, 2005a. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the European Parliament related the Safety Assessment of Wild and Farmed fish. The EFSA Journal (2005), 236, 1-118.
http://www.efsa.eu.int/science/contam/contam_opinions/1007/contam_opinion_ej236_swaff_v2_en1.pdf

EFSA, 2005b. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to camphechlor as undesirable substance in animal feed. The EFSA Journal (2005) 179, 1 – 39. http://www.efsa.eu.int/science/contam/contam_opinions/803/finalversion2camphechlor1.pdf

EFSA, 2005c. Opinion of the scientific panel on contaminants in the food chain on a request from the commission related to the presence of non dioxin-like polychlorinated biphenyls (PCB) in feed and food. The EFSA Journal (2005) 284, 1 – 137.
http://www.efsa.eu.int/science/contam/contam_opinions/1229/contam_op_ej284_ndl-pcb_en1.pdf

Eigenmann, P.A., Sicherer, S.H., Borkowski, T.A., Cohen, B.A. & Sampson, H.A. (1998). Prevalence of IgE-mediated food allergy among children with atopic dermatitis. Pediatrics. 101.

Engeset, D., Alsaker, E., Ciampi, A. & Lund, E. (2005). Dietary patterns and lifestyle factors in the Norwegian EPIC cohort – The Norwegian Women and Cancer (NOWAC) study. Eur J Clin Nutr. Accepted.

Ervik, A., Thorsen, B., Eriksen, V., Lunestad B.T. & Samuelsen, O.B. (1994). Impact of administrated antibacterial agents on wild fish and blue mussels *Mytilus edulis* in the vinicity of fish farms. Dis. Aquat. Org. 18, 45-51.

EU, 2000. European Union risk assessment report. Diphenyl ether pentabromo derivate (Pentabromodiphenyl ether). Report No.: CAS No.: 32534-81-EINECS No.: 251-084-2.

EU, 2002. European Union risk assessment report. bis(penta bromophenyl)ether. Report No.: CAS No.:1163-19-5, EINECS No.: 214-604-9.

EU, 2003. European Union risk assessment report. Diphenyl ether octabromo deriv. Report No.: CAS No.: 32536-52-0, EINECS No.: 251-087-9.

Facinelli, B., Varaldo, P.E., Toni, M., Casolari, C. & Fabio, U. (1989). Ignorance about *Listeria*. Br. Med. J. 299, 738.

Fakta om fisk, 2005. Fakta om fisk. Eksportutvalget for fisk AS, Fiskeridirektoratet, Nasjonalt institutt for ernærings- og sjømatforskning. Art. nr. 19. Desember 2005.

Fewtrell, M.S., Abbott, R.A., Kennedy, K., Singhal, A., Morley, R., Caine, E., Jamieson, C., Cockburn, F. & Lucas, A. (2004). Randomized, double-blind trial of long-chain polyunsaturated fatty acid supplementation with fish oil and borage oil in preterm infants. J Pediatr. 144(4), 471-9.

Flood, A., Velie, E.M., Sinha, R., Chaterjee, N., Lacey, J.V. Jr., Schairer, C. & Schatzkin, A. (2003). Meat, Fat, and Their Subtypes as Risk Factors for Colorectal Cancer in a Prospective Cohort of Women. Am J Epidemiol. 158, 59-68.

Folsom, A.R. & Demissie, Z. (2004). Fish intake, marine omega-3 fatty acids, and mortality in a cohort of postmenopausal women. Am.J.Epidemiol. 160, 1005-1010.

Foran, J.A., Good, D.H., Carpenter, D.O., Hamilton, M.C., Knuth, B.A. & Schwager, S.J. (2005). Quantitative Analysis of the Benefits and Risks of Consuming Farmed and Wild Salmon J. Nutr. 135, 2639-2643.

Frøyland, L., Madsen, L., Vaagenes, H., Totland, G. K., Auwerx, J., Kryvi, H., Staels, B. & Berge, R. K. (1997). Mitochondrion is the principal target for nutritional and pharmacological control of triglyceride metabolism. J. Lipid Res. 38, 1851-1858.

FSA, 2004. COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT. TETRABROMOBISPHENOL A – REVIEW OF THE TOXICOLOGICAL DATA. TOX/2004/06.

Fødevaredirektoratet (2003): Helhedssyn på fisk og fiskevarer. FødevareRapport 2003:17. Fødevaredirektoratet, Ministeriet for Fødevarer, Landbrug og Fiskeri.

Geelen, A., Brouwer, I.A., Zock, P.L., & Katan, M.B. (2004). Antiarrhythmic effects of n-3 fatty acids: evidence from human studies. Curr.Opin.Lipidol. 15, 25-30.

Gislason, D., Björnsson, E., Gislason, T., Janson, C., Sjöberg, O., Elfman, L. & Boman, G. (1999). Sensitization to airborne and food allergens in Reykjavik (Iceland) and Uppsala (Sweden) – a comparative study. Allergy. 54, 116-1167.

GISSI, 1999. Dietary supplementation with n-3 polyunsaturated fatty acids and vitamin E after myocardial infarction: results of the GISSI-Prevenzione trial. Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto miocardico (1999). Lancet. 354, 447-455.

Gjedrem, T. (1993). "Fiskeoppdrett. Vekstnæring for distrikts-Norge". Landbruksforlaget, 1993.

Graff, I.E., Høye S., Totland, G.K. & Lie, Ø. (2002). Three different levels of dietary vitamin D_3 fed to first-feeding fry of Atlantic salmon (Salmo salar L.): effect on growth, mortality, calcium content and bone formation. Aquaculture Nutrition. 8, 103-111.

Gram, L. (2001). Potential hazards in cold-smoked fish: *Clostridium botulinum* type E. J. Food Science, suppl. 66 (7), 1082-1087.

Grandjean, P., Weihe, P., White, R.F., Debes, F., Araki, S., Yokoyama, K., Murata, K., Sorensen, N., Dahl, R. & Jorgensen, P.J. (1997). Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicol Teratol. 19(6), 417-28.

Grandjean, P., Weihe, P., Burse, V.W., Needham, L.L., Storr-Hansen, E., Heinzow, B., Debes, F., Murata, K., Simonsen, H., Ellefsen, P., Budtz-Jorgensen, E., Keiding, N. & White, R.F. (2001). Neurobehavioral deficits associated with PCB in 7-year-old children prenatally exposed to seafood neurotoxicants. Neurotoxicol Teratol. 23(4), 305-17.

Grandjean, P., Weihe, P., Burse, V.W., Needham, L.L., Storr-Hansen, E., Heinzow, B., Debes, F., Murata, K., Simonsen, H., Ellefsen, P., Budtz-Jørgensen, E., Keiding, N. & White, R.F. (2001). Neurobehavioral deficits associated with PCB in 7-year-old children prenatally exposed to seafood neurotoxicants. Neurotoxicol Teratol 23, 305-17.

Grandjean, P. 2003. Adverse health effects of PCBs: Interpreting the epidemiological evidence Keynote presentation at DIOXIN2003, Boston.

Grandjean, P., Murata, K., Budtz-Jorgensen, E. & Weihe, P. (2004). Cardiac autonomic activity in methylmercury neurotoxicity: 14-year follow-up of a Faroese birth cohort. J Pediatr. 144(2), 169-76.

Grave, K., Engelstad, M. & Søli, N.E. (1991). Utilization of dichlorvos and trichlorfon in salmonid farming in Norway during 1981-1988. Acta Vet Scand. 32, 1-7.

Grave, K., Markestad, M. & Bangen, M. (1996). Comparison in prescribing patterns of antibacterial drugs in salmonid farming in Norway during the periods 1989-1994 and 1980-1988. J Vet Pharmacol Therap. 19, 184-91.

Grave, K., Litleskare, I. & Lunestad, B.T. (2002). Forbruksmønsteret for legemidler til oppdrettfisk i Norge i perioden 1996-2001: Et gullkantet eksportsertifikat for norsk oppdrettsnæring. Nor Vet Tidsskr. 114, 564-567.

Grave, K., Horsberg ,T.E., Lunestad, B.T. & Litleskare, I. (2004). Consumption of drugs for sea lice infestations in Norwegian fish farming: Methods for the assessment of treatment patterns and treatment rates. Dis Aq Org. 6, 123-131.

Gray, K.A., Klebanoff, M.A., Brock, J.W., Zhou, H., Darden, R., Needham, L. & Longnecker, M.P. (2005). In utero exposure to background levels of polychlorinated biphenyls and cognitive functioning among school-age children. Am J Epidemiol. 162(1), 17-26.

Grønvik, S. & Klemetsen, A. (1987). Marine food and diet overlap of co-occuring Artic char *Salvelinus alpinus* (L.) brown trout *Salmo trutta* L. and Atlantic salmon *S. salar* L. off Senja, , N. Norway. Pol. Biol. 7, 173-177.

Guallar, E., Sanz-Gallardo, M.I., van't Veer, P., Bode, P., Aro, A., Gomez-Aracena, J., Kark, J.D., Riemersma, R.A., Martin-Moreno, J.M. & Kok, F.J. (2002). Mercury, fish oils, and the risk of myocardial infarction. N.Engl.J.Med. 347, 1747-1754.

Gäfvert, T., Føyn L., Brungot A.L. Kolstad A.K., Lind B., Christensen G.C., Strålberg E., Drefvelin, J. & Rudjord A.L. (2003). Radioactivity in the Marine Environment 2000 and 2001 – Results from the Norwegian national monitoring programme (RAME). StrålevernRapport 2003:8.

Hamre, K. (1995). Metabolism, interactions and requirement of vitamin E in Atlantic salmon (*Salmo salar,* L.). Dissertation for the degree of doctor scientarium. University of Bergen & Institute of Nutrition, Directorate of Fisheries, Bergen, Norway.

Hamre, K. & Lie, Ø. (1997). Retained levels of dietary α-, γ- and δ-tocopherol in tissues and body fluids of Atlantic salmon, *Salmo salar*, L. Aquaculture Nutrition. 3, 99-107.

Hansen, P.K., Lunestad, B.T. & Samuelsen, O.B. (1992). Effects of oxytetracycline, oxolinic acid and flumequine on bacteria in an artificial marine fish farm sediment. Canadian Journal of Microbiology. 38, 1307-1312.

He, K., Song, Y., Daviglus, M.L., Liu, K., Van Horn, L., Dyer, A.R., Goldbourt, U. & Greenland, P. (2004a). Fish consumption and incidence of stroke: a meta-analysis of cohort studies. Stroke. 35, 1538-1542.

He, K., Song, Y., Daviglus, M.L., Liu, K., Van Horn, L., Dyer, A.R. & Greenland, P. (2004b). Accumulated evidence on fish consumption and coronary heart disease mortality: a meta-analysis of cohort studies. Circulation. 109, 2705-2711.

Helland, I.B., Smith, L., Saarem, K., Saugstad, O.D. & Drevon, C.A. (2003). Maternal supplementation with very-long-chain n-3 fatty acids during pregnancy and lactation augments children's IQ at 4 years of age. Pediatrics. 111(1), 39-44.

Hemre, G.I., Juell, J.E., Hamre, K., Lie, Ø., Strand, B., Arnesen, P. & Holm, J.Chr. (1997). Cage feeding of Atlantic mackerel (Scomber scombrus): effect on muscle lipid content, fatty acid composition, oxidation status and vitamin E concentration. Aquat. Living Resour. 10, 365-370.

Hemre, G.I. & Sandnes, K. (1998). Effect of dietary lipid upon muscle composition in Atlantic salmon (*Salmo salar*). Aquaculture Nutrition. 5, 9-16.

Hemre, G.I., Karlsen, Ø., Eckhoff, K., Tveit, K., Mangor-Jensen, A. & Rosenlund, G. (2004). Effect of season, light regime and diet on muscle nutrient composition and selected quality parameters in farmed Atlantic cod, *Gadus morhua* L. Aquaculture Research., 35, 683-697.

Hielm, S., Hyytiä, E., Andersin, A.B. & Korkeala, H. (1998). High prevalence of *Clostridium botulinum* type E in Finnish freshwater and Baltic Sea sediment samples. J. Appl. Microbiol. 84, 133-137.

Hill, D.J., Firer, M.A., Ball, G. & Hosking, C.S. (1989). Recovery from milk allergy in early childhood: antibody study. J Pediatr. 114, 761-766.

Hites, R.A., Foran, J.A., Carpenter, D.O., Hamilton, M.C., Knuth, B.A. & Schwager, S.J. (2004). Global Assessment of Organic Contaminants in Farmed Salmon. Science. 303(5655), 226 – 229.

Hjartåker, A. (2003). Fish consumption and risk of breast, colorectal and prostate cancer: a critical evaluation of epidemiological studies. Scand J nutr. 47, 111-122.

Hoffmann, D.R., DeMar, J.C., Heird, W.C., Birch, D.G. & Anderson, R.E. (2001). Impaired synthesis of DHA in patients with X-linked retinitis pigmentosa. J Lipid Res. 42, 1395-1401.

Hooper, L., Thompson, R., Harrison, R., Summerbell, C., Moore, H., Worthington, H., Durrington, P., Ness, A., Capps, N., Davey, S.G., Riemersma, R. & Ebrahim, S. (2004). Omega 3 fatty acids for prevention and treatment of cardiovascular disease. Cochrane.Database.Syst.Rev. CD003177.

Huss, H.H. (1980). Distribution of *Clostridium botulinum*. Appl. Environ. Microbiol. 39, 764-769.

Huss, H.H. & E. Rye Pedersen. (1980). *Clostridium botulinum* in fish. Scan. J. Vet. Med. 31, 214-221.

Huss, H.H., Ababouch, L. & Gram, L. (2004). Assessment and management of seafood safety and quality, FAO Fisheries Technical Paper No. 444, Rome.

Høi, L., Larsen, J.L., Dalsgaard, I. & Dalsgaard, A. (1998). Occurrence of *Vibrio vulnificus* biotypes in Danish marine environments, Appl. Environ. Microb., 64(1), 7-13.

IARC, 1987. Arsenic and arsenic compounds. IARC Monographs, Supplement 7 p. 100.

IARC, 1997. Monographs on the Evaluation of Carcinogenic Risks to Humans. Polychlorinated dibenzo-*para*-dioxins and polychlorinated dibenzofurans. IARC Scientific Publ. No. 69, Lyon, France.

IARC, 2004a. Arsenic in drinking-water, IARC Summary & Evaluation, Volume 84.

IARC, 2004b. Inorganic and organic lead, Vol 87, February 10-17, 2004. http://www.iarc.fr/

Isosaari, P., Vartiainen, T., Hallikainen, A. & Ruohonen, K. (2002) Feeding trial on rainbow trout: comparison of dry fish feed and Baltic herring as a source of PCDD/Fs and PCBs. Chemosphere. 48, 795-804.

Isosaari, P., Kiviranta, H., Lie, O., Lundebye, A.K., Ritchie, G. & Vartiainen, T. (2004). Accumulation and distribution of polychlorinated dibenzo-p-dioxin, dibenzofuran, and polychlorinated biphenyl congeners in Atlantic salmon (*Salmo salar*). Environ. Toxicol. Chem. 23, 1672-1679.

Isosaari, P., Lundebye, A.K., Ritchie, G., Lie, O., Kiviranta, H. & Vartiainen, T. (2005). Dietary accumulation efficiencies and biotransformation of polybrominated diphenyl ethers in farmed Atlantic salmon (Salmo salar). Food Addit Contam. 22(9), 829-37.

Jacobsen, B. K. & Thelle, D.S. (1987). The Tromso Heart Study: food habits, serum total cholesterol, HDL cholesterol, and triglycerides. Am.J.Epidemiol. 125, 622-630.

Jacobson, J.L. & Jacobson, S.W. (1996). Intellectual impairment in children exposed to polychlorinated biphenyls in utero. N Engl J Med. 335(11), 783-9.

Jacobson, J.L. & Jacobson, S.W. (2002). Association of prenatal exposure to an environmental contaminant with intellectual function in childhood. J Toxicol Clin Toxicol. 40(4), 467-75.

Jacobson, J.L. & Jacobson, S.W. (2003). Prenatal exposure to polychlorinated biphenyls and attention at school age. J Pediatr. 143(6), 780-8.

Jay, J.J. (1992). Modern food microbiology, pp. 641-651, Chapman & Hall, New York.

JECFA, 2001. Joint FAO/WHO Expert Committee on Food Additives, Summary and conclusions. Fifty-seventh meeting, Rome, 2001. Report No.: Fifty-seventh meeting, Rome, 2001.

JECFA, 2003. JOINT FAO/WHO EXPERT COMMITTEE ON FOOD ADDITIVES. Sixty-first meeting. Rome, 10-19 June 200. SUMMARY AND CONCLUSIONS. Food and Agriculture Organization of the United Nations, World Health Organization, 1-22. 2003. http://www.who.int/ipcs/food/jecfa/summaries/en/summary_61.pdf

JECFA, 2005. JOINT FAO/WHO EXPERT COMMITTEE ON FOOD ADDITIVES. Sixty-fourth meeting. Rome, 8-17 February 2005. SUMMARY AND CONCLUSIONS. Food and Agriculture Organization of the United Nations, World Health Organization, 1-47. 2005. http://www.who.int/ipcs/food/jecfa/summaries/en/summary_report_64_final.pdf

Jeebhay, M.F., Lopata, A.L. & Robins, T.G. (2000). Seafood processing in South Africa: a study of working practices, occupational health services and allergic health problems in the industry. Occup Med (Lond). 50, 406-413.

Jin, T., Lu, J. & Nordberg, M. (1998). Toxicokinetics and biochemistry of cadmium with special emphasis on the role of metallothionein. Neurotoxicology. 19(4-5), 529-35. Review.

Johansson, L. & Solvoll, K. (1999). Norkost 1997. Landsomfattende kostholdsundersøkelse blant menn og kvinner i alderen 16-79 år. Statens råd for ernæring og fysisk aktivitet.

Joint FAO/IOC/WHO. Ad hoc Expert Consultation on Biotoxins in Molluscan Bivalves, Oslo, Norway, 27 September - 1 October 2004.

Julshamn, K., Haugsnes, J. & Utne, F. (1988). The content of 14 major and minor elements (minerals) in Norwegian fish species and fish byproducts, determined by atomic absorption spectrophotometry. Fisk. Dir. Skr., Ser. Ernæring. 1, 117-135.

Julshamn, K., Dahl, L. & Eckhoff, K. (2001). Determination of iodine in seafood by inductively coupled plasma/mass spectrometry. J AOAC.Int., 84, 1976-1983.

Julshamn, K., Berntssen, M.H.G., Lundebye, A.K., Måge, A. & Lorentzen, M. (2004a). Overvåkning av fremmedstoffer i norskprodusert laksefilet og laksefôr i perioden 1995-2003. Norsk Fiskeoppdrett. 10b, 15-19.

Julshamn, K., Kjellevold Malde, M., Bjorvatn, K. & Krogedal, P. (2004b). Fluoride retention of Atlantic salmon (*Salmo salar*) fed krill meal. Aquaculture Nutrition. 10, 9-13.

Kannan, K., Yamashita, N., Imagawa, T., Decoen, W., Khim, J.S., Day, R.M., Summer, C.L. & Giesy, J.P. (2000). Polychlorinated naphtalenes and polychlorinated biphenyls in fishes from Michigan waters including the Great Lakes. Environ Sci Technol. 34, 566-572.

Kato, I., Akhmedkhanov, A., Koenig, K., Toniolo, P.G., Shore, R.E. & Riboli, E. (1997). Prospective study of diet and female colorectal cancer: the New York University Women's Health Study. Nutr Cancer. 28, 276-81.

Kato, S. (2000). The function of vitamin D receptor in vitamin D action. J Biochem. 127, 717-722.

Keshan Disease Research Group. (1979). Observations on effect of sodium selenite in prevention of Keshan disease.Chin Med J (Engl). 92(7), 471-6.

Kierkegaard, A., Balk, L., Tjärnlund, U., de Wit, C. & Jansson, B. (1999). Dietary uptake and biological effects of decabromodiphenyl ether in rainbow trout (*Oncorhynchus mykiss*). Environmental Science and Technology. 33, 1612-1617.

Kimbrough, R.D. & Krouskas, C.A. (2003). Human exposure to polychlorinated biphenyls and health effects: a critical synopsis. Toxicol Rev. 22(4), 217-33. Review.

King, L.J. & Soares, J.H. Jr. (1978). Mercury metabolism in Japanese quail, II.The effects of dietary mercury and selenium on blood and liver glutathione peroxidase activity and selenium concentration. Poultry Science. 57, 1286-1292.

Kjellstrom, T., Kennedy, P., Wallis, S. & Mantell, C. (1986). ‘‘Physical and Mental Development of Children with Prenatal Exposure to Mercury From Fish, Stage I: Preliminary Tests at
Age 4.’’ National Swedish Environmental Protection Board, Solna, Sweden. Report 3080.

Kjellstrom, T., Kennedy, P. & Wallis, S. (1989). ‘‘Physical and Mental Development of Children with Prenatal Exposure to Mercury From Fish, Stage II: Interview and Psychological.

Knutsen, H.K., Sanner, T. & Alexander, J. (2004). Risikovurdering av PAH i skjell. Risikovurdering fra Underarbeidsgruppen for miljøgifter, SNTs vitenskapelige komité.

Kohlmeyer, U., Kuballa, J. & Jantzen, E. (2002). Simultaneous separation of 17 inorganic and organic arsenic compounds in marine biota by means of high-performance liquid chromatography/inductively coupled plasma mass spectrometry.Rapid Commun Mass Spectrom. 16(10), 965-74.

Koopmans, M. (2002). Viruses, p. 439 – 452, in C.W. Blackburn and P.J. McClure (eds.). Foodborne pathogenes, CRC Press, Woodhead Publishing, Cambridge.

Kris-Etherton, P.M., Harris, W.S. & Appel, L.J. (2002). Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. Circulation. 106, 2747-2757.

Kvalem, H.E. (2005). Dioksiner og PCB fra kostholdet. Kosteksponering i et utvalg nordmenn fra innlands- og kystkommuner; Del C i Fisk- og viltundersøkelsen [cand. scient. oppgave]. Oslo: Universitetet i Oslo: Nasjonalt folkehelseinstitutt; 2005.

Kvalem, H.E., Knutsen, H.K., Thomsen, C., Haugen, M., Bergsten, C., Sletta, A., Trygg, K.U., Alexander, J., Becher, G. & Meltzer, H.M. (2005). Dietary dioxin and PCB exposure in a selected group of Norwegians. Organohalogen Compounds 67. CD-rom of Proceedings of Dioxin 2005 and ISPAC-20, Abstract 1476.

Kvalitetsforskrift for fisk og fiskevarer, FOR 1996-06-14 nr 667. Fiskeri- og kystdepartementet, 2003.

König, A., Bouzan, C., Cohen, J.T., Connor, W.E., Kris-Etherton, P.M., Gray, G.M., Lawrence, R.S., Savitz, D.A. & Teutsch, S.M. (2005). A quantitative analysis of fish consumption and coronary heart disease mortality. Am.J.Prev.Med. 29, 335-346.

Lai, V.W., Sun, Y., Ting, E., Cullen, W.R. & Reimer, K.J. (2004). Arsenic speciation in human urine: are we all the same? Toxicol Appl Pharmacol. 198(3), 297-306. Review.

Laidlaw, S.A., Grosvenor, M. & Kopple, J.D. (1990) The taurine content of common foodstuffs. J Parenter Enteral Nutr. 14, 183-188.

Lande, B. (2003). Spedkost 6 måneder. Landsomfattende kostholdsundersøkelse blant spedbarn i Norge. Sosial- og helsedirektoratet. Rapport nr. IS-1074.

Lande, B. & Andersen, L.F. (2005a). Spedkost 12 måneder. Landsomfattende kostholdsundersøkelse blant spedbarn i Norge. Oslo, 2005, Sosial- og helsedepartementet. Rapport nr. IS-1248.

Lande, B. & Andersen, L.F. (2005b). Kosthold blant 2-åringer. Landsomfattende kostholdsundersøkelse - Småbarnskost. Sosial- og helsedirektoratet. Rapport nr.IS-1299.

Landmark, K. & Aursnes, I. (2004). Kvikksølv, fisk, fiskeolje og risiko for hjerte- og karsykdommer. Tidsskr.Nor Lægeforen. 124, 198-200.

Lanphear, B.P., Dietrich, K., Auinger, P. & Cox, C. (2000). Cognitive deficits associated with blood lead concentrations <10 microg/dL in US children and adolescents. Public Health Rep. 115(6), 521-9.

Lauritzen, L., Jorgensen, M.H., Mikkelsen, T.B., Skovgaard, M., Straarup, E.M., Olsen, S.F., Hoy, C.E. & Michaelsen, K.F. (2004). Maternal fish oil supplementation in lactation: effect on visual acuity and n-3 fatty acid content of infant erythrocytes.Lipids. 39(3), 195-206.

Lavik, R. (2005). Kjøtt, holdninger og endring 1997 til 2004. Statens institutt for forbruksforskning.

Le, X.C., Cullen, W.R. & Reimer, K.J. (1994). Human urinary arsenic excretion after one-time ingestion of seaweed, crab, and shrimp. Clin Chem. 40(4), 617-24.

Leaf, A., Kang, J.X., Xiao, Y.F. & Billmann, G.E. (2003). Clinical prevention of sudden cardiac death by n-3 polyunsaturated fatty acids and mechanism of prevention of arrhytmias by n-3 fish oils. Circulation. 107, 2646-2652.

Lees, D. (2000). Viruses and bivalve shellfish. In. J. Food Microbiol. 59, 81-116.

Levsen, A & Lunestad, B.T. (2002). Allergisk mot fisk? Kveis kan være årsaken. *Fisk – Industri & Marked* Nr. 9/10, desember 02, s. 24.

Levsen, A., Lunestad, B.T & Berland, B. (2005). Low detection efficiency of candling as a commonly recommended inspection method for nematode larvae in the flesh of pelagic fish. Journal of Food Protection. 68, 828-832.

Lie, Ø. (1991). Studies on digestion, deposition and fatty acid composition of lipids in cod (*Gadus morhua*). Ph.D. thesis, University of Bergen, Norway.

Lie, Ø., Fjeldstad L., & Hemre G.-I. (1991). Hippoglossus, subproject 2: Cultivation of young halibut, (Institute of Nutrition, Directorate of Fisheries), annual report to The Nordic Industrial Fund, grant 87135.

Lie, Ø. & Huse, I. (1992). The effect of starvation on the composition of Atlantic salmon (Salmon salar). Fisk. Dir. Skr., Ser.Ernæring. 5(1), 11-16

Lopata, A.L. & Jeebhay, M.F. (2001). Seafood allergy in South Africa – Studies in the domestic and occupational setting. ACI International. 13, 204-210.

Lorentzen, M., Maage, A. & Julshamn, K. (1994). Effects of dietary selenite or selenomethionine on tissue selenium levels of Atlantic salmon (Salmo salar). Aquaculture. 121, 359-367.

Lund, E., Engeset, D., Alsaker, E., Skeie, G., Hjartåker, A., Lundebye, A.K. & Niebor, E. (2004). Cancer risk and salmon intake. Science. 305, 477.

Lundebye, A.K., Berntssen, M.H.G., Lie, O., Ritchie, G., Isosaari, P., Kiviranta, H. & Vartiainen, T. (2004). Dietary uptake of dioxins (PCDD/PCDFs) and dioxin-like PCBs in Atlantic salmon (*Salmo salar*). Aquacult. Nutr. 10, 199-207.

Lunestad, B.T. (2003). Absence of nematodes in farmed Atlantic salmon (*Salmo salar* L.) in Norway. Journal of Food Protection. 66, 122-124.

Lunestad, B.T. & Grave, K. (2005).Therapeutic agents in Norwegian aquaculture from 200 to 2004: Usage and residue control. Bull Eur Ass Fish Pathol. 25, 284-290.

Magan, N. & Olsen, M. (2004). Mycotoxins in food – detection and control, Woodhead Publishing, CRC Press, Cambridge.

Malcolm, C.A., McCulloch, D.L., Montgomery, C., Shepherd, A., Weaver, L.T. (2003). Maternal docosahexaenoic acid supplementation during pregnancy and visual evoked potential development in term infants: a double blind, prospective, randomised trial. Arch Dis Child Fetal Neonatal Ed. 88(5), 383-90.

Mangor-Jenssen, A., Holm, J. C., Rosenlund, G., Lie, Ø. & Sandnes, K. (1994). "Effects of dietary vitamin C on maturation and egg quality of cod *Gadus morhua* L." Journal of the World Aquculture Society. 25(1), 30-40.

Marchioli, R., Barzi, F., Bomba, E., Chieffo, C., Di Gregorio, D., Di Mascio, R., Franzosi, M.G., Geraci, E., Levantesi, G., Maggioni, A.P., Mantini, L., Marfisi, R.M., Mastrogiuseppe, G., Mininni, N., Nicolosi, G.L., Santini, M., Schweiger, C., Tavazzi, L., Tognoni, G., Tucci, C. & Valagussa, F. (2002). Early protection against sudden death by n-3 polyunsaturated fatty acids after myocardial infarction: time-course analysis of the results of the Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto Miocardico (GISSI)-Prevenzione. Circulation. 105, 1897-1903.

McKeown-Eyssen, G., Reudy, J. & Neims, A. (1983). Methylmercury exposures in northern Quebec, II: Neurologic 7ndings in children. Am. J. Epidemiol. 118, 470-479.

Meironyte, D., Noren, K. & Bergman, A. (1999). Analysis of polybrominated diphenyl ethers in Swedish human milk. A time-related trend study, 1972-1997. J Toxicol Environ Health A. 58(6), 329-41.

Meironyte, Guvenius, D. & Noren, K. (2001), The Second International Workshop on Brominated Flame Retardants, 14.-16.05.2001, Stockholm, Sweden

Meltzer, H.M., Bergsten, C. & Stigum, H. (2002): Fisk- og viltundersøkelsen. Konsum av matvarer som kan ha betydning for inntaket av kvikksølv, kadmium og PCB/dioksin i norsk kosthold. SNT, The Norwegian Food Control Authority.

Mills, P.K., Beeson, W.L., Phillips, R.L. & Fraser, G.E. (1989). Dietary habits and breast cancer incidence among Seventh-day Adventists. Cancer. 64, 582-90.

Mortz, C.G., Lauritsen, J.M., Andersen, K.E. & Bindslev-Jensen, C. (2003). Type I sensitization in adolescents: prevalence and association with atopic dermatitis. The Odense Adolescence Cohort Study on Atopic Diseases and Dermatitis (TOACS). Acta Derm Venereol. 83(3), 194-201.

Moss, M. (2002). Toxogenic fungi, pp. 479-488, in: C.W. Blackburn and P.J. McClure, Foodborne pathogenes, Woodhead Publishing, CRC Press, Cambridge.

Mozaffarian, D., Lemaitre, R.N., Kuller, L.H., Burke, G.L., Tracy, R.P. & Siscovick, D.S. (2003). Cardiac benefits of fish consumption may depend on the type of fish meal consumed: the Cardiovascular Health Study. Circulation. 107, 1372-1377.

Mozaffarian, D., Psaty, B.M., Rimm, E.B., Lemaitre, R.N., Burke, G.L., Lyles, M.F., Lefkowitz, D. & Siscovick, D.S. (2004). Fish intake and risk of incident atrial fibrillation. Circulation. 110, 368-373.

Mozaffarian, D., Longstreth, W.T.Jr., Lemaitre, R.N., Manolio, T.A., Kuller, L.H., Burke, G.L. & Siscovick, D.S. (2005a). Fish Consumption and Stroke Risk in Elderly Individuals: The Cardiovascular Health Study. Arch.Intern.Med. 165, 200-206.

Mozaffarian, D., Bryson, C.L., Lemaitre, R.N., Burke, G.L. & Siscovick, D.S. (2005b). Fish intake and risk of incident heart failure. J.Am.Coll.Cardiol. 45, 2015-2021.

Mukherjee, P.K., Marcheselli, V.L., Serhan, C.N. & Bazan, N.G. (2004). Neuroprotectin D1: A docosahexaenoic acid-derived docosatriene protects human retinal pigment epithelial cells from oxidative stress. Proc Natl Acad Sci USA. 101, 8491-8496.

Murata, K., Weihe, P., Renzoni, A., Debes, F., Vasconcelos, R., Zino, F., Araki, S., Jorgensen, P.J., White, R.F. & Grandjean, P. (1999). Delayed evoked potentials in children exposed to methylmercury from seafood. Neurotoxicol Teratol. 21(4), 343-8.

Murata, K., Weihe, P., Budtz-Jorgensen, E., Jorgensen, P.J. & Grandjean P. (2004). Delayed brainstem auditory evoked potential latencies in 14-year-old children exposed to methylmercury. J Pediatr. 144(2), 177-83.

Myers, G.J., Davidson, P.W., Cox, C., Shamlaye, C.F., Palumbo, D., Cernichiari, E., Sloane-Reeves, J., Wilding, G.E., Kost, J., Huang, L.S., Clarkson, T.W. (2003). Prenatal methylmercury exposure from ocean fish consumption in the Seychelles child development study. Lancet. 361(9370), 1686-92.

Myrmel, M., Berg, E.M.M., Rimstad, E. & Grinde, B. (2004). Detection of enteric viruses from shellfish from the Norwegian coast. Appl. Environ. Microbiol. 70 (5), 2678-2684.

Maage, A., Julshamn, K. & Ulgenes, Y. (1991). A comparison of tissue levels of four essential trace elements in wild and farmed Atlantic salmon (Salmo salar). Fisk. Dir. Skr., Ser. Ernæring, IV, 111-116.

Måge, A., Julshamn, K., Hemre, G.I. & Lunestad, B.T (2005). Overvåkningsprogram for fôrvarer til fisk og andre akvatiske dyr. Årsrapport 2004. Tilgjengelig på Mattilsynets hjemmeside: www.mattilsynet.no

Nakamura, Y., Ueshima, H., Okamura, T., Kadowaki, T., Hayakawa, T., Kita, Y., Tamaki, S. & Okayama, A. (2005). Association between fish consumption and all-cause and cause-specific mortality in Japan: NIPPON DATA80, 1980-99. Am.J.Med. 118, 239-245.

Ness, A.R., Hughes, J., Elwood, P.C., Whitley, E., Smith, G.D. & Burr, M.L. (2002). The long-term effect of dietary advice in men with coronary disease: follow-up of the Diet and Reinfarction trial (DART). Eur.J.Clin.Nutr. 56, 512-518.

Nielsen, C.R., Berdal, K.G., Bakke-McKellep, A.M. & Holst-Jensen, A. (2005). Dietary DNA in blood and organs of Atlantic salmon (Salmo salar L.). European Food Research and Technology. 10.1007/s00217-005-1160-1, 1-15.

Nilsen, D.W., Albrektsen, G., Landmark, K., Moen, S., Aarsland, T. & Woie, L. (2001). Effects of a high-dose concentrate of n-3 fatty acids or corn oil introduced early after an acute myocardial infarction on serum triacylglycerol and HDL cholesterol. Am.J.Clin.Nutr. 74, 50-56.

Norat, T., Bingham, S., Ferrari, P., Slimani, N., Jenab, M., Mazuir, M., Overvad, K., Olsen, A., Tjonneland, A., Clavel, F., Boutron-Ruault, M.C., Kesse ,E., Boeing, H., Bergmann, M.M., Nieters, A., Linseisen, J., Trichopoulou, A., Trichopoulos, D., Tountas, Y., Berrino, F., Palli, D., Panico, S., Tumino, R., Vineis, P., Bueno-de-Mesquita, H.B., Peeters, P.H., Engeset, D., Lund, E., Skeie, G., Ardanaz, E., Gonzalez, C., Navarro, C., Quiros, J.R., Sanchez, M.J., Berglund, G., Mattisson, I., Hallmans, G., Palmqvist, R., Day, N.E., Khaw, K.T., Key, T.J., San Joaquin, M., Hemon, B., Saracci, R., Kaaks, R. & Riboli, E, (2005). Meat, fish, and colorectal cancer risk: the European Prospective Investigation into cancer and nutrition. J Natl.Cancer Inst. 97, 906-916.

Nordgarden, U., Oppedal, F., Taranger, G.L., Hemre, G.-I. & Hansen, T. (2003). "Seasonally changing metabolism in Atlantic salmon (Salmo salar L.), I - Growth and feed conversion ratio." Aquaculture Nutrition. 9, 287-294.

NNR, 2004. Nordic Nutrition Recommendations, 2004. Alexander, A., Anderssen, S., Aro, A., Becker, W., Fogelholm, M., Lyhne, N., Meltzer, H.M., Pedersen, A., Pedersen, J.I., and Thorsdottir, I. Copenhagen. Nordic Council of Ministers.

Nortvedt, 2003. Kronikk i Bergens Tidende, 2003.

NRPA, 2004. Radioactivity in the Marine Environment 2002 – Results from the Norwegian Marine Monitoring Programme (RAME). StrålevernRapport 2004:10.

Oidtmann, B., Baier, M. & R. Hoffmann. (2003). Nachweis von prion-proteinen bei fischen - wie wahrscheinlich sind transmissible spongiforme enzephalopatien bei fischen? *Arch. Lebensmittelhyg*. 54, 97-152.

Oliver, J.D. & Kaper, J.B. (2001). *Vibrio* species. In: Food Microbiology, Fundamentals and Frontiers. Doyle, M.P., Beuchat, L.R. and Montville, T.J. (eds.). ASM Press, Washington D.C. USA, p. 263-300.

Olsen, S.F., Hansen, H.S., Sorensen, T.I., Jensen, B., Secher, N.J., Sommer, S., Knudsen, L.B. (1986). Intake of marine fat, rich in (n-3)-polyunsaturated fatty acids, may increase birthweight by prolonging gestation.Lancet. 2(8503), 367-9.

Olsen, S.F. & Secher, N.J. (2002). Low consumption of seafood in early pregnancy as a risk factor for preterm delivery: prospective cohort study. BMJ. 324(7335), 447.

O'Neil K.R., Jones S.H. & Grimes D.J. (1992). Seasonal incidence of *Vibrio vulnificus* in the Great Bay Estuary of New Hampshire and Maine. Appl. Environ. Microb. 58 (10), 3257-3262.

Oterhals, Å., Berntssen, M., Solvang, M. & Nortvedt., R. (2005). Decontamination of persistent organic pollutants in fish oil by active carbon adsorption. Lipid forum, 12 September. Reykjavik.

Pascual, C.Y., Martin Esteban, M. & Crespo, J.F. (1992). Fish allergy: Evaluation of the importance of cross-reactivity. J Pediatr. 121, 29-S34.

Patandin, S., Lanting, C.I., Mulder, P.G.H., Boersmam, E.R., Sauerm, P.J.J. & Weisglas-Kuperus, N. (1999). Effects of environmental exposure to polychlorinated biphenyls and dioxins on cognitive abilities in Dutch children at 42 months of age. J Pediatr. 134, 33–41.

Patel, P.C. & Cockroft, D.W. (1992). Occupational asthma caused by exposure to cooking lobster in the work environment: a case report. Ann Allergy. 68, 360-361.

Pawlosky, R.J., Hibbeln, J.R., Novotny, J.A. & Salem, Jr. N (2001). Physiological compartmental analysis of alpha-linolenic acid metabolism in adult humans. J Lipid Res. 42, 1257-65.

Pollestad, M.L., Øverby, N.C. & Andersen, L.F. (2002). Kosthold blant 4-åringer. Landsomfattende kostholdsundersøkelse. UNGKOST-2000. Sosial- og helsedirektoratet.

RAFOA; Researching Alternatives to Fish Oils in Aquaculture, Q5RS-2000-30058.

Raitt, M.H., Connor, W.E., Morris, C., Kron, J., Halperin, B., Chugh, S.S., McClelland, J., Cook, J., MacMurdy, K., Swenson, R., Connor, S.L., Gerhard, G., Kraemer, D.F., Oseran, D., Marchant, C., Calhoun, D., Shnider, R. & McAnulty, J. (2005). Fish oil supplementation and risk of ventricular tachycardia and ventricular fibrillation in patients with implantable defibrillators: a randomized controlled trial. JAMA. 293, 2884-2891.

Rana, S.K. & Sanders, T.A.B. (1986) Taurine concentrations in the diet, plasma, urine and breast milk of vegans compared with omnivores. Br J Nutr. 56, 17-27.

Rembold, C.M. (2004). The health benefits of eating salmon. Science. 305, 475.

Reth, M., Zencak, Z. & Oehme, M. (2005). First study of congener group patterns and concentrations of short- and medium-chain chlorinated paraffines in fish from the North and Baltic Sea. Chemosphere. 58, 847-854.

Richardson, A.J & Montgomery, P. (2005). The Oxford-Durham study: A randomized, controlled trial of dietary supplementation with fatty acids in children with developmental coordination disorder. Pediatrics. 115, 1360-1366.

Rivera-Milla, E., Stuermer, C.A.O. & Málaga-Trillo, E. (2003). An evolutionary basis for scrapie disease: identification of a fish prion mRNA. Trends in Genetics. 19, 72-75.

Rogan, W.J., Gladen, B.C. & McKinney, J.D. (1986). Neonatal effects of transplacental exposure to PCBs and DDE. J Pediatr. 109, 335–341.

SACN/COT, 2004. Advice on fish consumption: benefits & risks. SACN (Scientific Advisory Committee on Nutrition) and COT (Committee on Toxicity) Joint report 2004.

Salonen, J.T., Alfthan, G., Huttunen, J.K., Pikkarainen, J. & Puska, P. (1982). Association between cardiovascular death and myocardial infarction and serum selenium in a matched-pair longitudinal study. Lancet. ii, 175-179.

Salonen, J.T., Seppanen, K., Nyyssonen, K., Korpela, H., Kauhanen, J., Kantola, M., Tuomilehto, J., Esterbauer, H., Tatzber, F. & Salonen, R. (1995). Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and any death in eastern Finnish men. Circulation. 91, 645-655.

Sampson, H.A. & Scanlon, S.M. (1989). Natural history of food hypersensitivity in children with atopic dermatitis. J Pediatr. 115, 23-27.

Samuelsen, O.B., Lunestad, B.T., Husevåg, B., Hølleland, T. & Ervik, A. (1992). Residues of oxolinic acid in wild fauna following medication in fish farms. Dis. aquat. Org. 12, 111-119.

Samuelsen, O.B., Lunestad, B.T., Ervik, A. & Fjelde, A. (1994). Stability of antibacterial agents in an artificial marine aquaculture sediment studied under laboratory conditions. Aquaculture. 126, 283-290.

Sanden, M. (2004). Genetically modified plant products in feed to farmed Atlantic salmon, Salmo salar L., - Effects on growth, feed utilization, fish health and assessment of potential risks. Dr.scient thesis, University of Bergen, Norway.

Sanderson, P., Finnegan, Y.E., Williams, C.M., Calder, P.C., Burdge, G.C., Wootton, S.A., Griffin, B.A., Millward, D.J., Pegge, N.C. & Bemelmans, W.J.E. (2002). UK Food Standards Agency α-linolenic acid workshop report. Br J Nutr. 88, 573-79.

Sandnes, K., Ulgenes, Y., Brækkan, O.R. & Utne, F. (1984). "The effect of ascorbic acid supplementation in Broodstock feed on reproduction of Rainbow trout (*Salmo gairdneri*)." Aquaculture. 43, 167-171.

SCAN, 2000. Opinion of the Scientific Committee on animal nutrition SCAN on the dioxin contamination of feedingstuffs and their contribution to the contamination of food of animal origin. http://europa.eu.int/comm/food/fs/sc/scan/outcome.en.html

Schantz, S.L., Gasior, D.M., Polverejan, E., McCaffrey, R.J., Sweeney, A.M., Humphrey, H.E.B. & Gardiner, J.C. (2001). Impairments of memory and learning in older adults exposed to polychlorinated biphenyls via consumption of Great Lakes fish. Environ Health Perspect. 109(6), 605-11.

Schantz, S.L., Widholm, J.J., Rice, D.C. (2003). Effects of PCB exposure on neuropsychological function in children.Environ Health Perspect. 111(3), 357-576. Review.

SCF, 1993. Nutrient and energy intakes for the European Community. Reports of the Scientific Committee for Food (Thirty-first series). Opinion expressed on 11 December 1992. http://europa.eu.int/comm/food/fs/sc/scf/out89.pdf

SCF, 2000a. Guidelines for the development of upper tolerable intake levels for vitamins and minerals" SCF/CS/NUT/UPPLEV/42 Final 28 November 2000.

SCF, 2000b. Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of vitamin B12 SCF/CS/NUT/UPPLEV/42 Final 28 November 2000.

SCF, 2000c. Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of Selenium SCF/CS/NUT/UPPLEV/25 Final 28 November 2000.

SCF, 2001. Opinion of the Scientific Committee on Food on the Risk assessment of dioxins and dioxin-like PCBs in food. 2001 May 30.

SCF, 2002a. Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of Preformes Vitamin A (retinol and retinyl esters). SCF/CS/NUT/UPPLEV/ 24 Final 7 October 2002.

SCF, 2002b.Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of Vitamin D. SCF/CS/NUT/UPPLEV/ 38 Final 16 December 2002.

SCF, 2002c. Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of Iodine SCF/CS/NUT/UPPLEV/ 26 Final 7 October 2002.

SCF, 2002d. Opinion of the Scientific Committee on Food on the risks to human health of Polycyclic Aromatic Hydrocarbons in food. SCF/CS/CNTM/PAH/29 Final4 December 2002 EUROPEAN COMMISSION HEALTH *and* CONSUMER PROTECTION DIRECTORATE-GENERAL http://europa.eu.int/comm/food/food/chemicalsafety/contaminants/out153_en.pdf

SCF, 2003. Tolerable upper intake levels for vitamins and minerals. http://europa.eu.int/comm/food/fs/sc/scf/out80_en.html

Seierstad, S.L., Poppe, T.T., Koppang, E.O., Svindland, A., Rosenlund, G., Frøyland, L. & Larsen, S. (2005). Influence of dietary lipid composition on cardiac pathology in farmed Atlantic salmon, Salmo salar L. Journal of Fish Diseases. 28, 677-690.

Selevan, S.G., Rice, D.C., Hogan, K.A., Euling, S.Y., Pfahles-Hutchens, A. & Bethel, J. (2003). Blood lead concentration and delayed puberty in girls. N Engl J Med. 348(16), 1527-36.

Similä, M., Fagt, S., Vaask, S., Thorgeirsdottir, H., Pudule, I., Petkeviciene, J., Johansson, L., Becher, W., Ovesen, L., Steingrimsdottir, L., Moltchanova, E. & Valsta, L. (2003). The NORBAGREEN 2002 study. Nordisk ministerråd.

Singh, R.B., Niaz, M.A., Sharma, J.P., Kumar, R., Rastogi, V. & Moshiri, M. (1997). Randomized, double-blind, placebo-controlled trial of fish oil and mustard oil in patients with suspected acute myocardial infarction: the Indian experiment of infarct survival--4. Cardiovasc.Drugs Ther. 11, 485-491.

Singh, P.N. & Fraser, G.E. (1998). Dietary risk factors for colon cancer in a low-risk population. Am J Epidemiol. 148, 761-74.

Sinclair, A.J., Attar-Bashi, N.M. & Li, D. (2002). What is the role of α-linolenic acid for mammals Lipids. 37, 1113-1123.

Slimani, N., Fahey, M., Welch, A.A., Wirfält, E., Stripp, C., Bergström, E., Linseisen, J., Schulze, M., Bamia, C., Chloptsios, Y., Veglia, F., Panico, S., Bueno-de-Mesquita, H.B., Ocké, M.C., Braaten, T., Lund, E., González, C.A., Barcos, A.., Berglund, G., Winkvist, A., Mulligan, A., Appleby, P., Overvad, K., Tjønneland, A., Clavel-Chapelon, F., Kesse, E., Ferrari, P., van Staveren, W.A. & Riboli, E. (2002). Diversity of dietary patterns observed in the European Prospective Investigation into Cancer and Nutrition (EPIC) project. Public Health Nutr. 5 (6B), 1311-28.

Sloth, J.J., Julshamn, K. & Lundebye, A.K. (2005a). Total arsenic and inorganic arsenic content in Norwegian fish feed products. Aquaculture Nutrition. 11, 61.

Sloth, J.J., Larsen, E.H. & Julshamn, K. (2005b). Report on three aliphatic dimethylarsinoyl compounds as common minor constituents in marine samples. An investigation using high-performance liquid chromatography/inductively coupled plasma mass spectrometry and electrospray ionisation tandem mass spectrometry Rapid Communications in Mass Spectrometry. 19(2), 227.

Smith, P. & Samuelsen, O.B. (1996). Estimates of the significance of out-washing of tetracycline from sediments under Atlantic sea-cages. Aquaculture. 144, 17-26.

Solomon, H.M & Lilly, T.Jr. (2001). *Clostridium botulinum*. Bacteriological analytical manual – online. U.S. Food and Drug Administration, Centre for Food Safety and Applied Nutrition. http://www.cfsan.fda.gov/~ebam/bam-17.html.

Sosial- og helsedirektoratet, 2004: Utviklingen av norsk kosthold 2004. Matforsyningsstatistikk og Forbruksundersøkelser. Rapport nr. IS-1218.
http://www.shdir.no/vp/multimedia/archive/00005/IS-1218_5390a.doc

Sosial- og helsedirektoratet, 2005a: Utviklingen av norsk kosthold 2005. Rapport nr. IS-1325.
http://www.shdir.no/vp/multimedia/archive/00006/IS-1325_6097a.pdf

Sosial- og helsedirektoratet, 2005b: Norske anbefalinger for ernæring og fysisk aktivitet. Rapport nr. IS-1219.
http://www.shdir.no/vp/multimedia/archive/00002/IS-1219_2606a.pdf

Statens råd for ernæring og fysisk aktivitet, 2002: Anbefalinger for spedbarnsernæring. Rapport nr. IS-1019.
http://www.shdir.no/vp/multimedia/archive/00001/IS-1019__1971a.pdf

Stapleton, H.M., Letcher, R.J. & Baker, J.E. (2002). Uptake, metabolism and depuration of polybrominated diphenyl ethers (PBDEs) by the common carp, (Cyprinus carpio). Organohalogen Compounds. 58, 201-204.

Stapleton, H.M., Alaee, M., Letcher, R.J. & Baker, J.E. (2004a). Debromination of the flame retardant decabromodiphenyl ether by juvenile carp (Cyprinus carpio) following dietary exposure. Environ. Sci. Technol., 38(1), 112-9.

Stapleton, H.M., Letcher, R.J., Li, J. & Baker, R.A. (2004b). Dietary accumulation and metabolism of polybrominated diphenyl ethers by juvenile carp (Cyprinus carpio). Environmental Toxicology and Chemistry. 23, 1939-1946.

Steuerwald, U., Weihe, P., Jorgensen, P.J., Bjerve, K., Brock, J., Heinzow, B., Budtz-Jorgensen, E. & Grandjean, P. (2000). Maternal seafood diet, methylmercury exposure, and neonatal neurologic function. J Pediatr. 136(5), 599-605.

Stewart, P.W., Reihman, J., Lonky, E.I., Darvill, T.J., & Pagano, J. (2003). Cognitive development in preschool children prenatally exposed to PCBs and MeHg. Neurotoxicol Teratol. 25(1), 11-22.

Stripp, C., Overvad, K., Christensen, J., Thomsen, B.L., Olsen, A., Møller, S. & Tjønneland, A. (2003). Fish intake is positively associated with breast cancer incidence rate. J Nutrition. 11. 3664-69.

Studer, M., Briel, M., Leimenstoll, B., Glass, T.R., & Bucher, H.C. (2005). Effect of different antilipidemic agents and diets on mortality: a systematic review. Arch.Intern.Med. 165, 725-730.

Suadicani, P., Hein, H.O. & Gyntelberg, F. (1992). Serum selenium concentration and risk of ischaemic heart disease in a prospective cohort study of 3,000 males. Atherosclerosis. 96, 33-42.

Sutherland, J. & Varnam, A. (2002). Enterotoxin-producing *Stahylococcus*, *Shigella*, *Yersinia*, *Vibrio*, *Aeromonas* and *Plesiomonas*. p. 385-415, in C.W. Blackburn and P. McClure, Foorborn pathogenes, Woodhead Publishing, Cambridge England, ISBN 1 85573 454 0.

Taylor, S.L. & Hefle, S.L. (2000). Hidden triggers of adverse reactions to foods. Can J Allergy Clin Immunol. 5, 106-110.

Telzak, E.E., Bell, E.P., Kautter, D.A.., Crowell, L., Budnick, L.D., Morse, D.L. & Shultz, S. (1990). An international outbreak of type E botulism due to unevisceration of fish. J. Inf. Dis. 161, 340-342.

Terry, P., Lichtenstein, P., Feychting, M., Ahlbom, A. & Wolk, A. (2001). Fatty fish consumption and risk of prostate cancer. Lancet. 357, 1764-6.

Thun, M.J., Calle, E.E., Namboodiri, M.M., Flanders, W.D., Coates, R..J., Byers, T., Bofetta, P., Garfinkel, L. & Heath, C.W.Jr. (1992). Risk factors for fatal colon cancer in a large prospective study. J Natl Cancer Inst. 84, 1491-1500.

Tiemersma, E.W., Kampman, E., Bueno de Mesquita, H.B., Bunschoten, A., van Schothorst, E.M., Kok, F.J. & Kromhout, D. (2002). Meat consumption, cigarette smoking, and genetic susceptibility in the etiology of colorectal cancer: results from a Dutch prospective study. Cancer Causes Control. 13, 383-393.

Tiews, K., Manthey, M. & Koops, H. (1982). The carry-over of fluoride from krill meal pellets into rainbow trout (*Salmo gairdneri*). Arch. Fisch Wiss. 32, 39-42.

Todar, K. (2004). Todars online textbook of microbiology. http://www.textbookofbacteriology.net/

Tomy, G.T., Fisk, A.T., Westmore, J.B. & Muir, D.C.G. (1998). Environmental chemistry and toxicology of polychlorinated n-alkanes. Rew Environ Contam Toxicol. 158, 53-128.

Tomy, G.T., Budakowski, W., Halldorson, T., Helm, P.A., Stern, G.A., Friesen, K., Pepper, K., Tittlmier, S.A. & Fisk, A.T. (2004a). Fluorinated organic compounds in the Eastern Arctic marine foodweb. Environ SciTechnol. 38, 6475-6481.

Tomy, G.T., Palace, V.P., Halldorson, T., Braekevelt, E., Danell, R., Wautier, K., Evans, B., Brinkworth, L. & Fisk, A.T. (2004b). Bioaccumulation, biotransformation, and biochemical effects of brominated diphenyl ethers in juvenile lake trout (Salvelinus namaycush). Environmental Science and Technology. 38, 1496-1504.

Torstensen, B.E., Frøyland, L., Ørnsrud, R. & Lie, Ø. (2004). Tailoring of a cardioprotective muscle fatty acid composition of Atlantic salmon (Salmo salar) fed vegetable oils. Food Chemistry. 87, 567-580.

Tuomisto, J.T., Tuomisto, J., Tainio, M., Niittynen, M., Verkasalo, P., Vartiainen, T., Kiviranta, H. & Pekkanen, J. (2004). Risk-benefit analysis of eating farmed salmon. Science. 305, 476-477.

US EPA, 2005. Draft risk assessment of the potensial human health effects associated with exposure to perfluorooctanoic acid and its salts. U.S Environmental Protection Agency Office of Pollution Prevention and Toxics Risk Assessment Division, January 4, 2005.

Vatten, L.J., Solvoll, K. & Løken, E.B. (1990). Frequency of meat and fish intake and risk of breast cancer in a prospective study of 14 500 Norwegian women. Int J Cancer. 46, 12-5.

Vermunt, S.H.F., Mensink, R.P., Simonis, M.M.G. & Hornstra, G. (2000). Effects of dietary α-linolenic acid on the conversion and oxidation of ^{13}C-α-linolenic acid. Lipids. 35(2), 137-42.

Vik, R. (1957). Studies of the helminth fauna of Norway. I. Taxonomy and ecology of *Diphyllobotrium norvegicum* n.sp. and the plerocercoid of *Diphyllobothrium latum* (L.). Nytt Magasin for Zoologi. 5, 26-93.

Vik, R. (1964). Studies of the helminth fauna of Norway. V. Plerocercoids of *Diphyllobothrium* spp. from the Røssåga water system, Nordland county. Nytt Magasin for Zoologi. 12, 1-9.

Villeneuve, D.L., Kannan, K., Khim, J.S., Falandysz, J., Nikiforov, V.A., Blankenship, A.L., Giesy, J.P. (2000). Relative potencies of individual polychlorinated naphtalenes to induce dioxin-like responses in fish and mammalian in vitro bioassays. Arch Environ Contam Toxicol. 39, 273-281.

Virtanen, J.K., Voutilainen, S., Rissanen, T.H., Mursu, J., Tuomainen, T.P., Korhonen, M.J., Valkonen, V.P., Seppanen, K., Laukkanen, J.A. & Salonen, J.T. (2005). Mercury, fish oils, and risk of acute coronary events and cardiovascular disease, coronary heart disease, and all-cause mortality in men in eastern Finland. Arterioscler.Thromb.Vasc.Biol. 25, 228-233.

Vitti, P., Delange, F., Pincherra, A., Zimmermann, M. & Dunn, J.T. (2003). Europe is iodine deficient. Lancet.. 361, 1226.

Vollset, S., Heuch, I. & Bjelke, E. (1985). Fish consumption and motality from coronary heart disease. N.Engl.J.Med. 313, 820-821.

VKM, 2004. Comments on proposed maximum levels for dioxin-like PCBs in food. Uttalelse fra Faggruppen for forurensninger, naturlige toksiner og medisinrester i matkjeden 25.november, 2004. http://www.vkm.no/eway/default.aspx?pid=0&oid=-2&trg=__new&__new=-2:15777

VKM, 2005. Risikovurdering av PBDE. Uttalelse fra Faggruppen for forurensninger, naturlige toksiner og medisinrester i matkjeden 15. juli 2005. http://www.vkm.no/eway/default.aspx?pid=0&oid=-2&trg=__new&__new=-2:16185

Walkowiak, J., Wiener, J.A., Fastabend, A., Heinzow, B., Kramer, U., Schmidt, E., Steingruber, H.J., Wundram, S. & Winneke, G. (2001). Environmental exposure to polychlorinated biphenyls and quality of the home environment: effects on psychodevelopment in early childhood. Lancet. 358(9293), 1602-7.

WCRF, 1997. World Cancer Research Found and American Institute for Cancer Research: Food, nutrition and the prevention of cancer: a global perspective. Washington DC: American Institute for Cancer Research, 1997.

Weber, C., Bysted, A. & Holmer, G. (1994). The coenzyme Q_{10} content of the average Danish diet. Int J Vitam Nutr Res. 67, 123-129.

Weihe, P., Hansen, J.C., Murata, K., Debes, F., Jorgensen, P., Steuerwald, U., White, R.F. & Grandjean P. (2002). Neurobehavioral performance of Inuit children with increased prenatal exposure to methylmercury. Int J Circumpolar Health. 61(1), 41-9.

Welch, A.A., Lund, E., Amiano, P., Dorronsoro, M., Brustad, M., Kumle, M., Rodriguez, M., Lasheras, C., Janzon, L., Jansson, J., Luben, R., Spencer, E.A., Overvad, K., Tjonneland, A,, Clavel-Chapelon, F., Linseisen, J., Klipstein-Grobusch, K., Benetou, V., Zavitsanos, X., Tumino, R,, Galasso, R., Bueno-De-Mesquita, H.B., Ocke, M.C., Charrondiere, U.R. & Slimani, N.(2002). Variability of fish consumption within the 10 European countries participating in the European Investigation into Cancer and Nutrition (EPIC) study. Public Health Nutr. 5(6B), 1273-85.

West, P.A. (1989). The human pathogenic vibrios – A public health update with environmental perspectives. Epidem. Inf. 103, 1-34.

Whelton, S.P., He, J., Whelton, P.K. & Muntner, P. (2004). Meta-analysis of observational studies on fish intake and coronary heart disease. Am.J.Cardiol. 93, 1119-1123.

WHO, 1984. Camphechlor. Environmental Health Criteria 45. International Programme on Chemical Safety IPCS, World Health Organisation Geneva.

WHO, 1989. Toxicological Evaluations of Certain Food Additives and Contaminants; Arsenic. 33rd Report of the JECFA, WHO Food Additives Series No 24.

WHO, 1993. Evaluation of certain food additives and contaminants. Fourty-first report of the Joint FAO/WHO expert Committee on Food Additives. WHO technical report series no. 837. World Health Organization, Geneva, Switzerland

WHO, 2000. Lead. In: Safety Evaluation of Certain Food Additives and Contaminants. Joint FAO/WHO expert Committee on Food Additives, Food Additives Series: 44. World Health Organization, Geneva, Switzerland.

WHO, 2001. Cadmium. In: Safety Evaluation of Certain Food Additives and Contaminants. Joint FAO/WHO expert Committee on Food Additives, Food Additives Series: 46. World Health Organization, Geneva, Switzerland.

WHO, 2003. Cadmium (pre-published summary). In: Safety Evaluation of Certain Food Additives and Contaminants. 61st Meeting of Joint FAO/WHO expert Committee on Food Additives, WHO, Geneva, Switzerland,

WHO-IPCS, 1992. Cadmium, Environmental Health Criteria 134. World Health Organization, Geneva, Switzerland.

WHO-IPCS, 1995. Inorganic Lead, Environmental Health Criteria 165. World Health Organization, Geneva, Switzerland.

WHO-IPCS, 2001. Chlorinated naphthalenes. International Programme on Chemical Safety - Concise International Chemical Assessment Document 34. ISBN 92 4 153034 0/ISSN 1020-6167.

Waagbø, R., J. Glette, E., Nilsen, R. & Sandnes, K., (1993). "Dietary vitamin C, immunity and disease resistance in Atlantic salmon (*Salmo salar*)." Fish Physiology and Biochemistry. 12(1), 61-73.

Waagbø, R., Albrektsen, S., Berge, R.K., Brodtkorb, B.T., Christiansen, R., Lie, Ø., Lorentzen, M., Lygren, B., Maage, A., Wathne, E. & Hamre, K. (1998). Optimal supplementations of antioxidant vitamins, minerals and polyunsaturated lipids in diets to adult Atlantic salmon, with emphasis on growth, health and fillet quality. NFR project 112317/120. Final report - Part I, Institute of Nutrition, Directorate of Fisheries, Report 3 (Restricted distribution).

Zoonoserapporten, 2003. Norsk zoonosesenter,
http://www.vetinst.no/Arkiv/Zoonosesenteret/Zoonoserapport03-no.pdf/

Øverby, N.C. & Andersen, L.F. (2002). Ungkost 2000. Landsomfattende kostholdsundersøkelse blant elever i 4.- og 8. klasse i Norge. Sosial- og helsedirektoratet, Avdeling for ernæring.

Appendices

Appendix A Algal toxins

Pectenotoxin group (PTXs)
PTXs occur together with toxins from the DSP complex and.until recently, PTXs were included in this group. They were detected for the first time in 1984 in scallops in Japan and are produced by algae in the *Dinophysis* family. The effect mechanism is unknown, but the cytoskeleton is affected. No observations of toxic effects of PTXs have been reported in humans. The toxological base is too weak at present to establish an ARfD or TDI for pectenotoxins.

Brevetoxin group (BTXs)
The condition referred to as 'neurotoxic shellfish poisoning' (NSP) has been known to exist in/near the Gulf of Mexico since the end of the 1980s. The toxins are mainly produced by the algae *Karenia brevis*. Both the consumption of shellfish and the inhalation of aerosols can cause NSP. Nausea, diarrhoea and stomach pains as well as neurological symptoms such as hot-cold sensations, reduced coordination and slow heart rhythm have been observed in humans. The incubation time is approximately three hours, and the symptoms last for several days. No fatalities have been reported. Brevetoxins have not been detected in Norwegian shellfish. No ARfD exists.

Cyclomine group
This group includes spirolides, gymnodimine, prorocentrolides, etc. The group was discovered when, in a test on mice for DSP toxins, high acute toxicity occurred in mice injected with shellfish extracts (MBA). Spirolides are found in Norwegian mussels and are produced by the algae *Alexandrium ostenfeldii*. The effect mechanism is unknown. Other spirolides are far less toxic. The cyclomine group is important for toxicity. Little is known about the incidence of the other cyclomines, but they are probably not present in the Nordic countries. No observations of human poisoning from cyclomines in shellfish have been reported. There is insufficient information to establish ARfD and TDI values for cyclomines.

Appendix B Data on the level of radionuclides

Data on the level of radionuclides (activity concentration Bq/kg wet weight) can be obtained from the national monitoring programme *Radioactivity in the Maritime Environment (RAME)*. In the case of fish and seafood, most of the existing data is on ^{137}Cs. A considerable amount of data is also available on ^{99}Tc and ^{210}Po. For other radionuclides, the data used consists of seawater data or data from the available literature combined with concentration factors published by the International Atomic Energy Agency (IAEA). The table below shows the activity concentration measured or estimated in marine organisms.

Table 1, Appendix B – The average or 'typical'[14] activity concentration in marine organisms.

Nuclide	Activity concentration Bq/kg wet weight				
	Fish	Shrimp	Crab	Molluscs	Fish liver
^{137}Cs	0.5	0.2	0.15	0.2	0.5
^{90}Sr	0.5	0.01	0.01	0.02	0.5
$^{239+240}$Pu	0.003	0.006	0.006	0.09	0.003
^{99}Tc	0.16	0.75	0.26	0.7	0.16
^{241}Am	0.0002	0.0007	0.0007	0.002	0.0002
^{226}Ra	0.1	0.1	0.1	0.1	0.1
^{228}Ra	0.1	0.1	0.1	0.1	0.1
^{210}Pb	0.042	0.02	0.24	1.2	0.042
^{210}Po	0.82	9,1	19	42	10

Activity concentrations of $^{239+240}$Pu, ^{241}Am and ^{90}Sr have been estimated on the basis of the concentration factors published by IAEA (IAEA, 2004), together with the level of activity measured in seawater. Data from other nuclides is taken from the available literature.

[14] 'Typical' activity concentration refers to the presumed activity concentration of a nuclide in a marine organism in cases in which the database has been insufficient.

Appendix C
Fish consumption and cancer

Table 1, Fish and the risk of colon and rectal cancer

Study	Number of participants/number of cancer cases	Groups being compared	Relative risk (95% confidence interval)	Comments
Women				
Willett *et al.*, 1990	88751 / 150	Fish consumption ≥ 5 times/week vs. < once /month Ratio red meat /white meat 5th quintile vs. 1st quintile	1.1 (0.36-3.1) 2.5 (1.5-4.1)	
Goldbohm *et al.*, 1994	62573 / 110	> 20 g fish/day vs. 0 g fish/day	0.87 (0.52-1.5)	Case cohort
Gaard *et al.*, 1996	24897 / 63	Fish for dinner ≥ 5 times/week vs. ≤ 2 times/week	0.81 (0.30-1.9)	
Kato *et al.*,1997	14727 / 100	Fish and other seafood (gram) 4th quartile vs. 1st quartile Ratio of red meat /white meat 4th quartile vs. 1st quartile	0.49 (0.27-0.89) 1.8 (0.93-3.3)	
Bostick *et al.*, 1994	35215 / 212	Seafood > 2.5 times/week vs. < once/week	0.76 (0.49-1.2)	
Knekt *et al.*, 1999	Both genders: 9985 / 73 Women: 4711 / 37	Fish consumption 4th quartile vs. 1st quartile	1.1 (0.55-2.3)	Mutual risk estimate for men and women, adjusted for age
Tiermersma *et al.*, 2002	245 / 48 (control/cases)	Fish consumption > 4 times/month vs. 0-1 times/month.	0.5 (0.2-1.0)	Nested case-controls
Larsson *et al.*, 2005	61433 / 733	≥ 2 times/week vs. < 0.5 times/week	1.1 (0.81-1.4)	Adjusted for gender
Men				
Giovannucci *et al.*, 1994	47949 / 205	Fish consumption gram/day 5th quintile vs. 1st quintile Ratio of red meat /chicken and fish, 5th quintile vs. 1st quintile	1.1 (0.70-1.6) 1.8 (1.2-2.9)	From the same material as Ma *et al.*, 2001
Goldbohm *et al.*, 1994	58279 / 105	> 20 g fish/day vs. 0 g fish/day	0.73 (0.44-1.2)	Case cohort
Gaard *et al.*, 1996	25638 / 87	Fish serving ≥ 5 times/week vs. ≤ 2 times/week	0.46 (0.19-1.1)	
Ma *et al.*, 2001	14916 / 193	Fish servings /day 3rd tertile vs. 1st tertile	0.92 (0.56-1.5)	From the same material as Giovannucci *et al.*, 1994. Nested case-control
Hsing *et al.*, 1998	17633/145	Frequency of fish consumption 4th quartile vs. 1st quartile	1.4 (0.8-2.5)	Hsing *et al.*, 1998
Knekt *et al.*, 1999	Both genders: 9985 / 73 Men: 5274 / 36	Fish consumption 4th quartile vs. 1st quartile	1.1 (0.55-2.3)	Mutual analyses for men og women, adjusted for gender
Pietinen *et al.*, 1999	27111 / 185	Fish consumption gram 4th quartile vs. 1st quartile	0.9 (0.6-1.4)	
Tiemersma *et al.*, 2002	292/54 (control/case)	Fish consumption > 4 times/month vs. 0-1 times/month.	1.2 (0.6-2.4)	Nested case-controls
Men and women				
English *et al.*, 2004	37 112/ 452	Fish consumption in 4th quartile vs. 1st quartile	About 1.0 not significant	

Norat *et al.*, 2005	478 040/ 1329	Fish consumption per 100 g	0.46 (0.27-0.77)	The estimates are calibrated

Table 2, Appendix C. Fish consumption and the risk of breast cancer, cohort studies

Study	**Number of participants/number of cancer cases**	**Groups being compared**	**Relative risk**	**Comments**
Stampfer *et al.*, 1987	89538 / 601	≥2 times/week vs. ≤ 1 4 times/month	1.1 (0.5-2.4)	Se Holmes *et al.*, 2003
Mills *et al.*, 1989a	20341 / 115	Fish consumption ≥ 1 times/week vs. never	1.5 (1.0-1.8)	Adventists
Vatten *et al.*, 1990	14500 / 152	Fish for dinner > 2 times/week vs. ≤ 2 times/week	1.2 (0.8-1.7)	County studies
		Boiled fish for dinner ≥5 times/week vs. < 2 4 times/month	0.7 (0.4-1.0)	
Toniolo *et al.*, 1994	14 291 / 180	Fisk gram i 5th quentil vs. 1st quentil	1.0 (0.61-1.7)	Nested case-control approach
Gertig *et al.*, 1999	932 / 466	Fish consumption > 0.5 times/day vs. ≤ 0.14 times/day	1.3 (0.7-2.6)	Nested case-control approach
Holmes *et al.*, 2003	88647 / 4107	Fish consumption ≥ 0.4 times/day vs. ≤ 0.13 times/day	1.0 (0.93-1.1)	Same material as Stampfer *et al.*, 1987
Frazier *et al.*, 2003	8430 / 843	An increase of one serving per day	0.94 (0.64-1.4)	Nested case-control
Frazier *et al.*, 2004	47355 / 361	Servings of fish 5th quentil vs. 1st quentil	0.94 (0.67-1.3)	Adolescent diet
Stripp *et al.*, 2003	23643 / 424	An increase of 25 g/day. Fatty fish Lean fisk	1.1 (0.91-1.3) 1.1 (1.03-1.2)	
Lund *et al.*, 2004	57791 / 493	Fatty fish > 110 g/day vs. < 111 g/day	0.99 (0.82-1.2)	
Folsom *et al.*, 2004	41836 / 1885	Quentils 0.5 times per day vs. 2.5	0.92 (0.76-1.1)	

Table 3 Appendix C. Fish consumption and the risk of prostate cancer

Study	Number of participants /number of cancer cases	Groups being compared	Relative risk	Comments
Hirayama, 1979	122261 / 63	Fish consumption daily vs. rare/never	5.7 vs. 5.8	Death rates
Severson *et al.*, 1989	7 999 / 174	Fish consumption ≥5 times/week vs. ≤1 times/week	1.2 (0.74-2.0)	
Mills *et al.*, 1989b	Ca. 14000 / 180	Fish consumption ≥1 times/week vs. never	1.6 (0.88-2.9)	Adventists
Hsing *et al.*, 1990	17633 / 149	Fish consumption >4,0 4 times/month vs. <0.8 4 times/month	0.8 (0.5-1.3)	
Le Marchand *et al.*, 1994	20316 / 198	Fish consumption gram 4. quartile vs. 1. quartile	1.2 (0.8-1.8)	
Veierød *et al.*, 1997	25708 / 72	Main serving with fish	No association	No risk estimates provided
Schuurman *et al.*, 1999	58279 / 642	20 g fish/day vs. 0 g fish/day	1.0 (0.80-1.3)	
Terry *et al.*, 2001	6272 / 466	Fish consumption moderate part of the total diet vs. rare or never	0.4 (0.2-0.8)	
Augustsson *et al.*, 2003	47882 / 2482	Fish consumption >3 times/week vs. <2 times/week	5.7 vs. 5.8	Death rates
Allen *et al.*, 2004	18115 / 196	Total fish consumption low vs. high	1.2 (0.74-2.0)	

Appendix D Recipes for the scenarios

Table 1, Appendix D – Chapter 8 includes two scenarios: one of them estimates the impact of fish and other seafood on the intake of selected nutrients (Table 19), and the other estimates the impact of fish and other seafood on the intake of hazardous metals and organic contaminants (Table 22). This appendix presents the intake levels used as a basis for the scenarios. The various subgroups of fish (cold cuts/spreads, lean fish, etc.) are referred to as a 'recipe', and the 'recipe' forms the basis for the intake estimate.

	Ingredient	% of recipes
Cold cuts		
	Mackerel, july-sept	12
	Mackerel, may-june	12
	Herring, summer herring	12
	Herring, winter herring	12
	Salmon	25
	Caviar	25
	Spawn liver patè	2
Fish food	Cod	33
	Saithe	33
	Haddock	33
Lean fish	Cod	45
	Saithe	20
	Haddock	4
	Fish food	31
Fatty fish	Salmon	32
	Trout	11
	Herring, summer herring	8
	Herring, winter herring	8
	Mackerel, july-sept	8
	Mackerel, may-june	8
	Cold cuts	26
Fish, lean 2/3 and 1/3 fatty		
	Cod	26
	Saithe	12
	Haddock	4
	Fish food	18
	Salmon	10
	Trout	3
	Herring, summer herring	2
	Herring, winter herring	2
	Mackerel, july-sept	2
	Mackerel, may-june	3
	Cold cuts	9
	Shrimp	7
	Crab, hermetic	2

Appendix E Intake of Vitamin D in children and adults

Table 1, Appendix E

Vitamin D intake in children and adults, average and percentiles for percentage intake of the recommended daily intake from different food sources. The intakes are estimated on the basis of Norkost 1997, Ungkost 2000 and Småbarnskost 1999'. Note that the percentiles cannot be added because the samples of participants in each category (food source) are not identical.

Vitamin D intake, % of recommended daily intake									
Age	**Source***	**5-percentile**	**10-percentile**	**25-percentile**	**50-percentile**	**75-percentile**	**90-percentile**	**95-percentile**	**Average**
1 year-olds	**Total intake**	**12**	**19**	**44**	**86**	**131**	**170**	**208**	**94**
	From fish and other food	6	9	16	28	50	78	95	37
	From fish	0	0	0	1	3	8	12	3
	From other food	6	8	14	24	48	75	92	34
	From dietary supplements	0	0	0	50	100	108	151	57
2 year-olds	**Total intake**	**23**	**30**	**57**	**121**	**187**	**258**	**325**	**136**
	From fish and other food	13	17	23	32	44	57	67	35
	From fish	0	0	1	4	10	19	25	7
	From other food	11	14	19	26	34	45	53	28
	From dietary supplements	0	0	27	86	144	211	288	100
4 year-olds	**Total intake**	**14**	**20**	**33**	**76**	**131**	**200**	**230**	**92**
	From fish and other food	12	14	20	28	39	57	84	34
	From fish	0	0	0	1	5	18	43	8
	From other food	11	13	18	24	33	42	50	26
	From dietary supplements	0	0	0	37	100	150	200	58
9 year-olds	**Total intake**	**9**	**15**	**27**	**54**	**106**	**172**	**211**	**76**
	From fish and other food	8	11	20	31	45	65	92	37
	From fish	0	0	0	0	5	19	43	8
	From other food	7	10	17	27	38	49	61	29
	From dietary supplements	0	0	0	0	67	133	150	39
13 year-olds	**Total intake**	**6**	**9**	**18**	**34**	**69**	**123**	**173**	**56**
	From fish and other food	5	8	15	25	42	65	88	34
	From fish	0	0	0	0	3	19	48	8
	From other food	5	7	13	21	34	48	58	25
	From dietary supplements	0	0	0	0	17	67	125	22
Adults	**Total intake**	**21**	**29**	**53**	**109**	**191**	**327**	**413**	**148**
	From fish and other food	15	21	34	59	89	129	154	69
	From fish	1	3	10	23	47	78	104	35
	From other food	8	10	15	26	47	68	83	34
	From dietary supplements	0	0	0	16	104	251	294	79

* "Total intake" means the sum of the contributions from food and dietary supplements. "From fish and other food" means intake from all kind of food except of dietary supplements. "From fish" means intake from fish alone. "Other food" means intake from all other food except of fish and dietary supplements. "From dietary supplemens" means intake from supplements alone.

Table 2, Appendix E

The Vitamin D intake of children and adults in µg/person/day. Intake estimates are based on Norkost 1997, Ungkost 2000 and Småbarnskost 1999. Note that the percentiles cannot be totalled because the samples in each category (food source) are not identical.

Vitamin D intake, (mg/person/day)									
Age	**Source***	**5-percentile**	**10-percentile**	**25-percentile**	**50-percentile**	**75-percentile**	**90-percentile**	**95-percentile**	**Average**
1 year-olds	**Total intake**	**1,2**	**1,9**	**4,4**	**8,6**	**13,1**	**17,0**	**20,8**	**9,4**
	From fish and other food	0,6	0,9	1,6	2,8	5,0	7,8	9,5	3,7
	From fish	0,0	0,0	0,0	0,1	0,3	0,8	1,2	0,3
	From other food	0,6	0,8	1,4	2,4	4,8	7,5	9,2	3,4
	From dietary supplements	0,0	0,0	0,0	5,0	10,0	10,8	15,1	5,7
2 year-olds	**Total intake**	**1,7**	**2,2**	**4,3**	**9,1**	**14,0**	**19,4**	**24,4**	**10,2**
	From fish and other food	1,0	1,3	1,7	2,4	3,3	4,3	5,0	2,6
	From fish	0,0	0,0	0,1	0,3	0,7	1,4	1,9	0,5
	From other food	0,8	1,1	1,4	1,9	2,6	3,3	3,9	2,1
	From dietary supplements	0,0	0,0	2,0	6,5	10,8	15,8	21,6	7,5
4 year-olds	**Total intake**	**1,1**	**1,5**	**2,5**	**5,7**	**9,8**	**15,0**	**17,3**	**6,9**
	From fish and other food	0,9	1,1	1,5	2,1	2,9	4,2	6,3	2,6
	From fish	0,0	0,0	0,0	0,1	0,4	1,3	3,2	0,6
	From other food	0,8	1,0	1,3	1,8	2,5	3,2	3,7	2,0
	From dietary supplements	0,0	0,0	0,0	2,8	7,5	11,3	15,0	4,4
9 year-olds	**Total intake**	**0,7**	**1,1**	**2,0**	**4,1**	**7,9**	**12,9**	**15,8**	**5,7**
	From fish and other food	0,6	0,9	1,5	2,3	3,4	4,8	6,9	2,8
	From fish	0,0	0,0	0,0	0,0	0,4	1,4	3,2	0,6
	From other food	0,5	0,8	1,2	2,0	2,9	3,7	4,6	2,2
	From dietary supplements	0,0	0,0	0,0	0,0	5,0	10,0	11,3	2,9
13 year-olds	**Total intake**	**0,5**	**0,7**	**1,3**	**2,6**	**5,1**	**9,2**	**13,0**	**4,2**
	From fish and other food	0,4	0,6	1,1	1,9	3,2	4,9	6,6	2,5
	From fish	0,0	0,0	0,0	0,0	0,3	1,4	3,6	0,6
	From other food	0,4	0,5	1,0	1,6	2,5	3,6	4,4	1,9
	From dietary supplements	0,0	0,0	0,0	0,0	1,3	5,0	9,4	1,6
Adults	**Total intake**	**1,5**	**2,2**	**4,0**	**8,2**	**14,3**	**24,6**	**31,0**	**11,1**
	From fish and other food	1,1	1,6	2,6	4,4	6,7	9,6	11,6	5,2
	From fish	0,1	0,2	0,8	1,8	3,5	5,8	7,8	2,6
	From other food	0,6	0,7	1,1	2,0	3,5	5,1	6,3	2,6
	From dietary supplements	0,0	0,0	0,0	1,2	7,8	18,9	22,0	5,9

* "Total intake" means the sum of the contributions from food and dietary supplements. "From fish and other food" means intake from all kind of food except of dietary supplements. "From fish" means intake from fish alone. "Other food" means intake from all other food except of fish and dietary supplements. "From dietary supplemens" means intake from supplements alone.

Table 3, Appendix E

Intake of omega-3 calculated from the Fish and Game Study, part A

		5-percentile	**10-percentile**	**25-percentile**	**50-percentile**	**75-percentile**	**90-percentile**	**95-percentile**	**Average**
1 year-olds	Total	0,0	0,1	0,1	0,3	0,9	1,3	1,5	0,5
	Fish	0,0	0,0	0,0	0,0	0,1	0,3	0,6	0,1
	Supplement	0,0	0,0	0,0	0,0	0,6	1,0	1,2	0,3
2 year-olds	Total	0,1	0,1	0,1	0,5	1,1	1,6	1,9	0,7
	Fish	0,0	0,0	0,0	0,1	0,3	0,6	0,7	0,2
	Supplement	0,0	0,0	0,0	0,0	1,0	1,4	1,4	0,4
4 year-olds	Total	0,0	0,1	0,1	0,3	0,8	1,2	1,4	0,5
	Fish	0,0	0,0	0,0	0,0	0,2	0,5	0,7	0,2
	Supplement	0,0	0,0	0,0	0,0	0,5	1,0	1,0	0,3
9 year-olds	Total	0,0	0,1	0,1	0,2	0,7	1,1	1,4	0,4
	Fish	0,0	0,0	0,0	0,1	0,2	0,5	0,8	0,2
	Supplement	0,0	0,0	0,0	0,0	0,2	0,7	1,0	0,2
13 year-olds	Total	0,0	0,1	0,1	0,2	0,5	1,1	1,3	0,4
	Fish	0,0	0,0	0,0	0,1	0,2	0,6	0,9	0,2
	Supplement	0,0	0,0	0,0	0,0	0,0	0,5	0,7	0,1
Adults	Total	0,1	0,2	0,3	0,6	1,2	2,2	2,7	0,9
	Fish	0,0	0,1	0,1	0,3	0,6	1,0	1,3	0,5
	Supplement	0,0	0,0	0,0	0,0	0,3	1,1	2,0	0,3

Table 4, Appendix E

Vitamin D intake in adults from fish and other seafood, estimated on the basis of the Fish and Game Study, Part A.

	5th percentile	10th percentile	20th percentile	50th percentile	90th percentile	95th percentile
µg/person/day	0.7	1.1	1.7	3.1	6.7	8.4
% of recommended intake	10	15	22	41	90	112

Table 5, Appendix E

Intake of omega-3 calculated from the Fish and Game Study, part A

	5th percentile	10th percentile	20th percentile	50th percentile	90th percentile	95th percentile
g/person/day	0.1	0.2	0.3	0.5	1.2	1.5

References Appenices

Allen, N.E., Sauvaget, C., Roddam, A.W., Appleby, P., Nagano, J., Suzuki, G., Key, T.J., & Koyama, K. A., (2004). Prospective study of diet and prostate cancer in Japanese men. Cancer Causes Control. 15, 911-920.

Augustsson, K.M., Michaud, D.S., Rimm, E.B., Leitzmann, M.F., Stampfer, M.J., Willett, W.C. & Giovannucci, E. (2003). A prospective study of intake of fish and marine fatty acids and prostate cancer. Cancer Epidemiol Biomark Prev. 12, 64-7.

Bostick, R.M., Potter, J.D., Kushi, L.H., Sellers, T.A., Steinmetz, K.A., McKenzie, D.R., Gapstur, S.M. & Folsom, A.R. (1994). Sugar, meat and fat intake, and non-dietary risk factors for colon cancer incidence in Iowa women (United States). Cancer Causes Control. 5, 38-52.

English, D.R., MacInnis, R.J., Hodge, A.M., Hopper, J.L., Haydon, A.M. & Giles, G. (2004). Read meat, chicken, and fish consumption and risk of colorectal cancer. Cancer Epi Biomarker Prev. 13, 1509-14.

Folsom, A.R. & Demissie, Z. (2004). Fish intake, marine omega-3 fatty acids, and mortality in a cohort of postmenopausal women. Am.J.Epidemiol. 160, 1005-1010.

Frazier, A.L., Li, L., Cho, E., Willett, W.C. & Colditz, G.A. (2004). Adolescent diet and risk of breast cancer. Cancer Causes Control. 15, 73-82.

Frazier, A.L., Ryan, C.T., Rockett, H., Willett, W.C. & Colditz, G.A. (2003). Adolescent diet and risk of breast cancer. Breast Cancer Res. 5, R59-R64.

Gertig, D.M., Hankinson, S.E., Hough, H., Spiegelman, D., Colditz, G.A., Willett, W.C., Kelsey, K.T. & Hunter, D.J. (1999). *N*-acetyl transferase 2 genotypes, meat intake and breast cancer risk. Int J Cancer. 80, 13-7.

Holmes, M.D., Colditz, G.A., Hunter, D.J., Hankinson, S.E., Rosner, B., Speizer, F.E. & Willett, W.C. (2003). Meat, fish and egg intake and risk of breast cancer. Int J Cancer. 104, 221-7.

Giovannucci, E., Rimm, E.B., Stampfer, M.J., Colditz, G.A., Ascherio, A. & Willett, W.C. (1994). Intake of fat, meat and fiber in relation to risk of colon cancer in men. Cancer Res. 54, 2390-7.

Goldbohm, R.A., van den Brandt, P.A., van't Veer. P., Brants, H.A., Dorant, E., Sturmans, F. & Hermus, R.J. (1994). A prospective cohort study on the relation between meat consumption and risk of colon cancer. Cancer Res. 54, 718-23.

Gaard, M., Tretli, S. & Løken, E.B. (1996). Dietary factors and risk of colon cancer: A prospective study of 50,535 young Norwegian men and women. Eur J Cancer Prev. 5, 445-54.

Hirayama, T. (1979). Epidemiology of prostate cancer with special reference to the role of diet. Natl Cancer Inst Monogr. 53, 149-55.

Hsing, A.W., McLaughlin, J.K., Chow, W-H., Schuman, L.M., Co Chien, H.T., Gridley, G., Bjelke, E., Wacholder, S. & Blot, W.J. (1998). Risk factors for colorectal cancer in a prospective study among U.S. white men. Int J Cancer. 77, 549-553.

Hsing, A.W., McLaughlin, J.K., Schuman, L.M., Bjelke, E., Gridley, G., Wacholder, S., Chien, H.T. & Blot, W.J. (1990). Diet, tobacco use and fatal prostate cancer: Results from the Lutheran Brotherhood cohort study. Cancer Res. 50, 6836-40.

Kato, I., Akhmedkhanov, A., Koenig, K., Toniolo, P.G., Shore, R.E. & Riboli, E. (1997). Prospective study of diet and female colorectal cancer: the New York University Women's Health Study. Nutr Cancer. 28, 276-81.

Knekt, P., Järvinen, R., Dich, J., Hakulinen, T. (1999). Risk of colorectal and other gastro-intestinal cancers after exposure to nitrate, nitrite and *N*-nitroso compounds: a follow-up study. Int J Cancer. 80, 852-856.

Larsson, S.C., Rafter, J., Holmberg, L., Bergkvist, L. & Wolk, A. (2005). Red meat consumption and risk of cancers of the proximale colon, distal colon and rectum: The Swedish Mammography Cohort. Int J Cancer. 113, 829-834.

Le Marchand, L., Kolonel, L.N., Wilkens, L.R., Myers, B.C. & Hirohata, T. (1994). Animal fat consumption and prostate cancer: a prospective study in Hawaii. Epidemiology. 5, 276-82.

Lund, E., Engeset, D., Alsaker, E., Skeie, G., Hjartåker, A., Lundebye, A.K. & Niebor, E. (2004). Cancer risk and salmon intake. Science. 305, 477.

Ma, J., Giovannucci, E., Pollak, M., Chan, J.M., Gaziano, J.M., Willett, W. & Stampfer, M.J. (2001). Milk intake, circulating levels of insulin-like growth factor-I, and risk of colorectal cancer in men. J Natl Cancer Inst. 93, 1330-6.

Mills, P.K., Beeson, W.L., Phillips, R.L & Fraser, G.E. (1989a). Dietary habits and breast cancer incidence among Seventh-day Adventists. Cancer. 64, 582-90.

Mills, P.K., Beeson, L., Phillips, R.L. & Fraser, G.E. (1989b). Cohort study of diet, lifestyle and prostate cancer in Adventist men. Cancer. 64, 598-604.

Norat, T., Bingham, S., Ferrari, P., Slimani, N., Jenab, M., Mazuir, M., Overvad, K., Olsen, A., Tjonneland, A., Clavel, F., Boutron-Ruault, M.C., Kesse ,E., Boeing, H., Bergmann, M.M., Nieters, A., Linseisen, J., Trichopoulou, A., Trichopoulos, D., Tountas, Y., Berrino, F., Palli, D., Panico, S., Tumino, R., Pietinen, P., Malila, N., Virtanen, M., Hartman, T.J., Tangrea, J.A., Albanes, D., & Virtamo, J. (1999). Diet and risk of colorectal cancer in a cohort of Finnish men. Cancer Causes Control. 10, 387-96.

Schuurman, A.G., van den Brandt, P.A., Dorant, E. & Goldbohm, R.A. (1999). Animal products, calcium and protein and prostate cancer risk in the Netherlands Cohort Study. Br J Cancer. 80, 1107-13.

Severson, R.K., Nomura, A.M.Y., Grove, J.S. & Stemmermann, G.N. (1989). A prospective study of demographics, diet, and prostate cancer among men of Japanese ancestry in Hawaii. Cancer Res. 49, 1857-60.

Stampfer, M.J., Willett, W.C., Colditz, G.A., Speizer, F.E. (1987). Intake of cholesterol, fish and specific types of fat in relation to risk of breast cancer. In: Lands WEM, ed.: Proceedings of the AOCS short course on polyunsaturated fatty acids and eicosanoids. AOCS Champaign, Illinois.

Stripp, C., Overvad, K., Christensen, J., Thomsen, B.L., Olsen, A., Møller, S. & Tjønneland, A. (2003). Fish intake is positively associated with breast cancer incidence rate. J Nutrition. 11, 3664-69.

Terry, P., Lichtenstein, P., Feychting, M., Ahlbom, A. & Wolk, A. (2001). Fatty fish consumption and risk of prostate cancer. Lancet. 357, 1764-6.

Tiemersma, E.W., Kampman, E., Bueno de Mesquita, H.B., Bunschoten, A., van Schothorst, E.M., Kok, F.J. & Kromhout, D. (2002). Meat consumption, cigarette smoking, and genetic susceptibility in the etiology of colorectal cancer: results from a Dutch prospective study. Cancer Causes Control. 13, 383-393.

Toniolo, P., Riboli, E., Shore, R.E. & Pasternack, B.S. (1994). Consumption of meat, animal products, protein and fat and risk of breast cancer: a prospective cohort study in New York. Epidemiology. 5, 391-7.

Vatten, L.J., Solvoll, K. & Løken, E.B. (1990). Frequency of meat and fish intake and risk of breast cancer in a prospective study of 14 500 Norwegian women. Int J Cancer. 46, 12-5.

Veierød, M.B., Laake, P. & Thelle, D.S. (1997). Dietary fat intake and risk of prostate cancer: a prospective study of 25,708 Norwegian men. Int J Cancer. 73, 634-8.

Vineis, P., Bueno-de-Mesquita, H.B., Peeters, P.H., Engeset, D., Lund, E., Skeie, G., Ardanaz, E., Gonzalez, C., Navarro, C., Quiros, J.R., Sanchez, M.J., Berglund, G., Mattisson, I., Hallmans, G., Palmqvist, R., Day, N.E., Khaw, K.T., Key, T.J., San Joaquin, M., Hemon, B., Saracci, R., Kaaks, R. & Riboli, E, (2005). Meat, fish, and colorectal cancer risk: the European Prospective Investigation into cancer and nutrition. J Natl.Cancer Inst. 97, 906-916.

Willett, W.C., Stampfer, M.J., Colditz, G.A., Rosner, B.A., Speizer, F.E. (1990). Relation of meat, fat, and fiber intake to the risk of colon cancer in a prospective study among women. New Engl J Med. 323, 1664-72.