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Risk and Benefit Assessment of Herring and Salmonid Fish from the Baltic Sea Area

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Content

Short summary

This report is an English translation of a report published in Swedish 2011. The aim of this risk and benefit assessment of consumption of fish contaminated with dioxins and dioxinlike (dl-) PCBs is to determine the public health consequences of 2 different options: a continuation of the Swedish exemption from maximum limits of the contaminants for certain fish from the Baltic Sea area, or a cessation of the exemption. The assessment is focused on the two most important risk groups for negative health effects of dioxins and PCBs, children and women in childbearing age. Children are at risk because they are most likely more sensitive to these compounds than are adults. Women in childbearing age is a risk group because high levels of the contaminants in the body during pregnancy may be a health risk for the developing fetus. There are however also possible health benefits with consumption of contaminated fish. The development of the fetus and infant may benefit from the mother´s intake of long-chain fatty acids EPA+DHA and vitamin D from the fish. Moreover, sufficient intake of these nutrients from fish is most likely important for normal development during childhood.

This risk and benefit assessment mainly deals with consumption of BS herring, which is the "exemption fish" that is most readily available on the food market in Sweden. Consumption of wild salmonids with high dioxin and dl-PCB levels is very low in Sweden, since these types of fish only are available locally in the few areas where the fish are landed by fishermen.

The consumption of BS herring appears not to have changed among adults during the last decade, and average consumption is in general low. There is however a proportion of the Swedish population that could be regarded as high consumers of BS herring. In the the population-based National Environmental Health Survey (MHE 2007) about 6 % of the women in childbearing age reported that they consumed BS herring twice a month or more. When scaled to the total Swedish population, this represents about 100,000 women in the ages of 18-45 with high consumption in 2007. This rate of consumption is strongly related to a dioxin and dl-PCB intake above the health-based tolerable weekly intake (TWI). Among children in the population-based MHE survey from 2003 4-5 % of the children consumed BS herring once a month or more, corresponding to about 45,000 children in Sweden in the year 2003 having a consumption that is strongly associated with an intake above the TWI.

Scenario calculations of dioxin and dl-PCB intake from BS herring were performed using consumption data from the nation-wide food consumption surveys Riksmaten. The calculations suggested that a continued exemption from the maximum limits for BS herring can, in the worst case, result in thousands of more children and young women exceeding the TWI than would be the case if Sweden had no exemption. With an exemption in place, BS herring with very high levels of dioxins and dl PCBs from the northern part of the Baltic Sea (Gulf of Bothnia) will be available for sale on the market. In this type of BS herring the weighted mean level of dioxins and dl-PCBs was estimated to 9 pg TEQ_{2005}/g

fresh weight, based on the catch statistics of commercially available BS herring and TEQ levels in BS herring from the contaminated areas in question. With no exemption this type of fish would not be for sale and the weighted mean level of dioxin and dl-PCBs in BS herring on the market would drop to about 3 pg TEQ/g fresh weight also in contaminated areas. In the case of wild salmonid fish from the Baltic Sea, and lakes Vänern and Vättern, intake calculations show that for women in childbearing ages TWI is exceeded already at an average consumption of a few portions a month. Among young children the TWI is exceeded already at a regular consumption of less than once a month. A cessation of the exemption would not lead to any limitations of the beneficial intake of nutrients, since BS herring and salmon not complying with the maximum limits would be replaced by BS herring and salmon complying with the limits.

In conclusion, a cessation of the exemption from maximum limits would be more beneficial from a public health point-of view than a continued exemption. In the case of no exemption there would be a decreased exposure of the population to dioxins and dl-PCB without any limitation of the intake of beneficial nutrients.

Executive summary

Background

This report is an English translation of a report published in Swedish 2011. The health risk and benefit assessment of fish with high dioxin and PCB levels was conducted as a scientific input to the negotiations on dioxin/PCB regulation for food within EU during 2011. At that time Sweden had a temporary exemption from the maximum limits of dioxins and dioxin-like (dl-) PCBs in certain fish from the Baltic Sea and Lakes Vänern and Vättern.

The aim of the assessment is to determine the health consequences of 2 different negotiations options; a continuation of the exemption from maximum limits for certain fish from the Baltic Sea area, or a cessation of the exemption.

Fish is a large source of the Swedish population's exposure to dioxins and dl-PCBs, even though fish consumption is low in relation to consumption of staple foods such as dairy products, meat and meat products. Fish is also an important source of nutrients such as vitamin D and essential long-chain n-3-fatty acids (omega-3), especially eicosapentaeonic acid (EPA) and docosahexanoic acid (DHA).

The focus of this risk and benefit assessment is the two risk groups for negative health effects of dioxins and PCBs: children and women in childbearing age. Children are at risk because they are most likely more sensitive to these compounds than are adults. Women in childbearing years are a risk group because the developing fetus is sensitive to environmental pollutants. Dioxins and dl-PCBs are very persistent in the human body and the body burden of the compounds during pregnancy, which determines the exposure of the developing fetus, is a result of a long-term exposure before pregnancy. The development of the fetus also benefits from sufficient intake of EPA+DHA and vitamin D by the pregnant and nursing mother, and sufficient intake of these nutrients is also important for normal development during childhood.

Herring from the Baltic Sea is the "exemption fish" which is readily available in food stores. Wild-caught salmonid fish from the Baltic Sea (trout and salmon), Lake Vänern (trout and salmon) and Lake Vättern (trout, salmon and char), which up to the end of 2011 also were exempted from the maximum limits, are most likely mostly sold locally in the areas where they are caught. Knowledge about the consumption of Baltic Sea (BS) herring among Swedish consumers derives mainly from population-based food consumption surveys, and the quality of data is relatively good. BS herring is a food product that the consumer fairly easily can distinguish from other herring products manufactured from herring caught in the Atlantic Ocean which has lower levels of dioxins and PCBs. The consumers have however a difficulty to distinguish between farmed salmon, which dominate the

Swedish market, and wild-caught salmon and trout. This makes the data on consumption of wild-caught salmonids unreliable. Based on statistics for commercial fishing from the Swedish Board of Fisheries, the consumption of commercial BS herring is substantially higher than the consumption of commercially caught wild salmonid fish. For these reasons this risk-benefit assessment focuses on BS herring.

The present report consists of the following main sections:
-An update of the knowledge about fish consumption in Sweden, with special emphasis on BS herring.
-An update of the intakes of dioxins and dl-PCBs, vitamin D and EPA/DHA from food in Sweden.
-A characterization of the health risks and benefits of consumption of BS herring among Swedish consumers

Dioxins, dl-PCBs, EPA+DHA and vitamin D

Dioxins and dl-PCBs are organic chlorinated substances which are lipid-soluble and persistent in the environment. Food is the most important source of human exposure to the compounds in Sweden. Animal studies and studies of human populations exposed to high levels in accidents or occupational settings have shown that the compounds can cause cancer and negative effects on the immune system and reproduction. The fetal stage is the most sensitive period and high exposures early in life may negatively affect child health development later in life.

Fish is a large source of the population's exposure to dioxins and dl-PCBs, since the levels of environmental contaminants in fish are much higher than in other kinds of foods. Fish is also an important source of nutrients such as vitamin D and essential long-chain n-3-fatty acids (omega-3), especially eicosapentaeonic acid (EPA) and docosahexanoic acid (DHA).

Fish consumtion in Sweden

Data on fish consumption have mainly been taken from the population-based food consumption surveys performed by the Swedish National Food Agency (SNFA), Riksmaten 1997-98 (adults, N=1212)) and Riksmaten 2003 (children (N=2463), and partly from the survey Riksmaten 2010 (adults, N=672). Data are based on the answers of the survey participants to questions about fish consumption, where the participants tell how frequently they consume fish.

A similar survey question regarding the consumption of BS herring, as in the Riksmaten studies, was posed in the population-based survey Miljöhälso-enkäten (MHE) 2003 (children) and MHE 2007 (adults). Results regarding the consump-tion of Baltic herring in the MHE surveys are in concordance with the results from the Riksmaten studies mentioned above, which suggest that consumers have a relatively clear idea of how to correctly separate consumption of

BS herring from Atlantic herring consumption. The MHE studies cover the entire Swedish popu-lation with 15,000 children (2003) and 25,000 adults (2007) participating. These studies were conducted by the Swedish National Board of Health and Wellfare and the Institute of Environmental Medicine (IMM) at Karolinska Institutet, Stockholm.

Fish consumption in general

SNFA recommends consumers to eat fish 2-3 times a week and to choose different kinds of fish. In the SNFA surveys Riksmaten 1997-98 and Riksmaten 2010 about 30 % of the adult consumers followed the recommendations. In the MHE from 2007 the proportion of adults which followed the recommendations was about 20 %. The differences between the Riksmaten surveys and MHE probably, at least partially, depends the fact the questions about fish consumption was posed differently between the studies. For example, shellfish were included in the questions about fish consumption in the Riksmaten studies but not in the MHE. The Riksmaten studies do not suggest that the total fish consumption has decreased between the end of 1990's and 2010 among adults in Sweden.

The SNFA study of fish consumption among over 400 young pregnant and nursing women in the Uppsala region between 1996 and 2008 (POPUP study) suggests that fish consumption has slowly increased in this group of women. If this increase is representative for the rest of the population of young women in Sweden is unclear. A large proportion of the increase among the young women in the Uppsala region depends on the increased consumption of farmed salmon. An increase of the salmon consumption among adult women in general is also indicated in the Riksmaten 1997-98 and 2010 studies. The average consumption in the Riksmaten 1997-1998 was about 1 g/day among women as well as men, whereas the average consumption among women was 10 g/day and among men 4 g/day in Riksmaten 2010. There has been a concern that the fish consumption has decreased in Sweden because of consumer´s worries about the presence of environmental contaminants in fish. The data from the Riksmaten studies and the POPUP study indicates that the fish consumption has not decreased since the middle of the 1990's. It seems that salmon consumption has dramatically increased.

There is no recent data on fish consumption by children in Sweden. The most recent Riksmaten study of children was conducted in 2003. The same year the MHE 2003 was finalized with a focus on children. In the Riksmaten 2003 fish and shellfish were on average consumed 1-2 times per week, and 4 yr old children consumed fish more often than children in school grade 2 (8 yr) and grade 5 (12 yr). Among the school children, 8 year old children consumed more fish than 12 year old children. This is in accordance with the results in the MHE 2003 study, where 28 % of 4 year old children consumed fish twice a week or more, whereas 21 % of children 12 years of age consumed fish that often.

Consumption of Baltic Sea herring

The Riksmaten studies indicate that consumption of Baltic Sea (BS) herring among adults has not significantly changed between 1997-98 and 2010. Similar results have been observed in the POPUP study during the period 1996-2008. Consumption is generally low. Among adult consumers the consumption is on average 1 g/day, which corresponds to about 3 portions per year. In Riksmaten 1997-98 over 90 % of women between the ages of 17 and 45 reported that they consumed BS herring at most 6 times per year. Among the participating children in Riksmaten 2003 more than 50 % was reported not to consume BS herring at all.

There is however a proportion of the population that could be regarded as high consumers of BS herring. In the MHE 2007 study about 6 % of the women in childbearing age reported that they consumed herring twice a month or more. When scaled to the total Swedish population, this represents about 100,000 women between the ages of 18-45 during 2007. Approximately 2 % of the women consumed BS herring once a week or more, which corresponds to 35,000 women in the Swedish population. Among children in the MHE 2003 study 4-5 % of the children consumed herring once per month or more. Based on the population size in Sweden 2003, this proportion corresponds to about 4,000 4 year-olds and 6,600 12 year-olds. Assuming that there were on average 5,000 children who consumed herring once a month or more in each age group between the ages of 4 and 12 then we estimate that 45,000 children consumed herring once a month or more in the year 2003.

Consumption of fermeted BS herring

Fermented BS herring consumption is very low among consumers in Sweden. This traditional food is usually only eaten on special occasions. In 2010 the SNFA did a survey of fermented BS herring consumption in Sweden. Among families with small children (N=1000), which include the risk groups of children and women in their childbearing years, 84 % reported that they never consumed fermented BS herring, 6 % that they only consumed it once a year, and 9 % that they consumed fermented BS herring a few times per year. Among the general public (N=2000) only 5 % said that they consumed fermented BS herring more than 2 times per year. The highest consumption was found among professional fishermen (N=200) where 13 % said that they consumed fermented herring five times per year or more.

Consumption of fish caught by anglers

The consumption of fish that anglers catch has scarcely been studied in Sweden. In the ongoing Riksmaten 2010, however, the question of consumption of BS herring and wild salmon caught by the study participants themselves, a relative or an acquaintance, was addressed. The preliminary results indicate that consumption of these fish is low in relation to the consumption of commercially caught BS herring and farmed salmon. For instance, 92 % of the participating adults reported that they never or at most 1-3 times each year consumed angler-caught salmon.

The corresponding percentage for the same frequency of salmon consumption in general (mostly farmed) was 15 %. Among professional fishermen (N=500), participating in the SNFA fish consumption survey in 2010, the consumption of herring and salmon from their own catch was reported to be high. About 60 % of the professional fishermen reported that they consumed BS herring or salmon once a week or more.

Per capita consumption of fish

The per capita consumption of fish gives a measure of the average consumption of fish that are sold on the Swedish market. Estimates for BS herring and wild-caught salmonids from the Baltic Sea, and the lakes Vänern and Vättern, are based on the Swedish National Fisheries Board statistics on commercial fishing volumes during the period 2007-2009, as well as on the population size of Swedish residents who were one year of age or older in 2009. The statistics is for whole fish and do not account for amounts actually consumed. The fact that some herring caught in the southern Baltic are exported to other countries is either not accounted for. In this context it is also important to remember that the consumption of fish varies greatly within the population; many persons never or very seldom eat fish while a small number of persons consume the largest proportion of all fish on the Swedish market.

The per-capita consumption of BS herring is currently about 2.06 kg/year. The per capita consumption of BS herring on the Swedish market with dioxin and dl-PCB levels below the EU maximum level in fish is estimated to be approximately 1.90 kg/ year. This fish consists of BS herring caught in the southern Baltic Sea proper and BS herring with a length of 17 cm or shorter caught in other areas of the Baltic Sea. Only 10 % of the per capita consumption consists of BS herring from the Baltic Sea which may have dioxin and dl-PCB levels above the maxi-mum limit. The per capita consumption of the wild-caught salmon and trout from the Baltic Sea and the lakes Vänern and Vättern, as well as char from Lake Vättern, is estimated to be about 30 g/year. This is to be compared with the per capita consumption of farmed Norwegian salmon, which was in 2007 estimated to be 3.5 kg/ year. A certain percentage of "re-exported" Norwegian salmon occurs from Sweden which means that the per capita consumption of farmed salmon is somewhat over-estimated.

Exposure assessment

Consumer exposure to dioxin and dioxin-like PCBs

The Swedish National Food Administration's intake estimates, based upon Riksmaten 1997-98 and on Riksmaten 2010 (adults), as well as on Riksmaten 2003 (children), indicate that the average intake of dioxins and dioxin-like PCBs among consumers in Sweden has dropped since the end of the 1990's. Among adults the average intake of dioxins and dl-PCBs in the end of the 1990s was estimated to 1 pg/kg body weight/day, and around 2010 it was estimated to 0.5

pg/kg body weight/day. Among 4 year old children corresponding average intakes were 2.4 and 0.94 pg/kg body weight/day. This conclusion about decreasing intakes is however preliminary since the recruitment of study participants in Riksmaten 2010 (adults) had not been terminated when the intake estimation was made and the estimates for children were only based on food consumption data from 2003 (Riksmaten 2003). An actual decrease in the intake is however supported by the results from the Swedish National Food Administration's market-basket studies of per capita intake of dioxins and dl-PCBs from 1999 and 2005.

The lower intake can in part be explained by decreasing levels of dioxins in food on the Swedish market. Improvements in the analytical methods for measuring dioxin and dl- PCBs in food could also have contributed to the observed decrease in intake; better analysis methods lead to fewer samples falling below the limit of quantification (LOQ) of the analytical method. In the intake calculations, levels that were below the LOQ were set to one half of the LOQ. As a consequence, the use of analytical methods with high LOQs often causes over-estimations of dioxin and dl-PCB levels. Moreover, in 2005 there was a revision of the WHO toxicity equivalent system (WHO-TEF), which is used when estimating dioxin and dl-PCBs levels in food. This revision resulted in a decrease in total levels of dioxin and dl-PCB toxicity equivalents (TEQ) with 10-20 % in food. A comparison between the estimated average TEQ intake for consumers in Sweden and the average intake in other European countries indicates that the intake in Sweden is at the same level or somewhat lower than the average adult intake in other highly-industrialized countries in Europe.

Levels of dioxins and dl-PCBs in breast milk give a good measure of long-term exposure to these substances from food among young women. Studies of temporal trends of dioxins and dl-PCBs in breast milk in Sweden show that the long-term exposure is slowly decreasing by about 6% per year. Breast milk from Sweden has somewhat lower average levels of the contaminants than breast milk from more population-dense countries such as the Netherlands, Belgium, the Czech Republic, Germany and Italy.

Intake of n-3 fatty acids and vitamin D in Sweden

The average intake of n-3 fatty acids (omega 3) was estimated to be 1.6–2 g per day among adults and 1.1–1.3 g per day among children 4-12 years old. The intake of EPA and DHA is on average 320-340 mg per day for adults and 140 – 160 per day for children. Fish and shellfish contribute with about 80 % of the intake of EPA+ DHA among adults and about 60 % among children. The intake of vitamin D for adults and children is on average between 5-7 µg per day. The main source for vitamin D is enriched milk products, dietary fats and oils and fish.

Hazard and positive health effect characterization

Tolerable intake of dioxin and dioxin-like PCBs

The EU and WHO tolerable weekly intake (TWI) of dioxins and dl-PCBs was used as a guideline for negative health effects of these substances in girls and women in childbearing years (TWI, 14 pg, TEQ/kg body weight/week). This TWI is based upon negative effects on male reproduction in offspring of female rats which were exposed for dioxins during gestation. The margin between the TWI and the levels where negative effects are measurable in experimental animals is relatively small (a factor of 10). The low margin makes it important for girls and young women not to exceed the TWI in the long-term perspective.

For boys, men and older women a range of TWI of 14 -70 pg TEQ/kg body weight/week was used. This TWI range has been proposed in a risk assessment of non-developmental exposure to dioxins and dl-PCBs made by experts from the SNFA and IMM at Karolinska Institutet. For men and older women a guideline TWI at the middle point of the range was used, at 35 pg TEQ/kg body weight/week. This gives a margin of 25x to the lowest exposure levels where negative health effects have been detected (cancer). The guideline level for boys was established to 14 pg/kg/week since boys seem to be more sensitive for dioxins and dl-PCBs than are adult men. This gives a safety margin of 50x.

Reference intake of the fatty acids EPA+DHA and vitamin D

Efsa, the European Agency for Food Security, has suggested a reference intake (adequate intake) for EPA+DHA of 250 mg/day for adults based upon the beneficial effects on heart disease. No reference levels have been established for younger children. A reference level for children was therefore estimated from Efsa's level for adults with adjustments made for the reference levels established for the energy intake according to the Nordic (NNR) and the Swedish dietary recommendations (SNR). For 4 and 8 year old children a reference value of 150 mg EPA+DHA was used, whereas for 12 year old children it was set to 250 mg/d.

For vitamin D the recommended intake according to the NNR/SNR was used, which is 7-5 µg per day for adults and children over two years of age.

Risk and benefit characterization

Consumption data and data on occurrence levels

For scenario intake calculations covering Swedish consumers, consumption data for adults from Riksmaten 1997 – 98 and 2010 were used, whereas consumption data for children were from Riksmaten 2003. Data on concentrations of dioxins and dl-PCBs in basic food stuffs, other than fish, were taken from the foods sampled between 2007 and 2010, while the concentrations in fish came from samples taken between 2000 and 2010. Concentration data for vitamin D and EPA + DHA were taken from the Swedish National Food Administration's food database.

Scenario intake estimates for consumption of BS herring

In the risk and benefit characterization of BS herring consumption it was assumed that availability of BS herring on the Swedish market for the consumer is independent of EU legal regulations, since most of the BS herring sold on the market currently have levels of dioxins and dl-PCBs below EU's maximum limits for the contaminants. The herring on the Swedish market, with levels above the maximum limits, would most certainly be replaced by herring with levels below the maximum limits, in the case of a decision that Sweden should not have an exemption from the maximum limits. As a consequence of this, the intake of vitamin D and EPA + DHA from BS herring was estimated to be the same in the different scenario estimations tested for BS herring.

Weighted means of dioxins and dl-PCB in BS herring from different catchment areas were based upon catch statistics and average dioxin and dl-PCBs levels in BS herring. Three scenarios were assumed: (1) Consumption of BS herring with average dioxin and dl-PCB levels (4.2 TEQ/g fresh weight) estimated for the whole Swedish market in case of an exemption from the maximum limits; (2) Consumption of BS herring with average levels detected in BS herring caught in the Gulf of Bothnia (9.4 pg TEQ/fresh weight) in case of an exemption; (3) Consumption of BS herring with average levels estimated for the whole Swedish market in the case of no exemption (2.8 pg TEQ/g fresh weight).

Adults

The counties along the coast of the Norrland region is the area of Sweden where the locally caught BS herring has the highest dioxin and dl-PCB levels (weighted average concentration: 9.4 pg TEQ/g fresh weight). In the scenario 2 estimations of the consumption of "Norrland's herring" there were 3 -5 times as many young women which were estimated to exceed the TWI than if consumption consisted only of BS herring with a mean level as estimated in scenario 3 (weighted mean level 2.8 pg TEQ/g fresh weight). The women exceeding the TWI in scenario 2 had an average BS herring consumption of 2-3 times per month. Counted in terms of number of women in the Norrland's region, an exemption may in the worst case result in between 4000 and 5000 more young women exceeding TWI than if the exemption would be removed, assuming consumption of locally caught herring. There are however uncertainties in this estimation since the Riksmaten has few participants with high herring consumption. The uncertainty in this estimation is illustrated by the estimation of BS herring consumption among young women based on MHE 2007. Between 3,000 and 30,000 (95 % confindence interval) young women in the Norrland region eat BS herring 2-3 times per month. Even though this uncertainty exists, the scenario estimations indicates that a continued exemption in the worst case may result in thousands more young women in the Norrland region exceeding TWI than if the exemption would be removed.

The scenario estimations for the rest of the adult population in Sweden as a whole indicate that about 1-2 % of women in their childbearing years exceed the TWI regardless if Sweden has an exemption for BS herring or not (scenarios 1 and 3). For men and older women there were none or a very small proportion which exceeded the TWI in the various scenarios.

In all three scenarios, based on consumption data from Riksmaten 2010, 70 % of the older women reached the reference intake for EPA + DHA of 250 mg/day. Among men and younger women about 55 and 44 % respectively reached the recommended intake of the fatty acids. Twenty-six percent of the men reached the recommended intake of vitamin D (7.5 µg/day). Among older women 15 % reached of the recommended intake and among younger women 6 %.

Children

The scenario intake estimations for children, based upon the Rikmaten 2003 survey, show that consumption of locally-caught herring from the Gulf of Bothnia (scenario 2) increase the proportion of 4 year-olds exceeding the TWI from 7% (scenario 3) to 9% (scenario 2). Among the 8 year-olds the proportion increased from 5 % (scenario 3) to 8 % (scenario 2), while for the 12 year-olds the proportion which exceeded the TWI was not affected. Based on the number of children living in the Norrland counties, these increases in the proportion of children exceeding the TWI, if there is an exemption, would amount to 200 4 year old children and 400 8 year old children. In Riksmaten 2003 the average BS herring consumption among children exceeding the TWI was of 1 portion per month.

The MHE 2003 study shows that between 200 and 900 (95 % confidence interval) 4 year old children in the region of Norrland had high enough consumption of BS herring (once a month or more) that they were faced with a large risk of exceeding the TWI if there was a continued exemption. Among 12 year old children in this region there were between 300 and 1,900 children who consumed herring once a month or more and thereby were faced with the risk of exceeding the TWI. All in all, these estimations indicate that in the worst case, there are several thousand more children between the ages of 4-12 years in the region of Norrland that would exceed the TWI if the exemption is permanently granted than if it is removed. For most of the children in the rest of Sweden, there would be no great difference in intake of dioxins and dl-PCBs if Sweden gets a permanent exemption or not.

Among 4 year old children 30 % reached the estimated reference intake for EPA + DHA in all 3 scenarios. About 30 % of the 8 year old children and 24 % of 12 year old children reached the reference levels for these fatty acids. With regard to vitamin D intake, 35 % of four-year-olds reached the recommended intake of 7.5 µg/day. Among older children in the age groups of 8 and 12 years there were 14 % and 11% respectively who reached the recommended intake.

Scenario intake estimates for consumption of wild salmonid fish
Similar scenario estimations are not possible to conduct for wild-caught salmonid fish from the Baltic Sea, or the lakes Vänern and Vättern, because there is no reliable consumption data for wild-caught salmon from these areas in the Riksmaten studies. The problem with the high levels of dioxins and dl-PCBs in these kinds of fish can however be illustrated by calculating how many portions that could be eaten by the consumers without exceeding the TWI. In these calculations the dioxin and dl-PCB intake from other foods was set at the median level estimated in Riksmaten 2010 (adults) and Riksmaten 2003 (children). These calculations show that it is enough with a few portions each month for a woman in childbearing years in order to exceed the TWI. Among young children the TWI is exceeded even if the consumption is less that once per month.

Conclusion of risk/benefit characterization
In conclusion, the scenario calculations of dioxin and dl-PCB intake from fish suggest that a continued exemption can, in the worst case, result in thousands of children and women in childbearing years facing the risk of exceeding the TWI. Since the availability of BS herring and farmed salmon with relatively low levels of dioxins and dl-PCB on the Swedish market is high, there is no increased health benefit related to consumption of store-bought BS herring and wild salmononid fish that have high levels of dioxins and dl-PCB.

Introduction

This risk-benefit assessment of fish with high dioxin and PCB levels was conducted as a scientific background to the negotiations about dioxin/PCB regulations of food in 2011. At the time of the assessment Sweden had an exemption from the EU maximum limit of dioxins and dioxin-like (dl-) PCBs for certain fish from the Baltic Sea, and for the lakes Vänern and Vättern. This temporary exemption was due to expire January 1, 2012.

The current report contains Appendices used as background information when completing the assessment. Appendix 1 was authored by Anders Glynn (National Food Agency, NFA) and Thomas Lind (Institute of Environmental Medicine, Karolinska Institutet, Stockholm), Appendix 2 by Magnus Lundgren, Niclas Johansson, Anders Glynn, Helene Enghardt Barbieri and Wulf Becker at the NFA, and Appendix 3 by Niclas Johansson and Anders Glynn at the NFA.

The risk and benefit assessment focuses on children and women in their childbearing years. Children are a risk group since they are most likely more sensitive to dioxins and dl-PCBs than are adults. Women in their childbearing years are risk group because the developing foetus is sensitive for these contaminants, and the body burden that pregnant women have is a result of a long-term exposure before pregnancy.

Besides being an important source of exposure to dioxins and dl-PCBs, fish is also an important source of vitamin D and the essential long-chained n-3-fatty acids (omega-3), eicosapentaenoic acid (EPA) och docosahexaenoic acid (DHA). Consumption of fish is therefore often beneficial for human health. In the present assessment the health risks of dioxin and dl-PCBs intake from fish is weighed against the health benefit of intake of vitamin D and EPA+DHA from fish.

Herring from the Baltic Sea and the Bothnian Bay, here called BS herring (in Swedish “strömming”), were included in the exemption from maximum limits. These fish are easily available for consumers in the food stores. BS herring is mostly sold as fillets (fresh or frozen), whereas most of the Atlantic herring is sold as pickled herring. It is therefore possible for the consumers to separate consumption of BS herring from Atlantic herring consumption in food consumption surveys. Wild-caught salmonid fish from the Baltic Sea (trout and salmon), Lake Vänern (salmon and trout) and Lake Vättern (trout, salmon and arctic char) were also exempted from the maximum limits of dioxins and dl-PCBs. These types of fish are most probably sold locally in the areas where they are caught. Consumers have a more difficult time to discern wild-caught salmonid fish from farmed salmon, mostly originating from Norway. The data for consumption of wild-caught salmonid fish is therefore of poorer quality than the data regarding BS herring. Based upon commercial fishing statistics from the Swedish Board of Fisheries, the consumption of commercially caught BS herring is considerably higher than is the consumption of commercially caught salmonid fish. Thus, consumption of BS herring is the focus of this risk and benefit assessment.

Fish consumption in Sweden

Introduction

The objective of this chapter is to describe the current knowledge on fish consumption in Sweden in general and consumption of BS herring and salmonid fish in particular. Consumption data for fish comes mainly from the food consumption surveys conducted by the Swedish National Food Administration (SNFA), called Riksmaten. In the Riksmaten 1997-98 (adults 17-74 years of age; N = 1215) and Riksmaten 2003 (children of ages 4, 8 and 12 years; N = 2495) study participants answered a questionnaire with questions about how often they consumed different types of fish during the most recent year (Becker och Pearson 2002; Enghardt Barbieri, Pearson et al. 2006). The participation rate in the Riksmaten 1997-98 was 60 % and in Riksmaten 2003 80-89 % (Becker and Pearson 2002; Enghardt Barbieri, Pearson et al. 2006). Currently Riksmaten 2010 (adults) is ongoing, and 676 participants had completed the survey and answered questions about their fish consumption in the end of October 2010. Fish consumption data also comes from two other SNFA studies. Between 1996 and 2010 women from the Uppsala area, close to the Swedish capital Stockholm (POPUP-study, N=325), who gave birth to their first child, have answered the same questions about fish consumption as those found in the Riksmaten studies (Lignell, Glynn et al. 2006). Moreover, during 2010 SNFA conducted a study of the current knowledge among the consumers in Sweden about the SNFA fish consumption advisories (Knowledge 2010). In that study questions about fish consumption were posed to the participants, including families with small children (N=1000) and professional fishermen (N=400).

Data on fish consumption in general, and BS herring consumption in particular, also come from the Environmental Health Survey (Miljöhälsoenkät (MHE)) 2003 (children of ages 4 and 12) and 2007 (adults, ages 18-80), conducted by the Swedish National Board of Health and Welfare and the Institute for Environmental Medicine, Karolinska institutet (IMM) (MHE 2005; MHE 2009). In these surveys there was a general question about how often the participants consumed fish and a specific question about their consumption of BS herring. The result from these two surveys are considered to be more representtative for the Swedish population than are the results from the Riksmaten studies, since the number of participants was much greater in the MHE 2003 (N=17769) and MHE 2007 (N=25851). Moreover the data from MHE were adjusted for biases in study participation regarding certain key variables. In MHE 2003 the participation rate was 70 % and in MHE 2007 59 %.

There is uncertainty built into data obtained from food frequency questionnaires, since different consumers can interpret a question in different ways. Questions about the consumption of BS herring can illustrate this problem. For example, some consumers might overestimate their consumption of this kind of fish by also including their consumption of Atlantic herring in their answers.

Other consumers might underestimate their consumption of BS herring if they only report consumption of BS herring from the Baltic Sea proper and fail to include consumption of BS herring caught in the Gulf of Bothnia.

The results from the questionnaires regarding the consumption of BS herring in the MHE surveys are however in concordance with the results from the Riksmaten studies (see below). This indicates that consumers have a relatively clear picture of how to distinguish between BS herring (mostly sold as fresh or frozen fillets in the stores) and Atlantic herring (mostly sold as pickled herring). In the SNFA surveys data on salmon consumption was regarded as representative for consumption of farmed salmon, which is what consumers find in the stores.

Table 1. *Total fish consumption (g/day) and the proportion (%) of consumers that consumed fish twice or more each week in the SNFA's studies*

Study	Study group (N)	Mean	SD	Median	95th perc	≥2-3/week
Riksmaten 1997-98	Women (618)	35	28	29	90	37
	Men (597)	34	33	26	99	34
Riksmaten 2010	Women (375)	34	38	27	76	41
	Men (297)	28	30	22	68	31
Riksmaten 2003	Children 4 yrs (584)	15	11	13	32	
	8 yrs (877)	21	22	17	57	
	12 yrs (1002)	23	28	18	70	
POPUP (1996-2006)	Women (325)	29	23	25	66	27

SD=standard deviation; perc= percentile

Total fish consumption

The total fish consumption among adults was at similar levels in the Riksmaten studies 1997-98 and 2010 (Table 1). The median consumption varied between 22 and 29 g/day, with a tendency of higher median consumption among women than among men. However, conclusions on possible sex differences in fish consumption in the Riksmaten 2010 study is not possible since the study was not completed when data were analysed. Results for children in the Rikmaten 2003 showed that the four-year-olds had a lower consumption measured in g/day than children in the eight-year-old or 12-year-old age groups (Anova $p<0.001$). There was no significant difference between girls or boys (t-test, $p=0.196$-0.844).

An increased fish consumption with age was observed in the Riksmaten 1997-98 study, the median consumption ranged from 17 g/day for both women and men of the ages 17-24 years to 26-29 g/day for women and men in the age group of 65-74 years (Becker and Pearson 2002). SNFA recommends that consumers should eat fish 2-3 times per week and that the consumers should choose to eat several different kinds of fish (Livsmedelsverket 2010). Among the adult con-sumers in the SNFA studies there were between 27 % and 41 % who followed this advice using a serving size of 125 g. The most relevant comparison between the current recommendations and the consumption among adults can be

made for the Riksmaten 2010 study. Preliminary results indicate that more women than men follow the recommendations (Table 1).

During 2008 an interview survey was conducted where 1000 randomly chosen adults between the ages of 16 and 80 were asked about their food habits during the most recent year (Becker 2009). The participation rate was 50 %. In this study about 30 % of the respondents reported that they ate fish/shellfish twice a week or more.

Table 2. *Fish consumption of the adult population in Sweden (18-80 year of age) during 2007, based on the MHE 2007 survey*

Fish consumption	**% (number)**	**95 % CI[a]**	
		Lower	**Upper**
Seldom/ never	7.2 (1500)	6.7	7.7
1 time/month	11 (2300)	9.9	11
2-3 times/month	23 (5700)	22	24
1 time/week	39 (10300)	38	40
2-3 times/week	19 (4900)	18	19
≥4 times/week	1.5 (350)	1.3	1.8

[a]Confidence interval

In the MHE 2007 study about 40 % of the participants reported that they consumed fish less than once per week whereas 39 % consumed fish about once per week (Table 2). Around 20 % of the respondents reported eating fish 2-3 times per week or more, which is lower lower than reported for Riksmaten 2010. The difference between the Riksmaten and the MHE surveys may depend on the fact that the questions on fish consumption were posed differently. For example, in the Riksmaten surveys shellfish was included in the questions, which was not the case in the MHE surveys.

Similarly as in the Riksmaten studies, fish consumption increased with increased age in the MHE surveys. Among women between the ages of 18-24, 15 % reported consumption of fish twice a week or more, whereas 31 % of the respondents between the ages of 65 and 80 reported this frequency of fish consumption. Similar results were reported for men.

An analysis of the proportion which followed the SNFA fish recommend-dations in different regions of Sweden revealed that the Stockholm County had the largest proportion of consumers that consumed fish 2 times per week or more (Fig. 1).

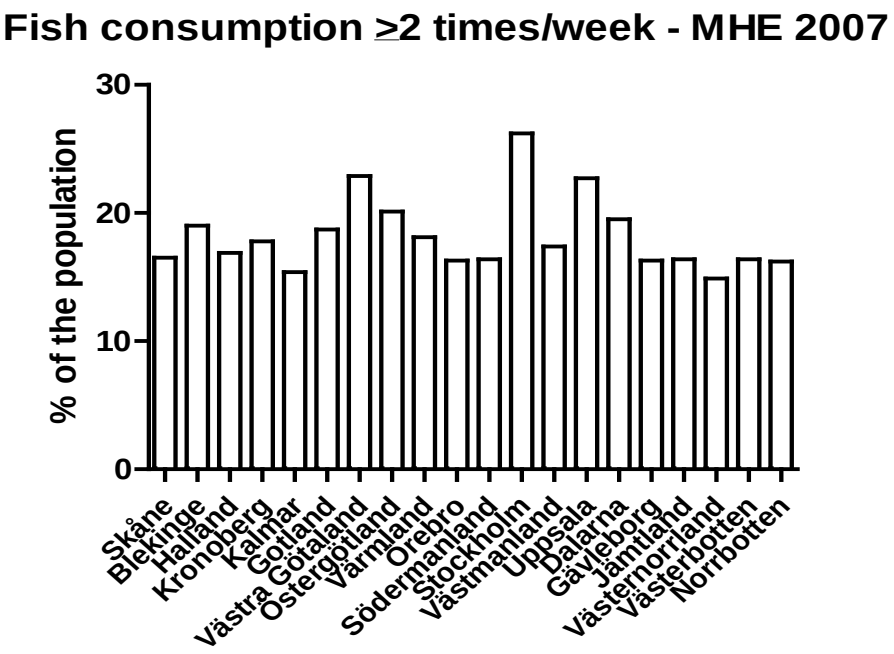

Figure 1. *The proportion of the population in different Swedish counties that followed SNFA's recommendations for fish consumption, based on data from the MHE 2007 study.*

In the POPUP study of primiparous women in Uppsala the median consumption of fish during the year the women got pregnant was at the same level as in the Riksmaten studies (Table 1). In the POPUP study temporal trends in fish consumption were also studied (Fig. 2). Regression analysis of the results shows a significant increase of consumption between 1996 and 2006 (Fig. 2). If this result is representative for pregnant women from other parts of the country is however not known.

There is a concern that the fish consumption slowly has decreased due to the frequent news about the presence of environmental contaminants in fish. Data from the Riksmaten studies and the POPUP studies indicate that fish consumption has not decreased since the middle of the 1990's. The POPUP study suggests an increased fish consumption among young women. With regard to salmon, the consumption has increased drastically (see the section "Salmon consumption" below).

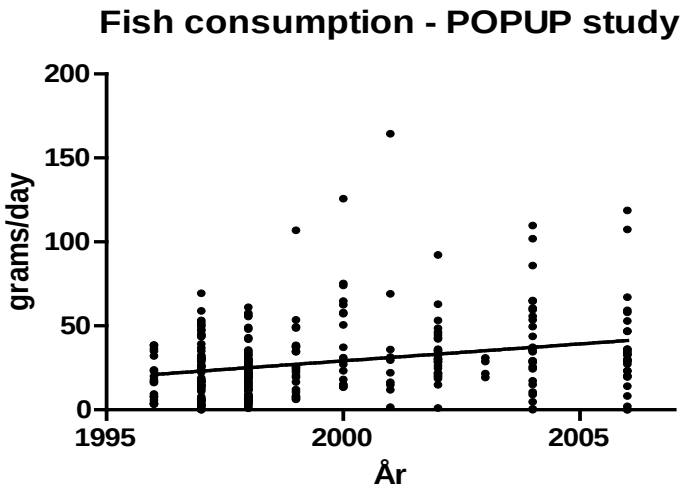

Figure 2. *Fish consumption among primaparous women in the POPUP study. The positive association between year and fish consumption is statistically significant and implies an increase in average fish consumption of 2 grams/ day each year (regression analysis, p<0.001, N=293).*

According to MHE 2003, 50 % of the children consumed fish once a week (Table 3). Twenty-eight percent of the four year old children ate fish twice or more each week, which is a larger proportion than that of younger women and men in the MHE 2007 study. However the proportion of children who ate fish twice or more often each week was lower among 12-year-olds (21 %), this was at that same level as for adult consumers in the MHE 2007 study (Tables 2 and 3).

Table 3. *Fish consumption frequencies among children of different ages during the year 2003 (MHE 2003, mean and 95 % confidence interval)*

Age (N)	Consumption (% of the population)					
	Never	**<1 /month**	**1-3/month**	**1/week**	**2/week**	**≥3/week**
4 (8264)	1.9 (1.5-2.5)	3.4 (2.9-4.1)	19 (18-21)	48 (46-50)	25 (23-27)	2.7 (2.2-3.3)
12 (9505)	3.3 (2.9-3.8)	6.3 (5.8-7.0)	24 (22-25)	46 (44-47)	20 (19-21)	1.5 (1.2-1.8)

Baltic Sea (BS) herring consumption

All of SNFA's investigations indicate that consumption of BS herring in general is low in Sweden (Table 4). The median consumption for adults is approximately 1 g/day which is about three servings per year (serving size 125 g). Over 50 % of the children in the Riksmaten 2003 study never ate herring (Table 4).

Table 4. *Consumption of herring (g/day) in the SNFA studies*

Study	Study group (N)	Mean	SD	Median	95th percentile
Riksmaten 1997-98	Women (618)	2.2	3.7	1.0	9.1
	Men (597)	2.6	4.9	1.0	9.1
Riksmaten 2010	Women (375)	1.8	3.4	0.7	10
	Men (297)	1.7	3.6	0.7	10
Riksmaten 2003	Children 4 yrs (584)	0.5	3.3	0	6.0
	8 yrs (877)	0.6	1.6	0	3.2
	12 yrs (1002)	0.2	0.5	0	1.1
POPUP (1996-2006)	Women (325)	1.1	2.3	0	4.9

SD=standard deviation

The Riksmaten 1997-98 study revealed that there was a strong positive association between BS herring consumption and the age of the participant (linear regression $p<0.001$). The mean consumption increased from 0.4 g/day for women of ages 17-24 years to 5.2 g/day for women 65 years or older. Among men the mean consumption increased from 1.3 g/day to 7.7 g/day.

Women in childbearing age (17-45 yrs) in the Riksmaten 1997-98 study had a lower BS herring consumption than older women (46-75 yrs) (Table 5). Seventy-nine percent of the younger women in the study ate herring at most three times per year, which is SNFA's current recommendation for herring consumption for women in childbearing age. At the time of the investigation (1997-98) SNFA's recommended that women in childbearing years should not to eat BS herring more than once a month. Seven percent of women in this group reported eating BS herring at this rate or more while one percent reported eating BS herring once per week. Since 1995 the SNFA has recommended that men and older women should not eat BS herring more than once per week. The majority of both men and older women in the Riksmaten 1997-98 study had a BS herring consumption which did not exceed this recommendation (Table 5).

Table 5. *BS herring consumption frequencies among men and women during the year 1997-98 as reported in Riksmaten 1997-98*

Age (N)	Consumption (% of participants)					
	Never	3/yr	6/yr	1-3/month	1/week	>1/week
Women 17-45 yr (347)	55	24	14	6	1	
46-84 yr (268)	22	26	22	25	5	
Men 18-84 yr (567)	35	28	19	15	2	1

In the MHE 2007 study about 80 % of the women in childbearing age (18-45 yrs) rarely or never consumed BS herring, which is in concordance with the data from the Riksmaten 1997-98 study (Table 5 and 6). In MHE 2007 5.8 % of the women in this age group consumed BS herring 2-3 times per month. This is a much higher consumption than currently recommended by SNFA as a measure to protect young women from high body burdens of dioxins and dl-PCBs at pregnancy. Of a population of 1,647,000 women between the ages of 18-45 in Sweden in 2007 (SCB 2010), about 100,000 women ate BS herring 2-3 times or more often each month. About 2 % of these young women consumed BS herring once a week or more which corresponds to about 35,000 women in their childbearing years in the year 2007.

Table 6. *BS herring consumption frequencies among men and women during the year 2007 (MHE 2007, mean and 95 % confidence interval)*

Age (N)	**Consumption (% of population)**					
	Seldom/never	**1/month**	**2-3/month**	**1/week**	**2-3/week**	**≥4/week**
Women						
18-45 yrs	83	11	3.7	1.5	0.5	0.1
(5674)	(82-84)	(10-12)	(3.0-4.5)	(1.1-2.1)	(0.3-0.9)	(0.1-0.4)
46-65 yrs	63	21	9.7	5.0	1.2	0.5
(5283)	(61-65)	(19-22)	(8.6-11)	(4.2-5.9)	(0.8-1.8)	(0.2-0.9)
66-80 yrs	36	26	16	18	3.6	0.2
(2665)	(34-39)	(23-28)	(14-19)	(16-20)	(2.7-4.7)	(0.1-0.6)
Men						
18-45 yrs	73	18	5.4	3.3	0.1	0.1
(4326)	(71-75)	(16-20)	(4.6-6.5)	(2.6-4.1)	(0.0-0.3)	(0.1-0.6)
46-65 yrs	55	25	12	7.2	0.9	0.2
(4588)	(53-57)	(23-26)	(11-14)	(6.2-8.3)	(0.6-1.3)	(0.1-0.4)
66-80 yrs	33	27	20	18	2.9	0.6
(2312)	(30-35)	(24-29)	(17-22)	(16-20)	(2.1-4.0)	(0.3-1.3)

Among women between the ages of 45 and 65 years, there were 1.7 % who consumed BS herring more often than once a week, which is more than the current recommendations set by the SNFA. Based upon a population of 1,186,912 women in this age group in the year 2007, about 20,000 women consumed BS herring more often than the SNFA recommendations. Using the same principles of estimation, MHE 2007 revealed that about 22,000 women between the ages of 66 and 80 years consumed BS herring more often than recommended, based upon a population of 590,100 women in this age group. The same calculations for men show that about 3,000 men between the ages of 18-45 consumed BS herring more often than the SNFA recommendation. For men between the ages of 46-65 years, the corresponding number was 13,000 and among men in the age group of 66-80 years there were about 18,000 who did not follow the recommendations.

Table 7. *BS herring consumption frequencies among women in childbearing age living in the northernmost counties of Sweden during the year 2007 (MHE 2007, mean and 95 % confidence interval)*

County (N)	Consumption (% of population)			
	Seldom/never	1/month	2-3/month	1/week
Gävleborg (67)	84 (73-92)	7.6 (3.1-17)	4.1 (1.3-12)	4.0 (1.0-15)
Västernorrland (215)	86 (81-91)	11 (6.8-16)	2.2 (0.9-5.3)	0.9 (0.2-3.8)
Jämtland (72)	83 (72-90)	11.4 (5.7-21)	4.0 (1.3-12)	1.7 (0.2-11)
Västerbotten (200)	87 (79-89)	11 (7.5-16)	1.3 (0.4-4.0)	2.8 (1.3-6.3)
Norrbotten (70)	86 (75-92)	11 (5.2-20)	1.5 (0.2-10)	2.5 (0.6-9.5)

Since the levels of dioxins and dl-PCBs are higher in BS herring from the coast of northernmost part of Sweden than in the rest of the Baltic Sea, a more detailed analysis of BS herring consumption in the northernmost counties was conducted. This analysis shows that consumption of BS herring among women in their childbearing years was in general low (Table 7). However, a few percent of these women reported that they consumed BS herring 2-3 times a month or more, with the county of Gävleborg having the largest proportion of young women eating BS herring this often. The wide confidence intervals for the percentages show that the differences were not statistically significant (Table 7).

Table 8. *BS herring consumption frequencies among children of different ages during the year 2003 (MHE 2003, mean and 95 % confidence interval)*

Age (N)	Consumption (% of population)					
	Never	<1/month	1-3/month	1/week	2/week	≥3/week
4 yr (8264)	65 (63-66)	31 (29-33)	3.4 (2.8-4.0)	0.9 (0.6-1.3)	0.1 (0.1-0.3)	0.1 (0.0-0.4)
12 yr (9505)	64 (62-65)	31.2 (30-32)	4.3 (3.8-4.9)	0.7 (0.5-1.0)	0.1 (0.1-0.3)	0.0 (0.0-0.1)

Data for BS herring consumption among children in Sweden comes from the Riksmaten 2003 and the MHE 2003 study. More recent data is not available for children. However in the 2010 SNFA Knowledge study it was estimated that 93 % of families with small children consumed BS herring at the most a few times per year which is in line with the current recommendations. Six percent of the families with young children did however report a BS herring consumption of several times per month, which indicates that there is a group of children in

Sweden who eat more BS herring than is recommended by SNFA. This is in concordance with data from the MHE 2003 study where 4-5 % of the children ate BS herring once a month or more (Table 8). Based upon the population in Sweden 2003 (SCB 2010), there were about 4,000 4 year old children who consumed more than is recommended. About 6,600 12 year old children consumed BS herring more often than recommended. Assuming that there are about 5000 children in each age group between 4 and 12 who do not follow the recommendations, then there were approximately 45,000 children in total who did not follow the recommendations.

In the Riksmaten 2003 study about 70 % of the children in the ages of 4, 8 and 12 never consumed BS herring. About 90 % of the children had a consumption which was within the limits of the current recommendations (2-3 times per year), which corresponds with the percentages for 4 and 12 year old children in the MHE 2003 study, as well as with the consumption among families with small children in the SNFA's Knowledge study. In Riksmaten 2003, consumption of BS herring more than once a month was reported for 2.3% of the 4 and 8 year old children and for 3.2 % of the 12 year old children.

In the MHE 2003 study it was reported that about 95 % of four year old children who lived in the northernmost counties of Sweden, consumed BS herring more seldom than once per month (Table 9). The county of Jämtland had the highest percentage of four-year-olds that did not eat herring while the county of Norrbotten that had the lowest percentage who never ate herring. The differences among 12 year old children were not as great, but the county of Jämtland still had the highest proportion of children who did not eat BS herring (Table 9). Between 3-5 % of four year old children consumed BS herring once per month or more often, while the corresponding proportion for 12 year old children was 2-7 %. The uncertainty of these data was however relatively large (Table 9).

Table 9. *BS herring consumption frequencies among children of different ages living in the northernmost counties of Sweden during the year 2003 (MHE 2003, mean and 95 % confidence interval)*

County (N)	**Consumtion (% of population)**			
	Never	**<1/month**	**1-3/month**	**≥1/week**
4 yr				
Gävleborg (162)	59 (51-66)	37 (30-45)	3.4 (1.4-8.0)	0.5 (0.1-3.4)
Västernorrland (244)	62 (56-68)	34 (29-41)	2.7 (1.2-6.1)	0.7 (0.1-4.8)
Jämtland (189)	71 (64-77)	26 (20-33)	2.7 (1.1-6.5)	0.0
Västerbotten (173)	61 (54-68)	35 (28-42)	2.7 (1.1-6.4)	1.6 (0.5-4.9)
Norrbotten (156)	47 (39-55)	49 (41-56)	4.6 (2.2-9.3)	0.0
12 yr				
Gävleborg (146)	60 (51-68)	33 (26-42)	5.8 (2.8-11.3)	1.0 (0.3-4.1)
Västernorrland (223)	61 (54-68)	35 (29-42)	2.9 (1.2-6.9)	1.0 (0.2-4.0)
Jämtland (174)	71 (63-77)	28 (21-35)	1.8 (0.6-5.6)	0.0
Västerbotten (175)	65 (58-72)	31 (24-38)	4.3 (2.0-8.7)	0.0
Norrbotten (167)	63 (55-70)	34 (27-42)	2.4 (0.9-6.6)	0.7 (0.1-4.9)

Salmon consumption

The compilation of data on salmon consumption in Sweden shows a notable increase among adults since the end of the 1990's (Table 10). Data on time trends for children is lacking but the situation is most likely similar for children and adults. In the Riksmaten 1997-98 study, the median salmon consumption was estimated to 1 gram per day (median value) for both men and women. The preliminary data from the Riksmaten 2010 study indicate a ten-fold increase in the median consumption among women and a four-fold increase among men. The salmon that are consumed are mainly farmed (see the per capita calculations below). In the POPUP study there was a statistically significant increase in salmon consumption between the years of 1996 and 2006 (Fig. 3).

Table 10. *Salmon consumption in SNFA's studies (g/day)*

Study	Sex (N)	Mean	SD	Median	95th percentile
Riksmaten 1997-98	Women (618)	2.7	4.8	1.0	9.4
	Men (597)	2.6	4.2	1.0	9.4
Riksmaten 2010	Women (375)	9.4	9.8	10	18
	Men (297)	7.6	7.9	4.1	18
Riksmaten 2003	Children 4 yr (584)	1.8	2.8	0.5	6.4
	8 yr (877)	3.1	7.8	0.7	16
	12 yr (1002)	3.1	6.4	0.7	14
POPUP (1996-2006)	Women (325)	6.8	8.8	3.9	21

SD=standard deviation

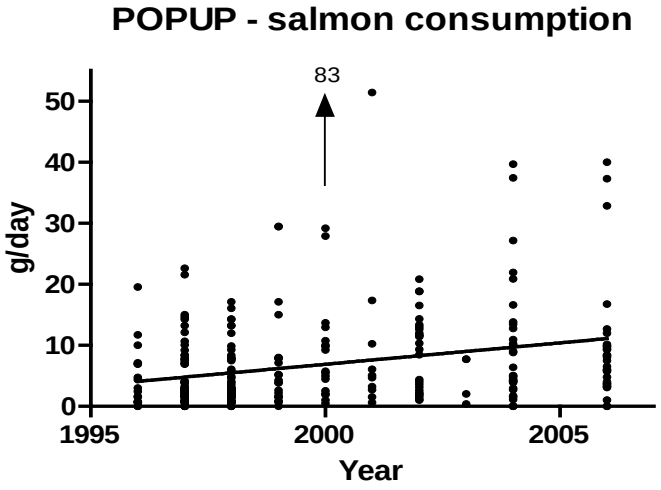

Figure 3. *Salmon consumption among primaparous women in the Uppsala area 1996-2006 (POPUP-study). The increase is statistically significant and corresponds to an average increase in consumption of 0.7 grams/day and year (regression analysis, p<0,001, N=293).*

Consumption of fermented BS herring

Consumption of fermented BS herring is very low in Sweden. In the SNFA Knowledge 2010 it was reported that among families with small children, which include both risk groups of children and women in their childbearing years, 84 % reported never eating fermented herring, 6 % consumed the product only at the once-yearly fermented BS herring festivity, and 9 % a few times per year. Among the general population only 5 % reported eating fermented BS herring 3-5 times per year. Among professional fishermen 13 % consumed the product more than five times each year.

Consumption of fish caught by anglers

There is a lack of knowledge about consumption of BS herring and wild salmon from the Baltic Sea, Lake Vänern and Lake Vättern that are caught by the consumers themselves ("angler-caught"). In Riksmaten 2010 (adults), however, there is a question about consumption of angler-caught salmon and BS herring. In the end of October 2010 666 participants had answered this question and a complete data analysis cannot be done before the Riksmaten 2010 study is concluded. Preliminary results show that angler-caught salmon was eaten by 16 % of the participants, while 94% of them reported eating salmon in general (Table 11). Ninety-two percent responded that they never or at most 1-3 times each year ate angler-caught salmon. The corresponding percentage for consumption of salmon in general was 15 %. Only 0.65 % responded that they ate angler-caught salmon once a week or more. The consumption of salmon in general at the same rate was reported by 18 % of the participants. Overall the Riksmaten 2010 survey indicates that consumption of angler-caught salmon was very small in relation to the consumption of salmon in general, the latter most probably mainly bought in the store.

If the participants in the Riksmaten 2010 are representative for the entire adult population in Sweden, then approximately 40,000 consumers consumed angler-caught salmon at least once a week. This number is uncertain since the number of participants in Riksmaten 2010 was low. If the consumption of angler-caught salmon in this group on average is about once per week, then about 300 tons of angler-caught salmon was consumed in 2010. This corresponds well with the 400 tons of wild salmon that the Swedish Board of Fisheries reports were caught by sport fishermen in the year 2006.

Ninety-six percent of the participants in the Riksmaten 2010 responded that they at most consumed angler-caught BS herring 1-3 times per year (Table 11). The corresponding percentage for the total herring consumption was 67 %. About 1.4 % reported that they consumed angler-caught herring once a month or more, while 15 % reported the same consumption frequency of BS herring in general. The results indicate that the consumption of angler-caught herring is small in relation to the total herring consumption.

Table 11. *BS herring and salmon consumption frequencies among adults participating in Riksmaten 2010 divided into total consumption and consumption of fish caught by the consumers themselves (angler-caught, N=666, mean and 95 % confidence interval)*

Gender	Consumption (% of participants)				
	Never	**1-3/yr**	**4-11/yr**	**1-3/month**	**≥1/week**
Total consumption					
	BS herring				
Women	42	27	16	14	2.1
Men	35	29	20	15	1.0
Total	39	28	18	13	1.7
	Salmon				
Women	8.6	9.2	16	47	22
Men	5.1	9.8	18	53	14
Total	5.7	9.4	17	50	18
Angler-caught					
	BS herring				
Women	93	4.1	2.3	0.58	0.29
Men	87	7.7	3.3	1.1	0.36
Total	90	5.7	2.7	1.1	0.32
	Salmon				
Women	86	8.1	3.2	2.0	0.87
Men	81	11	5.1	3.0	0.36
Total	84	9.4	4.0	2.4	0.65

The Swedish Board of Fisheries has estimated that 1,800 tons of Baltic herring/Atlantic herring was caught by sport fishermen in 2006. Between 2007 and 2009 about 20,000 tons of BS herring were caught commercially. Consequently, the annual catch of BS herring/Atlantic herring by sportfishers was less than 10 % of the annual commercial catch of BS herring. The Swedish Board of Fisheries did not give information about the proportion of BS herring in the annual catch of BS herring/Atlantic herring by sportfishers.

In SNFA's Knowledge study 2010, 200 professional fishermen were asked about their consumption of BS herring and wild-caught salmonid fish from the Baltic Sea and the lakes Vänern and Vättern. It is assumed that a large proportion of the fish that the professional fishermen eat are from their own catches. Only 15 % of them reported that they never or seldom ate BS herring or salmonid fish. Sixty-three percent answered that they consumed BS herring or wild-caught salmonid fish once a week or more. This confirms the result from earlier studies of fish consumption among the professional fishermen, i.e. they consume much more BS herring and wild-caught salmon than other consumers in Sweden (Ankarberg, Aune et al. 2007).

Per capita consumption of BS herring and wild salmonids

Per capita consumption of fish gives a measure of the average consumption of fish available on the market in Sweden. The calculations for BS herring and wild-caught salmonids from the Baltic Sea and the lakes Vänern and Vättern are based on the statistics from Swedish National Board of Fisheries on commercial catch volumes during 2007-2009 and on the number of inhabitants in Sweden who were one year or older in 2009. The per capita calculation is for whole, un-gutted fish and does not reflect the actual amount of fish that were eaten. Nor does it take into consideration that the consumption of the BS herring and wild-caught salmon most probably in reality is skewed; with many consumers who never or seldom eat these fish and a small proportion of the consumers who eat the great majority all fish consumed. The catch statistics for BS herring do not reveal information on how much of the fish that is exported to other countries.

According to the Swedish National Board of Fisheries statistics a total of 18,932 tons of BS herring were caught for consumption during 2007, 22,244 tons during 2008 and 15,651 tons during 2009. On average about 19,000 tons of BS herring were caught for consumption in Sweden during the period 2007-2009. The per capita consumption BS herring is estimated to 2.06 kg/year if a population size of 9,228,562 consumers is used (population 2009 ≥1 yr of age) (SCB 2010). The per capita consumption of BS herring that is below 17 cm in size (catch of 13,800 tons/year) is 1.5 kg/year. BS herring below 17 cm in general have levels of dioxins and dl-PCBs below the maximum limits. The per capita consumption of herring that is over 17 cm is 0.55 kg/yr. Per capita consumption of BS herring with levels in general below the maximum limits is 1.9 kg/yr, including fish below 17 cm from all areas of the Baltic Sea and BS herring of all sizes in the southernmost part of the Baltic Sea (ICES areas 24 and 35). Consequently, only about 10 % of the per capita consumption consists of BS herring with dioxin and dl-PCB levels above the maximum limit. If the BS herring with the highest dioxin and dl-PCB levels from the northernmost ICES areas 30 and 31 consumes is assumed to be consumed only locally in in the northern counties then the per capita consumption of this kind of fish is about 1.4 kg/yr based upon a population of 1,164000 in the five northernmost counties county (age ≥1 yr) and a consumption of 1,680,000 kg herring.

The average catch of wild-caught Baltic Sea salmon between 2007 and 2009 was about 300 tons/year according the Swedish National Board of Fisheries statistics. In Lake Vänern 16 tons and in Lake Vättern 1 ton were caught in 2009. With at population size of 9,228,562 this makes for a per capita consumption of wild caught commercial salmon of 30 grams per year. In this case no consideration was taken to the fact that the consumed amount of fish was lower due to the losses when the fish were cleaned. It is likely that the greatest consumption occurs locally which means that a small portion of the population can have significantly higher consumption than the per capita calculations indicate. The commercial catch of brown trout from the lakes Vänern and Vättern 2009 was 22 tons, resulting in a per capita consumption of about 2 grams per year. Also for this fish it

may be that local consumption is most likely larger. The catch of arctic char from Lake Vättern during 2009 was 3 tons, which makes for a per-capita consumption of 0.3 gram per year. Once again the local consumption is likely to be much higher. According to the organisation ”Exportutvalget for fisk” in Norway, the farmed Norwegian salmon had 98 % of the Swedish market 2007 (Norsksjömat 2010). The export of salmon to Sweden was 32,000 tons which makes for a per capita consumption of about 3.5 kg/yr. A certain “re-export” of Norwegian salmon occurs from Sweden which means that the per capita consumption is somewhat overestimated.

Exposure assessment

Dioxin and PCB exposure in Sweden

Introduction

Food is clearly the most important source of exposure to dioxins and dl-PCB (Ankarberg, Aune et al. 2007). There are several ways to estimate exposure in the population; indirectly and directly. Calculations of intakes of substances from food can be used as an indirect way of estimating exposure. Measurement of dioxin and dl-PCB in tissues/fluids from humans gives a direct estimate of the exposure. Intake calculations and measurements of biological samples get different time perspectives on the exposures. Intake calculations, which are a product of how much food the consumers have eaten and the levels of dioxins and dl-PCB in consumed food, give an estimate of exposure which is representative for the time period when the food was consumed and when the levels of dioxins and dl-PCBs in consumed food were measured. The levels in the biological samples from humans give a measure of the more long-term exposure since dioxins and dl-PCBs persists and accumulate in the body during a long time period. This means that the levels of these substances in a biological sample give a picture of the total exposure during a long time period before the sample was taken.

Food of animal origin and fats of vegetable origin make up the greater proportion of the population's exposure to dioxins and dl-PCBs. Consequently intake calculations have focused on the consumption of dairy products, meat and meat products, eggs and egg products, fish, as well as vegetable fats. SNFA's studies on consumer food habits, Riksmaten, are suitable for intake calculations since the study participants have registered all their food consumption during four to seven days and have answered a questionnaire on fish consumption during the most recent year. With help of these data and data regarding the levels of dioxins and dl-PCBs in the foods in question the intake of the substances of each study participant can easily be calculated.

Market basket studies are another way to estimate the population's intake of dioxins and dl-PCBs from food. Market basket studies give an estimate of the per capita intake of the contaminants in question. In this type of study the foods, which on average is consumed in amounts from ½ kg per year or more per inhabitant in Sweden, is purchased in relevant food store. The purchased foods are divided into different food groups and a pooled sample for each group is produced. Individual foods in the pooled samples are added to the sample in proportion to the contribution of this food type to the total per capita consumption of the food group in question. After dioxin and dl-PCB analyses of the pooled samples, the results can easily be recalculated to a per-capita intake of the substances.

Breast milk is well suited for measuring long-term exposure of young women to dioxins and dl-PCBs. Breast milk has a relatively high fat content which simplifies the chemical analysis of the fat-soluble dioxins and PCBs. Sampling of breast milk is non-invasive. Besides a measure of young women's exposure, the levels in breast milk also give a measure on the foetal exposure during pregnancy. This is because the fat soluble substances are distributed evenly in the lipid fraction of tissues in both the mother and the foetus. Consequently the foetus have similar dioxin and dl-PCB levels in lipids as the levels detected in breast milk lipids. In addition, the dioxin and PCB levels in breast milk give a measure of the breast-feeding child's exposure.

Table 12. *Intake of total dioxin and dl-PCB TEQ (median (95th percentile)) from food in the Riksmaten studies*

		Intake (pg/kg body weight/day)	
Study	**Year**	**TEF-1998**	**TEF-2005**
Adults			
Riksmaten 1997-98	2005	1.1 (2.9)	
Riksmaten 1997-98	2010		0.46 (1.4)
Riksmaten 2010			0.51 (1.4)
Children			
Riksmaten 2003 4 yr	2006	2.4 (4.8)	
Riksmaten 2003 4 yr	2010		0.94 (2.3)
Riksmaten 2003 8 yr	2006	1.9 (4.2)	
Riksmaten 2003 8 yr	2010		0.77 (2.1)
Riksmaten 2003 12 yr	2006	1.3 (3.0)	
Riksmaten 2003 12 år	2010		0.53 (1.7)

TEF=toxicity equivalent factor (Van den Berg, Birnbaum et al. 1998; Van den Berg, Birnbaum et al. 2006). TEQ=toxicity equivalents

Intake from food

Since Riksmaten 2010 had not been concluded at the time of intake calculations, the intake calculations for adults were also based upon the consumption data from Riksmaten 1997-98. Data on dioxins and dl-PCBs in animal food and vegetable fat originated from samples obtained 2007-2010. Data on levels in fish come from the years 2000-2010. Results from intake calculations based on Riksmaten 1997-98 consumption data were compared with the intake calculations based on available consumption data from the Riksmaten 2010 study in the end of October 2010 (Table 12). Comparisons were also made with earlier intake calculations from 2005, based upon the level data from the end of the 1990's and the beginning of the 2000's. Riksmaten 2003 was used for children since no new food consumption survey has been made for children (Table 12).

The calculations show that the average intake and the intake at the 95th percentile in the Riksmaten 1997-98 study is higher if the newer data on food dioxin and dl-PCB levels are used than if older food level data are used (Table 12). Similar results were observed for the calculations for children based on Riksmaten 2003. This is in part because the new level data is based upon WHO

toxicity equivalent factors (TEF) from 2005 instead of WHO TEF from 1998 (Van den Berg, Birnbaum et al. 1998; Van den Berg, Birnbaum et al. 2006). In TEF-2005 a certain type of dl-PCBs, the mono-*ortho* PCBs, got a lower TEF than in TEF-1998, which gives a somewhat lower total TEQ level in food (about 10-20 %).

Table 13. *Average levels of dioxins and dl-PCBs in the various food groups that were included the intake calculations in the Riksmaten studies*

Food group	**Riksmaten 1997-98**		**Riksmaten 2003**	
	2010[a]	**2005[b]**	**2010[a]**	**2006[b]**
Game (pg TEQ/g fat)	2.2	3.5	2.2	3.5
Beef	0.54	1.5	0.54	1.5
Pork	0.066	0.19	0.066	0.19
Chicken	0.13	0.65	0.13	0.65
Dairy products	0.35	0.98	0.35	0.98
Butter	0.38	0.59	0.38	0.59
Vegetable oils/fat	0.067	0.61	0.067	0.61
Egg (pg TEQ/g fresh weight)	0.065	0.18	0.065	0.066
Sausage	0.040	0.08	0.045	0.08
Liverworth	0.051	0.61	0.051	0.61
Liver	1.4	0.61	1.4	0.61
Fish sticks, fish balls, fisk au gratin	0.11	0.16	0.11	0.47
Lean marine fish	0.11	0.47	0.11	0.47
Flat fish	0.98	0.47	0.98	0.47
Atlantic herring	0.61	1.5	0.61	1.6
Baltic Sea herring	4.0	10	4.0	10
Farmed salmonids	1.4	2.1	1.4	2.1
Wild salmon and trout Baltic Sea	9.4	10	9.4	10
Pike, perch, pike-perch	1.0	1.3	1.0	1.3
Eel	4.7	4.7		
Sardines, anchovies	0.96	0.95	0.96	0.95
Canned tuna			0.028	0.31
Fish liver		100		
Caviar, rom	0.26	0.95	0.26	0.95

[a]Levels calculated with WHO TEF-2005 (Van den Berg, Birnbaum et al. 2006) and derived from analyses conducted in 2007-2010, with the exception of fish (2000-2010).
[b]Levels calculated with WHO TEF-1998 (Van den Berg, Birnbaum et al. 1998) and derived from analyses conducted at the end of 1990's and early 2000's.

Table 14. *Food consumption of the study participants in the Riksmaten 1997-98 and Riksmaten 2010 studies*[a]

Food groups	Riksmaten 1997-98				Riksmaten 2010			
	Mean	SD	Median	95 perc	Mean	SD	Median	95 perc
Fat of animal origin (g fat/day)								
Game	0.05	0.31	0	0.21	0.06	0.38	0	0.22
Beef	2.9	2.3	2.4	7.0	2.6	6.3	1.7	7.6
Pork	2.5	3.0	2.1	8.2	3.6	4.7	2.0	13
Chicken	***0.45***	***0.87***	***0***	***2.4***	***1.6***	***3.3***	***0.49***	***7.3***
Dairy products	14	8.3	12	29	17	15	14	35
Butter	1.3	5.3	0	6.9	1.2	3.3	0	8.2
Vegetable oils/fat (g fat/day)	23	16	21	51	23	54	18	45
Other foods of animal origin (g fresh product/day)								
Eggs	***12***	***16***	***7.1***	***43***	***23***	***24***	***15***	***73***
Sausage	***25***	***26***	***20***	***71***	***20***	***26***	***10***	***75***
Liver paté	3.7	6.3	0	17	1.8	4.8	0	11
Liver	1.0	4.5	0	8.6	0.02	0.28	0	0
Fish (g fresh product/day)								
Fish sticks, fish balls, fish au gratin	***5.2***	***7.9***	***1.3***	***18***	***2.6***	***4.6***	***0.69***	***10***
Lean marine fish	***8.5***	***8.2***	***8.3***	***17***	***7.1***	***8.5***	***4.1***	***18***
Flat fish	3.4	5.9	1.0	8.3	2.4	4.3	0.69	10
Herring	***0.17***	***1.9***	***0***	***0.75***	***1.7***	***25***	***0.03***	***0.14***
BS herring	2.4	4.3	1.0	9.1	1.8	3.5	0.69	10
Farmed salmonids	***3.5***	***5.7***	***2.1***	***10***	***8.6***	***9.0***	***10***	***18***
Wild salmonids Baltic Sea	0.20	1.1	0	1.0				
Pike, perch, pike perch	0.87	2.3	0	7.2	1.1	4.2	0	4.1
Eel	0.19	0.59	0	0.83	0.13	0.43	0	0.49
Fresh tunafish, swordfish, shark					0.26	0.85	0	2.1
Sardines, anchovies, canned tuna	***2.4***	***4.2***	***0.60***	***10***	***2.5***	***4.9***	***1.2***	***11***
Shellfish/caviar	***3.8***	***6.2***	***0.75***	***12***	***4.5***	***5.8***	***3.0***	***13***

[a] Food groups in the bold italics had an increased or a decreased median consumption by a factor of two or more. SD=standard deviation, perc=percentil

The difference, however, between the intake cannot be completely explained by the changes of TEF. Levels of dioxins and dl-PCBs have, most likely, decreased in many foods of animal origin. This is most probably due to the enforcement of relatively strict maximum limits for dioxins and dl-PCBs in animal feed from the beginning of the 2000's. This has forced feed producers to use feed raw materials with lower dioxin- and PCB-levels than earlier. A portion of the lower levels can also be explained by the availability of better analytical methods, which means that fewer samples have had levels below the limit of quantification (LOQ) of the analytical method. In the intake calculations levels in foods below the LOQ are set to 50 % of the LOQ, which in many cases cause an over-estimation of the levels in foods with many dioxin and PCB compounds below the LOQ.

Table 13 shows the average levels of dioxins and dl-PCB's which were used in the intake calculations. Average levels in foods sampled for the 2010 calculations are lower than levels in foods used in the 2005 and 2006 calculations. Based on these data, however, it is not possible to establish that the levels in food have decreased during the 2000's, since the SNFA studies were not designed to investigate time trends for dioxins and PCBs in food.

A comparison was done between the dioxin and dl-PCB intake calculations, based on the consumption data from the Riksmaten 1997-98 or Riksmaten 2010 and more recent dioxin and dl-PCB levels in food. This comparison show similar median intake and intake at the 95 percentile (Table 12). This indicates that food consumption among adults in Sweden has not changed enough to result in mark-edly different intakes of dioxins and dl- PCBs between the two food consumption surveys. (Table 12). A closer scrutiny of the consumption data indi-cates that the consumption of chicken, eggs, Atlantic herring, salmon, canned fish, and shellfish has increased between 1997-98 and 2010, while the consumption of sausage, fish sticks/fish balls and lean marine fish has gone down (Table 14). The conclusions about differences in consumption are preliminary since Riksmaten 2010 had not been completed at the time of data analyses.

Table 15. *Contribution of different food groups, in percent (median), to the total intake of dioxins and dl-PCBs among adults using consumption data from different food surveys*

Food group	**Riksmaten 1997-98**		**Riksmaten 2010**
	2005 (%)	**2010 (%)**	**(%)**
Meat and meat products	12	11	7.4
Dairy products	17	17	17
Eggs	0.70	2.3	3.6
Vegetable fats	18	4.8	3.6
Lean fish	12	16	13
Herring	21	13	12
Other fatty fishes	15	19	31
Shellfish, caviar	2.0	17	13

2005=data on dioxin and dl-PCB levels in food from the late 1990's until the early 2000's
2010= data on dioxin and dl-PCB levels in food from 2007-2010, for fish from 2000-2010

A comparison of the contribution of the different food groups to the total intake of dioxins and dl-PCBs indicates that the contribution from fatty fish (excluding BS herring) has increased (Table 15). That depends most likely on the increased consumption of salmon. A similar tendency can be found for shellfish. The contribution from vegetable fats has decrea-sed dramatically, probably because the analytical methods have improved resulting in fewer samples with levels below the LOQ.

Table 16. *Contribution of different food groups, in percent (median), to the total intake of dioxins and dl-PCBs among children*

Food group	**Riksmaten 2003**	
	2006 (%)	**2010 (%)**
Food of animal origin	30	27
Milk fats	23	26
Eggs	0	1.8
Vegetable fats	14	2.3
Fish/shellfish	33	43

2006=data on dioxin and dl-PCB levels in food from the late 1990's until the early 2000's
2010= data on dioxin and dl-PCB levels in food from 2007-2010, for fish from 2000-2010

There is no consumption data for children that is more recent than 2003. Comparisons between the intake calculations based on older and more recent data on dioxin and dl-PCB levels in food and on consumption data from Riksmaten 2003 shows that the contribution from vegetable fats has been reduced whereas the contribution from fish has increased (Table 16).

Intakes of dioxins and dl-PCBs – international perspective

Intakes of dioxins and dl-PCBs among adults in Sweden seem to be within the lower range of the interval of average intake reported from different European countries (Fig. 4). The results should be viewed with caution since the study designs differ between studies. Additionally, WHO TEF-1998 was used in the studies during the 1990's and the beginning of the 2000's, whereas the WHO TEF-2005 was used for the later studies. WHO TEF-2005 gives a some-what lower intake (not more than 30 %) than do the WHO TEF-1998 (Van den Berg, Birn-baum et al. 1998; Van den Berg, Birnbaum et al. 2006).

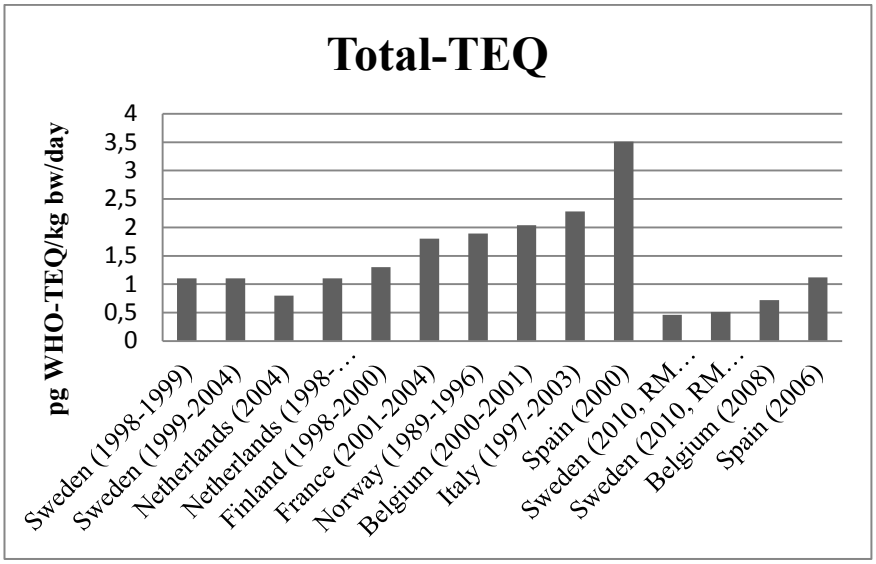

Figure 4. *Average intake of dioxins and dl-PCBs from food among adults in different European countries (SCOOP 2000; Kiviranta, Hallikainen et al. 2001; Focant, Eppe et al. 2002; Baars, Bakker et al. 2004; Fattore, Fanelli et al. 2006; Ankarberg, Aune et al. 2007; Tard, Gallotti et al. 2007; Colles, Koppen et al. 2008; Llobet, Marti-Cid et al. 2008; Windal, Vandevijvere et al. 2010). RM=Riksmaten study.*

Only a few market basket studies have been published in the open literature (Fig. 5). In concordance with the intake calculations in the Riksmaten studies, it seems that the per capita intake in Sweden has decreased between 1999 and 2005 (Fig. 5).

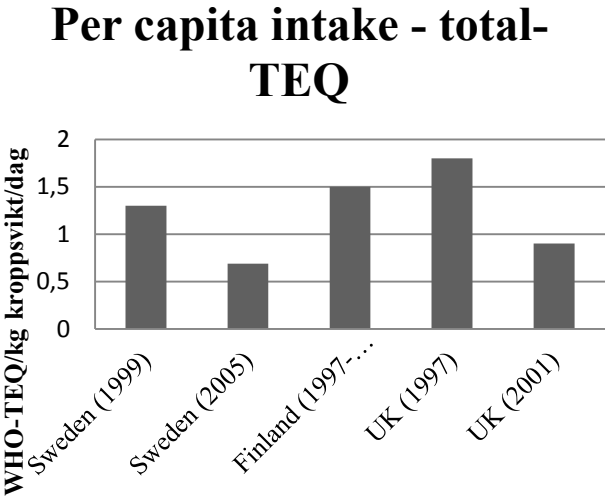

Figure 5. *The per capita intake of dioxins and dl-PCBs from food in Sweden, Finland and Great Britain (FSA 2003; Kiviranta, Ovaskainen et al. 2004; Ankarberg, Aune et al. 2007). Based on results from market basket or total diet studies.*

Levels of dioxins and dl-PCBs in human tissue

The Swedish National Food Administration has since 1996 studied the levels of dioxins and dl-PCBs in breast milk from the primiparous women in the Uppsala area (POPUP-study). Primiparous women were recruited since women normally have the highest levels of the contaminants in their bodies right before the start of nursing of their first baby. Women who nurse their babies eliminate the fat-soluble substances and the levels of the compounds in the body decrease with the number of infants nursed by the woman. The results from the POPUP study show that levels of dioxins and dl-PCBs in breast milk from primiparous women have slowly decreased between 1996 and 2008 (Fig. 6), which shows that the long-term exposure from food has dropped during a long time period. The levels have on average decreased 6.3 % per year, which means that it has taken about 11 years for the average levels to be halved.

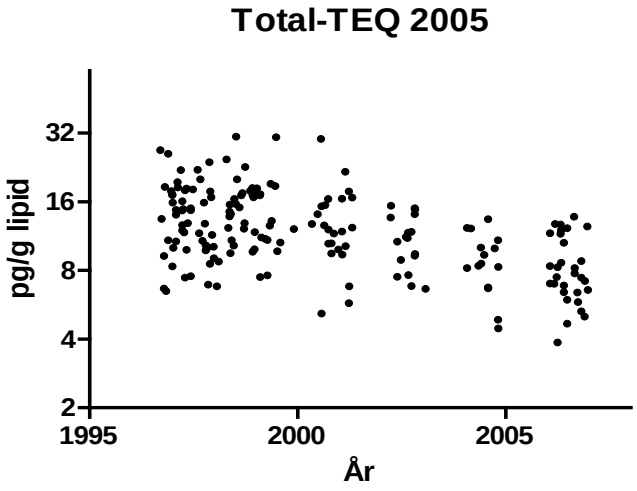

Figure 6. *Levels of dioxins and dl-PCBs (total TEQ, WHO TEF-2005) in breast milk from primiparous women who lived in the Uppsala region (POPUP-study) between 1996 and 2006. Each point represents one breast milk sample.*

During the years 2000-2003 WHO conducted a study of dioxins and dl-PCBs in breast milk where the goal was to get comparable data for levels in breast milk from different areas of the world (Fig. 7) (van Leeuwen and Malisch 2002). WHO established certain criteria so that the results would be comparable. The participating women should be giving birth for the first time and all breast milk samples should be analyzed by the same laboratory. At least one pooled sample of breast milk from at least ten randomly recruited women was analyzed from each country. The results showed that the average level of dioxins and dl-PCBs in breast milk from Sweden was lower than in more densely populated industrialized countries in Europe, such as Germany, Italy, the Netherlands and Belgium. The levels in the Swedish samples were somewhat higher than in the samples from Finland and Norway, and were clearly higher than in less industrialized countries, such as Hungary and Bulgaria (Fig. 7).

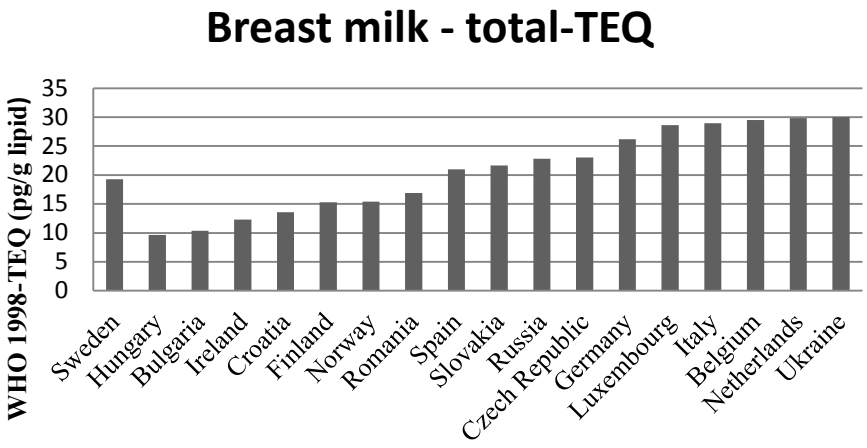

Figure 7. *Levels of dioxins och dl-PCB in pooled samples of breast milk from participating European countries in WHO breast milk study 2000-2001 (van Leeuwen and Malisch 2002).*

Similar results were acquired in the WHO study from 2006-2007 where levels in Swedish samples were measured to 13 pg total-TEQ/g lipid, whereas levels in samples from Belgium, the Chech Republic, Luxemburg and Slovania were in the interval 16-23 pg TEQ/g lipid (Adu-Kumi, Malisch et al. 2010). Data for Germany, Italy and the Netherlands were not reported.

There can however be regional differences in levels of substances in breast milk within a country. Regional differences of dioxins and dl-PCBs in breast milk have not been studied in Sweden. The SNFA has, however, investigated if there are regional differences in levels of non-dl-PCB in breast milk (di-*ortho* PCB) (Glynn, Lignell et al. 2011). This type of PCB can work as a marker for the levels of dioxins and dl-PCBs, since the levels of the two groups of contaminants are strongly correlated in breast milk (Glynn, Lignell et al. 2011). No differ-ences were observed between the average levels of di-*ortho* PCB in breast milk from random-ly sampled primiparous women in Lund, Gothenburg, Uppsala and Lycksele (Fig. 8). This strongly suggests that the long-term exposure of young women for dioxins and dl-PCB are comparable in different part of Sweden.

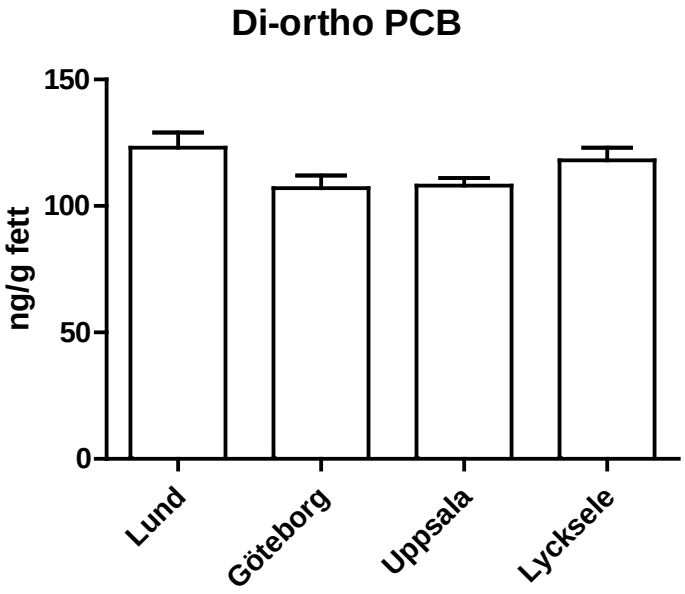

Figure 8. *Levels of non-dioxin like PCBs (di-ortho PCBs) in breast milk from randomly sampled primiparous women from different regions in Sweden. Levels were not significantly different (p>0.05, N=204).*

Intake of n-3-fatty acids and vitamin D in Sweden

The average intakes of total n-3-fatty acids (omega-3), and EPA+DHA among children and adults in Sweden according to population-based food consumption surveys are shown in Table 17. In the sum of total n-3 fatty acids, alpha-linolenic acid and docosapentanoic acids are included (22:5, n-3). Fish and shellfish contribute with about 80 % of the intake of EPA+DHA among adults and 60 % among children.

Table 17. *Intake of n-3-fatty acids in Sweden estimated in the Riksmaten 2003 (children) and 1997-98 (adults) studies(mean (standard deviation))*

Study	n-3, total g/d	n-3, total E%	EPA+DHA mg/d
Children 4 year old	1.14 (0.46)	0.7 (0.2)	140 (250)
Second graders (~9 yrs)	1.34 (0.51)	0.6 (0.2)	155 (181)
Fifth graders (~11 yrs)	1.30 (0.55)	0.7 (0.2)	160 (210)
Women	1.6 (0.7)	0.8	320 (380)
Men	2.0 (0.9)	0.7	340 (390)

*E% = % of daily energy intake. References: Enghardt Barbieri, Pearson et al. 2006; Becker och Pearson 2002

The mean vitamin D intake, according to the ”Riksmaten 2003 – children study” is 6.6 µg/day among 4 year old children , 5 µg/day for children of ages around 9 years, and 4.6 µg/dag for children of ages around 11 years (Enghardt Barbieri, Pearson et al. 2006). The main source of vitamin D is enriched dairy products, fats and oils, and fish. The higher the average intake among four year old children can be attributed to the fact that some of the children were given vitamin A and D supplements. Intake among young vegans has been reported to be lower (2-3.7 µg/dag) than for young persons who eat varied diets (5.1-7.7 µg/dag) (Larsson och Johansson 2002).

Table 18. *Intake of vitamin D among children and adults in Sweden*

Study	Intake (µg/d) mean (SD)
Children (Riksmaten 2003)	
Children 4 year old*	6.6 (4.5)
Second graders (~9 yr)*	5.0 (2.8)
Fith graders (~11 yr)*	4.6 (2.7)
8 year old children from Gothenburg	
Girls	6.9 (4.8)
Boys	5.7 (3.2)
Young vegans	
Girls	2.0 (1.3)
Boys	3.7 (1.2)
Adults (18-74 years, Riksmaten 1997-98)	
Women	4.9 (1.9)
Men	6.2 (2.7)

*Riksmaten 2003, intake from vitamin D supplements included.
(quartile 1-quartile 3)
References: Enghardt Barbieri, Pearson et al. 2006; Eriksson och Strandvik 2010; Larsson och Johansson 2002; Becker och Pearson 2002

Hazard/positive health effect characterization

Tolerable intake of dioxins and dl-PCB

Girls and women in childbearing age
Both WHO's expert group on contaminants and food additives (JECFA) and EU's expert group, Scientific Committee on Food (SCF), conducted a risk assessment of dioxins in food where exposure during the fetal stage was identified as the most sensitive period (SCF 2001, JECFA 2002). Both expert groups reached the same tolerable weekly intake of 14 pg/kg body weight for 2,3,7,8-TCDD, and they concluded that TWI could be applied on all 2,3,7,8 – substituted dioxins and dl-PCBs by using WHO's toxicity equivalent factors (TEF). The most sensitive effects which were identified were effects on the immune system and reproductive development in rats which were exposed to TCDD *in utero*. TWI represents a life-long tolerable intake for women who try to become pregnant. The safety margin is small (10x) between TWI and the levels which gave negative health effects on the offspring of the rats.

Boys, men and older women
In 2007 the Swedish National Food Agency and IMM, Karolinska Institutet, conducted a risk assessment of exposure of children and adults to dioxins and dl-PCB (Hanberg, Öberg et al. 2007). This risk assessment of dioxin exposure during childhood and adulthood is focused on the portion of the population which will not experience pregnancy. The risk assessment was based mainly on toxicological studies of animals which were exposed to the most poisonous dioxin, 2,3,7,8-tetraklorodibenzp-p-dioxin (TCDD). The development of cancer seems to be the most sensitive negative health effect in young and adult animals. The expert group arrived at a tolerable intake interval of 14-70 pg/kg body weight/week. They concluded that the present knowledge on cancer risks of dioxin exposure among humans indicates that the cancer risks for humans are likely to be small or nonexistent when long-term exposures are in the level 14-70 pg/kg body weight/week.

Reference intake of n-3-fatty acids and vitamin D

The Nordic and Swedish nutritional advisories recommend adults and children over two years that *cis*-poly-unsaturated fatty acids should contribute 5-10 energy (E)%, including about 1 E% from n-3-fatty acids (NNR 2004: SNR 2005). *n*-6-fatty acids should contribute at least 4 E% for children 6-11 months old and 3 E%

for children 12-23 months old. *n*-3-fatty acids should contribute at least 1 E% among 6-11 months old children and 0.5 E% among children 12-23 months of age.

In SNR/NNR there are no specific recommendations for the long-chained n-3-fatty acids. EFSA has suggested a reference intake (adequate intake) of EPA+DHA of 250 mg/day for adults, based on the beneficial effects on heart diseases (EFSA 2010). No reference values were provided for children. In the present report the reference values for children is estimated from the EFSA values for adults which are adjusted with the reference values for energy intake according to NNR/SNR. For 4 and 8 year old children the reference intake was estimated to 150 mg/d, and for 12 year old children it was set to 250 mg/d.

In the Nordic and Swedish nutritional advisories, the recommended intake (RI) for adults and children older than two years is 7.5 µg/d (NNR 2004; SNR 2005).

Risk and benefit characterization

Introduction

Intake calculations of dioxins and dl-PCB, vitamin D and EPA+DHA are used to characterize health benefits and risks with consumption of the fish concerned in the exception negotiations. Two main scenarios were analyzed, one assuming a permanent exemption and the other a removal of the exemption. Consumption data are derived from the Riksmaten 1997-98 (adults) and 2010 (adults), and Riksmaten 2003 (children) studies. The data for levels of dioxins and dl-PCB in staple foods comes from food samples taken between 2007 and 2010, whereas the data for levels in fish come from samples taken between 2000 and 2010. Data concerning vitamin D and EPA+DHA were taken from the SNFA's food data base and a food analysis project from 2010. Scenario calculations include only herring consumption since consumption data for wild-caught salmonid fish is lacking. Consumers, in most cases, cannot differentiate between wild-caught or farmed salmon that are available in the food stores. As a consequence, there are currently no reliable consumption data for commercially caught salmon in the Riksmaten investigations. The problem with the high levels of dioxins and dl-PCBs in wild-caught salmonids from the Baltic Sea and the lakes Vänern and Vättern was instead illustrated by calculation of how many portions of wild-caught salmonid fish could be consumed by different consumers without exceeding the TWI. In these calculations the intake of dioxins and dl-PCBs from other foods was set at the median, estimated from the studies Riksmaten 1997-98 (adults) and Riksmaten 2003 (children).

In the risk and benefit characterization, EU's and WHO's tolerable intake of dioxins and dl-PCBs was used as guideline value for safe intakes of dioxin and dl-PCB exposure for girls and women in childbearing age (TWI, 14 pg TEQ/kd body weight/week). For boys, men and older women, a TWI interval of 14-70 pg TEQ/kg body weight/week was used. This TWI interval represents intakes that are not associated with non-developmental health effects in children and adults, and was proposed by experts from the SNFA and IMM, Karolinska Institutet. For men and older women the guideline value was set in the middle of the interval, that is to say at 35pg TEQ/kd body weight/week. The guideline value for boys was set to the lower threshold of the TWI interval (14 pg/kg body weight/week), since boys seem to be more sensitive to dioxins and dl-PCBs than adult men (Hanberg, Öberg et al. 2007).

The guideline values for positive health effects were based on Efsa's reference intake for EPA+DHA and the Nordic and Swedish recommended intake of vitamin D. The guideline value for EPA+DHA for adults and 12 years old children was set to 250 mg/day, whereas value for 4 and 8 year old children the value was set to 150 mg/day. With regard to vitamin D, 7.5 µg/day was used as a guideline value for adults and children.

Scenario calculations for BS herring

In the risk and benefit characterizations of BS herring consumption, it was assumed that the availability of BS herring in the food stores is independent of the presence of a Swedish exemption from the maximum limits or not in the EU's regulation. According to the Swedish Board of Fisheries´ commercial fisheries statistics and the SNFA's data on levels of dioxins and dl-PCBs in BS herring, most of the BS herring that is sold in food stores in Sweden comply with the maximum limits of dioxins and dl-PCBs. If Sweden lost the exemption the BS herring not complying with the maximum limits would be replaced with BS herring complying with the limits. Consequently, the intake of vitamin D and EPA+DHA among the consumers is the same, independent of if there is an exemption or not. In the scenario calculations the intake of vitamin D and EPA+DHA was therefore the same in all scenarios and was compared with the guideline intakes for vitamin D and EPA+DHA presented above.

In the scenario calculations, the daily intake of dioxins and dl-PCBs was compared with a daily intake equivalent to the guideline values for dioxins and dl-PCBs presented above. For children and women in childbearing age, 14 pg TEQ/kg body weight/week is equivalent to a daily intake of 2 pg TEQ/kg body weight/year. For men and older women a guideline intake of 35 pg TEQ/kg body weight/week is equivalent to a daily intake of 5 pg TEQ/kg body weight/day.

Results from the scenario intake calculations for dioxin and dl-PCBs, the fatty acids EPA+DHA, and vitamin D are shown in Tables 19-21. The scenarios are based on the consumption data from the Riksmaten 1997-1998 and 2010 (adults), and the Riksmaten 2003 (children) studies:

Dioxin and dl-PCB levels in BS herring in scenario 1: Exemption for the entire Baltic Sea: In this case all data on dioxin and dl-PCB levels in BS herring from 2000 to 2010 were weighted against the total catch (tons) from the different ICES areas of the Baltic Sea. Mean values of contaminant levels in BS herring from the different ICES areas were weighted depending on the total annual catch in the respective ICES area, and a total average mean dioxin and dl-PCB level was calculated for a "normal BS herring" on the Swedish market. The weighted mean value was estimated to 4.2 pg WHO-2005 TEQ/g fresh weight.

Scenario 2. Exemption northern Sweden: The mean levels for all BS herring samples from the ICES areas 30 and 31 (Gulf of Bothnia), weighted against the total annual catch in the two areas. In this scenario we assumed that the fish which were caught in the northern part of Sweden are consumed locally. This is a "worst-case scenario". The weighted mean level of dioxin and dl-PCB in BS herring was estimated to 9.4 pg WHO-2005 TEQ/g fresh weight.

Scenario 3: No exemption: The same data base as above, but include only those fish which have contaminant levels below the maximum limits. In this case the weighted average level was estimated to 2.8 pg WHO-2005 TEQ/g fresh weight.

Scenario 4: No exemption northern Sweden: Similar as scenario 3 above, since we assumed that the inhabitants living in the northern part of Sweden will only consume herring with contaminant levels below the maximum limits.

Table 19. *Intake of dioxins and dl-PCBs, omega 3 fatty acids and vitamin D among adults, based on the consumption data from Riksmaten 1997-1998.*

Dioxin intake (pg WHO-TEQ$_{2005}$/kg/day)							
Group	**Scenario[a]**	**P05**	**Median**	**P95**	**N**	**Percentage above the guideline intake[b]**	**Number over the guideline intake**
Men 17-84 yrs	1	0.15	0.44	1.4	567	0	0
	2	0.15	0.51	2.0	567	0.4	2
	3	0.15	0.42	1.2	567	0	0
Women 17-45 yrs	1	0.15	0.40	1.1	347	0.9	3
	2	0.15	0.46	1.8	347	3	10
	3	0.14	0.38	1.1	347	0.6	2
Women 46-84 yrs	1	0.21	0.63	1.8	268	0.7	2
	2	0.22	0.73	2.7	268	0.7	2
	3	0.21	0.58	1.6	268	0.4	1
Intake EPA + DHA (mg/day)							
Group	**Scenario**	**P05**	**Median**	**P95**	**N**	**Percentage above the guideline intake[c]**	**Number over guideline intake**
Men 17-84 yrs	1.2.3	40	280	990	567	55	314
Women 17-45 yrs	1.2.3	50	220	760	347	44	154
Women 46-84 yrs	1.2.3	93	360	1050	268	70	187
Intake vitamin D (µg/day)							
Groupp	**Scenario**	**P05**	**Median**	**P95**	**N**	**Percentage above the guideline intake[d]**	**Number over guideline intake**
Men 17-84 yrs	1.2.3	2.8	6.0	12	567	26	146
Women 17-45 yrs	1.2.3	2.5	4.6	7.7	347	6	20
Women 46-84 yrs	1.2.3	2.8	5.3	9.8	268	15	41

[a] Scenario 1: Exemption for the entire Baltic Sea. Scenario 2: Exemption and consumption of locally caught BS herring from ICES 30 and 31. Scenario 3: No exemption.
[b] Tolerable daily intake (TDI) for dioxins of 2 pg/kg/day (women 17-45 yrs) och 5 pg/kg/day (men 17-84 yrs, and older women 46-84 yrs).
[c] Adequate intake for EPA+DHA of 250 mg/day.
[d] Recommended intake for vitamin D of 7.5 µg/day.

Scenario intake calculations adults

According to the intake calculations, using consumption data from Riksmaten 1997-1998 study, the dioxin exposure in scenario 2 is higher relative to the other scenarios (for which the intake is of a similar size) (Table 19). Older women have the highest intakes (46-84 yrs; median = 0.63-0.73 pg WHO-2005 TEQ/kg body weight/day), followed by men (17-84 yrs; median = 0.42-0.51 pg/kg/day) and younger women (17-45 yrs; median = 0.40-0.46 pg/kg/day). The percentage of the population exceeding the guideline values (tolerable intake) for dioxins and dl-PCB are low (below 1%) in scenarios 1, 3, and 4. For women in childbearing years, however, 3 % exceed the tolerable intake of 2 pg/kg body weight/day in scenario 3 (Table 19).

Among women in childbearing age, who had an estimated intake over the tolerable intake for dioxins and dl-PCBs in scenario 2, the median consumption of BS herring was 9 g/day. This is comparable to about two portions per month, when a serving size is 125 g. The result indicates that a consumption of herring 2-3 times or more a month results in an increased risk of exceeding the tolerable intake for young women in the northern part of Sweden when consuming locally caught BS herring in the scenario of exemption from the maximum limits.

According to the Riksmaten 1997-1998 study, the intake of EPA+DHA was highest among older women (46-84 yrs; median = 360 mg/day), followed by men (17-84 yrs; median = 280 mg/day) and younger women (17-45 yrs; median = 220 mg/kg/day). 70 % of the older women reached the guideline intake of 250 mg/day. Among the men and younger women 55 % and 44 %, respectively, had an intake at or above the guide-line intake (Table 19). The vitamin D intake was highest among men (17-84 yrs; median = 6 µg/day), somewhat lower among older women (46-84 yrs; median 5.3 µg/day), and lowest among younger women (17-45 yrs; median 4.6 µg/day). 26 % of the men reached up to the guide-line intake of 7.5 µg/day. Among older women and younger women about 15 % and 6 %, respectively, reached the guide-line intake (Table 19).

The same types of calculations of dioxin intake were also conducted based on the consumption data from the on-going Riksmaten 2010 study of food habits for adults (Table 20). Consumption data on 645 individuals could be used (compared with 1182 individuals in the Riksmaten 1997-1998 study). Similarly as for Riksmaten 1997-98, the dioxin intake was generally higher in scenario 2 as compared with the other scenarios. Older women had the highest median intake (46-84 yrs; median = 0.61-0.71 pg/kg/day), similar to that in the Riksmaten 1997-1998 study. The intake for men (17-84 yrs; median = 0.45-0.52 pg/kg/day) were also similar to those in the Riksmaten 1997-1998. The percentage of women of ages 46-84 years exceeding the guideline value for dioxins and dl-PCBs was low (under 0.5 %) in scenarios 1, 2 and 3.

Among younger women, 17-45 years old, the median intakes were slightly higher (17-0.52-0.61 pg/kg/day) than in the intake calculations based on Riksmaten 1997-1998 (0.38-0.46 pg/kg/day). Similarly as in the Riksmaten 1997-1998 study, the intake calculations in scenario 2 resulted in the highest percentage of women exceeding the guideline intake of dioxins and dl-PCBs; in total about 5 % exceeded the guideline intake (Table 20). As in the case of the Riksmaten 1997-

1998 study, the young women who exceeded the tolerable intake in scenario 2 had a median consumption of BS herring of about 2 portions per month.

Table 20. *Intake of dioxins and dl-PCBs among adults, based on the consumption data from the Riksmaten 2010 study.*

Dioxin exposure (pg/kg/day)							
Group	**Scenario[a]**	**P05**	**Median**	**P95**	**N**	**Percentage above the guideline intake[b]**	**Number over guideline intake**
Men 17-84 yrs	1	0.17	0.47	1.2	286	0	0
	2	0.17	0.52	1.7	286	0.3	1
	3	0.16	0.45	1.0	286	0	0
Women 17-45 yrs	1	0.16	0.54	1.5	167	2	3
	2	0.16	0.61	2.1	167	5	9
	3	0.16	0.52	1.4	167	2	3
Women 46-84 yrs	1	0.19	0.64	1.7	192	0	0
	2	0.19	0.71	2.8	192	0.5	1
	3	0.18	0.61	1.4	192	0	0

[a] Scenario 1: Exemption for the entire Baltic Sea. Scenario 2: Exemption and consumption of locally caught BS herring from ICES 30 and 31. Scenario 3: No exemption.
[b] Tolerable daily intake (TDI) for dioxins of 2 pg/kg/day for younger women (17-45 yrs) and 5 pg/kg/day for men (17-84 yrs) and older women (46-84 yrs).

Scenario intake calculations children

According to the Riksmaten 2003 study, the dioxin intake was higher for 4 year old children and 8 year old children in scenario 2 as compared with the other scenarios (Table 21). Dioxin intake among children decreased with increasing age; it was greatest among 4 year old children (median = 0.93-1.0 pg/kg/day), followed by 8 year old children (median = 0.75-0.81 pg/kg/day), and 12 year old children (median = 0.53-0.54 pg/kg/day). The percentage of children exceeding the tolerable intake was 4-7 % in scenarios 1 and 3, and for scenario 2 the percentage increased to 8-9 % among 4 and 8 year old children. Among the 4 year old children that exceeded tolerable intake in scenario 2, the median BS herring consumption was six servings per year. Among the 8 year old children exceeding the tolerable intake the median BS herring consumption was 1.5 portions per month.

According to the Riksmaten 2003 study, the intake of EPA+DHA was somewhat higher for 12 and 8 year old children (median = 120 mg/day) compared to the 4 year old children (median = 92 ng/day) (Table 21). Among 12 and 8 year old children 24 % and 29 %, respectively, reached the guideline intake of the fatty acids. Among the 4 year old children 30 % had intakes at or above the guideline intake of the fatty acids (Table 21).

The vitamin D intake was highest among the 4 year old children (median = 5.1 µg/dag), somewhat lower for 8 year old children (median = 4.8 µg/day), and lowest among the 12 year old children (median = 4.3 µg/day). Thirty-five percent of the 4 year old children reached the recommended intake of 7.5 µg vitamin D/day. Among the older children 11-14 % reached the recommended intake (Table 21).

Table 21. *Intake of dioxins and dl-PCBs, fatty acids and vitamin D among children, based on consumption data from Riksmaten 2003.*

Dioxin intake (pg/kg/day)							
Group	**Scenario[a]**	**P05**	**Median**	**P95**	**N**	**Percentage above the guideline intake[b]**	**Number over guideline intake**
Children 4 yrs	1	0.45	0.94	2.3	488	7	36
	2	0.45	1.0	2.5	488	9	45
	3	0.44	0.93	2.1	488	7	33
Children 8 yrs	1	0.31	0.77	2.1	718	6	43
	2	0.31	0.81	2.6	718	8	56
	3	0.31	0.75	2.1	718	5	39
Children 12 yrs	1	0.19	0.53	1.7	876	4	39
	2	0.19	0.54	1.8	876	4	39
	3	0.19	0.53	1.7	876	4	39
Intake EPA + DHA (mg/day)							
Group	**Scenario**	**P05**	**Median**	**P95**	**N**	**Percentage above the guideline intake[c]**	**Number over guideline intake**
Children 4 yrs	1.2.3	16	92	350	488	30	144
Children 8 yrs	1.2.3	13	120	530	718	29	207
Children 12 yrs	1.2.3	10	120	540	876	24	211
Intake vitamin D (µg/day)							
Group	**Scenario**	**P05**	**Median**	**P95**	**N**	**Fraction over guideline intake[d]**	**Number over guideline intake**
Children 4 yrs	1.2.3	2.2	5.1	15	488	35	169
Children 8 yrs	1.2.3	2.3	4.8	10	718	14	98
Children 12 yrs	1.2.3	1.9	4.3	9.8	876	11	99

[a] Scenario 1: Exemption for the entire Baltic Sea. Scenario 2: Exemption and consumption of locally caught BS herring from ICES 30 and 31. Scenario 3: No exemption.
[b] Tolerable daily intake (TDI) for dioxins of 2 pg/kg/day.
[c] Adequate intake for EPA + DHA of 150 mg/day (4-year-olds), 150 mg/day (8-year-olds) and 250 mg/day (12-year-olds).
[d] Recommended intake of vitamin D of 7.5 µg/day.

Estimations of number of women/children at risk of exceeding TWI
Based on the results from scenarios 2 and 3 a rough estimate can be made of how many more young women and children in northern Sweden that would exceed TWI for dioxins and dl-PCBs by consuming locally caught herring in the case of a continued exemption from the maximum limits, as compared with the scenario with no exemption (Table 23). The calcu-lations indicate that between 4,000 and 6,000 more women risk getting an intake above TWI if the exemption is made permanent. A similar calculation among children indicates that between 200 and 400 more 4 and 8 year old children face the risk of exceeding TWI in the case of a permanent exemption.

Table 23. *Number of young women in ages 18-45 years and children from the northern counties of Sweden exceeding TWI in case of an exemption from the maximum limits based on intake scenario 2 and 3*

Group	Total number[a]	% exceeding TWI no exemption	% exceeding TWI with exemption	Number of women/children
Women Riksmaten 1997-98	190260	0.6	3.0	4500
Women 2010	189924	2.0	5.0	5700
Children 4 yrs 2003	10675	7.0	9,0	213
Children 8 yrs 2003	12740	5.0	8.0	382
Children 12 yrs 2003	17063	4.0	4.0	0

[a]Number of women in the northern counties of Sweden in the ages of 18-45 years, and children of 4, 8 and 12 years of age 1997 and 2010 (women) and 2003 (children) (SCB 2010).

Number of consumers with high BS herring intake

From the scenario calculations presented above estimation was made of the BS herring consumption among women and children exceeding the TWI in the scenario of a continued exemption from the maximum limits of dioxins and dl-PCBs. It was shown that the median consumption of BS herring among children exceeding the TWI ranged from 6 servings per year among 4 year old children to 18 servings per year for 8 year old children (1.5 portion/ month). Among women of ages 18 to 45 years exceeding the TWI the median BS herring consumption was estimated to about 2 portions/month. Based on this information and BS herring consumption data from the MHE surveys the number of consumers with high BS herring consumption in Sweden was estimated.

MHE 2003 and 2007
The Riksmaten studies have relatively few participants which makes the results uncertain. The uncertainties can better be illustrated with the help of the consump-tion data from MHE 2007 (adults) and MHE 2003 (children). These studies had between 15,000 and 25,000 participants. In Riksmaten 1997-98 and Riksmaten 2010 the young women who exceeded the tolerable intake of dioxins and dl-PCBs in scenario 2 of the intake calculations had a median consumption of BS herring

of about 2 portions per month. Using the data in MHE 2007 on the proportion of women, living in the northern counties of Sweden, who consumed BS herring twice a month or more, an estimation was made of the number of women who risk exceeding TWI if Sweden gets a permanent exemption for herring (Table 24).

Table 24. *Number of young women (18-45 yrs) living in the northern counties of Sweden who consume BS herring twice a month or more, based on consumption data from MHE 2007*

County	Total number of women[a]	Lower 95 % CI % / number	Mean % / number	Upper 95 % CI % / number
Gävleborg	44563	2.3 / 1024	8.1 / 3610	27 / 12077
Västernorrland	38984	1.1 / 440	3.1 / 1209	9.1 / 3548
Jämtland	20799	1.5 /312	5.7 / 1186	23 / 4721
Västerbotten	46306	1.7 /787	4.1 / 1899	10 / 4630
Norrbotten	39518	0.8 / 316	4.0 / 1581	20 / 7904
Total number	190170	2879	9485	32880

[a]Number of women in the age of 18-45 yrs in northern counties of Sweden in 2007 (SCB 2010).
CI=confidence interval.

This calculation suggests that on average 9,500 women in the northern counties of Sweden had a consumption of BS herring, which gives an increased risk of exceeding TWI if Sweden is exempted from the maximum limits in BS herring (Table 24). The uncertainty in this calculation is illustrated by the fact that the 95 % confidence interval ranges from 2,900 to 33,000 women. Taken together the calculations reported in Table 23-24 indicate that many thousands of women in childbearing age, living in the northern counties of Sweden, are faced with an increased risk of exceeding TWI for dioxins and dl-PCBs if the exemption is made permanent.

Tabell 25. *Number of children of ages 4 and 12 years, living in the northern counties of Sweden, who consume BS herring once a month or more, based on consumption data from MHE 2003*[a]

County	Total number of children [b]	Lower 95 % CI % / number	Mean % / number	Upper 95 % CI % / number
4 years				
Gävleborg	2436	1.7 / 41	3.9 / 95	8.5 / 207
Västernorrland	2303	1.6 / 37	3.4 / 78	7.2 / 166
Jämtland	1145	1.1 / 13	2.7 / 31	6.5 / 74
Västerbotten	2436	2.1 / 51	4.3 / 105	8.4 / 205
Norrbotten	2355	2.2 / 52	4.6 / 108	9.3 / 219
Total number	10675	194	417	871
12 year				
Gävleborg	4078	3.1 / 126	6.8/ 277	15 / 612
Västernorrland	3422	1.4 / 48	3.9 / 133	11 / 376
Jämtland	1899	0.6 / 11	1.8 / 34	5.6 / 106
Västerbotten	3908	2.0 / 78	4.3 / 168	8.7 / 340
Norrbotten	3756	1.0 / 38	2.4 / 90	12 / 451
Total number	17063	301	702	1885

[a]Number of children of ages 4 and 12 years in the northern counties of Sweden in 2003 (SCB 2010).
CI=confidence interval.

Using the data on BS herring consumption from the MHE 2003 study it was estimated that on average 400 children 4 years of age, living in the northern counties of Sweden, consume BS herring once a month or more, thus facing a risk of exceeding the TWI if Sweden gets an exemption (95 % confidence interval: 190-870). For 12 year old children the corresponding number is 700 children (95 % CI: 300-1 900 children) (Table 25).

Consumption of wild salmonids

Similar scenario calculations, as those for BS herring, are not possible to conduct for wild-caught salmonid fish, since the consumption data for this type of fish is very uncertain, or totally lacking. The problem with the high levels of dioxin and dl-PCBs in this type of fish can however be illustrated by calculations of how many portions of these types of fish that can be consumed without exceeding the TWI, if the dioxin intake from other foods were equal to the median intake in the Riksmaten surveys. For women in childbearing age, two to three servings of wild salmonid fish per month were, in most cases, enough to exceed the TWI (Table 26). The TWI was in many cases exceeded when 4 year old children consumed wild-caught salmonids once a month (Table 26). Since there is a good availability of salmon with relatively low levels of dioxins and dl-PCBs on the Swedish food market, there is no increased health benefits connected to an exemption for wild-caugth salmonid fish from the maximum limits of dioxins and dl-PCBs.

Table 26. *Consumption of wild salmonid fish from the Baltic Sea, Lake Vänern and Lake Vättern, and the risk for exceeding TVI among women in childbearing age and 4 year old children*

Type of fish	Average level (pg TEQ/g)	Median intake (pg/kg/week)	2-3/yrs (pg/kg/w)	1/month (pg/kg/w)	2-3 /month (pg/kg/w)	1/w (pg/kg/w)
Women						
Baltic salmon	9.4	3.5	4.7	7.2	14	22
Baltic trout	8.5	3.5	4.6	6.8	13	20
Vänern salmon	5.3	3.5	4.2	5.6	9.4	14
Vänern trout	5.3	3.5	4.2	5.6	9.4	14
Vänern whitefish	8.3	3.5	4.6	6.8	13	20
Vättern salmon	7.0	3.5	4.4	6.3	11	17
Vättern trout	5.7	3.5	4.2	5.7	9.9	15
Vättern arctic char	15	3.5	5.4	9.4	20	33
Vättern whitefish	2.6	3.5	3.8	4.5	6.4	8.6
Children 4 yrs						
Baltic salmon	9.4	6.5	9.6	22	44	72
Baltic trout	8.5	6.5	9.3	21	40	66
Vänern salmon	5.3	6.5	8.2	15	28	43
Vänern trout	5.3	6.5	8.2	15	28	43
Vänern whitefish	8.3	6.5	9.2	20	40	64
Vättern salmon	7.0	6.5	8.8	18	34	55
Vättern trout	5.7	6.5	8.4	16	29	46
Vättern arctic char	15	6.5	11	31	66	110
Vättern whitefish	2.6	6.5	7.4	11	17	25

Serving size =125 g; Women's weight: 64,5 kg (SNV, 2008); Weight 4 year old children: 18 kg;
TVI: 14 pg/kg body weight/week.

Conclusion – risk and benefit characterization

In conclusion, the scenario calculations indicate that children and women in childbearing age, who live in the northern counties of Sweden and who eat locally-caught BS herring, face the risk of exceeding the TWI without gaining an increased health benefit from consuming this type of fish. In this case, a continued exemption from the established maximum limits of dioxins and dl-PCBs may result, in the worst case, that thousands more children and young women will exceed the TWI than if there is no exemption. Calculations, with regard to consumption of wild-caught salmonid fish, reveal that just a few servings per month would be enough for young women to exceed the TWI. A high risk for small children to exceed TWI was evident at a consumption level of just once per month.

The data on commercial fishing of BS herring show that only a small portion of the BS herring commercially caught in Sweden do not comply with the maximum limits of dioxin and dl-PCB. It is therefore most likely that the availability of BS herring on the Swedish market will not be influenced if the exemption was to be terminated, since the fish not complying with the limits would most certainly be replaced with BS herring complying with the limits. Moreover, farmed salmon with dioxin and dl-PCB levels below the maximum limit dominates the Swedish market. The availability of salmon in the food stores would not be influenced if Sweden lost the exemption. As a consequence there is no risk of negative health effects in the general Swedish population due to a decreased consumption of BS herring and salmon, causing a decreased intake of the fatty acids EPA and DHA, and vitamin D, in the case Sweden lost the exemption. In case of an exemption there would be no increased health benefit for the general Swedish consumers connected to consumption of BS herring and wild-caught salmonid fish with dioxins and dl-PCB levels above the maximum limits.

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Appendix 1
Fish consumption in Sweden
- The Swedish Environmental Health Reports

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Background

In 2003 and 2007 nationwide questionnaire surveys were carried out by the Swedish National Board of Health and Welfare, and the Institute of Environmental Medicine (IMM), Karolinska Institutet [1-2]. The aim of the Children´s Environmental Health Questionnaire Survey 2003 (BMHE 2003) was to describe the health status of children in Sweden and the survey included questions about food allergy, skin allergy, asthma and other airway symptoms [1]. Questions regarding the child´s exposure to pets, parental smoking, mould, noise, air pollutants and toxic substances were also answered by the survey participants, as well as questions about dietary habits. The questionnaire was sent out to 40 000 children of ages 4, 8 and 12 years, and the response rate was 71 % [1]. In the National Environmental Health Survey 2007 (NMHE 2007) 43 905 randomly selected adults of ages 18-80 years were approached with a questionnaire [2]. The aim was to determine exposure to various prioritised environmental factors, and assess the health risks associated with these environmental factors. The survey aimed at, if possible, estimating the extent to which health effects are due to environmental factors. The response rate was 59 %. [2]

BMHE 2003 and NMHE 2007 included questions about total fish consumption in general and consumption of Baltic Sea herring in particular [1-2]. The aim of the current report was to use the data from these questions to investigate the fish consumption in general in Sweden and more specifically the consumption of Baltic Sea (BS) herring. The surveys give an opportunity to look at how fish consumption is related to age and sex of consumers, and if there are regional differences in consumption. The results in this report have been used in the risk-benefit assessment of dioxin- and PCB-contaminated Baltic Sea herring, performed by the Swedish National Food Agency (SNFA) as a part of SNFA´s report to the Swedish Government regarding dioxins and PCBs in fish from the Baltic Sea area.

Methods

NMHE 2007 and BMHE 2003 are cross-sectional studies and the study participants were selected by stratified sampling [1-2]. In NMHE 2007 a post-stratification was also performed by Statistics Sweden (SCB) with the aim to correct for biases in study participation regarding certain key variables. In the statistical analyses of data, weights that SCB determined for stratification and post-stratification were used in correction of data for differences in study participation between strata.

The results are presented as percentages of the Swedish population that consumes fish in general and Baltic Sea herring. Confidence intervals are based on analyses of logarithmic transformed data. Data for 8 year old children in BMHE 2003 were not included in the analysis, since population sampled included Stockholm County only.

The questions about fish consumption were as follows:

NMHE 2007

How often do you on average eat fish?
A. Total fish consumption
B. Baltic Sea herring

Frequencies	
1	4 times/week or more
2	2-3 times/week
3	1 time/week
4	2-3 times/months
5	1 time/month
6	More seldom/never

BMHE 2003

How often does your child on average eat fish?
How often does your child on average eat Baltic Sea herring?

Frequencies	
1	3 times/week or more
2	2 times/week
3	1 time/week
4	1-3 times/month
5	less than 1 time/month
6	never

In BMHE 2003 the questions about fish consumption were included in the nation-wide questionnaire to children of ages 4 and 12 years.

Results and discussion

NMHE 2007 – adults in the general population

Total fish consumption

Fish is generally a good source of several nutrients and contributes on average one-quarter to the total intake of vitamin D, B12 and selenium. Moreover, fish consumption commonly contributes 80 % to the total intake long-chain n-3 fatty acids from the diet [3]. As a part of the advice regarding healthy food habits, SNFA recommends the consumers to eat fish and shellfish 2-3 times per week. The consumers are also advised to vary the type of fish consumed [4].

Table 1. *Total fish consumption among Swedish consumers of ages 18-80 years in 2007, based on NMHE 2007*

Consumption	% (N)	95 % CI[a]	
	Mean	Lower	Upper
Seldom/never	7.2 (1541)	6.7	7.7
1 time/month	10.5 (2311)	9.9	11.0
2-3 times/month	23.0 (5671)	22.3	23.8
1 time/week	39.2 (10264)	38.3	40.0
2-3 times/week	18.6 (4937)	18.0	19.3
≥4 times/week	1.5 (350)	1.3	1.8

[a]Confidence interval

The NMHE 2007 shows that 40 % of Swedish adults ate fish less than once a week in 2007 (Table 1). A consumption of fish once a week was reported by 39 %, whereas 20 % consumed fish 2-3 times per week. The survey suggests that only one fifth of the adult consumers in Sweden consumed fish at the level of SNFA´s recommendation for healthy food habits. This is probably a slight underestimation, since the question about fish consumption in the NMHE 2007 did not include shellfish. In 2008 SNFA did a survey of food habits among adults in Sweden with 1000 participants of ages 16-80 years [5]. The participation rate was 50 % compared to 59 % in the NMHE 2007. The participants were asked about how often they consumed fish and shellfish as a main course. About 30 % of the participants answered that they consumed fish and shellfish twice a week or more [5].

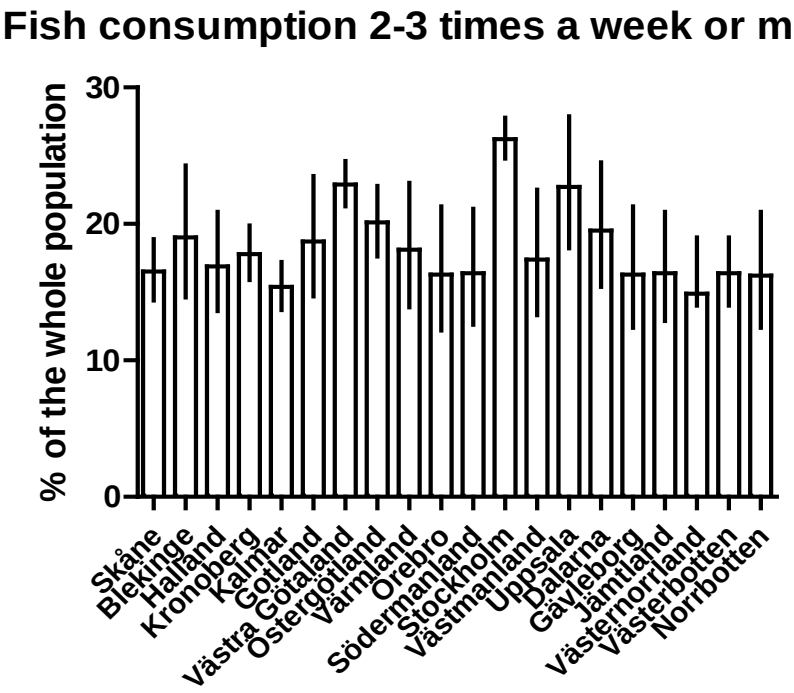

Figure 1. *Percentage of the Swedish adult population (18-80 years old) who consumed fish 2-3 times a week or more in 2007 (N=25074). Results from different Swedish counties.*

A detailed analysis of the percentage of adults eating fish 2-3 times/week or more in NMHE 2007 shows that the adult population in the counties of Stockholm, Västra Götaland and Uppsala had the highest percentages of consumers with high fish consumption (over 20 % of the population) (Figure 1). These three regions represent about 1/3 of the total population in Sweden, with urban areas such as Stockholm/Uppsala and Gothenburg.

Total fish consumption increased with age, both among men and women (Table 2). Among women of ages 18-44 years on average 15-16 % consumed fish 2-3 times/week or more, whereas 31 % of the women of ages 65-80 had the same consumption rates (Table 2). The percentage of women seldom or never consuming fish decreased with age from on average 16 % at ages 18-24 years to 3 % at 65-80 years. A similar pattern was observed for men (Table 2).

This positive association between age and fish consumption has been proposed to depend on several factors, among them an increased positive attitude toward fish consumption with age, an increased health involvement with age, and increased perception of convenience of fish consumption with age [6].

Table 2. *Age dependency of total fish consumption among Swedish women and men (mean and 95 % confidence interval) of ages 18-80 years in 2007*

Age (years)	Seldom/never (%)	Once/mo (%)	2-3 times/mo (%)	Once/wk (%)	2-3 times/wk (%)	≥4 times/wk (%)
Women						
18-24	16.2 (13.3-19.6)	13.7 (11.1-16.8)	25.3 (21.9-29.0)	29.8 (26.2-33.6)	13.3 (10.9-16.3)	1.7 (0.9-3.1)
25-34	11.1 (6.0-9.0)	12.7 (10.7-14.9)	26.6 (24.0-29.3)	34.2 (31.4-37.1)	14.3 (12.4-16.5)	1.1 (0.7-1.8)
35-44	7.4 (6.0-9.0)	12.0 (10.2-14.1)	25.8 (23.5-28.3)	38.8 (36.1-41.5)	14.6 (12.8-16.7)	1.4 (0.9-2.2)
45-54	4.4 (3.4-5.8)	9.4 (7.9-11.1)	24.2 (21.9-26.7)	40.3 (37.6-43.0)	19.4 (17.4-21.6)	2.2 (1.5-2.3)
55-64	4.3 (3.3-5.6)	6.9 (5.7-8.5)	17.5 (15.7-19.6)	45.3 (42.7-47.9)	24.1 (22.0-26.3)	1.9 (1.2-2.8)
65-80	3.1 (2.3-4.1)	4.4 (3.4-5.6)	14.3 (12.6-16.3)	47.0 (44.4-49.6)	30.1 (27.8-32.5)	1.2 (0.7-2.0)
Men						
18-24	11.6 (9.0-14.8)	13.8 (10.9-17.3)	25.5 (21.7-29.8)	31.6 (27.4-36.0)	15.3 (12.3-19.0)	2.2 (1.0-4.4)
25-34	11.2 (9.2-13.7)	14.9 (12.4-17.7)	27.9 (24.8-31.1)	31.1 (27.9-34.4)	13.8 (11.5-16.4)	1.2 (0.6-2.6)
35-44	7.8 (6.3-9.7)	14.8 (12.7-17.2)	27.8 (25.2-30.6)	35.7 (32.9-38.6)	12.4 (10.6-14.4)	1.5 (0.9-2.5)
45-54	6.8 (5.4-8.7)	10.1 (8.5-12.1)	25.3 (22.7-28.0)	40.0 (37.0-43.0)	16.4 (14.3-18.7)	1.4 (0.9-2.2)
55-64	4.7 (3.6-6.1)	8.7 (7.1-10.5)	22.2 (20.0-24.6)	43.0 (40.4-45.8)	19.6 (17.6-21.7)	1.8 (1.3-2.7)
65-80	3.6 (2.7-4.9)	6.8 (5.5-8.4)	15.8 (14.0-17.8)	45.7 (43.0-48.4)	27.0 (24.7-29.5)	1.0 (0.6-1.6)

Fish consumption differed between adults born in Sweden and adult residents in Sweden born in other countries (Table 3). Low fish consumption (once a month or less) was more common among adult immigrants than among adults born in Sweden (Table 3). Moreover, a higher percentage of Sweden-born adults than adult immigrants consumed fish 2-3 times/ week, whereas the reverse was evident for consumption rates of 4 times/week or more (Table 3).

Table 3. *Total fish consumption (mean and 95 % confidence interval) among adults of ages 18-80 years in 2007, born in Sweden or in other countries*

Country of birth	Seldom or never (%)	Once/mo (%)	2-3 times/mo (%)	Once/wk (%)	2-3 times/wk (%)	≥4 times/wk (%)
Sweden	6.9 (6.4-7.4)	9.7 (9.1-10.2)	23.4 (22.6-24.2)	39.2 (38.8-40.6)	19.2 (18.5-19.9)	1.3 (1.1-1.5)
Other	9.0 (7.6-10.6)	14.7 (12.9-16.8)	21.2 (19.2-23.3)	36.5 (34.0-38.9)	15.8 (14.1-17.7)	2.8 (2.0-3.8)

Consumption of Baltic Sea (BS) herring

The SNFA has issued an advice regarding consumption of BS herring due to high levels of dioxins and PCBs in this type of fish. Since 2008, children and women in childbearing age are advised to consume BS herring not more than 2-3 times per year [4]. The advice for girls and women in childbearing age in 2007 was to eat BS herring not more than once a month, and for boys not more than once a week. Other consumers (men and older women) have since 1995 been advised not to eat this type of fish more than once a week [7].

Table 4. *Consumption of BS herring among Swedish consumers of ages 18-80 years in 2007*

Consumption	**% (N)**	**95 % CI[a]**	
	Mean	**Lower**	**Upper**
Seldom/never	64.3 (15355)	63.4	65.1
1 time/month	19.3 (4953)	18.6	20.0
2-3 times/month	9.0 (2308)	8.5	9.5
1 time/week	6.2 (1634)	5.8	6.6
2-3 times/week	1.0 (265)	0.9	1.2
≥4 times/week	0.2 (42)	0.2	0.4

[a]Confidence interval

NMHE 2007 showed that over 80 % of adults in Sweden consumed BS herring once a month or less (Table 4). About 16 % consumed herring 2-3 times per month or more. Based on the data in Table 4, it is possible to do a rough calculation of the amount of BS herring that was consumed in Sweden by adults in 2007, using an estimated average portion size of 125 g (Table 5). The total population of adults in ages 18-80 years was 7 251 000 in 2007 [8]. Although only 6 % of the population consumed BS herring once a week, this part of the population in total consumed almost 3000 tonnes of BS herring according to MHE 2007, which is about one third of the total amount of BS herring consumed (9 600 tonnes) (Table 5). The total amount of herring caught for human consumption in 2007 was, according to the Swedish Board of Fisheries, about 20 000 tonnes. This refers to whole fish weight. The estimate of BS herring from NMHE consequently was well within the amount caught for human consumption by the fishery industry in 2007. If a weight loss of 50 % during preparation of the herring for consumption is assumed, the total amount of BS herring caught for consumption was 10 000 tonnes, which is close to the estimate in Table 5. This shows that the reported BS herring consumption in NMHE 2007 gives a realistic estimate in relation to the amount of BS herring caught for consumption by the industry. In the estimate in Table 5, consumption of non-commercial caught BS herring is included. As shown below (see Table 13), children contribute very little to the total BS herring consumption in Sweden.

Table 5. *Total amount of BS herring consumed by adults (18-80 years) in 2007 in Sweden, based on NMHE 2007*

Consumption	Seldom/never	1/mo	2-3/mo	1/wk	2-3/wk	≥4/week
Percent	64.3	19.3	9.0	6.2	1.0	0.2
Number of consumers	4662400	1399400	653500	449600	72500	14500
Portions/year	1	12	30	52	130	208
g herring/year	125	1500	3750	6500	16250	26000
Total consumption (metric tonnes/yr)	582	2099	2451	2922	1178	377
Sum of consumption (tonnes/yr)	9609					

Total population of adults in ages 18-80 years was 7 251 000 in 2007 [8].

As with the total fish consumption, BS herring consumption increased with age among both women and men (Table 6). The percentage of women consuming BS herring once a week or more increased from 2.1 % in the age group 18-45 years to 22 % in the age group 66-80 years. Among men of ages 18-45 years 3.5 % consumed BS once a week or more whereas 21 % of men in the age group 66-80 years had the same consumption frequency (Table 6). The young women were reported to consume BS herring less frequently than the young men, since 83 % of the young women reported a very low consumption compared with 73 % of the young men (Table 6).

Table 6. *Age-dependent BS herring consumption (mean and 95 % conficence interval) among Swedish women and men in 2007*

Age (N)	**Consumption (% of the Swedish population)**					
	Seldom/never	**1/month**	**2-3/month**	**1/week**	**2-3/week**	**≥4/week**
Women						
18-45 yr	83.1	11.1	3.7	1.5	0.5	0.1
(5674)	(81.6-84.4)	(10.0-12.3)	(3.0-4.5)	(1.1-2.1)	(0.3-0.9)	(0.1-0.4)
46-65 yr	62.9	20.7	9.7	5.0	1.2	0.5
(5283)	(61.0-64.8)	(19.2-22.4)	(8.6-10.9)	(4.2-5.9)	(0.8-1.8)	(0.2-0.9)
66-80 yr	36.2	25.5	16.3	18.2	3.6	0.2
(2665)	(33.6-38.9)	(23.2-28.0)	(14.4-18.5)	(16.1-20.4)	(2.7-4.7)	(0.1-0.6)
Men						
18-45 yr	72.9	18.1	5.4	3.3	0.1	0.1
(4326)	(71.1-74.7)	(16.0-19.8)	(4.6-6.5)	(2.6-4.1)	(0.0-0.3)	(0.1-0.6)
46-65 yr	55.1	24.5	12.2	7.2	0.9	0.2
(4588)	(53.1-57.1)	(22.8-26.3)	(10.9-13.6)	(6.2-8.3)	(0.6-1.3)	(0.1-0.4)
66-80 yr	32.6	26.7	19.6	17.6	2.9	0.6
(2312)	(30.0-35.4)	(24.2-29.3)	(17.4-22.1)	(15.5-20.0)	(2.1-4.0)	(0.3-1.3)

In the risk assessment of dioxins and PCB in food, performed by the SNFA in 2007, it was estimated that about 5 % of women in childbearing age in Sweden had an intake of dioxin and dioxin-like PCB at or above the health-based WHO and EU tolerable intake [9]. Among these women 70 % had a BS herring consumption of more than once a month. A consumption of BS herring 2-3 times per month or more among women in childbearing age may therefore be regarded as a "high consumption". Among women in childbearing age (18-45 years) in NMHE

2007 5.8 % (95 % confidence interval (CI): 5.0-6.8 %) consumed BS herring 2-3 times per month or more. The total population of women of ages 18-45 years was 1 647 000 in 2007. Based on the NMHE data it could be estimated that about 103 000 (95 % CI: 82 000-112 000) women consumed BS herring in 2007 at a level that could be considered to entail a high risk for young women to exceed the tolerable intake of dioxins and dioxin-like PCB.

In 2008 NFA revised the health-based advisory regarding BS herring consumption, and currently women in childbearing age are advised to eat BS herring not more than 2-3 times per year [4]. In 2007 about 83% of the women in childbearing age (18-45 yrs) seldom or never consumed BS herring (Table 6), and can be said to have complied with the current advisory to women in child-bearing age. The proportion of women consuming BS herring once a month or more, thus not complying with the current advise, was 16.9 % (95 % CI: 15.6-18.4 %), corresponding to 280 000 women (95 % CI: 257 000-303 000) in 2007.

Among women of ages 46-65 years 1.7 % (95 % CI: 1.2-2.3 %) consumed BS herring more than once a week, thus not complying with the SNFA advice in 2007 and current advice. Based on a population of 1 181 200 women in this age group in 2007, about 20 000 (95 % CI: 14 000-27 000) women consumed more BS herring than advised by the NFA. For ages 66-80 years, 3.8 % (2.9-5.0 %) consumed BS herring more than once a week, corresponding to 22 000 women (17 000-29 000). In total approximately 40 000 women in ages 46-80 years consumed more herring than the SNFA advice in 2007.

A similar calculation for men of ages 18-80 years shows that 1 % (95 % CI: 0.8-1.3 %) consumed BS herring more than once a week in 2007. In total there were 3 416 900 men in 2007, and of those 34 169 men (95 % CI: 27 335-44 420) consumed more BS herring than advised by the SNFA.

Taken together, the results from NMHE 2007 show that the majority of the adults in Sweden had acceptable consumption rates of BS herring from a health risk point-of-view. Nevertheless, about 100 000 young women consumed BS herring at rates that may be considered too high from a health risk point-of-view. Moreover, about 40 000 older women and 34 000 men had a BS herring consumption that was too high in comparison the NFA´s advice to these consumer groups.

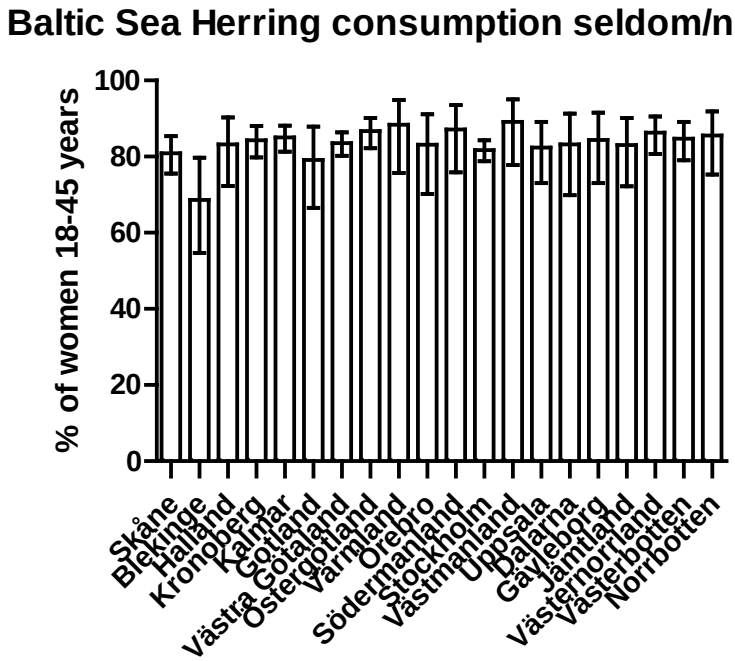

Figure 2. *The percentage of women in childbearing age (18-45 years) consuming Baltic Sea herring less than once a month (seldom or never) in the different counties of Sweden in 2007. Results are presented as mean and 95 % confidence interval.*

A more detailed analysis of regional differences in BS herring consumption suggested that the counties of Blekinge and Gotland had the lowest proportion of women in childbearing age (less than 80 %) with a low consumption of BS herring (Figure 2). Both these counties are located along the Baltic Sea coast in the southern part of Sweden, with a high availability of BS herring for the consumers. In Södermanland, Östergötland, Kalmar, Värmland, Västmanland, Västernorrland and Västerbotten counties, ≥85 % of young women reported low BS herring consumption. These counties are both situated in the eastern part of Sweden along the Baltic Sea coast and in the western part of the country. When looking at young women with high BS herring consumption (2-3 times per month or more), on average over 10 % of the women in childbearing age in Blekinge and Gotland consumed BS herring 2-3 times per month or more (Figure 3). However, as shown in Figure 2 and 3 the uncertainty of the data makes it difficult to draw firm conclusions about regional differences in BS herring consumption among young women.

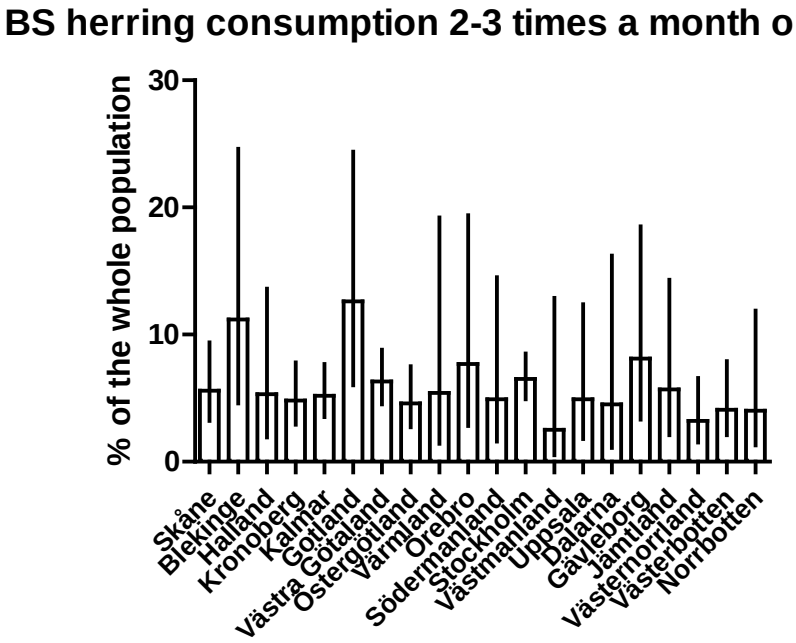

Figure 3. *The percentage of women in childbearing age (18-45 years) consuming Baltic Sea herring 2-3 times per month or more in the different counties of Sweden in 2007. Results are presented as mean and 95 % confidence interval.*

The BS herring caught in the northernmost part of the Baltic Sea, called the Gulf of Bothnia, show higher levels of dioxins and dioxin-like PCBs than BS herring from other parts of the Baltic Sea [10]. The counties of Gävleborg, Jämtland, Västernorrland, Västerbotten and Norrbotten are the Swedish counties closest to the Gulf of Bothnia. In these "Gulf of Bothnia counties" more than 90 % of the women in ages 18 to 45 years consumed BS herring once a month or less in 2007 (Table 7). Gävleborg county had the highest proportion of young women eating BS herring twice a month or more. However, since the uncertainty of the data was large, it is not possible to conclude if there were differences in BS herring consumption between the studied counties.

Table 7. *Consumption of Baltic Sea herring among women in childbearing age (18-45 year) in the counties of Sweden closest to the Gulf of Bothnia in 2007(mean (95 % confidence interval))*

County (N)	Consumption (% of population)	
	1/month or less	2-3/month or more
Gävleborg (67)	91.9 (81.5-96.7)	8.1 (3.3-18.5)
Västernorrland (215)	96.8 (93.4-98.5)	3.2 (1.5-6.6)
Jämtland (72)	94.3 (85.7-97.9)	5.7 (2.1-14)
Västerbotten (200)	95.9 (92.1-97.9)	4.1 (2.1-7.9)
Norrbotten (70)	96.0 (88.1-98.7)	4.0 (1.3-12)

Despite the uncertainty of the data, it is possible to estimate the number of women in child-bearing age in the Gulf of Bothnia counties that in 2007 consumed BS herring 2-3 times per month or more (Table 8). As suggested above, this consumption pattern may increase the risk for young women to exceed the tolerable intake of dioxins and dioxin-like PCBs. The calculations suggest that on average 10 000 women in ages 18-45 years had a high consumption of BS herring in 2007 (Table 8). Using the lower and upper confidence intervals, the number of women with a "risk consumption" of BS herring ranged from 4 000 to 22 000 in the Gulf of Bothnia counties.

Table 8. *The number of young women (18-45 years old) living in the 5 northern-most counties of Sweden consuming BS herring twice a month or more*[a]

County	Total number of women[b]	Lower 95 % CI % / number	Mean % / number	Upper 95 % CI % / number
Gävleborg	44563	3.3 / 1471	8.1 / 3610	19 / 8467
Västernorrland	38984	1.5 / 585	3.2 / 1247	6.6 / 2573
Jämtland	20799	2.1 /437	5.7 / 1186	14 / 2912
Västerbotten	46306	2.1 /972	4.1 / 1899	7.9 / 3658
Norrbotten	39518	1.3 / 514	4.0 / 1581	12 / 4742
All 5 counties	190170	3979	9523	22352

[a]CI=confidence interval.
[b]Number of women of ages 18-45 years living in the five counties in 2007 [11].

Based on the population statistics and the data on the regional consumption of BS herring in the 5 "Gulf of Bothnia counties", it is possible to do a rough calculation of the amount of BS herring consumed by adults in this area in 2007 (Table 9). The calculation suggests that about 1200 tonnes of BS herring was consumed by adults in the Gulf of Bothnia counties. The total amount of herring caught for human consumption in the Gulf of Bothnia (ICES 30 and 31) was according to the Swedish Board of Fisheries, on average 1300 tonnes per year in 2007-2009. The estimated BS herring consumption among adults from NMHE

consequently was close to the amount caught for human consumption by the fishery industry in the Gulf of Bothnia. If a loss of 50 % during preparation of the herring for consumption is assumed, the average amount of BS herring comercially caught for consumption was 600 tonnes in ICES 30 and 31, which is close to the estimate in Table 9. Even when taking into account that some of the reported consumption in NMHE consisted of non-commercially caught herring, the reported BS herring consumption in the 5 counties (Table 8) probably gives a realistic estimate of BS herring consumption in comparison the amount of BS herring locally caught for consumption by the fishery industry.

Table 9. *Total amount of Baltic Sea herring consumed by adults (18-80 years) living in the 5 northernmost counties of Sweden in 2007, based on NMHE 2007*

County	Consumers[a]	Consumption (% of consumers)					
	(N)	Seldom/never	1/month	2-3/month	1/week	2-3/week	≥4/week
Gävleborg	205991	59.2	19.1	12.7	7.8	0.9	0.3
Västernorrland	181826	57.8	23.5	9.2	8.5	1.1	0
Jämtland	94279	68.0	19.4	6.5	5.4	0.6	0
Västerbotten	193424	67.5	19.8	5.7	6.0	0.7	0.2
Norrbotten	189928	62.8	21.2	8.3	6.4	1	0.4
Total number of consumers		540987	178549	75806	60374	7672	1764
Portions per year		1	12	30	52	130	208
Kg/year		0.125	1.5	3.75	6.5	16.25	26
Consumption (kg/year)		67623	267823	284273	392433	124685	45877
Total consumption (metric tonnes)							1182.717

[a][11]

NMHE 2007 – adult immigrants

In NMHE 2007, 11 % of the participants were born in other countries than Sweden. A comparison of fish consumption among this consumer group and adults born in Sweden reveals some differences in consumption pattern. Among participants born abroad a higher percentage reported that they seldom or never consumed fish (Table 10). The proportion of adults consuming fish in general according to the SNFA´s advisory (2-3 times/week) was higher among Swedish-born adults than among adults born in other countries. However, a higher percentage of adults born abroad reported that they consumed fish 4 times a week or more (Table 10).

When looking at herring consumption the results were reversed, since a lower percentage of adults born abroad consumed BS herring seldom or never (Table 10). High consumption of BS herring (more than once a month) also seemed to be more common among adult immigrants. NMHE 2007 did not give information about possible reasons behind this difference in BS herring consumption, but it could be speculated that the easy accessibility of the reasonable priced BS herring in the grocery stores could be a factor to consider. On average immigrant families have a lower income than the mean income in the total population in Sweden [11].

Table 10. *Fish consumption in 2007 among adults (18-80 years old) born in Sweden and adult immigrants in Sweden (mean (95 % confidence interval))*

Country of birth	Seldom/never	1/month	2-3/month	1/week	2-3/week	≥4/week
Total fish consumption (% of the total population)						
Sweden	6.9 (6.4-7.4)	9.7 (9.1-10.2)	23.4 (22.6-24.2)	39.7 (38.8-40.6)	19.2 (18.5-19.9))	1.3 (1.1-1.5)
Other countries	9.0 (7.6-10.6)	14.7 (12.9-16.8)	21.2 (19.2-23.3)	36.5 (34.0-38.9)	15.8 (14.1-17.7)	2.8 (2.0-3.8)
Herring consumption						
Sweden	65.0 (64.1-65.9)	19.2 (18.5-20.0)	8.6 (8.1-9.2)	6.1 (5.6-6.5)	0.9 (0.7-1.0)	0.2 (0.1-0.3)
Other countries	60.0 (57.4-62.5)	19.7 (17.7-21.9)	10.8 (9.3-12.6)	7.0 (5.8-8.4)	1.9 (1.3-2.6)	0.6 (0.3-1.4)

BMHE 2003 – children in the general population

Total fish consumption

Among the 4 year old children about 75 % consumed fish once a week or more, whereas 67 % of the 12 year old children had the same consumption pattern (Table 11). The children in BMHE 2003 seemed to consume more fish on average than the adults in NMHE 2007 (Table 1 and 11), especially the 4 year old children. In comparison, about 60 % of the adults consumed fish once a week or more. Although the two surveys were carried out 4 years apart it can be speculated that the higher fish consumption among the children is due to the fact that most children eat lunch at child care centres and in school. In 2003 the SNFA advised the municipalities of Sweden, responsible for the child care centres and schools, to serve one meal of fish per week for lunch to the children [12].

The tendency of a higher rate of fish consumption among the 4 year old children than among the 12 year old children was also reflected by the higher percentage following SNFA's general fish consumption advisory in the younger age group (Table 11). Furthermore, a lower proportion of 4 year old children were reported to seldom or never consume fish. These age-related differences in fish consumption among children is in accordance with the results from SNFA's food consumption survey Riksmaten 2003 regarding children [13].

There were clear regional differences in the proportions of 4 year old children that consumed fish according to the SNFA advisory (Figure 4). The lowest percentages of children consuming fish 2-3 times/week or more were reported from the counties of Blekinge and Västerbotten. The highest percentages were found in Stockholm and Uppsala counties, which is in accordance with the results for adults in MHNE 2007 (Figure 1 and 4).

Table 11. *Total fish consumption among Swedish consumers of ages 4 and 12 years in 2003 (mean (95 % confidence interval))*

Age (N)	Consumption (% of the total population)					
	Never	**<1 /month**	**1-3/month**	**1/week**	**2/week**	**≥3/week**
4 (8264)	1.9 (1.5-2.5)	3.4 (2.9-4.1)	19.3 (17.9-20.8)	47.8 (46.0-49.6)	24.8 (23.3-26.5)	2.7 (2.2-3.3)
12 (9505)	3.3 (2.9-3.8)	6.3 (5.8-7.0)	23.5 (22.4-24.6)	45.6 (44.4-46.9)	19.8 (18.8-20.8)	1.5 (1.2-1.8)

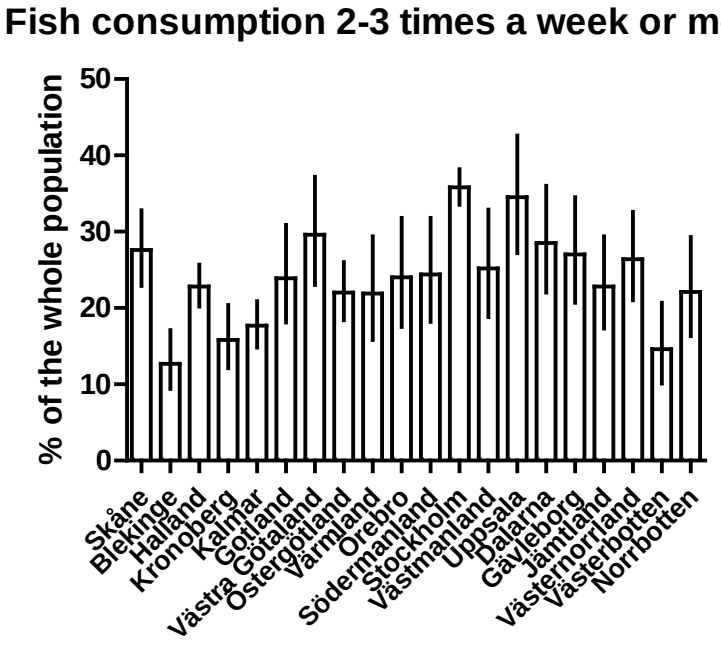

Figure 4. *Percentage of 4 year old children in different counties of Sweden who consumed fish 2-3 times a week or more in 2003 (N=8264).*

Also among the 12 year old children, Blekinge and Västerbotten counties were among the counties that had the lowest percentages of children consuming fish according to SNFA´s advisory, and Stockholm County had the highest percentage of children following the advice (Figure 5). In comparison with the situation for the 4 year old children, fewer counties had a proportion of 20 % or more children that consumed fish 2 times per week or more (Figure 4 and 5).

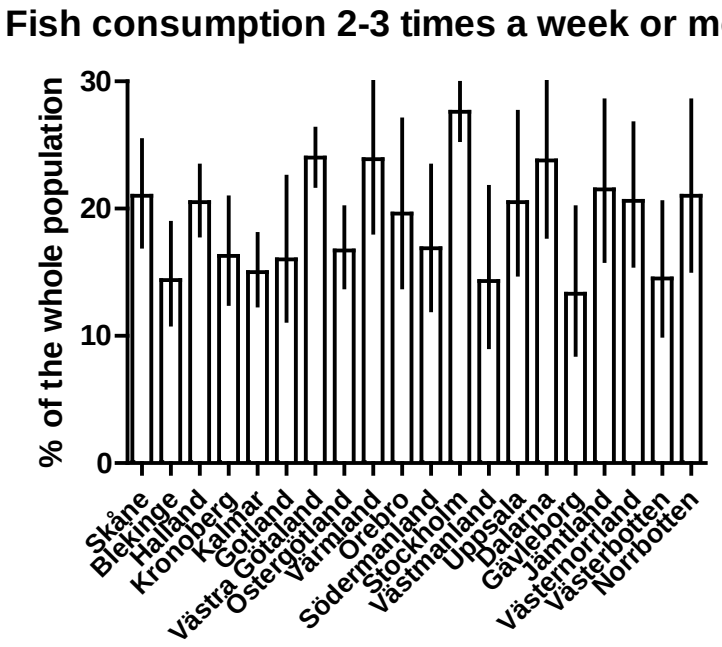

Figure 5. *Percentage of 12 year old children in different counties of Sweden who consumed fish 2-3 times a week or more in 2003 (N=9505).*

BS herring consumption

Close to 95 % of the children consumed BS herring less than once a month (Table 12). It was suggested that the BS herring consumption in general was lower among the children in 2003 than among adults in 2007, since consumption of BS herring less than once a month was reported among 73-83 % young men and women (Table 6). The interpretation of the results has however to be done with caution since the consumption frequencies in the answer to the herring consumption questions differed between BMHE 2003 and MNHE 2007.

In contrast to the age-dependent differences in total fish consumption among the children, no marked differences in BS herring consumption was seen between 4 and 12 year old children (Table 12).

Table 12. *BS herring consumption among Swedish consumers of ages 4 and 12 years in 2003 (mean (95 % confidence interval))*

Age (N)	Consumption (% of the total population)					
	Never	<1 /month	1-3/month	1/week	2/week	≥3/week
4 (8264)	64.7 (63.0-66.4)	30.8 (29.2-32.5)	3.4 (2.8-4.0)	0.9 (0.6-1.3)	0.1 (0.1-0.3)	0.1 (0.0-0.4)
12 (9505)	63.6 (62.4-64.8)	31.2 (30.1-32.4)	4.3 (3.8-4.9)	0.7 (0.5-1.0)	0.1 (0.1-0.3)	0 (0-0.1)

The data in Table 12 can be used to estimate the number of children with high consumption of BS herring in Sweden 2003 (once a month or more). The total number of 4 year old children was 90 459. Consumption of BS herring once a month or more was reported for 4.4 % (95 % CI: 3.8-5.2%) children 4 years of age. This corresponds to 3980 children (CI: 3437-4704). The number of 12 year old children in 2003 was 128 065 and 5.2 % (4.6-5.8 %) of these were high consumers of BS herring. Consequently, 6659 children in this age group (CI: 5891-7428) had a high BS herring consumption.

Similar as for adults in MNHE 2007, the data in BMHE was used in a calculation of the amount of BS herring consumed by the population of 4 and 12 year old children in Sweden 2003 (Table 13). The total consumption of BS herring was estimated to 27 metric tonnes in 2003 among 4 year old children and 46 tonnes among 12 year old children. Consequently, the consumption of BS by children of ages 1 to 17 years in 2003 (about 600 metric tonnes per) were less than 10 % of that of adults (18-80 years) in 2007 (see Table 5). This shows that BS herring consumption among children only gives a small contribution to the total amount of BS herring consumption in Sweden.

Table 13. *Total amount of Baltic Sea herring consumed by 4 and 12 year old children in 2003, based on BMHE 2003*

Consumption	Never	<1/mo	1-3/mo	1/wk	2/wk	≥3/week
4 year old						
Percent	64,7	30,8	3,4	0,9	0,1	0,1
No. of consumers	58721	27954	3085	817	91	91
Portions/year	1	6	24	52	104	208
g herring/year	75	450	1800	3900	7800	15600
Total consumption (tonnes/yr)	4.4	12	5.6	3.2	0.7	1.4
Sum of consumption (tonnes/yr)	27					
12 year old						
Percent	63,6	31,2	4,3	0,7	0,1	0
No. of consumers	81449	39956	5507	896	128	0
Portions/year	1	6	24	52	104	208
g herring/year	88	528	2112	4576	9152	18304
Total consumption (tonnes/yr)	7.2	21	12	4.1	1.2	0
Sum of consumption (tonnes/yr)	46					

The total population of 4 and 12 year old children was 90 459 and 128 065, respectively, in 2003 [11].

Regional differences were obvious when looking at BS herring consumption among the 4 year old children, although the uncertainty of the data sometimes was high (Figure 6). In the counties of Skåne and Blekinge, at the southern BS coast of Sweden, on average more than 6 % children were reported to have a BS herring consumption of once a month or more. In the counties of Örebro, Södermanland and Dalarna less than 1 %, on average, had a BS herring consumption of once a month or more.

As in the case of 4 year old children, regional differences in BS herring consumption were seen among the 12 year old children in 2003 (Figure 7). Similarly as in the case of 4 year old children, the county of Skåne had the highest percentage of 12 year old children consuming BS herring once a month or more, on average more than 8 %. The lowest mean percentages of BS herring consumers, around 2 %, were observed in the counties of Jämtland, Kalmar, Östergötland and Värmland (Figure 7).

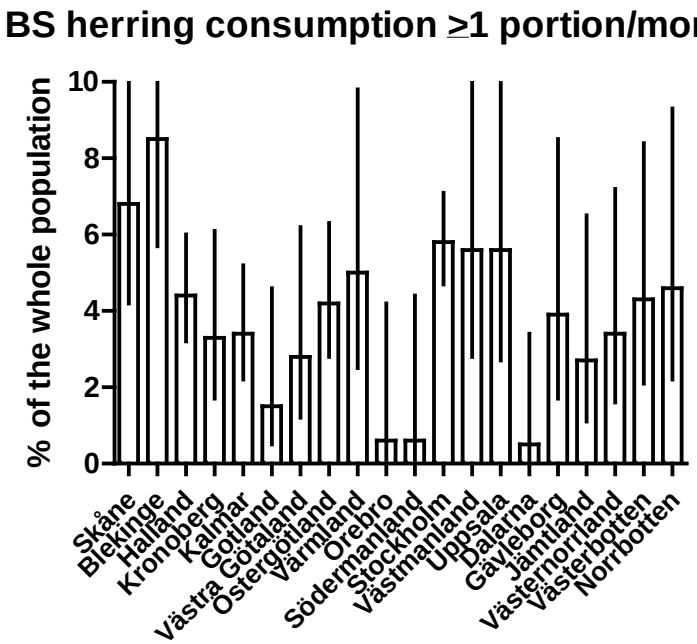

Figure 6. *Percentage of 4 year old children in different counties of Sweden who consumed BS herring once a month or more (mean and 95 % confidence interval; N=8264) in 2003.*

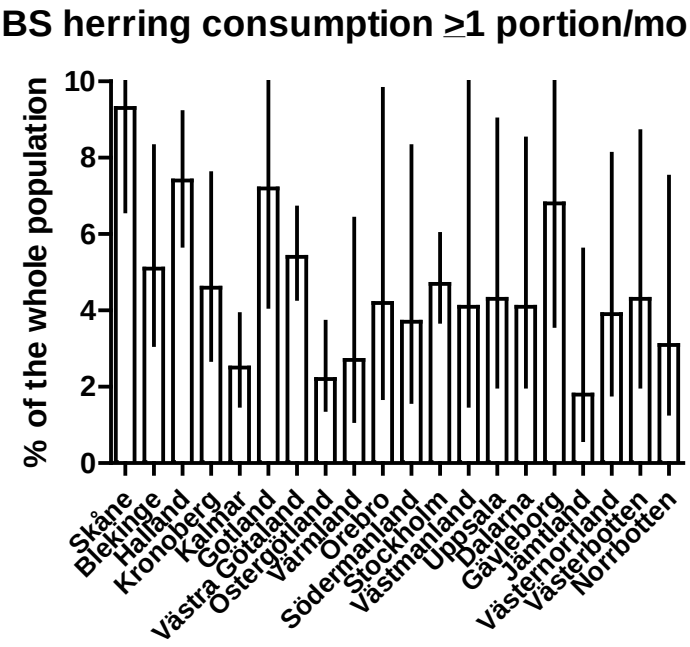

Figure 7. *Percentage of 12 year old children in different counties of Sweden who eat BS herring once a month or more (N=9505).*

No marked differences in BS herring consumption were observed between the "Gulf of Bothnia counties" Gävleborg, Jämtland, Västernorrland, Västerbotten and Norrbotten. On average, more than 95 % of the 4 year old children and over 90 % of the 12 year old children consumed BS herring less than once a month in 2003 (Table 11). On average 3-4 % of the children at the age of 4 years and 2-7 % of the 12 years old children were reported to consume BS herring once a month or more, which may be regarded as a high consumption. The current advice from the NFA is that children should not eat BS herring more than 2-3 times per year.

The number of children in the "Gulf of Bothnia counties" with a high consumption of BS herring was estimated from the percentages in Table 11 and the number of children living in these counties in 2003 (Table 12). Among the 4 year old children about 200 to 900 children had a high consumption, whereas among 12 year old children 300 to 1500 were high consumers (Table 12). The results strongly suggest that in the worst case thousands of children are high consumers of BS herring in the area where the dioxin and dioxin-like PCB levels are highest in BS herring.

Table 11. *Consumption of BS herring among 4 and 12 year old children in the "Gulf of Bothnia" counties of Sweden in 2003(mean and 95 % confidence interval)*

County (N)	Consumption (% of population)	
	<1/month	**≥1/month**
4 year old children		
Gävleborg (163)	96.1 (91.5-98.3)	3.9 (1.7-8.5)
Västernorrland (243)	96.6 (92.8-98.4)	3.4 (1.6-7.2)
Jämtland (189)	97.3 (93.5-98.9)	2.7 (1.1-6.5)
Västerbotten (174)	95.7 (91.6-97.9)	4.3 (2.1-8.4)
Norrbotten (158)	95.6 (94.8-96.2)	4.4 (3.8-5.2)
12 year old children		
Gävleborg (146)	93.2 (87.6-96.4)	6.8 (3.6-12.4)
Västernorrland (223)	96.1 (91.9-98.2)	3.9 (1.8-8.1)
Jämtland (174)	98.3 (94.4-99.4)	1.8 (0.6-5.6)
Västerbotten (175)	95.7 (91.3-98.0)	4.3 (2.0-8.7)
Norrbotten (167)	96.9 (92.5-98.7)	3.2 (1.3-7.5)

Tabell 12. *Estimated number of children of ages 4 and 12 years, living in the 5 northernmost counties closest to the Gulf of Bothnia in 2003, with a BS herring consumption of once a month or more*[a]

County	Total number of children in the counties[b]	Lower 95 % CI % / number	Mean % / number	Upper 95 % CI % / number
4 year old children				
Gävleborg	2436	1.7 / 41	3.9 / 95	8.5 / 207
Västernorrland	2303	1.6 / 37	3.4 / 78	7.2 / 166
Jämtland	1145	1.1 / 13	2.7 / 31	6.5 / 74
Västerbotten	2436	2.1 / 51	4.3 / 105	8.4 / 205
Norrbotten	2355	2.2 / 52	4.6 / 108	9.3 / 219
Total number	10675	194	417	871
12 year old children				
Gävleborg	4078	**3.6 / 147**	6.8/ 277	**12 / 489**
Västernorrland	3422	**1.8 / 62**	3.9 / 133	**8.1 / 277**
Jämtland	1899	**0.6 / 11**	1.8 / 34	**5.6 / 106**
Västerbotten	3908	**2.0 / 78**	4.3 / 168	**8.7 / 340**
Norrbotten	3756	**1.3 / 49**	**3.1** / 90	**7.5 / 282**
Totalt number	17063	**347**	702	**1494**

[a]CI=confidence interval.
[b]2003 [11].

BMHE 2003 – Children in immigrant families

A comparison of fish consumption between children born in Sweden and those not born in the country was done (Table 13). In this comparison the data from all participants in BMHE 2003 was used, also children 8 years of age from Stockholm county. Total fish consumption did not differ markedly between the two groups of children. However, BS herring consumption was more frequent among children not born in Sweden (Table 13). On average about 4 % of the Sweden-born children consumed BS herring once a month or more (CI:4.3-5.1 %), whereas 14.8 % of the immigrant children consumed BS herring at this rate (CI:11.0-19.7). BMHE did not give information about possible reasons

behind this difference in BS herring consumption, but it could be speculated that the easy accessibility of the reasonable priced BS herring in the grocery stores could be a factor to consider. On average immigrant families have a lower income than the mean income in the total population in Sweden [11].

Table 13. *Fish consumption in 2003 among children born in Sweden and not born in Sweden (mean (95 % confidence interval)).*

Country of birth	Never	<1/month	2-3/month	1/week	2/week	≥3/week
Total fish consumption						
Sweden	2.8 (2.4-3.1)	5.1 (4.7-5.5)	21.6 (20.8-22.4)	46.6 (45.6-47.6)	22.1 (21.2-22.9)	1.9 (1.7-2.2)
Other countries	3.6 (2.0-6.6)	8.4 (5.6-12.5)	22.0 (17.5-27.3)	40.4 (34.6-46.4)	22.4 (17.8-27.9)	3.1 (1.8-5.3)
BS herring consumption						
Sweden	64.1 (63.1-65.0)	31.2 (30.3-23.1)	3.8 (3.5-4.2)	0.7 (0.6-0.9)	0.1 (0.1-0.2)	0.1 (0.0-0.2)
Other countries	57.3 (51.4-63.0)	27.9 (23.2-33.2)	9.3 (6.4-13.5)	4.2 (2.2-7.7)	1.2 (0.4-3.7)	0.0 (0.0-0.2)

Conclusions

In conclusion, the BMHE 2003 and NMHE 2007 show that age of the consumer and region of residence are important determining factors for fish consumption in general and BS herring consumption in particular. Among adults, these differences may depend on several factors, among them an increased positive attitude toward fish consumption with age, regional traditions and availability, an increased health involvement with age, and age-dependent perception of convenience of fish consumption with age/region. For children the serving of fish as a lunch meal in day care centres and schools may have an impact on the consumption.

BS herring consumption was generally low among young women and children. Nevertheless, in 2007 on average about 100 000 young women was estimated to consume BS herring twice a month or more, a consumption giving a high risk for young women to exceede the health-based tolerable intake of dioxins and dioxin-like PCBs set by EU. In 2003 on average 4 000 4 year old children and 7000 12 year old children was estimated to consume BS herring once a month or more, which can be regarded as a high consumption for children. In the region in closest proximity to the Gulf of Bothnia, where the levels of dioxins and dioxin-like PCBs are very high in BS herring, several thousand children and young women had a high consumption of this type of fish.

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Appendix 2
Fish consumption in Sweden – the Riksmaten surveys

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Riksmaten 1997-98 - adults

Methods

In 1997-98, 2027 households were randomly sampled in a nationwide food consumption survey, called Riksmaten 1997-98 [1]. One adult (17-74 years) in each household was asked to participate in the study. New households were invited to participate every second week during the year, thus covering the whole year. In the total sample of 2027 households, 1 215 persons participated and completed the survey (589 men and 626 women) corresponding to 60 % of the initial households [1].

The study participants filled in a pre-coded 7-day record book over 7 consecutive days [1]. All days of the week were equally represented in the surveys, and the survey covered the all seasons of the year. The pre-coded record book gives pre-printed alternatives (with quantity indications in household measures) for foods and meal components. The record book also include a portion guide with photographs for estimation of sizes of cooked food portions and salads eaten at main meals. Snacks and other in-between meal eating was recorded in household measures, pieces, etc., using pre-coded alternatives. Additional consumption of food and drink was recorded in free text. In addition, a questionnaire contained questions about weight, height, education and profession, ethnic background and regional residence.

The questionnaire also contained questions about the frequency of consumption of fish and shellfish, including rarely consumed species that could give a large contribution to the total intake of dioxins and polychlorinated biphenyls (PCBs). In the fish and shellfish consumption frequency questions, participants were asked about consumption of different types of fish/shellfish during the previous year. Nine predefined frequency categories were used, ranging from "never" to "once or more per day". In questions about fish/shellfish consumption, single fish species was specified and information about the origin of some of the fish species was also indicated [1]. Dioxin and PCB levels in fish vary considerably, depending on fat content of the fish and area of origin [2]. Pre-defined portion sizes were used for conversion of frequencies to grams per day.

Results and discussion

Age distribution of study participants

The age was normally distributed (Anderson-Darling test) among both men and women, as well as for both sexes together. The mean age among women was 43.4 years and for men 42.8 years (Table 1). The mean age for the total sample was 43.1 years. There was no significant difference between the age of men and women (*t*-test, p=0.420).

Table 1. *Age distribution in years among women, men and for both sexes (All) presented as mean age, median age and maximum (Max) and minimum (Min) age. N = number of individuals*

Sex	N	Mean	Min	Median	Max
Women	618	43	17	43	75
Men	597	43	17	42	79
All	1185	43	17	42	79

Total consumption of fish and shellfish

There was no significant difference in total fish/shellfish consumption as assessed from the questionnaire between women and men (*t*-test, p=0.109). The mean total consumption of fish/shellfish was 27 g/day for the entire population (Table 2). Fish/shellfish consumption was age-dependent (ANOVA, p=0.000) with the highest mean consumption in the older age groups (Table 3). Currently SNFA advise the consumers to eat fish/shellfish 2-3 times a week corresponding to at least 36 g fish/shellfish per day (portion size: 125 g) [3]. In the survey from 1997-98 34 % of the men and 37 % of the women reported a daily consumption of at least 36 g fish/day (Table 2). The proportion of women and men eating fish/shellfish 2-3 times per week or more increased with increasing age, and among men and women of ages ≥65 years over 50 % reported to consume fish/shellfish according to SNFA's advice (Table 2).

Table 2. *The total consumption of fish and shellfish (g/day) by women and men in Riksmaten 1997-98*

Age	N	Mean	StDev	Min	Median	95th percentile	≥2-3 portions/week
Women							%
17-24	70	26	28	0	17	87	25
25-34	132	27	23	0	21	68	28
35-44	132	34	24	0	30	80	36
45-54	153	38	30	0	31	96	39
55-64	81	45	27	0	39	98	48
65-	57	48	36	0	37	123	54
All	625	35	28	0	29	90	37
Men							%
17-24	67	29	31	0	17	96	29
25-34	128	25	25	0	20	73	23
35-44	143	33	34	0	23	95	27
45-54	118	41	34	0	34	126	36
55-64	68	42	40	0	32	133	36
65-	65	43	34	0	34	104	53
All	589	34	33	0	26	99	34

Consumption of Baltic Sea herring

The median consumption of Baltic Sea herring was 1 g per day for men, women and both sexes combined, corresponding to a consumption of about 3 times a year (Table 3). A significant (ANOVA, p=0.000) increase in the consumption of Baltic Sea herring with increasing age was evident.

Table 3. *Consumption of Baltic herring (g/day) among women and men in Riksmaten 1997-98.*

Age	N	Mean	StDev	Min	Median	95th percentile	>SNFA advice[a]
Women							%
17-24	68	0.4	1.1	0	0	1.8	1.5
25-34	132	0.6	1.2	0	0	1.8	1.5
35-44	129	1.6	2.9	0	0.8	9.1	12
45-54	152	2.9	4.2	0	1.0	9.1	0
55-64	81	4.0	4.2	0	1.8	9.1	0
65-	56	5.2	5.2	0	1.8	17	3.6
All	618	2.2	3.7	0	1.0	9.1	
Men							%
17-24	63	1.3	2.7	0	0.8	9.1	0
25-34	124	1.0	1.9	0	0	1.8	0
35-44	137	1.8	3.1	0	1.0	9.1	0
45-54	115	2.5	3.5	0	1.0	9.1	0
55-64	66	3.8	4.4	0	1.7	9.1	1.5
65-	62	7.7	10	0	8.3	22	6.5
All	567	2.6	4.9	0	1.0	9.1	

Women in childbearing age is a specific risk group for health effects of high consumption of Baltic Sea herring with high levels of dioxins and dioxin-like PCBs, since high body burdens of the compounds during pregnancy may cause negative effects on the developing foetus [2]. In 1997-98 the advice regarding safe consumption of Baltic Sea herring was to consume Baltic Sea herring not more than once a month [2].

Table 4. *Frequency of Baltic Sea herring consumption (times/year, month or week) among women and men in Riksmaten 1997-98*

Age (N)	Consumption (% of study participants)					
	Never	3/year	6/year	1-3/month	1/week	>1/week
Women						
17-45 (347)	55	24	14	6	1	
46-84 (268)	22	26	22	25	5	
Men						
18-84 (567)	35	28	19	15	2	1

Among women of ages 17-45 years, 93 % consumed Baltic Sea herring less than once a month (Table 4), showing that the majority of the young women did follow the consumption advisory. In total there were 7 % that reported eating Baltic Sea herring once a month or more. The current advice of Baltic Sea herring to women in childbearing age is not to consume this type of fish more than 2-3 times per year [3]. In 1997-98 73 % of the young women consumed Baltic Sea herring 3 times per year or less (Table 4).

Among older women in ages 46 years and older, about 5 % reported eating Baltic Sea herring once a week (Table 4). None consumed Baltic Sea herring more than once a week, which was the maximum consumption recommended by the SNFA, and still is [3]. Among the participating men 99 % reported a consumption of Baltic Sea herring of one a week or less. The results regarding the proportion of high consumers of Baltic Sea herring in Riksmaten 1997-98 are uncertain, due to the relatively low number of study participants (about 1200 participants).

Consumption of farmed salmon

There were no significant difference in the consumption of farmed salmon between men and women (*t*-test, p=0.823). The median consumption was 1 g/day for both men and women. However, the consumption of farmed salmon increased with increasing age (Table 5, ANVOA, p=0.015). Although the consumption of farmed salmon increased with increasing age this association was not as strong as compared with the consumption of Baltic Sea herring.

Table 5. *The consumption of farmed salmon (g/day) among women and men in Riksmaten 1997-98*

Age	N	Mean	StDev	Min	Median	95th percentile
Women						
17-24	68	1.7	3.3	0	1.0	8.3
25-34	132	2.5	4.1	0	1.0	9.4
35-44	129	2.1	3.1	0	1.0	9.4
45-54	152	3.4	6.4	0	2.1	9.4
55-64	81	3.8	6.2	0	2.1	17
65-	56	2.4	3.7	0	1.0	9.4
All	618	2.7	4.8		1.0	9.4
Men						
17-24	63	2.5	4.0	0	1.0	9.4
25-34	124	2.0	3.0	0	1.0	8.3
35-44	137	2.2	3.5	0	1.0	9.4
45-54	115	3.0	4.2	0	1.0	12
55-64	66	3.5	6.2	0	1.0	9.4
65-	62	3.5	4.6	0	1.6	16
All	567	2.6	4.2	0	1.0	9.4

Riksmaten 2003 - children

Methods

The children were recruited from 56 counties, representative for all the counties of Sweden. 4 year old children were randomly recruited from a register with information about households with a 4 year old child [4]. Children in grade 2 and 5 in school (8-9 years and 11-12 years) were representative for Swedish children in general. Consumption data were collected for 590 4 year old children, 889 children at the age of 8 or 9 years and 1016 children at the age of 11 and 12 years. Among the 4 year old children 64 % completed the study, whereas 75 % of the school children completed the study. The study participants filled in an open and estimated food diary over 4 consecutive days, with the help of parents or care-takers [4]. All days of the week were equally represented in the surveys, and the survey covered spring and autumn. The study participants used a picture book when portion sizes and amounts of all food consumed were estimated. For some food types, the participants registered the number of the specific foodstuff consumed, or number of glasses or bowls of the foodstuff consumed [4]. In addition, a questionnaire contained questions about weight, height, ethnic background, regional residence as well as parents' education and profession. The questionnaire also contained questions about the frequency of consumption of fish and shellfish similar to that used in the adult survey in 1997-98.

Results and discussion

Total consumption of fish

The mean total consumption of fish, estimated from the questionnaire, among children from all age groups was 21 g/day. The consumption was lowest among the 4 year old children (Table 6). The consumption was significantly different between age groups, mainly due to the lower consumption among 4 year old children (ANOVA, $p<0.001$). There was no significant difference between children in grade 2 and 5 (*t*-test, $p=0.066$). Moreover, no significant difference was found between girls and boys in any of the age groups (*t*-test, $p= 0.196$-0.844).

Table 6. *The total consumption (g/day) of fish and shellfish among children in Riksmaten 2003.*

Age	N	Mean	StDev	Min	Median	95th percentile	Max
4 years	593	14.6	10.7	0	12.5	32.2	142
Grade 2 (8-9 yr)	909	21.4	21.9	0	17.3	57.4	292
Grade 5 (11-12 yr)	1036	23.4	28.0	0	18	69.5	313
All	2538	20.6	23.0	0	16.3	58.5	313

When taking body weight in account, the total daily fish/shellfish consumption decreased with increased age (ANOVA, $p<0.001$). Among 4 year old children mean total fish consumption was 0.82 g/kg body weight/day (SD: 0.63), whereas among 8-9 and 11-12 year old children it was 0.72 (0.77) g/kg and 0.58 (0.66) g/kg body weight, respectively.

The children reported a median fish/shellfish consumption of 1.75 times/week [4], which is somewhat less than the current NFA fish consumption advisory about healthy food habits (2-3 times/week) [3].

Consumption of Baltic Sea herring

The mean consumption of Baltic Sea herring, according to the questionnaire, differed between the age groups (ANOVA, $p<0.001$) with the lowest consumption at the age of 11-12 years (Table 7). However, the median consumption was zero for all age groups.

Table 7. *The consumption (g/day) of Baltic Sea herring among children in Riksmaten 2003.*

Age	N	Mean	StDev	Min	Median	95th percentile	Max
4 years	579	0.5	3.3	0	0	6.0	75
8 years	867	0.6	1.6	0	0	3.2	23.5
11 years	996	0.2	0.5	0	0	1.0	8
All	2442	0.4	1.9	0	0	3.6	75

Among the 4 year old children 70 % were reported to never eat Baltic Sea herring. The corresponding percentages for 8-9 and 11-12 year old children were 70 % and 72 %, respectively (Table 7). Children is currently advised by the NFA to consume Baltic Sea herring not more that 2-3 times a year [3]. Among the 4 year old children in Riksmaten 2003, 91 % consumed Baltic Sea herring 4 times a year or less. A consumption of Baltic Sea herring more than once a month was reported by 2.3 % of the children. 88 % of the 8-9 and 11-12 year old children reported consumption of Baltic Sea herring 4 times a year or less. Consumption more than once a month was reported by 2.3 % and 3.2 % among the 8-9 and 11-12 year old children, respectively.

Table 8. *Consumption (g/day) of farmed salmon among children in Riksmaten 2003.*

Age	N	Mean	StDev	Min	Median	95th percentile	Max
4 years	584	1.8	2.8	0	0.5	6.4	39
Grade 2 (8-9 yr)	877	3.1	7.8	0	0.7	16	100
Grade 5 (11-12 yr)	1002	3.1	6.5	0	0.7	14	100
All	2463	2.8	6.4	0	0.7	13	100

Consumption of farmed salmon

The consumption of farmed salmon among children differed with age (ANOVA, $p<0.001$), with the 4 year old children having the lowest consumption. The median consumption corresponded to a frequency of 1-4 times/year (Table 8).

Riksmaten 2010 - adults

Methods

This new survey of food consumption among 18-80 years old adults in Sweden started in the spring of 2010, and will be finished in late spring 2011 [5]. Until October 2010, over 1000 study participants were randomly sampled, and approximately 35 % agreed to participate in the survey. The study participants filled in a webb-based open and estimated food diary over 4 consecutive days. All days of the week were equally represented in the survey. The study participants used a picture book when portion sizes and amounts of all food consumed were estimated. For some food types, the participants registered the number of the specific foodstuff consumed, or number of glasses or bowls of the foodstuff consumed. In addition,
a questionnaire contained questions about the frequency of consumption of fish and shellfish similar to that used in previous studies.

Table 9. *The age distribution among women and men participating in Riksmaten 2010 (to the end of September 2010).*

Sex	N	Mean	Min	Median	Max
Women	375	47	18	47	80
Men	297	49	18	50	80
All	675	48	18	48	80

Results and discussion

Total fish consumption

The median age was close to 50 years (Table 9), which is higher than the mean age in Riksmaten 1997-98 which was 42-43 years [1]. The median total fish/shellfish consumption, based on the questionnaire, among women ranged from 19 g/day to 31 g/day (Table 10), which is within the range of the median consumption found in Riksmaten 1997-98 [1]. Among men in Riksmaten 2010 the median fish/shellfish consumption ranged from 18 g/d to 22 g/day (Table 9), which was in the lower range of the median consumption reported in Riksmaten 1997-98 [1].

Using a portion size of 125 g, 37% of the participants consumed fish and shellfish at least twice a week. Among both women and men the proportion of participants consuming fish/shellfish according to the SNFA recommendation [3] appeared to be higher in the age group 45-80 years than in the age group 18-44 years (Table 10). Fewer men than women followed the recommendation.

Table 10. *Total consumption of fish/shellfish (g/day) by women and men in Riksmaten 2010.*

Age	N	Mean	StDev	Min	Median	95th percentile	≥2-3 portions/week
Women							%
18-24	41	28	22	0	24	59	
25-34	60	22	19	0	19	42	
35-44	67	41	56	0	30	95	36
45-54	68	37	50	0	25	81	
55-64	67	34	29	2.5	30	65	
65-	72	36	24	0	31	74	47
All	375	33	37	0	27	74	42
Men							%
18-24	34	25	29	0	18	91	
25-34	29	30	42	0	18	72	
35-44	55	29	49	0	20	54	23
45-54	60	26	17	0	22	55	
55-64	57	26	16	0	21	54	
65-	61	31	21	0	21	85	36
All	297	28	30	0	22	68	31

Consumption of Baltic Sea herring

The median consumption of Baltic Sea herring was 0.7 g per day for men, women and both sexes combined, corresponding to a consumption of about 2 times a year (portions size: 125 g) (Table 11). This is similar to the median consumption among adults in Riksmaten 97-98 (Table 3). Similarly as in Riksmaten 1997-98 the consumption of Baltic Sea herring increased with increasing age.

In 2010, 78 % of young women of ages 18-45 years consumed Baltic Sea herring 3 times per year or less, which is the current advisory for safe Baltic Sea herring consumption [3] (Table 12). 90 % consumed Baltic Sea herring less than once a month, which is similar to the result in Riksmaten 1997-98 (Table 4). In total there were 9 % that reported eating Baltic Sea herring once a month or more (Table 12).

Table 11. *The consumption of Baltic herring (g/day) in women and men.*

Age	N	Mean	StDev	Min	Median	95th percentile
Women						
17-24	41	1.9	3.5	0	0.7	10
25-34	60	0.6	1.0	0	0	3.4
35-44	67	1.4	3.1	0	0.7	10
45-54	68	1.7	3.3	0	0.7	4.1
55-64	67	2.0	3.6	0	0.7	10
65-	72	3.2	4.4	0	0.7	10
All	375	1.8	3.4	0	0.7	10
Men						
17-24	34	2.2	8.1	0	0	18
25-34	29	1.5	2.3	0	0	4.1
35-44	55	1.0	2.0	0	0.7	4.1
45-54	60	1.7	2.4	0	0.7	4.1
55-64	57	1.4	2.2	0	0.7	4.1
65-	62	2.5	3.0	0	1.4	10
All	297	1.7	3.6	0	0.7	10

Table 12. *Frequency of Baltic Sea herring consumption (times/year, month or week) among women and men in Riksmaten 2010.*

Age (N)	Consumption (% of study participants)						
	Never	1-3/yr	4-8/yr	9-11/yr	1/mo	2-3/mo	≥1/wk
Women							
17-45 (173)	47	31	9	3	5	3	1
46-84 (203)	34	27	11	8	11	6	3
Men							
18-84 (297)	40	26	13	7	8	5	1

Among women of ages 46 years and older, 3 % reported eating Baltic Sea herring once a week. None consumed Baltic Sea herring more than once a week. Among the participating men 99 % reported a consumption of Baltic Sea herring of less tan once a week. The results regarding the proportion of high consumers of Baltic Sea herring in Riksmaten 2010 are uncertain, due to the relatively low number of study participants (about 670 participants).

Consumption of farmed salmon

The median consumption of farmed salmon was lower among men (4 g/day) than among women (10 g/day) (Table 13). In comparison with Riksmaten 1997-98 (Table 5), the median consumption was 10-fold higher among the women and 4-fold higher among men. However, the consumption of farmed salmon did, in contrast to Riksmaten 1997-98, not seem to increase with age.

Table 13. *The consumption of farmed salmon (g/day) among women and men in Riksmaten 2010.*

Age	N	Mean	StDev	Min	Median	95th perc
Women						
17-24	41	9.8	10	0	10	18
25-34	60	7.2	7.4	0	4.1	18
35-44	67	11	11	0	10	45
45-54	68	11	10	0	10	45
55-64	67	9.8	12	0	10	18
65-	72	8.4	12	0	10	18
All	375	9.4	9.8	0	10	18
Men						
17-24	34	7.2	8.1	0	4.1	18
25-34	29	8.9	12	0	4.1	45
35-44	55	7.3	7.1	0	4.1	18
45-54	60	7.1	7.2	0	4.1	18
55-64	57	6.8	5.6	0	4.1	18
65-	62	8.9	8.9	0	4.1	18
All	297	7.6	7.9	0	4.1	18

Consumption of wild salmon and Baltic Sea herring caught by anglers

There is a poor knowledge about consumption of wild salmon and Baltic Sea herring, that have been obtained from e.g. sport fishing or directly from fishermen. In Riksmaten 2010 the participants were asked about this type of consumption. In the end of October 2010 666 participants had answered these questions, and a detailed analysis of the results have to wait until the survey is finished. ”Sportfisher” salmon was consumed by 16 % of the participants while 94 % consumed salmon in general (Tabell 14). 92 % answered that they consumed ”sportfisher” salmon 1-3 times per year or less, whereas 15 % had the same consumption frequency of salmon in general. Only 0.7% reported that they consumed ”sportfisher” salmon once a week or more. Consumption of salmon in general once a week or more was reported by 18 % of the survey participants. Taken together the results suggest that consumption of wild ”sportfisher” salmon is very low in comparison to total salmon consumption which mainly consists of farmed salmon.

Based on the total number of adults in Sweden in 2010 (7,055,233) [6], 49,000 adults in Sweden consumed ”sportfish” salmon once a week or more. This figure is however uncertain since the study size was small and may not be representative for the whole Swedish population. Nevertheless, consumption of 125 g of ”sportfish” salmon per week among 49,000 people corresponds to approximately 300 tons of ”sportfish” salmon per year. According to the Swedish Board of Fisheries the total catch of ”sportfisher” salmon was approximately 400 tons in 2006 [7].

Table 14. *Consumption of wild salmon and Baltic Sea herring caught by anglers in comparison with total salmon and Baltic Sea herring consumption.*

Fish	Consumption (%)						
	Never	**1-3/yr**	**4-11/yr**	**1/mo**	**2-3/mo**	**1/wk**	**≥2/wk**
Women (N=371)							
BS herring total	43	27	16	7.6	4.0	2.2	
BS herring sportfish	92	4.1	2.3	0.6		0.3	
Salmon total	6.9	9.2	16	16	32	18	3.8
Salmon sportfish	86	8.1	3.2	1.1	0.9	0.9	
Men (N=295)							
BS herring total	35	29	20	9.5	5.4	0.7	0.3
BS herring sportfish	87	7.7	3.3	1.1	0.7	0.4	
Salmon total	5.4	9.8	18	19	34	11	2.4
Salmon sportfish	80	11	5.0	1.1	1.8	0.4	

96 % of the survey participants (until September 2010) in Riksmaten 2010 reported that they never consumed ”sportfisher” Baltic Sea herring or only consumed such fish 1-3 times per year (Table 14). The corresponding figure for total Baltic Sea herring consumption was 67 %. Approximately 1.4 % reported that they consumed ”sportfisher” Baltic Sea herring once a month or more, whereas 15 % the same consumption frequency of Baltic Sea herring in general The results suggest that the consumption of ”sportfisher” Baltic Sea herring is considerably lower than consumption of Baltic Sea herring in general among adults in Sweden.

This conclusion is supported by the information from the Swedish Board of Fisheries that the total amount of herring caught by sportfishers in 2006 was 1 800 tons [7], in comparison with the commercial fisheries catch of 20 000 tons of Baltic Sea herring per year during the period 2007-2009 [8]. Since the statistics of “sportfisher” herring includes herring from the west coast of Sweden, the total catch of “sportfisher” Baltic Sea herring was most probably less than 1 800 tons in 2006.

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Appendix 3
Exposure of Swedish consumers to dioxins and dioxin-like PCBs-an international perspective

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Introduction

The objective with this report was to summarize the information about human exposure to dioxins and dioxin-like PCBs in Sweden, and to do a comparison with the exposures reported from other European countries. Exposure is estimated in two ways, by dietary intake calculations and levels in mother's milk. Dietary intakes of dioxins and dl-PCBs are based on data from food consumption surveys and occurrence data regarding dioxins and dl-PCBs in foods on the Swedish market. The intakes give estimates of exposure from food during the time period around the year the food consumption survey was performed. Dioxin and dl-PCB levels in mother's milk give an estimation of long-term exposure before pregnancy, due to the slow elimination of the compounds from the body.

Dietary intake of dioxins and dl-PCBs

Food consumption data in studies of dietary intake of dioxins and dl-PCBs

The food consumption data used in intake studies generally originates from food consumption surveys. The design of these surveys may differ, which makes it difficult to compare the results. The different survey methods include food consumption record studies of different duration, such as 7 day food registration, 24 h recall, as well as frequency questionnaire studies. Food registration studies generally give more comprehensive data on individual food consumption patterns than 24 h recall studies. The recall studies also suffer from the problem that it may be difficult to remember all foods consumed. In both food registration and recall studies it is difficult to get good estimates of consumption of foodstuffs that are consumed less frequently. Consumption of these types of foods may be estimated from frequency questionnaires which can be used as a complement to registration or recall methods. In studies using only frequency questionnaires there is a risk of bias in consumption estimates due to the fact that the questions usually do not capture information about portion sizes. Moreover, frequency questionnaires usually cover food consumption during an extended time period, often a year. It may therefore be difficult for the respondents to answer the questions correctly. With these uncertainties in mind, it is difficult to determine how much of the variation between studies is due to different methods used in food consumption surveys and how much are in fact real differences in consumption patterns.

To get information faster about the average intake of food contaminants, and about the food groups that are important sources of exposure, market basket studies can be conducted. This type of study is usually based on producers and sales statistics regarding different foods products or is based on average consumption data from for example food consumption surveys. The common denominator for this type of study is that it gives information about the *per capita* consumption of foods or the average consumption of different foods, but do not give information on individual consumption patterns. There is a risk that this average food consumption may represent an overestimation of the actual

consumption, when the consumption data are based on trade statistics. Not all food available in restaurants and homes is consumed, and goes to waste instead. Another factor that adds to the uncertainty is that the occurrence data of contaminants in market basket studies are often based on analyses of fresh foods without preparation for consumption, such as boiling or frying.

Dietary surveys in Sweden

Several food consumption surveys have been conducted by the Swedish National Food Agency (SNFA), kalled the Riksmaten Surveys. The result from a food consumption survey should reflect the food habits of the studied population. How representative the results are on an individual basis depends on the method of quantifying food consumption. In this case a 7 day food diary study most likely gives a better picture of long-term consumption habits than a 24 h recall study. Food habits with focus on the adult Swedish population were surveyed in Riksmaten 1997-98, where 1212 randomly selected individuals between 18 and 74 years registered their food habits during a seven-day period with the help of a food consumption diary. The fish consumption during the most recent year was also registered with help of a frequency questionnaire (Becker and Pearson, 2002). In a another study of temporal trends
of persistent organic pollutant exposure among young women in Sweden, food consumption habits of pregnant primiparous women from the Uppsala area were investigated 1996 and 2008. In this study a food frequency questionnaire was used, including the same questions about fish consumption as in Riksmaten 1997-98.

Riksmaten-barn 2003, a national food consumption survey among children (Enghardt Barbieri et al., 2006) show great similarities with the previous Riksmaten 1997-98. In the survey the children were divided into groups according to age, 4 years, 8-9 years, and 11-12 years. The method used was an open and estimated food diary over 4 consecutive days. Portion sizes and amounts of all food and drink consumed by the children were estimated with the help of a picture book. To get further knowledge about the consumption of specific types of fish, the survey included a food frequency questionnaire of fish consumption the most recent year (Concha et al., 2006).

In 1999 and 2005 market basket studies were conducted in Sweden. One of the aims in 1999 and 2005 was to estimate the *per capita* intake of persistent halogenated organic compounds from foods (Ankarberg et al., 2006, Darnerud et al., 2006).

Data on levels of dioxins and dl-PCB in food on the Swedish market

It is known that food of animal origin contribute to the major part of the dioxin and dl-PCBs intake from food and that vegetable food groups generally contain low levels of these compounds and consequently will add little to the total intake (Patandin et al., 1999, Freijer et al., 2001). Since beverages, like soft drinks and

mineral water, are expected to not contain dioxins and dl-PCBs they are most often excluded when conducting intake estimations. It is of importance that the consumption data and the data on levels of contaminants are from about the same time period in order to make as accurate as possible estimation of dietary intake.

When analyzing the levels of dioxins and dl-PCBs in different food items, some levels will be below the detection or quantification limit. When this happens it must be decided how to deal with these levels. Three different estimates of contaminant levels are usually used, upper-, middle- and lower-bound concentrations. Upper-bound concentrations of dioxins and dl-PCBs assume that all individual compounds with concentrations below the detection or quantification limit are present at the detection/quantification limit. This may lead to overestimation of the true concentrations. On the other hand, underestimations of the true concentrations may occur when estimations are made on lower-bound concentrations. Lower-bound concentrations means that the levels below the detection or quantification limit are assumed to be zero. The true concentrations will lie somewhere between the upper- and lower-bound values. When using the middle-bound concentrations the concentrations below the detection or quantification limit are set to half of the concentration of the detection/quantification limit. Differences in analytical methods between studies result in variation of detection or quantification limits between studies. Moreover, the food sampling strategies varies between studies. Another thing making it hard to compare the results from different studies is that in some cases the analysis of some dl-PCB congeners are missing.

Dietary intake of dioxins and dl-PCBs

The Scientific Co-operation (SCOOP) Task 3.2.5 (Dioxins)

In 2000, a compilation of available dioxin and dl-PCB intake data was conducted by 10 EU member states, including Sweden and the other Nordic countries. The average intakes seemed to be rather similar (SCOOP, 2000), although the relative contribution from different foods varied a great deal between the countries. The average dietary intake of PCDD/Fs in the adult or total population for the 1990s is presented in figure 1. The presented countries are Finland, France, Germany, Italy, the Netherlands, Norway, and Sweden. The intakes are based on surveys and occurrence data from the 1990s. The dietary estimations were based on upper- or middle-bound concentrations. Figure 1, clearly shows that in the estimated intake of PCDD/Fs in the Swedish population were estimated to be higher than in many of the other participating European countries at this time period (SCOOP, 2000). The SCOOP report does not give a complete picture on the total-TEQ intake in several countries. The reason for it is that the estimated intake of dl-PCBs was not reported. The total-TEQ intake was between 111.2 pg TEQ/day and 144.8 pg TEQ/day indicating that there was not a great difference between the five countries reporting total-TEQ intakes. The lower value derived from Finland and the higher value from the UK (SCOOP, 2000).

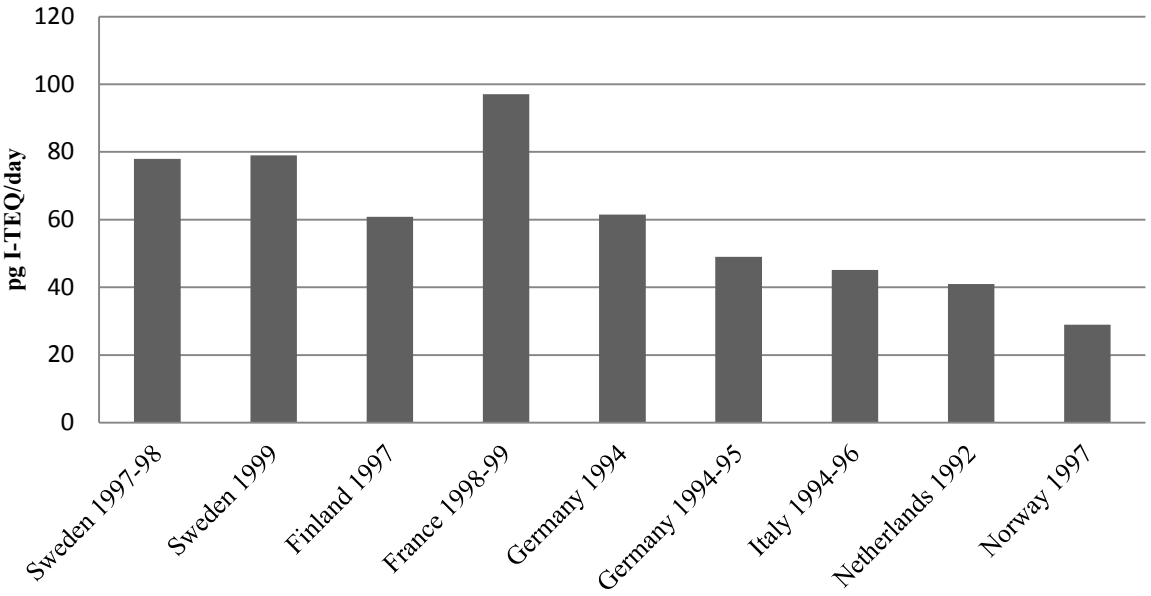

Figure 1. *Dietary intake of PCDD/Fs (pg I-TEQ/day) according to surveys from selected European countries in the middle-end of the 1990´s. The dietary estimations were based on upper- or middle-bound concentrations. The data are adopted from the SCOOP 2000.*

Population-based studies (food consumption surveys)-adults

In Figure 2 the results of the different studies of intake of dioxins and dl-PCBs in the general adult populations of different European countries are summarized. As can be seen the estimated average intake among adults in Sweden in the late 1990s-early 2000s were lower than those reported from more densely populated Europaean countries, such as Belgium, France, Italy, and Spain. The comparisons have, however, to be done with care, since there were differences in study design and methods between studies.

Results from the intake estimations of dioxins and dl-PCBs based on the consumption data derived from Riksmaten 1997-98 and occurrence data of dioxins and dl-PCBs from 1989-1999 showed that the median intake of dioxins and PCBs for all participants (n = 1185) was 75 pg WHO-TEQ/day and the corresponding value for the 95th percentile was 204 pg WHO-TEQ/day. The median intake of total-TEQ was estimated to be 1.1. pg WHO-TEQ/kg bw/day (Figure 2 and Table 1). The largest contributor was fish and shellfish with 51 % of the total dietary intake followed by dairy products (17 %), and meat (12 %) (Lind et al., 2002). In the intake calculations nd = ½ LOD, i.e. the middle-bound concentrations were used. Men had slightly higher median intake of PCDD/F-TEQ, PCB-TEQ and total-TEQ than women. The median total-TEQ intakes were 81.1 and 69.5 pg WHO-TEQ/day among men and women, respectively (Lind et al., 2002).

Women in child-bearing age, women aged 21 to 40 years, were divided into the age groups 17-20 years (N=24), 21-30 years (N=114) and 31-40 years (N=139). The median total-TEQ intake increased with age and was 49.0 pg WHO-TEQ/day, 51.8 pg WHO-TEQ/day, and 67.2 pg WHO-TEQ/day, for the respective age groups. For women in child-bearing age, i.e. 21-40 years the consumption of fish was estimated to account for about 32% of the total intake. (Lind et al., 2002).

In a report from the National Food Administration published in 2005, an intake estimation based on Riksmaten 1997-98 consumption data and occurrence data from 1998-2004 was reported. The median dietary intake of dioxins and dl-PCBs for the general population in Sweden was similar as in the earlier intake estimation by Lind et al. (Lind et al., 2002), i.e. 75 pg tWHO-TEQ/day, or 1.1 pg WHO-TEQ/kg bw/day (N=1185) (Figure 2) (Ankarberg and Petersson-Grawé, 2005). The 95th percentile intake was estimated to 2.9 pg WHO-TEQ/kg bw/day. For men aged 17-75 years (N=567) the median total-TEQ intake was estimated to 83 pg WHO-TEQ/day or 1.0 pg WHO-TEQ/kg bw/day. Women in the age group 17-40 years were estimated to have a median total-TEQ intake estimated to 62 pg WHO-TEQ/day or 0.93 pg WHO-TEQ/kg bw/day (Ankarberg and Petersson-Grawé, 2005).

In 1997, the Norwegian national dietary survey Norkost 1997 was performed (Johansson and Solvoll, 1999). The survey included 2672 participants in the age of 16 to 79 years. The method used was a quantitative food frequency questionnaire, representing the food consumption for the Norwegian men and women aged 16-79 years. Food products for chemical analyses were collected during the years 1989-96. The analyses of dioxins and dl-PCBs were carried out by the National

Institute of Public Health and other Norwegian institutes. It was shown that the average total-TEQ intake was 139 I-TEQ/day. For a person weighing 73.5 kg it was estimated that the intake would be 1.89 pg I-TEQ/kg bw/day using the upper-bound concentrations (Figure 2 and Table 1) (SCOOP, 2000).

In 2001, the dietary intakes of PCDD/Fs and PCBs were reported for the general adult Finnish population (Kiviranta et al., 2001). The food consumption data consisted of the average consumption derived from population data collected by the National Public Health Institute in 1997. The dietary survey was a 24 h dietary recall study and the average consumption of different food items was calculated from 2862 Finnish adults (aged 25-64 years) (NPHI, 1998). From this survey, foods relevant for the intake estimations of PCDD/Fs and PCBs were aggregated into different food groups. Cow milk, eggs, pork, beef, rainbow trout, flours and vegetables were sampled in 1998-2000. In the calculations of TEQs, results below LOD were considered as zero. The estimated average daily total-TEQ intake was 100 pg WHO-TEQ/day. For a person weighing 76 kg the intake was calculated to be 1.3 pg WHO-TEQ/kg bw/day (Figure 2 and Appendix). No information about intakes among risk groups were reported in the study or any estimation for the 95th percentile (Kiviranta et al., 2001).

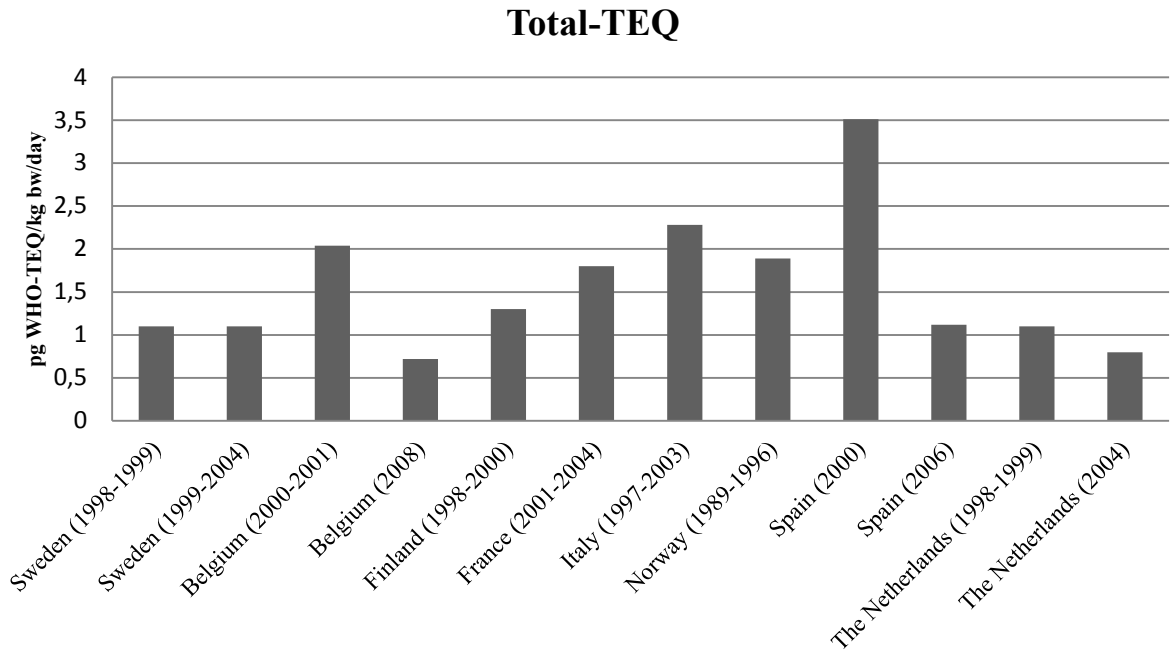

Figure 2. *Average dietary intake of PCDD/Fs + dl-PCBs (total-TEQ) (pg TEQ/kg bw/day) among adults in different European countries. The figures within the brackets are the respective sampling year. More detailed information concerning the studies can be found in the text above and in Table 1.*

In Belgium, the mean dietary intake for adults was in the year 2000-2001 estimated to 65.3 pg WHO-TEQ/day for PCDD/Fs (1.00 pg WHO-TEQ/kg bw/day for a 65 kg person) (Focant et al., 2002b). When co-planar PCBs were included, the estimated mean dietary intake was 132.9 pg WHO-TEQ/day (2.04 pg WHO-TEQ/kg bw/day) (Figure 2 and Table 1). The largest contributors of the intake were fish, meat and dairy products, each contributing about one third of the intake (Focant et al., 2002b). If the mono-*ortho* PCBs had been included the estimated daily intake of the total-TEQ would have been even higher. The method used for consumption quantification was not clearly reported, but the results were presented two years after the dioxin accident in 1999. The levels of 17 PCDD/Fs and 4 non-*ortho* PCBs were analyzed in 197 foodstuffs samples of animal origin from Belgium during the years 2000 and 2001. The lower bound concentrations were used in the estimations. No information was presented concerning intakes for different age groups (Focant et al., 2002a).

Since the beginning of the decade the levels in food products have decreased in Belgium and hence the dietary exposure of Belgian adults to PCDD/Fs and dl-PCBs. The mean dietary intake of PCDD/Fs and dl-PCBs in the Belgian adult population was in 2008 estimated to 0.72 pg WHO-TEQ/kg bw/day (middle-bound concentrations and the TEFs from 1998) (Figure 2 and Appendix) (Windal et al., 2010). The difference between the estimated dietary intake using the lower-bound (0.61 pg WHO-TEQ/kg bw/day) and the upper-bound 0.83 pg WHO-TEQ/kg bw/day) was rather small. No information concerning the average weight used in the intake calculations or differences in the intake between the genders and age groups were presented. If an average weight of 73.7 kg is used (as used in Riksmaten 1997-98 and the Market basket studies 1999 and 2005) the total-TEQ intake would be 53.1 pg WHO-TEQ/day. The contribution to the PCDD/F + DL-PCB from dietary intake was 50.7% from dairy products followed by 21.7 % from meat and meat products. Fish and fishery products was estimated to account for 17.8 % of the dietary intake of these compounds (Windal et al., 2010). Food consumption data came from a survey conducted in 2004 (De Vriese et al., 2005). The target population included all Belgian inhabitants of 15 years or older. In total 3245 participants were randomly selected from the National Register. The dietary information was collected by a repeated non-consecutive 24 h recall in combination with a food frequency questionnaire. During the 24 h recall interviews the persons reported the quantities of all foods and beverages consumed, during the preceding day. The reason for repeating the procedure was to get more information about within-person variation. The occurrence data focused on food products of animal origin, plus one composite sample of vegetable oil. The food samples were collected in 2008, in total 529 samples.

In the Netherlands, food consumption data has been collected in the Dutch National Food Survey (DNFCS). In the third survey, conducted in 1997/98, the food consumption of 6250 individuals (2770 households) aged 1 to 97 years was assessed by a 2-day dietary record, equally distributed over the 7 days of the week and over a year (Kistemaker et al., 1998). For each participant the quantities of various food items consumed over the day were recorded. This resulted in consumption data of 1209 different food products. After a screening procedure a

reduction was made to 807 food products ranked into food categories according to type of fat or oil (food products not expected to contain dioxins and PCBs were removed). The database at the DNFCS was also used to perform a secondary screening, aiming to identify the food categories most significantly contributing to total fat consumption. The remaining ones were sorted into 18 categories with differing types of fats or oils. For each of these food categories a set of food products was defined to cover at least 95 % of the total fat intake of the respective category. In 1999, Baars and co-workers investigated the dietary intake of dioxins and dl-PCBs, using the consumption data from 1997/98. Food samples were collected in 1999 from each food categories. The estimated median life-long intake of the sum of dioxins and dl-PCBs in the population was estimated to 1.2 pg WHO-TEQ/kg bw/day (Figure 2 and Table 1) and the 90th percentile 1.9 pg WHO-TEQ/kg bw/day. Age-specific intake was also presented and the median life-long intake for 2-year-olds was 2.8 pg WHO-TEQ/kg bw/day. Lower median intakes were reported for 10 year old children and adults at the age of 40 years. (1.5 and 1.1 pg WHO-TEQ/kg bw/day, respectively). The contribution of different food groups to the total-TEQ intake was fairly uniformly distributed over dairy products (27 %), meat products (23 %), and fish (16 %). Industrial oils and fats and vegetable products contributed to about the same extent as fish did. The lower bound concentrations were used (Baars et al., 2004).

A more recent study using the same food consumption survey but new data on the levels of the compounds in the food products (2001-2004) was published in 2008 (De Mul et al., 2008). The estimated long-term median dietary intake of the Dutch population to dioxins and dl- PCBs was estimated to 0.8 pg WHO-TEQ/kg bw/day (Figure 2 and Table 1). For the 90th percentile the intake was estimated to 1.4 WHO-TEQ/kg bw/day. The estimated exposure calculated with 2005 TEFs was said to 9-11 % lower than the estimate with the TEFs from 1998. When comparing the two Dutch studies, the contribution from meat and fish had decreased between the late 1990s and early 2000s, while the contribution of dairy product consumption had increased. This was in line with decreased levels in meat and fish. In the dairy category butter had increased whereas milk and cheese had decreased concentrations (De Mul et al., 2008).

In France, the French national dietary survey conducted in 1998 to 1999 was used for estimations of dietary intakes of PCDD/Fs and dl-PCBs. Data on levels of PCDD/Fs and dl-PCBs were collected from the French national monitoring programs (2001-2004). In total 3003 children and adults recorded their food consumption in a diary over 7 consecutive days. This survey recorded the body weight for almost all participants, and hence the intake per kg body weight could be calculated. The median total-TEQ intakes were estimated to 1.5 and 2.4 pg WHO-TEQ/kg bw/day for adults (15 years and older) (Figure 2 and Table 1) (Tard et al., 2007). For the 90th percentile the total-TEQ was 3.1 pg WHO-TEQ/kg bw/day for adults and children. The estimates were based on the lower-bound concentrations (Tard et al., 2007). The main contributors of the total intake were fish and dairy products (48 %).

In Catalonia, Spain, estimated average intake for males and females in the age groups, 4-9 years, 10-19 years, 20-65 years, and persons over 65 years ranged from 2.9 pg WHO-TEQ/kg body weight/day for the young children to 1.0 pg WHO-TEQ/kg body weight/day for the oldest consumers (Llobet et al., 2008). It is not stated in the report if the values are mean or median values. Food samples were randomly acquired from 12 cities in Catalonia in 2006. In calculations of dietary intake of PCDD/Fs and dl-PCBs 50 food items were analysed. The consumption data for the general population in Catalonia in 2003 were used. Data concerning fish and seafood were taken from another study conducted by the same research group (Bocio et al., 2007). Compared with a similar study from year 2000 (Llobet et al., 2003a, Llobet et al., 2003b), a 68 % reduction in intake was observed. Fish and seafood contributed 58 % to the total intake TEQ in 2006 (Llobet et al., 2008).

In Italy, Fattore and co-workers used data on food consumption from the INN-CA study 1994-1996 (Turrini et al., 2001, Turrini and Lombardi-Boccia, 2002) to estimate the dietary exposure to PCDD/Fs and dl-PCBs. Food intake was recorded for a week on a self-compiled diary over 3 to 7 consecutive days by 1940 persons (0-94 years) representing four major regions of Italy. Data on levels in food were obtained from different national and international surveys. The levels in food were not specifically a reflection on what the Italian eat, but instead concentrations in European foodstuffs available on the European market. The concentrations were expressed as upper-bound WHO-TEQ. It was estimated that the mean total-TEQ intake in general Italian population at the age of 13-94 years was 2.28 pg WHO-TEQ/kg bw/day (Figure 2 and Table 1) (Fattore et al., 2006). The main contributions to the total-TEQ intake were fish and fish products (44 %) and milk and dairy products (27 %). Another Italian study also showed that consumption of fish is one of the main sources of dioxins for Italians (Taioli et al., 2005). In this study, the food consumption data came from INN-CA study (Turrini et al., 2001) and EPIC-study on diet and cancer, that included 40 000 persons. They answered a food frequency questionnaire on dietary habits in the previous 12 months (Riboli et al., 2002). The food samples analyzed were from animal origin and included bovine meat, pork meat, milk, fish, poultry and eggs. Fish showed the highest dioxin content, but the major contribution to the intake was reported to come from cow´s milk, followed by fish.

As mentioned above, the variation of reported intakes of PCDD/Fs and dl-PCBs is not solely dependent on differences in food consumption and contaminant levels between countries. The variation can partially be explained by differences in study periods and study methods. The body weights used in the calculations also differ between studies. Therefore it is difficult to determine how much of the variation of intakes between countries is due to differences in food consumption and contaminant levels. Nevertheless, Figure 2 suggests that the total-TEQ intake among adults in Sweden in the late 1990s and early 2000s was within the range of those reported from other European countries. Estimated average intakes seem to be somewhat higher in more densely populated countries than Sweden, such as Belgium, France, Italy and Spain (Figure 1).

Population-based studies (food consumption surveys) - children

In 2006 the National Food Administration estimated the intake of dioxins and dl-PCBs in children (Concha et al., 2006), based on the national food consumption survey among children, Riksmaten-barn 2003 (Enghardt Barbieri et al., 2006). It was reported that the median intake of total-TEQ (PCDD/Fs + dl-PCBs) among the 4 year old children was 41.4 pg WHO-TEQ/day (2.3 pg/kg bw/day) for girls and 43.6 pg WHO-TEQ/day (2.4 pg/kg bw/day) for boys. Older children had lower intakes and there were no significant difference between boys and girls. The 95th percentile intake of total-TEQ was estimated to 4.8 pg/kg bw/day for 4 year old children. Among all age groups, fish/shellfish contributed the most (32-35 %) to the total intake of dioxins and dl-PCBs. Meat/poultry and dairy products contributed 27-32 % and 20-26 %, respectively.

Similar intake estimations were made by Bergkvist and co-workers (Bergkvist et al., 2008), using consumption data from the HULK diet survey (NFA, 1994). It was shown that the mean intake of total-TEQ for boys and girls was quite similar in the age groups 1-3 year (boys N=41, girls N=32) and 4-6 year old (boys N=53, girls, N=48). The mean daily TEQ intake of dioxin-like compounds for the youngest boys and girls (1-3 years) were estimated to be 4.2 and 4.3 pg WHO-TEQ/kg bw/day. Girls aged 4-6 years showed a slightly lower intake with an intake of 3.6 pg WHO-TEQ/kg bw/day. The 95th percentile for girls in the age group 1-3 years was 8.1 pg WHO-TEQ/kg bw/day and for boys in the age group 4-6 years was 9.3 pg WHO-TEQ/kg bw/day.

In other European countries similar results have been reported for intake estimations of dioxin-like compounds. In Catalonia, Spain, average intake of PCDD/Fs was reported to be 53.1 and 51.1 pg WHO-TEQ/day for boys and girls, respectively, in the age 4-9 years. With the mean weight of 24 kg the intake would be around 2.2 pg PCDD/F WHO-TEQ/kg bw/day (middle-bound concentrations) (Bocio and Domingo, 2005). It is not clear how or when the dietary habits were investigated. It is mentioned in the report that the foods were representative for the population of the area. The food samples were acquired in 2002. In 2008, an updated estimation was made using the same consumption data but new data on levels of PCDD/Fs in the food products (sampled in 2006). The estimated average intake of PCDD/Fs in the same age group had now decreased to 22.8 and 20.4 pg WHO-TEQ/day, for boys and girls, respectively. With the same average weight, 24 kg, the intake was estimated to 0.95 and 0.85 pg WHO-TEQ/kg bw/day, for boys and girls, respectively. In the estimations the middle-bound PCDD/F concentrations were used (Martí-Cid et al., 2008). The main explanation for this dramatic decrease in intake for children in Spain is the decrease in levels in the food products and especially in fish and seafood consumed by the children.

In France, dietary estimations for children (3-14 years) have been reported for PCDD/Fs and dl-PCBs. The French national dietary survey conducted in 1998 to 1999 was used for estimations of dietary intakes of PCDD/Fs and dl-PCBs. Data on levels of PCDD/Fs and dl-PCBs were collected from the French national monitoring programs (2001-2004). The median total-TEQ intake was estimated to 2.4 pg WHO-TEQ/kg bw/day (Tard et al., 2007).

In Italy it was also shown that toddlers and young children (0-6 years old) exhibited the highest estimated mean total intake of 5.34 pg WHO-TEQ/kg bw/day. The breastfed toddlers were excluded in this estimation (Fattore et al., 2006). Information concerning the consumption data has been described above, when presenting the information concerning adult exposure.

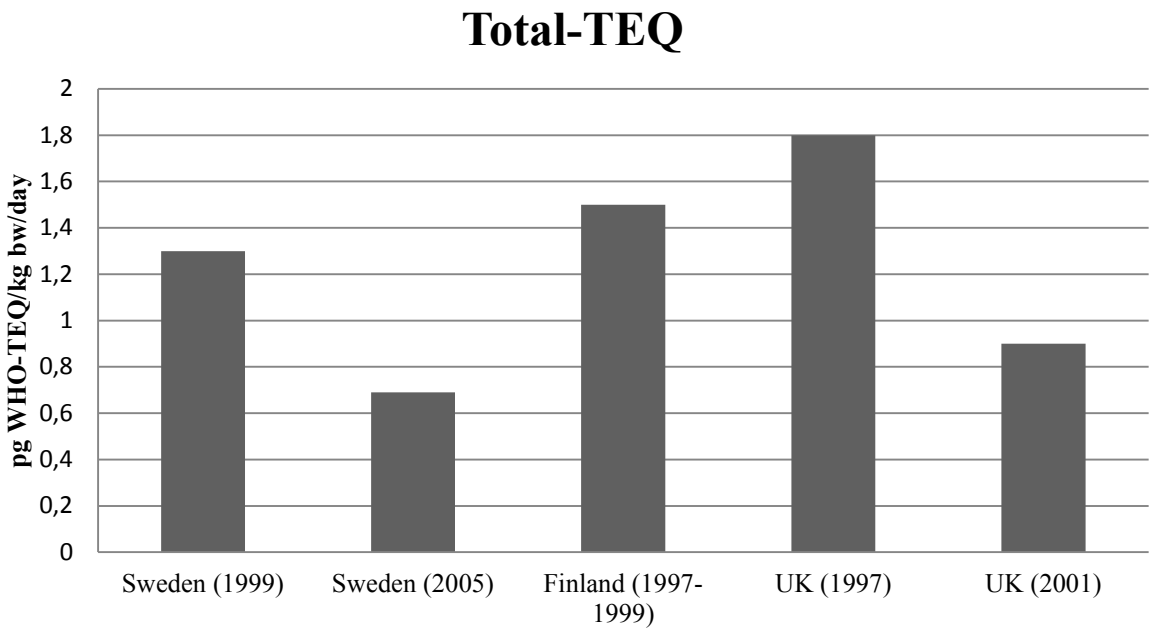

Figure 3. *Dietary intake of PCDD/Fs + dl-PCBs (total-TEQ) (pg TEQ/kg bw/day) based on market basket (MB) or total diet (TDS) in Sweden (MB), Finland (MB), and the UK (TDS). The figures within the brackets are the respective sampling year. More detailed information concerning the studies can be found in the text above and in Table 1.*

Market basket studies (total diet studies)

The results from the Swedish market basket studies conducted in 1999 and 2005 indicate that there has been a decline in PCDD/Fs and dl-PCBs level in foods on the Swedish market (Ankarberg et al., 2006, Darnerud et al., 2006). The estimated daily intake of total-TEQ *per capita* in 1999 was 95.8 pg WHO-TEQ/day or 1.30 pg WHO-TEQ/kg/day (average weight 73.7 kg), whereas in 2005 it had decreased to 50.9 pg WHO-TEQ/day or 0.69 ng WHO-TEQ/kg/day (average weight 73.7 kg) (Figure 3 and Appendix). The estimations were based on middle-bound concentrations (Ankarberg et al., 2006, Darnerud et al., 2006). The *per capita* intake of both PCDD/Fs and dl-PCBs decreased and the total-TEQ intake from the largest contributors, fish, meat and dairy products had decreased (Table 1). The main contributor fish was in 2005 calculated to contribute with 49 % of the intake. The average dietary intake estimations based on food consumption data from the market study in 1999 and the data from Riksmaten 1997-98 were similar, 1.30 vs. 1.1 pg WHO-TEQ/kg bw/day (same average, 73.7 kg used). In the market basket study in 1999 the LOQ of several PCDD/F and PCB congeners were higher than in the 2005 study. Consequently, lower levels of some congeners could be

detected in 2005 than in 1999, which complicate the comparisons between the studies.

In Finland, a market basket study on dietary intake of dioxins and PCBs was published in 2004. The average daily intakes of these substances by the Finnish adult population were assessed. The total-TEQ intake was estimated to be 115 pg WHO-TEQ/day. When using an average mean weight of 76 kg for the general population the intake was estimated to 1.5 pg WHO-TEQ/kg bw/day (Figure 3 and Table 1). The consumption of fish accounted for 95 % and 80 % of the daily intake of PCDD/Fs WHO-TEQ and PCB WHO-TEQ, respectively, when using the lower-bound intake (Kiviranta et al., 2004). The composition of the market basket was based on the Dietary Survey of Finnish Adults (NPHI, 1998). Ten individual market baskets were created, for example liquid milk products, fish, eggs, vegetables and beverages and spices. The food samples were collected between 1997 and 1999 (Kiviranta et al., 2004).

In the report about the total diet study from UK Food Standard Agency's (FSA) in 2003, it was concluded that the estimated average intake by adults of dioxins + dl-PCBs in the UK diet decreased from 1.8 pg WHO-TEQ/kg bw/day in 1997 to 0.9 pg WHO-TEQ/kg bw/day in 2001 (upper-bound concentrations) (Figure 3 and Table 1). In this report the average dietary intake of dioxins and dl-PCBs by the UK consumer were estimated using consumption data from the National Diet and Nutrition Survey (NDNS). Estimations for dietary intake of dioxins and dl-PCBs for earlier years are also to be found in the report, see (FSA, 2003).

Intakes among high consumers of fish - fishermen

In Sweden, fish is a major source of the intake of dioxins and PCBs (Darnerud et al., 2006). Individuals that consume fish frequently have been observed to have higher body burdens of dioxins and PCBs than the average consumer. One such group is professional fishermen that consume fatty fish from the Baltic Sea. In the 1990s, Swedish fishermen from the east coast consumed more fatty fish than fishermen from the west coast and had higher blood levels of dioxins and PCBs than fishermen from the west coast and the general population (Svensson et al., 1995b). Fishermen from the east coast were reported to consume on average 208 g herring per week and 119 g salmon from the Baltic Sea, in total about 300 g fatty Baltic Sea fish (Svensson et al., 1995a). In the early 2000s, a consumption of 300 g fatty fish per week from the Baltic Sea was estimated to result in a daily intake of dioxins and dl-PCBs of 430 pg TEQ, or 6 pg TEQ/kg bw/day (average weight 73.7 kg) (Ankarberg et al., 2007). It was further estimated that the highest consumption of fatty Baltic Sea fish reported among the east coast fishermen, 58 meals per month (Hagmar et al., 2004), would lead to a total intake of dioxins and dl-PCBs around 2500 pg TEQ/day, or 36 pg TEQ/kg/day for a 70 kg person in the early 2000s. The intake would be about 40 times higher than the median intake reported for adults during the same time period (Ankarberg and Petersson-Grawé, 2005, Ankarberg et al., 2007).

In a study on Swedish and Latvian men consuming large quantities of fatty fish from the Baltic Sea it was shown that both age and fish consumption were significantly correlated with the concentration of several halogenated contaminates including the sum PCB in blood plasma (Sjödin et al., 2000). Latvian high consumer showed blood levels of PCB almost twice as high as the Swedish high consumers. No estimations concerning the daily intake of these contaminates were made by Sjödin and co-workers.

In a study from Finland in the mid 1990´s it was shown that fishermen consuming fish at least twice a week showed plasma concentrations of PCDD/Fs over five times higher than general men in Finland (Kiviranta et al., 2000, Kiviranta et al., 2002). In these two Finnish studies no estimations were made for the dietary intake of PCDD/Fs or PCBs.

Biomonitoring of dioxin and dl-PCB in mother's milk

Biomonitoring of dioxin and dl-PCB in human tissues/fluids gives a good estimate of the long-term accumulation of the persistent contaminants from food. Due to the relative high lipid content of human mother's milk, it is a good matrix for analysis of the lipid-soluble dioxin and dl-PCB. It can be assumed that the levels PCDD/Fs and dl-PCBs in mother's milk lipids are representative for the levels in the lipid fraction of other tissues, such as adipose tissue and blood. Levels of the contaminants in mother´s milk give a good estimate of the exposure of the fetus and nursing infant.

Levels of PCDD/Fs and dl-PCBs

When comparing different biomonitoring studies one must keep in mind that the personal characteristics of the women participating in a study will influence on the results. To begin with, the levels depend on the number of children the mothers has delivered before the milk samples were collected, i.e. if the mother is primi-para, or multipara. It is known that the levels of PCDD/Fs and PCB in mother's milk decrease both with time spent breastfeeding and with increasing parity (Vaz et al., 1993, Schade and Heinzow, 1998). The age of the participants will also have effect on the outcome. It is known that older mothers have higher dioxin- and dl-PCB-levels in their breast milk (Albers et al., 1996, Schade and Heinzow, 1998, Herbstman et al., 2007, Lignell et al., 2009). The use of different TEF-systems makes it difficult to compare the levels reported in some of the studies.

Another factor that complicates the comparison of results from different studies is the use of pooled or individual samples. There are advantages and disadvantages with using pooled samples. The advantage with using pooled samples is the lower costs compared with the costs for analyses of individual samples. Moreover, analyses of pooled samples give quick information about the average exposure. A disadvantage is that studies using pooled samples lack data on ranges of body burdens within the study population. Information about ranges is important for risk assessment purposes. Moreover, in studies using pooled samples it is not possible to statistically adjust results for differences in personal characteristics between populations. For instance there are differences in average age at first pregnancy between different countries in Europe, and there is a strong association between age of the mother and dioxin and PCB levels in mother´s milk (Albers et al., 1996, Glynn et al., 2007).

WHO studies

The most systematic information on average dioxin and dl-PCB levels in mother´s milk in different countries is based on four rounds of studies of dioxins and PCBs in human milk coordinated by WHO (Tuomisto, 2009). Although some minor modifications have been made in the protocol between the different rounds, each participating country collected milk from well defined groups of 10 mothers and pooled the milk. The donating mothers had to fulfilled the following criteria: they

should be primipara, healthy, exclusively breastfeeding one child (i.e. no twins), and residing in the study area for about 5 years (Malisch et al., 2008). In the first round, in 1987/1988, 12 European countries were included. The results from the first round indicated large differences between the countries. For example the PCDD/F levels in Hungary were about 10 pg WHO-TEQ/g fat, in Sweden about 22 pg WHO-TEQ/g fat, whereas in the Netherlands around 40 pg WHO-TEQ/g fat was reported.

In the second round, 1992/93, Sweden did not take part, but in Belgium, the Netherlands, Germany, the U.K., Czech Republic, Slovakia, Ukraine, Norway, Denmark, Austria, Croatia, and Hungary all reported lower levels of dioxins and dl-PCBs in the mother's milk compared to the levels reported in the first round (Tuomisto, 2009).

The third round was initiated in 2000 and also included non-European countries (Malisch and van Leeuwen, 2003). Altogether, 100 pooled samples were collected and analyzed. In countries as Bulgaria, Croatia, Hungary, and Ireland the levels of PCDD/Fs and dl-PCBs were quite low (Figure 4). In densely populated western European countries, such as Belgium, Italy, Spain, Germany, Luxembourg, and the Netherlands, the level were highest (Malisch and van Leeuwen, 2003). The highest total-TEQ levels were found in mother's milk samples collected in the Ukraine (Figure 4). The total-TEQ levels in the Swedish mother's milk were about half of the levels found in milk from the Ukraine and twice as high as in Hungary (Figure 4). When comparing the total-TEQ level found in mother's milk collected in Sweden with the levels found in the other 17 European countries, the Swedish one are on the lower half, i.e. 10 countries showed higher levels and 7 countries lower levels. On average, the decline between the levels found in the second round in 1993 and the levels reported in the third round was about 40 %.

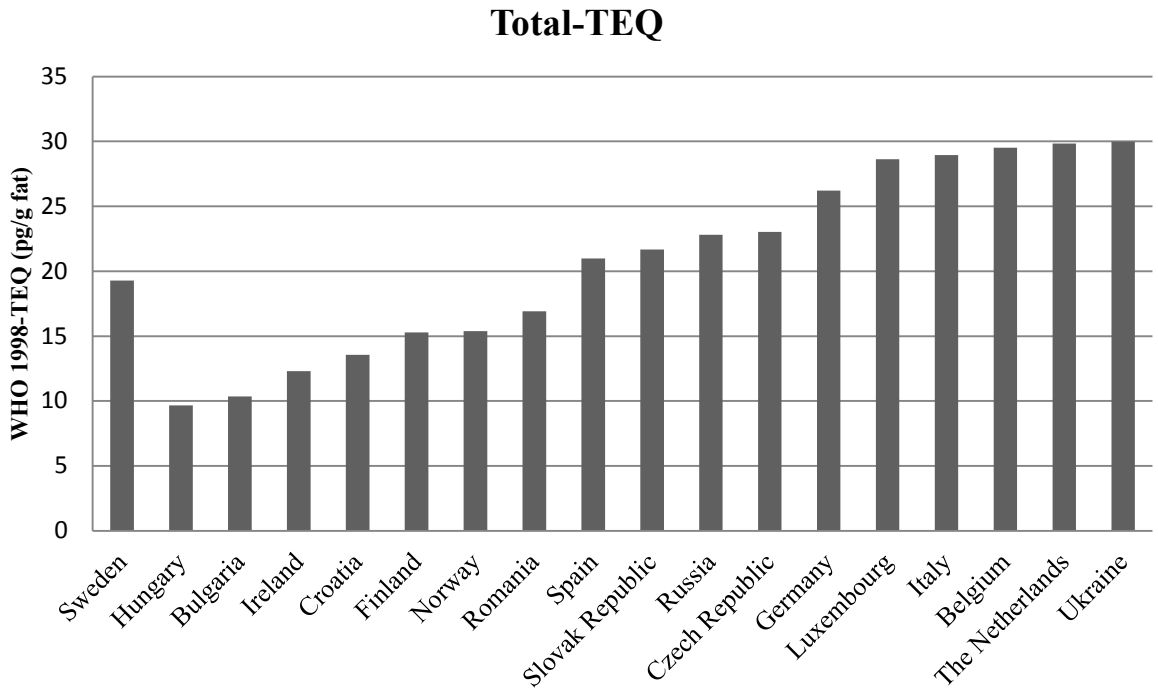

Figure 4. *Median levels of total-TEQ (WHO_{1998}-TEQ) in mother's milk collected in European countries during the third round of the WHO-coordinated exposure study. The samples were collected between 2001 and 2003.*

There is a lack of information about the results of the 4th round study. Mother's milk samples collected during the 3rd round (2001-2003) and the 4th round (2005-2007) in 19 European countries showed median levels of 8.9 and 9.4 pg WHO-TEQ/g fat for PCDD/Fs and PCBs, respectively (Malisch et al., 2008). Analysis of mother's milk samples from Sweden collected during the 4th round show that the average PCDD/F-TEQ level was 6.0 pg/g fat and that the PCB-TEQ level was 6.8 pg/g fat, giving an average total-TEQ level of 12.8 pg WHO-TEQ/g fat (CVUA, 2007).

Sweden

In Sweden, studies of temporal trends of dioxins and dl-PCBs in mother's milk have been reported with data from both pooled and individual milk samples. The Stockholm studies, conducted on pooled milk samples, showed that the body burden of PCDD/Fs and PCBs of women in the Stockholm area decreased markedly between the early 1970s and the late 1990s (Norén and Meironyte, 2000). In 1997 the average total-TEQ level was 28 % of that in 1972 (Norén and Meironyte, 2000).

In studies on individual milk samples from primiparas living in the Uppsala area, it has been reported that the downward trend of dioxin and dl-PCB levels has continued after the 1990s. The total-TEQ level decreased with 6.3 % per year between 1996 and 2006 (Lignell et al., 2009). The changes in concentrations were adjusted for age, pre-pregnancy BMI, weight gain during pregnancy and weight loss after delivery.

Finland Norway and Denmark

Temporal trends of dioxins and PCBs in mother's milk have also been investigated in other Scandinavian countries, although not as systematic as in Sweden. The trends are based on results from studies with different designs. In Finland and Norway, decreasing levels for both PCDD/Fs and PCBs has been reported between the 1980s to the mid 2000s (Johansen et al., 1994, Becher et al., 1995, Kiviranta et al., 1999, Polder et al., 2008, Polder et al., 2009). The WHO studies show similar average total-TEQ levels in Finland and Norway as in Sweden (Figure 4).

Denmark did take part in the first two rounds of the WHO studies of human milk (i.e. 1987/98 and 1992/93). The levels in the mother's milk at these time points were very similar to the levels in milk collected in Finland (Tuomisto, 2009). Since Denmark did only take part in the two first rounds, it is difficult to say anything about the trend in the levels in milk from the Danish mothers.

Other European countries

Long-term monitoring studies on temporal trends of dioxins and dl-PCBs in mother's milk in other European countries are scarce. Croatia and Germany are two countries that have reported levels of dioxins and dl-PCBs in mother's milk over several years. In both countries the levels of the compounds in mother's milk have decreased from the beginning of the 1980s (Furst, 2006, Raab et al., 2008, Zietz et al., 2008, Krauthacker et al., 2009). In a publication from Germany levels of PCDD/Fs and PCBs in mother's milk from samples collected from the mid 1980's to 2003 were presented (Furst, 2006). Mother's milk collected between 2001 and 2003 from 175 individuals showed that the PCDD/Fs mean level was 13.8 pg WHO-TEQ/g fat and the dl-PCB was 13.2 pg WHO-TEQ/g fat. The average levels measured in Germany were about 2-fold higher than in milk collected in Sweden at that time (unpublished data from NFA). A long-term temporal trend for PCDD/Fs was shown from 1989-2003. In total 1000 individual

samples were analyzed and in 1989 the median level was 33.9 pg I-TEQ/g fat and the corresponding level in 2003 was 9.8 pg I-TEQ/g fat or 11.5 pg PCDD/F WHO-TEQ/g fat.

However, when samples of mother's milk were collected in 2005 in Bavaria, Germany, similar average levels as the levels seen in Sweden at the time were reported. Milk samples were collected 12 weeks post-partum from 43 primipara mothers with an average age of 32.4 years. The PCDD/Fs and dl-PCB levels were 9.92 and 9.89 pg WHO-TEQ/g lipid, respectively. The decline in levels of PCDD/Fs in Germany seems to continue after 2003 (Furst, 2006).

The situation in Croatia has recently been described by Krauthacker and co-workers (Krauthacker et al., 2009). The paper describes previously reported data on levels in human milk and together with new data. Data from 1988, 1992, 1994, 1997 and 2000 were reported, including both primipara and multipara mothers of ages 18-43 years. Milk samples collected in Croatia in 2000 showed PCDD/Fs levels of 5.2 and 5.9 pg I-TEQ/g lipid, in 2 polled samples with 10 and 12 mother´s milk samples (Krauthacker et al., 2009). The average PCDD/F levels decreased about 50 % between 1988 and 2000 and that the annual decrease in dioxin levels was about 2 %. Croatia participated in the first three WHO coordinated exposure studies and the results from the 3rd one show that the total-TEQ levels were among the lowest of the investigated European countries in 2001-2003 (Figure 4).

Levels of PCBs in mother's milk

Two recent papers shown that the levels of PCBs are decreasing in mother's milk from Swedish primiparous mothers and that there are only small regional differences in the levels (Lignell et al., 2009, Glynn et al., 2011). In year 2000-2004, mother's milk was collected from 204 randomly recruited primiparas from four regions of Sweden. Among the PCB congeners, PCB 153 showed the highest median level in the samples. The level was 42 ng/g fat in Uppsala (N=92), 48 ng/g fat in Gothenburg (N=37), 43 ng/g fat in Lund (N=36). In Lycksele significantly lower levels were seen (31 ng/g fat, N=39) than in Lund. The regional differences were rather small and the lower levels seen in milk from Lycksele were due to the lower median age in Lycksele, 27 years compared to 29-30 years in the other cities (Glynn et al., 2011). Uppsala was the only city where samples were collected over several years and a decline could be seen in the di-*ortho* PCBs and the sum-PCB declined with 8.5 % per year, between 2000 and 2004 (Glynn et al., 2011). The decrease in PCB levels in mother's milk from primiparous women in Uppsala was also seen when analyzing samples collected from the year 1996-2006 (Lignell et al., 2009). The PCB levels declined 3.9-8.6 % per year.

Although the trend with decreasing levels of PCBs in mother's milk has been observed in several European countries, the Faroe Islands does not show the same pattern. The sum PCB level (11 congeners, PCB 105, PCB 118, PCB 128/167, PCB 138, PCB 146, PCB 153, PCB 156, PCB 170, PCB 183, PCB 187) in pooled milk samples were reported to be 2300 ng/g fat in 1987, 1600 ng/g in 1994/95, and 1800 ng/g in 1999 (Fängström et al., 2005). The mothers in the study were

between 20 and 29 years old and primiparous. Each pooled sample contained milk from 10 mothers. The reason for the high levels in the mother's milk is the consumption of whale blubber which holds high concentration of PCBs. The average sum PCB levels in mother's milk from the Faroe Islands exceed the levels in Sweden by a factor of about five (Norén and Meironyte, 2000). In eastern parts of Europe (e.g. the Czech Republic and Slovakia) high levels of PCBs have been found in milk from mothers living in areas where PCB production existed in the past (Yu et al., 2007, Cerná et al., 2010). In a Slovakian study the median level of PCB 153 was 184 ng/g fat in milk collected on day 4 or 5 postpartum in the year 2003. In the Czech Republic milk from mothers living close to a former PCB plant showed a median level of 3410 ng/g lipid for the sum of 35 PCBs analyzed. In the study, 90 milk samples were collected from seven urban areas in 1999-2000 according to the WHO protocol. Much lower levels were found in another area where the total PCB median level was 480 ng/g lw (Cerná et al., 2010). The median PCB 153 levels in the mother's milk also showed great variances between the locations, with the corresponding levels of 646 ng/g lipid and 97.5 ng/g lipid, respectively.

In the third round of the WHO coordinated exposure studies it was shown that the indicator PCBs (PCB 28, PCB 52, PCB 101, PCB 138, PCB 153, PCB 180) in mother's milk vary widely between the European countries. In mother's milk from Sweden the median level was reported to be 146 ng/g fat. High levels were found in Spain, Italy, the Slovak Republic, and the Czech Republic (Figure 5). The median levels of the sum indicator PCBs ranged from 241 ng/g fat to 502 ng/g fat in these countries. Much lower median levels were found in mother's milk from Hungary, Bulgaria, Ireland, and Finland, where the sum PCBs ranged from 60 ng/g fat to 91 ng/g fat (Malisch and van Leeuwen, 2003). The level of sum indicator PCBs in mother's milk collected in Sweden were in the lower half of that found in milk from the participating countries. In the 4th round of the WHO coordinated exposure studies the sum indicator PCBs level had decreased to 84.3 ng/g fat in mother's milk collected in Sweden (CVUA, 2007).

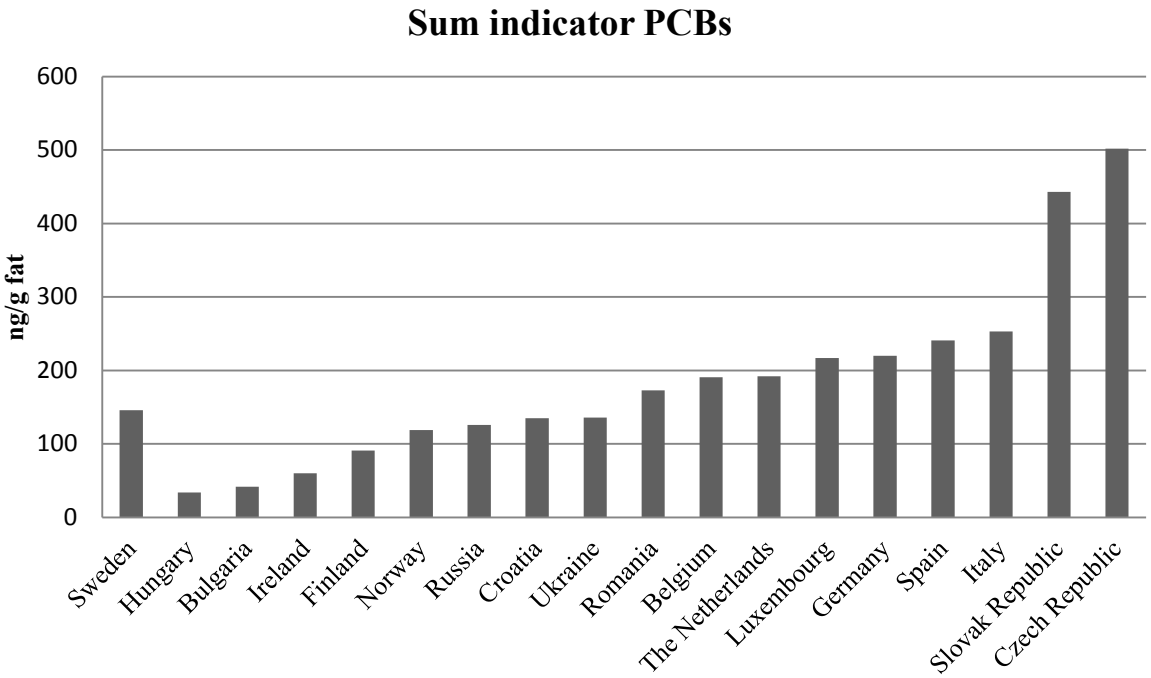

Figure 5. Average levels of sum indicator PCBs (PCB 28, PCB 52, PCB 101, PCB 138, PCB 153, PCB 180) in mother's milk collected in European countries during the third round of the WHO-coordinated exposure study. The samples were collected between 2001 and 2003.

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Table 1. Intake of dioxins (PCDD/Fs) and dioxinlike PCBs in Europe.

Country	Consumption data	Period	Sex/Age	Occurance data	Mean intake (pg WHO-TEQ/kg bw/day)			Method	Reference
					PCDD/Fs-TEQ	PCB-TEQ	Total-TEQ		
Belgium	Dietary survey	around 1999	M/F adults	2000/2001	1.00	1.04	2.04	Lower bound	Focant et al. (2002)
Belgium	two 24 h recall	2004	M/F 15 years and older	2008	Not specified	Not specified	0.72	Middle bound	Windal et al. (2010)
Finland	24 h recall	1997	M/F adults	1998-2000	Not specified	Not specified	1.3	Lower bound	Kiviranta et al. (2001)
Finland	24 h recall	1997	M/F adults	1997-1999	0.76	0.74	1.5	Lower bound	Kiviranta et al. (2004)
France	Dietary survey	1998-99	M/F 15 year and older	2001-2004	0.5	1.2	1.8	Lower bound	Tard et al. (2007)
Germany	Duplicate diet study	2005	M/F 14-60 years	2005	-	0.19	-	Middle bound	Fromme et al. (2009)
Italy	Dietary surveys	1994-96	M/F 13-94 years	1997-2003	0.96	1.30	2.28	Upper bound	Fattore et al. (2006)
Norway	Dietary survey	1997	M/F adults	1989-1996	0.39	1.50	1.89	Upper bound	SCOOP (2000)
Spain	Dietary survey	2000	M adults	2000	1.36	2.14	3.51	Middle bound	Llobet et al. (2008)
Spain	Dietary survey	2003	M adults	2006	0.37	0.75	1.12	Middle bound	Llobet et al. (2008)
Spain	24 h recall	2002	M adults	2006	0.40	Not analyzed	-	Middle bound	Martí-Cid et al. (2008)
Sweden	Riksmaten 1997-98	1997-98	M/F 17-79 years	1998-99	M 0.61 and F 0.62	M 0.41 F 0.44	M 1.0 F 1.1	Middle bound	Lind et al. (2002)
Sweden	Market basket	1999	M/F 17-79	1999	0.74	0.56	1.30	Middle bound	Darnerud et al. (2006)
Sweden	Market basket	2005	M/F 17-79	2005	0.34	0.36	0.69	Middle bound	Ankarberg et al. (2006)
Netherlands	48 h dietary record	1997-98	M/F 1-97 years	1998-1999	0.6	0.5	1.1	Lower bound	Baars et al. (2004)
Netherlands	48 h dietary record	1997-98	M/F 1-97 years	2004	0.4	0.32	0.8	Lower bound	De Mul et al. (2008)
UK	Dietary survey	2000-2001	M/F adults	1997	1.0	0.8	1.7	Upper bound	FSA (2003)
UK	Dietary survey	2000-2001	M/F adults	2001	0.3	0.4	0.7	Upper bound	FSA (2003)

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