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Undesirable substances in seafood products – results from the Icelandic marine monitoring activities in the year 2010

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Ágrip á íslensku:	Árið 2003 hófst, að frumkvæði Sjávarútvegsráðuneytisins, vöktun á óæskilegum efnum í sjávarafurðum, bæði afurðum til manneldis sem og afurðum til lýsis- og mjöliðnaðar. Matís hefur verið falin umsjón með vöktunarverkefninu. Tilgangurinn með vöktuninni er að meta ástand íslenskra sjávarafurða með tilliti til magns aðskotaefna. Sömuleiðis er markmiði að safna óháðum vísindagögnum um óæskileg efni í sjávarafurðum fyrir stjórnvöld, fiskiðnaðinn sem og kaupendur og neytendur íslensks sjávarfangs. Gögnunum sem safnað er í vöktunarverkefninu verða einnig notuð í áhættumat og til að byggja upp gagnagrunn um aðskotaefni í íslensku lífríki. Umfjöllun um aðskotaefni í sjávarafurðum, bæði í almennum fjölmiðlum og í vísindaritum, hefur margoft krafist viðbragða íslenskra stjórnvalda. Nauðsynlegt er að hafa til taks vísindaniðurstöður sem sýna fram á raunverulegt ástand íslenskra sjávarafurða til þess að koma í veg fyrir tjón sem af slíkri umfjöllun getur hlotist. Ennfremur eru mörk aðskotaefna í sífelldri endurskoðun og er mikilvægt fyrir Íslendinga að taka þátt í slíkri endurskoðun og styðja mál sitt með vísindagögnum. Þetta sýnir mikilvægi þess að regluleg vöktun fari fram og að á Íslandi séu stundaðar sjálfstæðar rannsóknir á eins mikilvægum málaflokki og mengun sjávarafurða er. Þessi skýrsla er samantekt niðurstaðna vöktunarinnar fyrir árið 2010. Mat á ástandi íslenskra sjávarafurða með tilliti til aðskotaefna er langtímaverkefni og verður einungis framkvæmt með sívirkri vöktun. Á hverju ári er því farið vandlega yfir hvaða gögn vantar og þannig stefnt að því að fylla inní eyðurnar. Árið 2010 voru eftirfarandi efni mæld í sjávarafurðum sem ætlaðar eru til manneldis sem og afurðum til lýsis- og mjöliðnaðar: dioxin, dioxinlík PCB og bendi PCB efni, PBDEs, málmar, auk þess 12 mismunandi tegundir varnarefna. Gert var sérstak átak í mælingum á PBDE og málmum árið 2010 og var styrkur þeirra almennt lágur í íslenskum sjávarafurðum. Eins og áður mældist almennt lítið magn óæskilegra efna í íslensku sjávarfangi árið 2010. Olía og mjöl gert úr kolmunna á það þó til að vera nálægt eða yfir leyfilegum mörkum fyrir viss efni.		
Lykilorð á íslensku:	*Sjávarfang, vöktun, Díoxín, díoxínlík PCB, PCB, varnarefni, PBDEs, málmar*		

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Summary in English:	This monitoring of undesirable substances in seafood products was initiated by the Icelandic Ministry of Fisheries and Agriculture in the year 2003. Until then, this type of monitoring had been limited in Iceland. Matis was assigned the responsibility of carrying out the surveillance programme, which has now been ongoing for seven consecutive years. The purpose of the project is to gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances. Further, the aim of the project is to provide independent scientific data on undesirable substances in Icelandic seafood for food authorities, fisheries authorities, industry, markets and consumers. The information will also be utilized for a risk assessment and gathering of reference data. This report summarizes the results obtained in the year 2010 for the monitoring of various undesirable substances in the edible part of marine catches, fish meal and fish oil for feed. The monitoring began in 2003 and has now been carried out for seven consecutive years. The evaluation of the status of the Icelandic seafood products in terms of undesirable substances is a long term project which can only be reached through continuous monitoring. For this reason, we carefully select which undesirable substances are measured in the various seafood samples each year with the aim to fill in the gaps in the available data. Thus the project fills in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. In the year 2010, data was collected on dioxins, dioxin-like PCBs, marker PCBs, 12 different types of pesticides, PBDEs and trace metals in the edible part of fish, fish oil and meal for feed. Samples collected in 2010 contained generally low concentrations of undesirable substances. These results are in agreement with our previous results obtained in the monitoring programmes in the years 2003 to 2009. In the year 2010 emphasis was laid on gathering information on the organic compounds PBDEs and inorganic trace elements in the edible part of marine catches as well as in the fish meal and fish oil for feed. The results reveal that the concentrations of PBDEs compounds are in low in fish and fish products for feed. Blue whiting meal and oil can contain undesirable substances in concentration close to or exceeding the maximum level set by the EU.
English keywords:	*Marine catches, monitoring, dioxin, PCB, pesticides, PBDEs, metals*

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1 Introduction

In 2003, the Icelandic Ministry of Fisheries initiated a project aimed at monitoring undesirable substances in the edible portion of marine catches, as well as in fish meal and fish oil for feed, captured in Icelandic waters. Matis was assigned the responsibility of carrying out the surveillance programme, which has now been ongoing for seven consecutive years. The goal of the surveillance programme is to gather information and evaluate the status of Icelandic seafood products regarding undesirable substances. The project is funded by the Ministry of Fisheries and Agriculture in Iceland. The project includes measurements of several marine species from Icelandic fishing grounds in order to gather information on various undesirable substances in a number of economically important marine species for Icelandic export. The substances investigated in this monitoring project are: polyaromatic hydrocarbons (PAHs), polychlorinated dibenzo dioxins and dibenzo furans (commonly called dioxins), dioxin-like polychlorinated biphenyls (PCBs), marker PCBs, polybrominated flame retardants (PBDEs) and 30 pesticides and breakdown products (i.e. HCB, DDTs, HCHs, dieldrin, endrin, chlordanes, toxaphenes and endosulfan substances) and inorganic trace elements such as heavy metals.

The purpose of this work is:

A) To gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances.
B) It provides scientific evidence that Icelandic seafood products conform to regulations on seafood safety. To evaluate how products measure up to limits currently in effect for inorganic trace elements, organic contaminants and pesticides in the EU (Regulation (EC) No 1881/2006, Commission Regulation (EC) No 629/2008, Commission Directive 2002/32/EC, Commission Directive 2003/100/EC).
C) To utilize the data gather in the programme for a risk assessment and the setting of maximum values that are now under consideration within EU e.g. for PAHs, PCBs, inorganic arsenic and brominated flame retardants.
D) To provide independent scientific data on undesirable substances in Icelandic seafood for food authorities, fisheries authorities, industry, markets and consumers.

This report summarizes results from the monitoring programme in the year 2010. The results obtained in the years 2003 to 2009 have already been published and are accessible at the Matis website (http://www.matis.is: Auðunsson, 2004, Ásmundsdóttir *et al*., 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir *et al*., 2008, Jörundsdóttir *et* *al*., 2009, Jörundsdóttir *et al*., 2010a, Jörundsdóttir *et al*., 2010b). The above mentioned EU regulations have now been implemented in the Icelandic legal framework regarding undesirable substances in food and feed (Reglugerð 265/2010).

2 Summary

This report summarizes the results obtained in 2010 for the monitoring of various undesirable substances in the edible part of marine catches, fish meal and fish oil for feed. The surveillance programme began in 2003 and has now been carried out for seven consecutive years. The project fills in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. It is considered to be a long-term project where extension and revision is constantly necessary.

In the year 2010 emphasis was laid on gathering information on the organic compounds PBDEs and inorganic trace elements in the edible part of marine catches as well as in the fish meal and fish oil for feed. Generally, the results obtained in 2010 are in agreement with our previous results on undesirable substances in the edible part of marine catches, fish meal and fish oil for feed obtained in the monitoring years 2003 to 2009.

The results show that the edible parts of Icelandic seafood products contain negligible amounts of persistent organic pollutants (POPs) such as; dioxins, dioxin like PCBs and pesticides. The results for PBDEs reveal that these compounds are also in very low amounts in fish and fish products. Further, the concentration of marker PCBs was found to be low in the edible part of fish muscle, compared to the maximum limits in the European countries, where such limits exist. The results showed that the concentrations of heavy metals, e.g. cadmium (Cd), lead (Pb) and mercury (Hg) in Icelandic seafood products was always well below the maximum limits set by EU.

The samples of fish meal and fish oil for feed measured are subjected to different maximum limits by the EU. Only one fish oil sample exceeded the EU maximum limits for sum of dioxins and dioxin like PCB as well as toxaphene and chlordane.

3 Contaminants measured in the project

The following contaminants are measured in edible parts of seafood and fish oil for human consumption, as well as in fish meal and fish oils used as feed ingredients:

Dioxins, PCDD/Fs: Dioxins (dibenzo-p-dioxins) and dibensofurans (17 congeners according to WHO): 2.3.7.8-Tetra-CDD, 1.2.3.7.8-Penta-CDD, 1.2.3.4.7.8-Hexa-CDD, 1.2.3.6.7.8-Hexa-CDD, 1.2.3.7.8.9-Hexa-CDD, 1.2.3.4.6.7.8-Hepta-CDD, OCDD, 2.3.7.8-Tetra-CDF, 1.2.3.7.8-Penta-CDF, 2.3.4.7.8-Penta-CDF, 1.2.3.4.7.8-Hexa-CDF, 1.2.3.6.7.8-Hexa-CDF, 1.2.3.7.8.9-Hexa-CDF, 2.3.4.6.7.8-Hexa-CDF, 1.2.3.4.6.7.8-Hepta-CDF, 1.2.3.4.7.8.9-Hepta-CDF, OCDF.

Dioxin like PCB (12 congeners according to WHO):
non-ortho (CB-77, CB-81, CB-126, CB-169) and mono-ortho (CB-105, CB-114, CB-118, CB-123, CB-156, CB-157, CB-167, CB-189).

Marker- PCB (7 congeners):
CB-28, CB-52, CB-101, CB-118, CB-138, CB-153, CB-180.

Pesticides:
DDT-substances (6 congeners: pp-DDT, op-DDT, pp-DDD, op-DDD, pp-DDE and op-DDE), HCH-substances (4 isomers: α-, β-, γ-(Lindane), and δ-hexachlorocyclohexan), HCB, chlordanes (4 congeners and isomers: α- and γ-chlordane, oxychlordane and trans-nonachlor), toxafen-substances (3 congeners, P 26, 50 and 62), aldrin, dieldrin, endrin, endosulfan (3 congeners and isomers: α- and β-endosulfan and endosulfansulfat) and heptachlor (3 congeners: heptachlor, cis-hepatchlorepoxid, trans-heptachlorepoxid).

PBDE-substances (10 congeners):
BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153, BDE-183, BDE-209.

Inorganic trace elements:
Hg (mercury), Cd (cadmium), Pb (lead), total As (organic and inorganic arsenic), chromium (Cr), iron (Fe), copper (Cu), zinc (Zn) and selenium (Se).

4 Sampling and analysis

4.1 Sampling

The collection of samples and the quality criteria for the analytical methods were in accordance with conditions set out by the EU for the information gathering campaign on dioxins and dioxin-like PCBs as well as for metals (Commission Directive 2001/22/EC, Commission directive 2002/69/EC). Fish samples were collected by the Marine Research Institute in Iceland. Fish meal and fish oil were gathered by collaborating partners in the industry.

4.1.1 Seafood

All the analysis was done on the edible parts of the seafood products. The fish was collected from the fishing grounds around Iceland which are divided into five areas, as illustrated on Figure 1. All samples were identified with the location of the fishing area, except when the sample contained individuals from more than one area. Each seafood sample consisted of a pooled sample from the entire edible part (e.g. skinless fish fillet) from at least ten individuals of a specific length distribution, except that the halibut (*Hippoglossus hippoglossus*) sample consisted of pooled sample obtained from a slice (without skin) from10 individual fish.

4.1.2 Fish meal and fish oil for feed

The fish meal and fish oil samples were taken at the production sites and, when possible, sampling was distributed over the year.

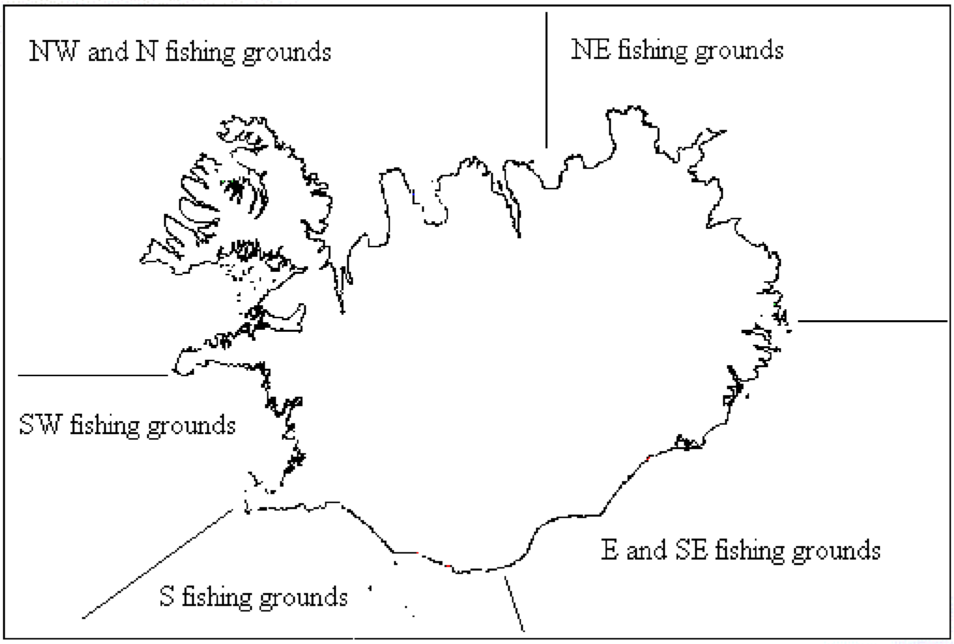

Figure 1: The division of the fishing grounds around Iceland used in this research.

4.2 Analysis

The organic contaminants were measured by Eurofins, Hamburg, Germany. Eurofins has taken part in international inter-laboratory quality control study organized by WHO and EU and uses accredited methods for analyzing dioxin, WHO-PCBs, marker-PCBs, pesticides and PBDEs.

Results are expressed as upper bond level, which means that when the concentration of a substance is measured to be below limit of detection (LOD) or limit of quantification (LOQ) of the analytical method, the concentration is set to be equal to the LOD/LOQ. In the case of dioxins and dioxin-like PCBs, the analytical data are converted to pg/g WHO-TEQ where the toxicity of each congener has been calculated using WHO-TEF (Toxic Equivalence Factor) based on the existing knowledge of its toxicity (Van den Berg et al., 1998). WHO-TEQ values have been adapted by the World Health Organization (WHO) in 1997 and by EU in its legislations.

5 Results of monitoring of fish and seafood products in Iceland

All results of the monitoring program in 2010 are listed in Tables 1-9 in the Appendix.

5.1 Dioxins (PCDD/Fs) and dioxin like PCBs

5.1.1 Dioxins and dioxin like PCBs in seafood

All the fish species measured are far below the limits set by EU for the sum of dioxins and dioxin like PCBs, except for a sample of halibut where the sum concentration of dioxins and dioxin like PCBs is 3,7 pg/g WHO-TEQ, which is almost half of the maximum limit of 8 pg/g WHO-TEQ (Figure 2 and Table 1 in the Appendix). As in previous years, a considerable difference was observed in the dioxin content between different fish species. The species that accumulate fat in the muscle, like for example Greenland halibut, halibut, and herring (samples no. 17-20), contain more dioxins and dioxin like PCBs than species which accumulate fat in the liver and thus have almost no fat in the muscle. Mackerel and capelin have also higher lipid content in the muscle and therefore higher dioxin and dioxin like PCB concentrations. The level of dioxin in the edible part of the fish increases as the fat percentage in the muscle increases, but other important variables are age (length) and habitat. Halibut can become quite old, which probably contributes considerably to the high dioxins and dioxin-like PCBs value obtained for this species (Figure 2).

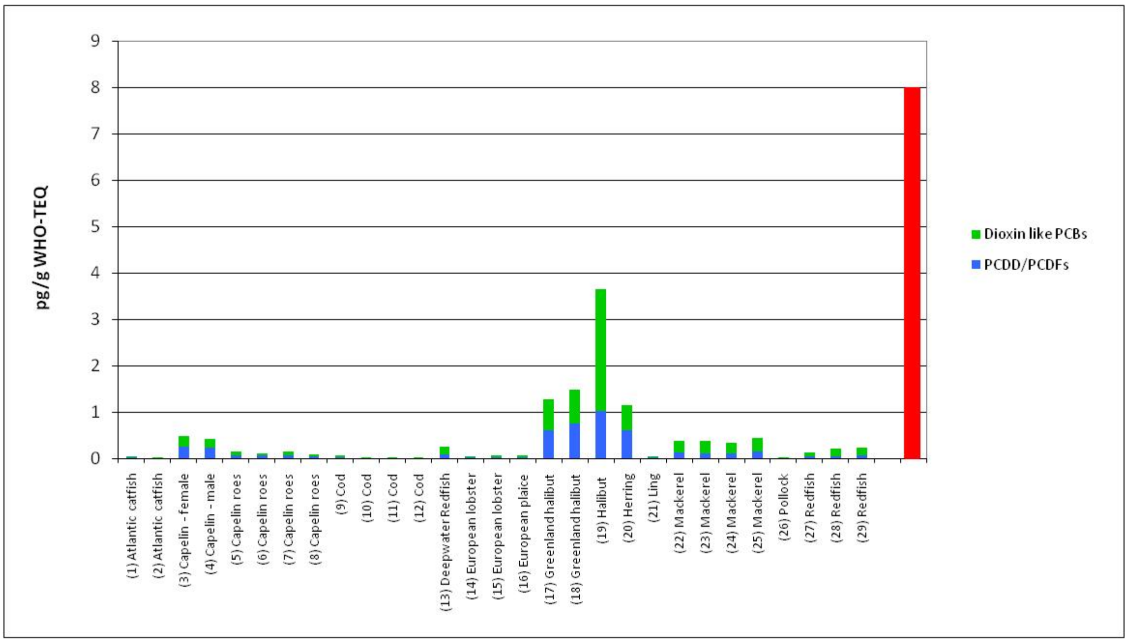

Figure 2: Dioxins and dioxin-like PCBs in the edible part of fish muscle from Icelandic fishing grounds in 2010 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1.

5.1.2 Dioxins and dioxin like PCBs in fish oil for human consumption

There were no samples of fish oil for human consumption analysed or collected from the fish oil industry this year. Earlier results from 2005 and 2006 showed concentrations below the EU maximum limit of 2 pg/g WHO-TEQ for dioxins or the EU maximum limit of 10 pg/g WHO-TEQ for the sum of dioxins and dioxin like PCBs (Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008, Regulation (EC) No 1881/2006).

5.1.3 Dioxins and dioxin like PCBs in cod liver

There were no samples of cod livers analysed or collected this year. Earlier results from 2008 showed that concentrations in one individual liver sample was above the EU maximum limit of 25 pg/g WHO-TEQ. Other samples and pooled sample were below the EU maximum limit (Jörundsdóttir et al., 2010).

5.1.4 Dioxins and dioxin-like PCBs in fish meal and fish oil for feed

Samples of fish meal and fish oil are taken annually. The samples taken in the year 2010 consisted of mueller's bristlemouth fish meal and blue whiting, capelin and herring meal and oil. The EU maximum limits for dioxins and dioxin-like PCBs in fish meal and fish oil for feed are set relatively low in order to prevent the accumulation of these toxic substances in the food chain (Commission Directive 2006/13/EC). For this reason, results for these products are closer to the maximum limits than in the edible part of the fish muscle as discussed in chapter 5.1.1.

The sum of dioxin and dioxin-like PCB was lower than the EU maximum limit in all fish meals tested (Figure 3). The same was observed for the fish oil with the exception of the blue whiting oil sample, which exceeded the limits for the sum of dioxins and DL-PCBs (Figure 4). Further the concentration of marker-PCBs was high in this sample (Figure 6 and Figure 7).

It has been shown that the level of persistent organic pollutants in fish meal and fish oil for feed is related to the fat content of the fish used as raw material. The fat content of the fish, however, depends very much on the nutritional condition of the fish and consequently varies through the seasons (Anon., 2003, Ásmundsdóttir et al., 2005). Figure 3 and Figure 4 show the amount of dioxins and dioxin-like PCBs in fish meal and fish oil samples compared to the EU maximum limits. The samples were taken throughout the year 2010 and further details on the results for dioxins and dioxin-like PCBs in these samples can be found in Tables 2 and 3 in the Appendix. Fish meal and fish oil samples from blue whiting contained the highest amounts of dioxin and dioxin-like PCBs compared to fish meal from other species. These samples were from meal and oil of blue whiting caught in April/ May which is the period just after spawning, when the fat content in the fish is low. All fish oil samples measured in this study are can be paired with specific fish meal samples, i.e. these fish oil and meal samples were obtained from the same original raw material and samples of the oil and meal were taken during production of this raw material. The following pairs are presented in the relevant Figures and Tables in this report; Fish oil no. 1 & meal no. 3, Fish oil no. 2 & meal no. 5, Fish oil no. 3 & meal no. 10.

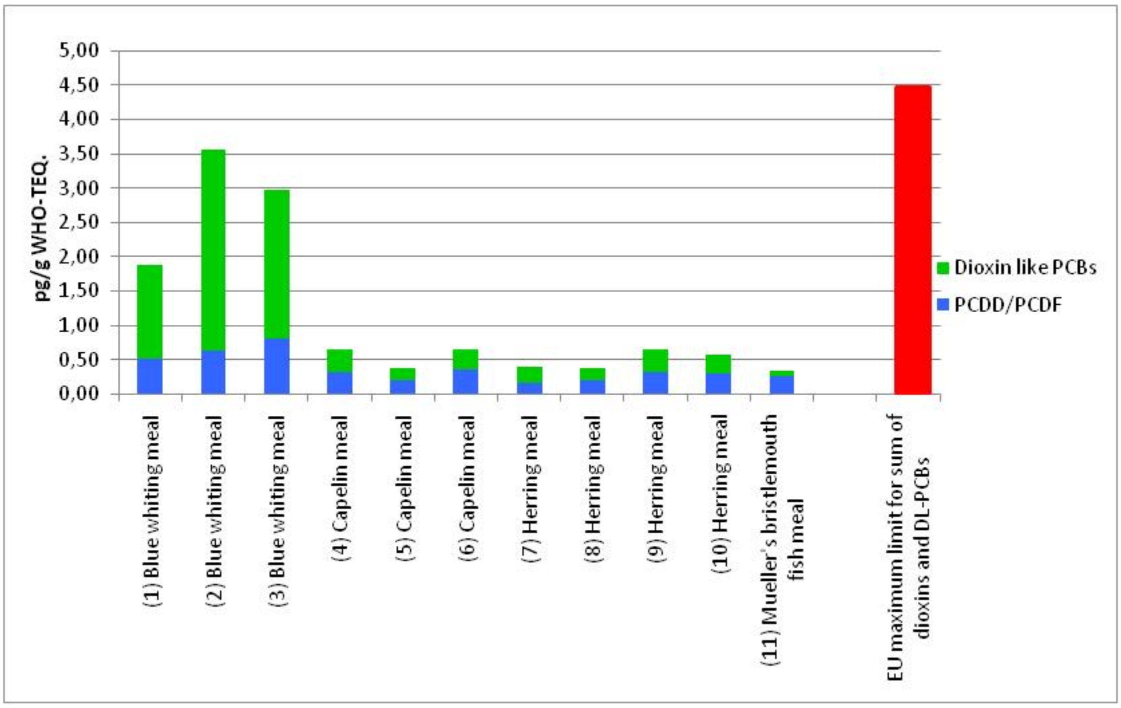

Figure 3: Dioxins and dioxin-like PCBs (in pg/g WHO-TEQ) in samples of fish meal from Iceland 2010 calculated in relation to 12% moisture compared to the EU maximum limit.

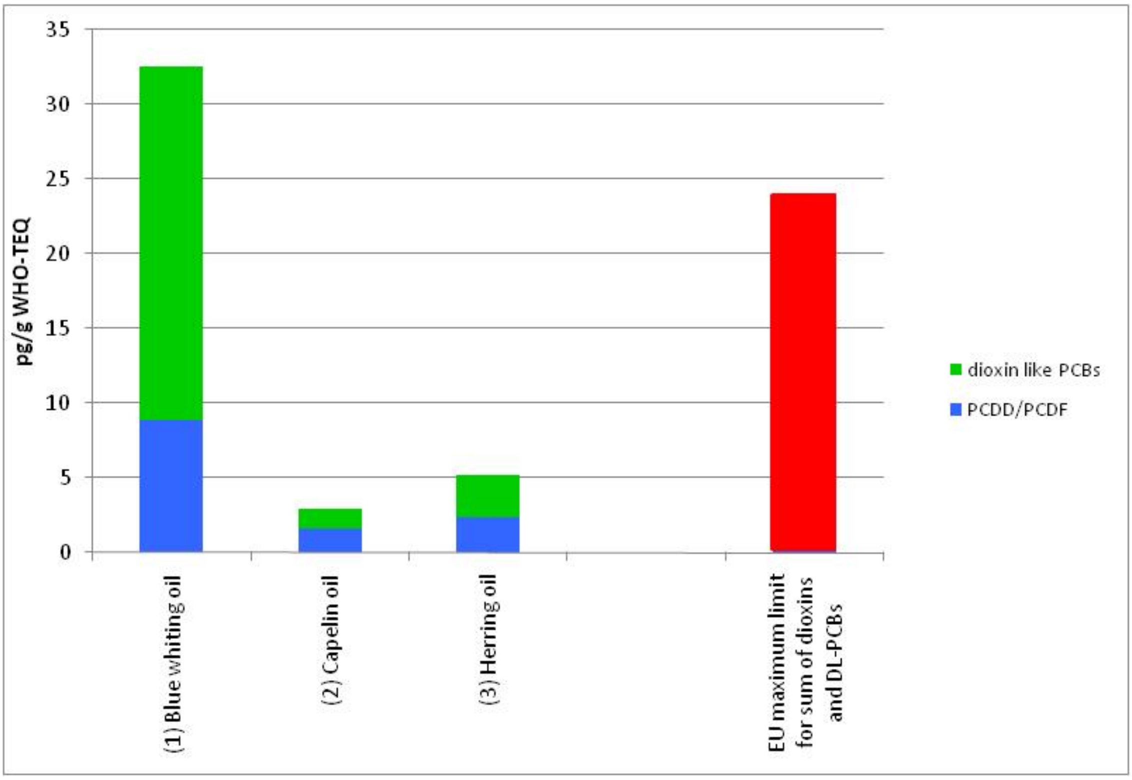

Figure 4: Dioxins and dioxin-like PCBs in samples of fish oil for feed from Iceland in 2010 (in pg/g WHO-TEQ) compared to the EU maximum limit.

5.2 Marker PCBs

Marker PCBs, sometimes called "Dutch seven" or ICES7, are seven PCBs that have been measured for many years as an indication of the total PCB contamination. One of these seven, PCB-118, is classified as a dioxin-like PCB, but the toxicity factor of the other six has not yet been estimated. The EU is working on a risk assessment for marker PCBs in order to establish a maximum level in the nearest future. Maximum levels of marker PCBs exist for some or all of the seven marker PCBs in several European countries and in USA.

5.2.1 Marker PCBs in seafood

The results obtained for the majority of the Icelandic fish species and capelin roes are well below the available limits for marker PCBs mentioned above, except for the PCB concentration in the halibut. The maximum level of each of the individual PCB congeners range from 40 µg/Kg to 120 µg/Kg in Germany, Holland and Sweden. In this research, the highest total concentration for the sum of all seven marker PCBs was measured in halibut (sample no. 19), a total of 33 µg/kg wet weight, the highest individual PCB congener measured in the halibut was PCB-153 with 12 µg/kg wet weight, or over third of the total. As for the dioxins and dioxin-like PCBs, the highest concentrations of PCBs are found in fish with high lipid content in the filet. For details, see Table 1 in the Appendix.

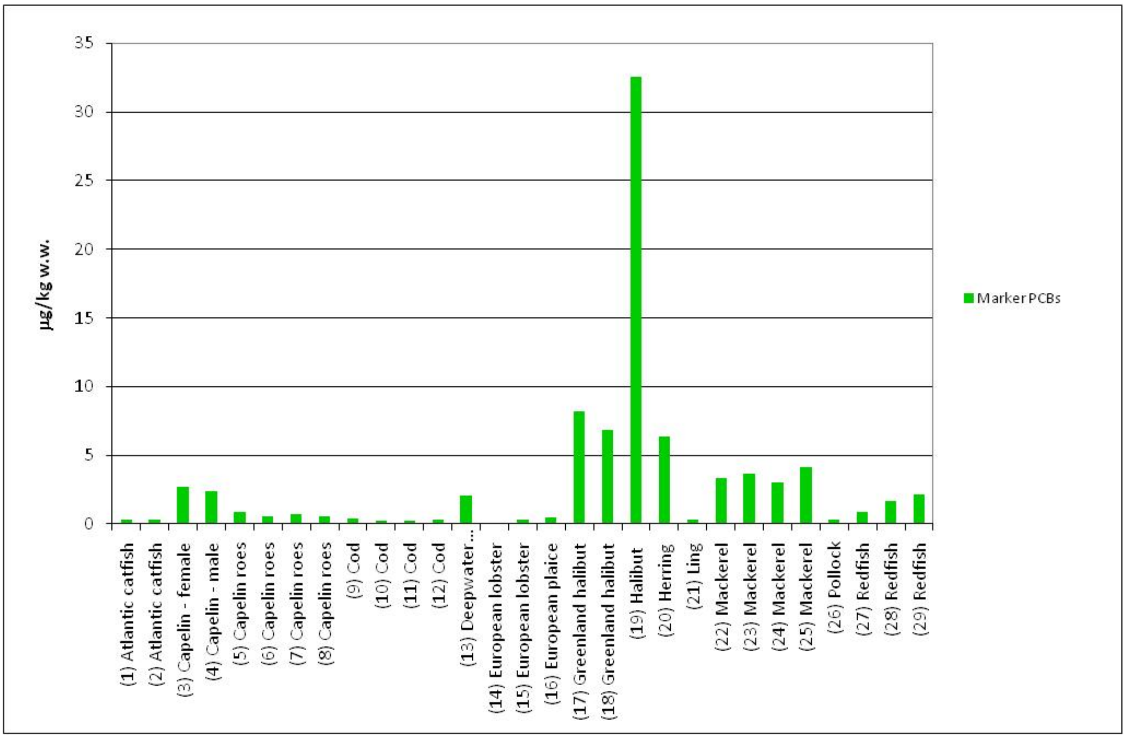

Figure 5: Marker PCBs in the edible part of fish muscle from Iceland in 2010 (in µg/kg wet weight). Number in parenthesis is the sample number designated to each sample, see Table 1 in Appendix.

5.2.2 Marker PCBs in fish oil for human consumption

There were no samples of fish oil for human consumption analysed this year. Earlier results from 2005 and 2006 were reported in previous reports from the Icelandic monitoring program (Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008).

5.2.3 Marker PCBs in cod liver

There were no samples of cod livers analysed or collected this year. Earlier results from 2008 were published in Jörundsdóttir *et al.* (2010). No maximum limits have been set by the EU for marker PCBs in fish liver or products derived from fish liver.

5.2.4 Marker PCBs in fish meal and fish oil for feed

The results for the marker PCBs in fish meal and fish oil samples measured in this study are shown in Tables 2 and 3 in the Appendix and in Figure 6 and Figure 7 below. No limits have yet been set for these substances in the EU. The concentration of marker PCBs was more than five times higher in the blue whiting oil and meal samples compared to the other fish oil samples.

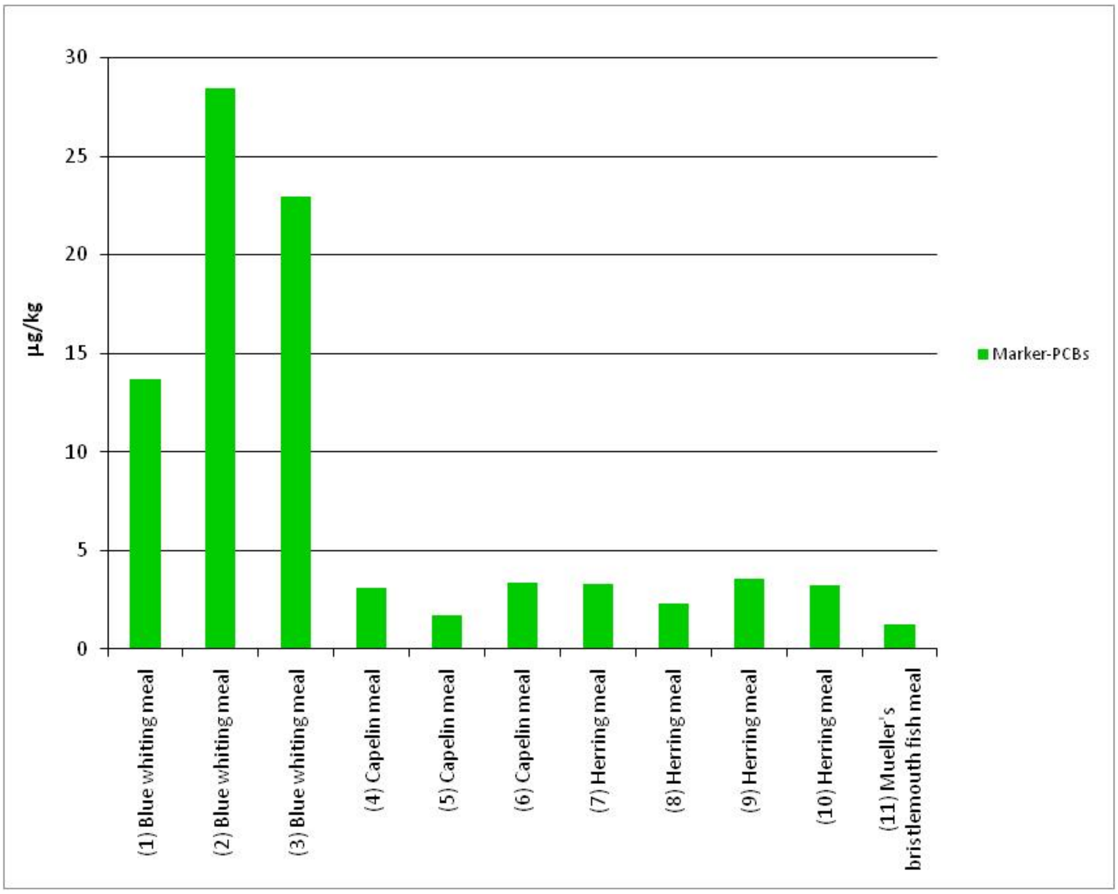

Figure 6: Marker PCBs in fish meal from Iceland in 2010 calculated in relation to 12% moisture

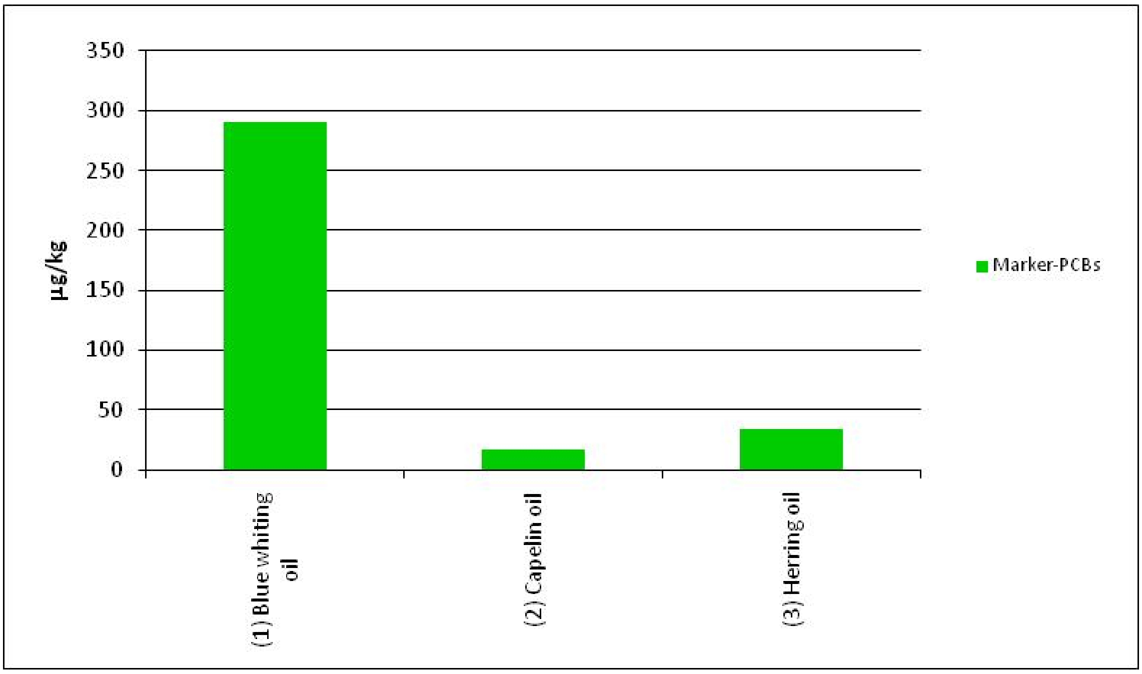

Figure 7: Marker PCBs in fish oils from Iceland in 2010.

As discussed in section 5.1.4 it has been shown that the level of persistent organic pollutants in fish meal and fish oil for feed is related to the fat content of the fish used as raw material. The blue whiting samples with the highest concentration of marker PCBs in this study are from meal and oil of blue whiting caught in April/May which is the period just after spawning, when the fat content in the fish is low.

5.3 Brominated flame retardants (BFRs)

Brominated diphenyl ethers (BFRs) have been accumulating in the environment over the last decade as their use in industry has increased. One group of BFR is Polybrominated dipheynyl ethers (PBDEs). No maximum limits have yet been set in the EU, but they have been estimated to be ten times less toxic than the pesticide DDT (Scientific Advisory Committee on Nutrition (SACN, 2005). There are three major PBDE products (PentaBDE, OctaBDE and DecaBDE) available on the global market and two of them, PentaBDE and OctaBDE, have been banned in the EU and all use of PBDEs has been restricted by the RoHS directive (Restriction of the use of certain Hazardous substances in electrical and electronic equipment).

5.3.1 PBDE in seafood

There is still limited data available on PBDEs in seafood from Iceland (Ásmundsdóttir et al., 2008; Rabieh et al., 2008, Jörundsdóttir et al., 2010 a, Jörundsdóttir *et al.*, 2010b). Therefore a special emphasis was laid on gathering information on PBDE in 2009 and again in 2010. PBDEs were measured in 29 samples of fish muscle and capelin roe. The PBDE are reported here as the upper bound sum of BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183. BDE-209 is not included in the sum as it was not detected in any of the samples tested. No maximum limits have been set for PBDEs in seafood.

The results in Figure 8 showed in general very low level of PBDEs in fish muscle and capelin roe from Icelandic fishing grounds except for the species that accumulate fat in the muscle, like the Greenland halibut, halibut, capelin, herring and mackerel. The results are reported in detail in Table 1 in the Appendix.

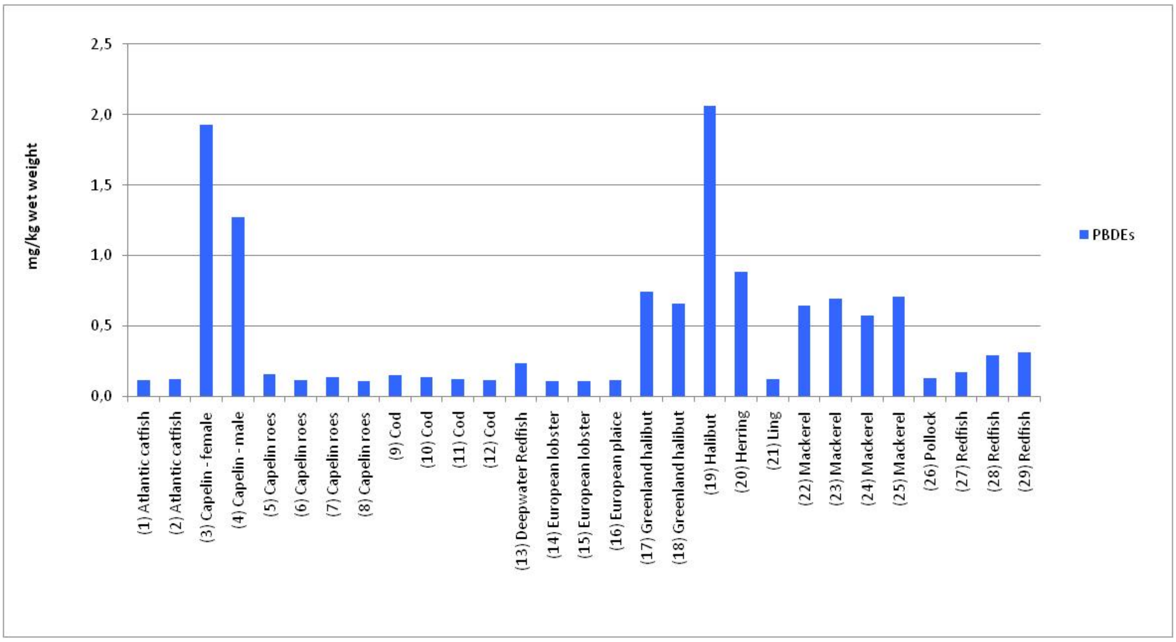

Figure 8: PBDE in fish muscle from Icelandic fishing ground in 2010 in µg/kg wet weight sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183.

5.3.2 PBDEs in cod liver

There were no samples of cod livers analysed or collected this year.

5.3.3 PBDEs in fish oil and fish meal for feed

Like last year a special emphasis was laid on gathering information on PBDEs in fish meal this year (2010). The results for PBDEs in fish meal and fish oil are shown in Tables 2 and 3 in the Appendix. PBDE in the table is the upper bound sum of BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183. BDE-209 is not included in the sum as it was not detected in any sample. As for the marker PCBs, the concentration of PBDEs was higher in the blue whiting meal and oil samples compared to the other meal and oil samples (Figure 9 and Figure 10).

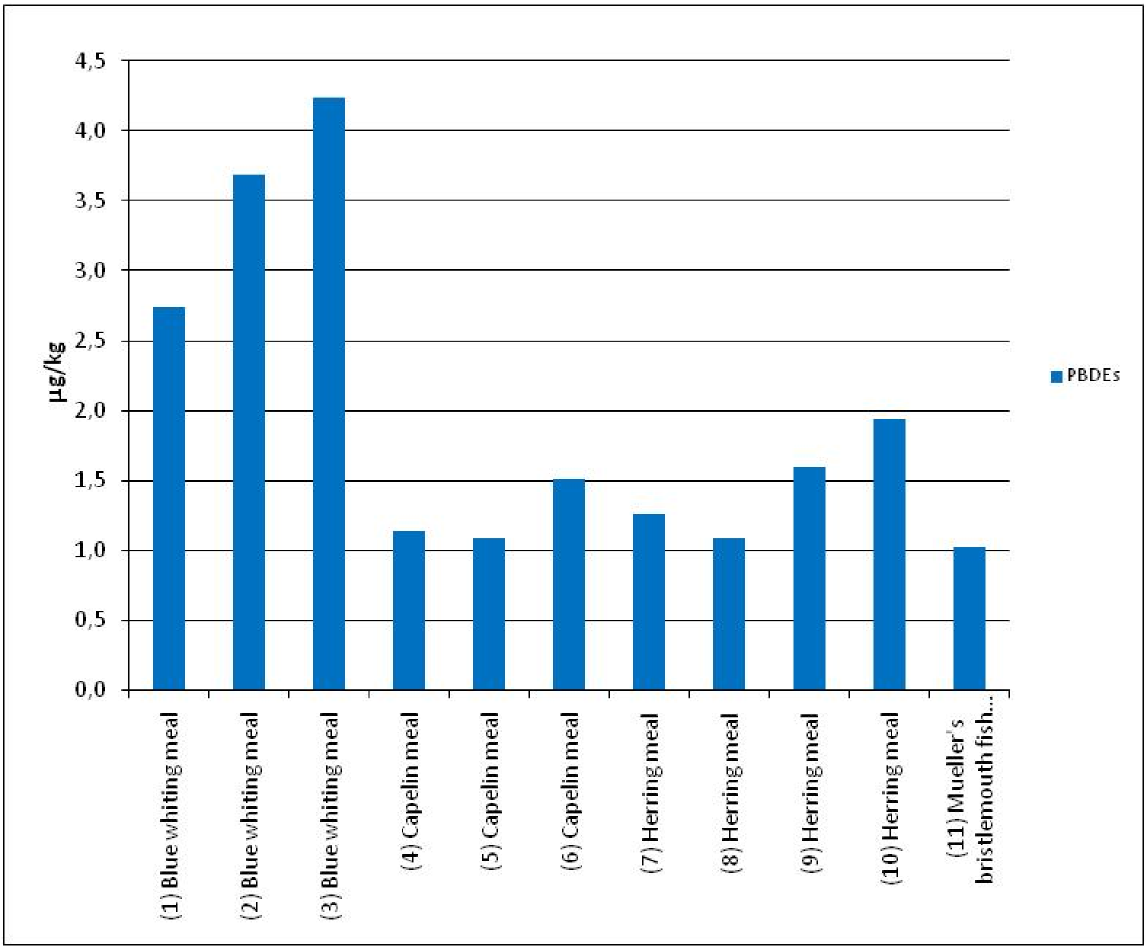

Figure 9: PBDE in fish meal from feed from Icelandic fishing ground in 2010 in µg/kg wet weight sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183.

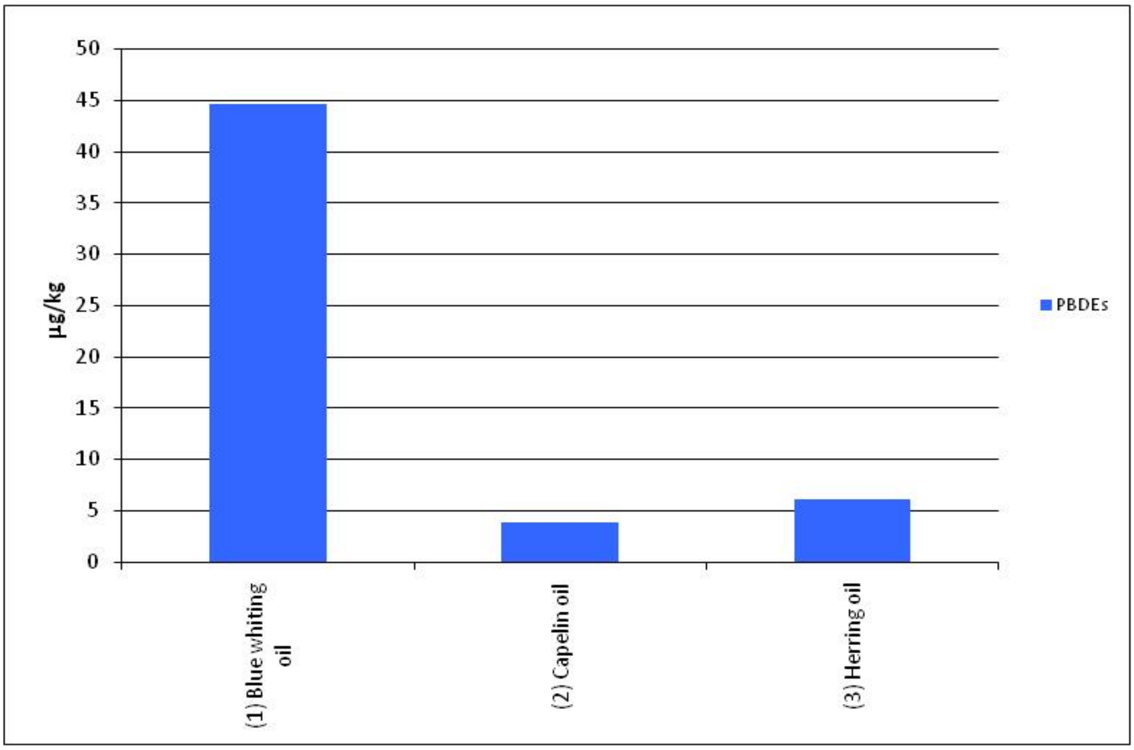

Figure 10: PBDE in fish oil from Icelandic fishing ground in 2010 in µg/kg sum of: BDE-28, BDE-47, BDE-66, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153 and BDE-183.

5.4 PAH

PAHs were not analysed in the samples this year. Results on PAHs in Icelandic seafood have been published in previous reports (Jörundsdóttir et al., 2010).

5.5 Pesticides

In this chapter, the results for 12 different classes of pesticides are discussed. Results are shown in Tables 4 to 6 in the Appendix. Without exception, the fish samples contained negligible amount of pesticides (Regulation (EC) No 396/2005). The fish oil samples contained more pesticides compared to the edible part of the fish muscle as seen when the results for the herring sample were compared to the herring meal and oil (Tables 5, 6 and 7). The meal sample contained lower concentration compared to the edible part, although still in the same order of magnitude. Blue whiting oil and meal contained higher concentrations of all pesticides compared to fish oil and fish meal from other species except for HCHs. All samples contained pesticides below the EU maximum limits except for the blue whiting fish oil which contained higher levels of toxaphene and chlordane than permitted in the EU regulation (Commission Directive 2002/32/EC, Commission Directive 2003/100/EC).

12 different pesticides or groups of pesticides were measured in the monitoring program.

DDT (dichloro diphenyl trichloroethan) is probably the best known insecticide. The technical product DDT is fundamentally composed of p,p'-DDT (80%) (Buser, 1995). DDT breaks down in nature, mostly to DDE but also to DDD. The concentration of DDT presented in this report is the sum of p,p'-DDT, o,p´-DDT, p,p'-DDE, o,p´-DDE, p,p´-DDD and o,p´-DDD.

HCH (hexachlorocyclohexan) is an insecticide which has been used since 1949. It is still produced and used in many countries, although it has been banned in many other countries since the 1970s. Technical-grade HCH is a mixture of mainly four isomers: α-, β-, γ-(Lindane), and δ-HCH. Of these, only Lindane is an active substance comprising of approximately 15% of the total mixture, while α-HCH is 60-70% of the mixture. The Food and Agriculture Organization of the UN (FAO) has prohibited the use of the HCH mixture since in the 1980s, after that it was only allowed to use 99% pure Lindane.

HCB (hexachlorobenzene) is a fungicide, but it has also been used for industrial purpose and was e.g. produced in Germany until 1993. Today, HCB is mainly a by-product in different industrial processes, as production of pesticides but also from waste incineration and energy production from fossil fuel.

Chlordanes is a group of compounds and isomers where α- and γ-chlordane, oxychlordane and trans-nonachlor are the most common, but over 140 different Chlordanes were produced from 1946 until 1988 when the production was banned. Chlordanes have been widely used all over the world as insecticides.

The **Toxaphenes** measured in the samples are the so-called parlar 26, 50 and 62. Toxaphene was used as an insecticide after the use of DDT was discontinued. Toxaphenes use was widespread and the toxaphene congeners are numerous. Several hundred have been analyzed but they are thought to be tens of thousands. The substances measured, i.e. the parlar 26, 50 and 62, are the most common toxaphenes (about 25% of the total amount in nature) and these are used as indicators of toxaphene pollution.

Aldrin and Dieldrin are widely used insecticides, but in plants and animals aldrin is transformed to dieldrin. Hence, the concentration of aldrin was below LOD in all the samples measured, while dieldrin was always above LOD. The maximum value in the EU is set for the sum of aldrin and dieldrin.

Two E**ndosulfans** were measured, α- and β-endosulfan, as well as endosulfansulfat which is the breakdown product of endosulfan. Endosulfans are not as persistent as the other insecticides measured in this project.

Other pesticides measured were **Endrin, Heptachlores, Pentachlorobenzene, Mirex and Octachlorostyrene.**

5.5.1 Pesticides in seafood

The results showed very low concentration of all pesticide groups measured in fish from Icelandic waters (see Table 4 in the Appendix). As mentioned before, the results are expressed as upper bond, but most of the pesticides were below the limit of detection and therefore the results presented are likely to be an overestimation. Negligible amounts of ΣDDT, Pentachlorobenzene, HCB, Heptachlores, Aldrin/Dieldrin, Toxaphene, Chlordane and *trans*-Nonachlore were measured in almost all fish species and δ-HCH was always below LOQ except in one sample of mackerel. Figure 11 shows the level of DDT in fish muscle. All fish samples have ΣDDT concentration lower than the EU maximum limit of 500 μg/kg w.w. Of the fish species analysed, halibut and the Greenland halibut had the highest concentrations of all pesticides.

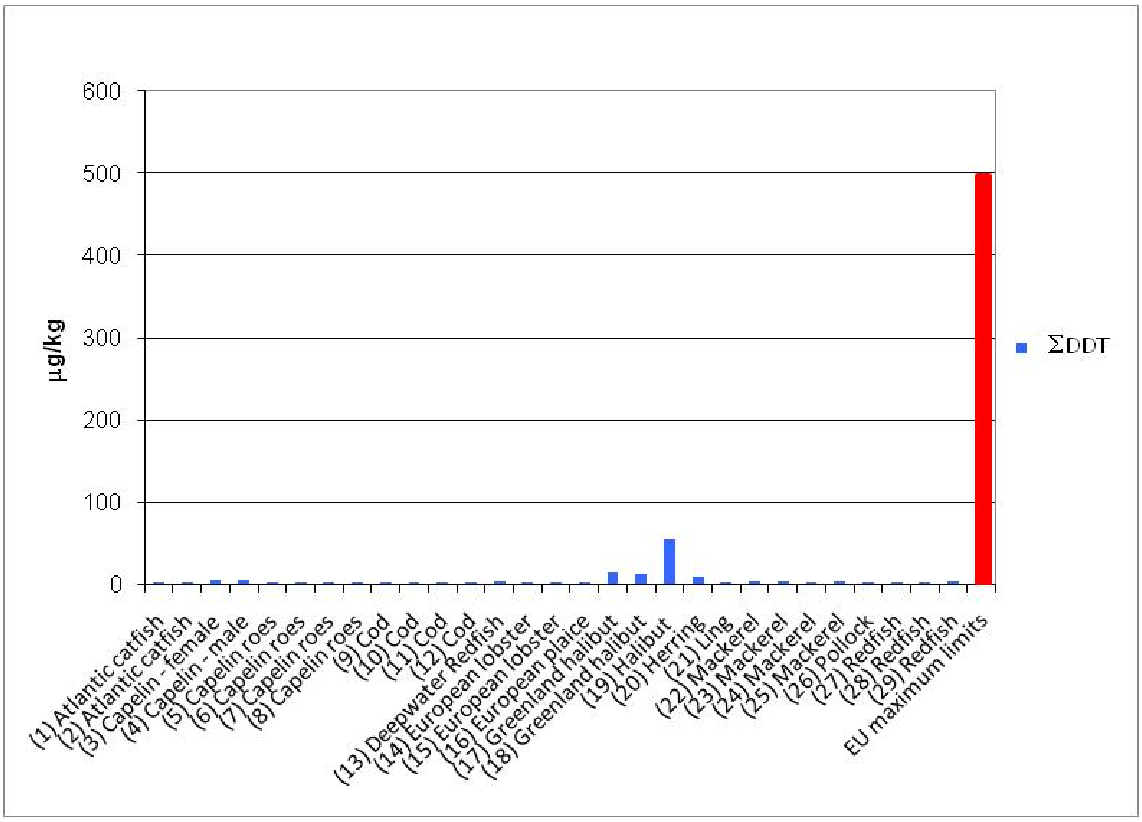

Figure 11: ΣDDT in fish muscle from Icelandic fishing grounds in 2010 in μg/kg wet weight.

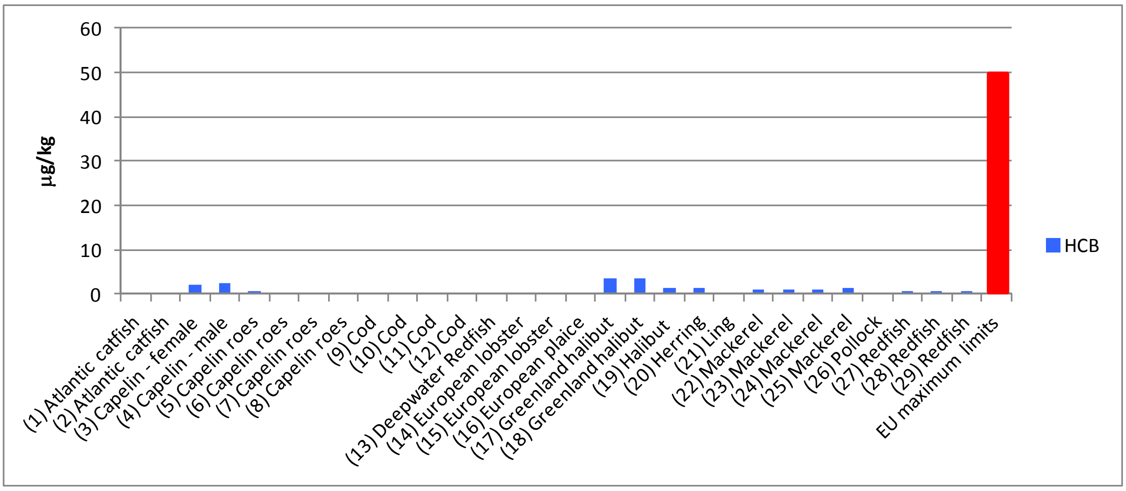

Figure 12: HCB in fish muscle from Icelandic fishing grounds in 2010 in µg/kg wet weight.

5.5.2 Pesticides in fish oil for human consumption

There were no samples of fish oil for human consumption analysed in the monitoring program in the year 2010.

5.5.3 Pesticides in fish meal and fish oil for feed

Several pesticides were measured in fish meal and fish oil for feed (see Tables 5 and Table 6 in the Appendix). The concentration of pesticides was highest in the blue whiting and capelin meal with the concentrations of ΣDDT and HCB an order of magnitude higher compared to the other meal samples, but nevertheless under the EU maximum limits. As shown in Figures 13 and 14 is there a great difference in concentration of DDT and HCB in the fishmeal samples originating from different fish species. It is difficult to determine why the concentration of these substances varies so much in the blue whiting meal (Figure 13 & 14), but factors such as season and condition of the fish are likely contributors. Much higher concentration was obtained in the capelin meal origination from fish caught east of the country few weeks before spawning than capelin caught during spawning in Faxaflói. For the herring the concentration in two samples caught in September (samples no. 9 and 10) were two times higher than in the herring (samples no. 7 and 8) caught in July and August (Figure 13 & 14).

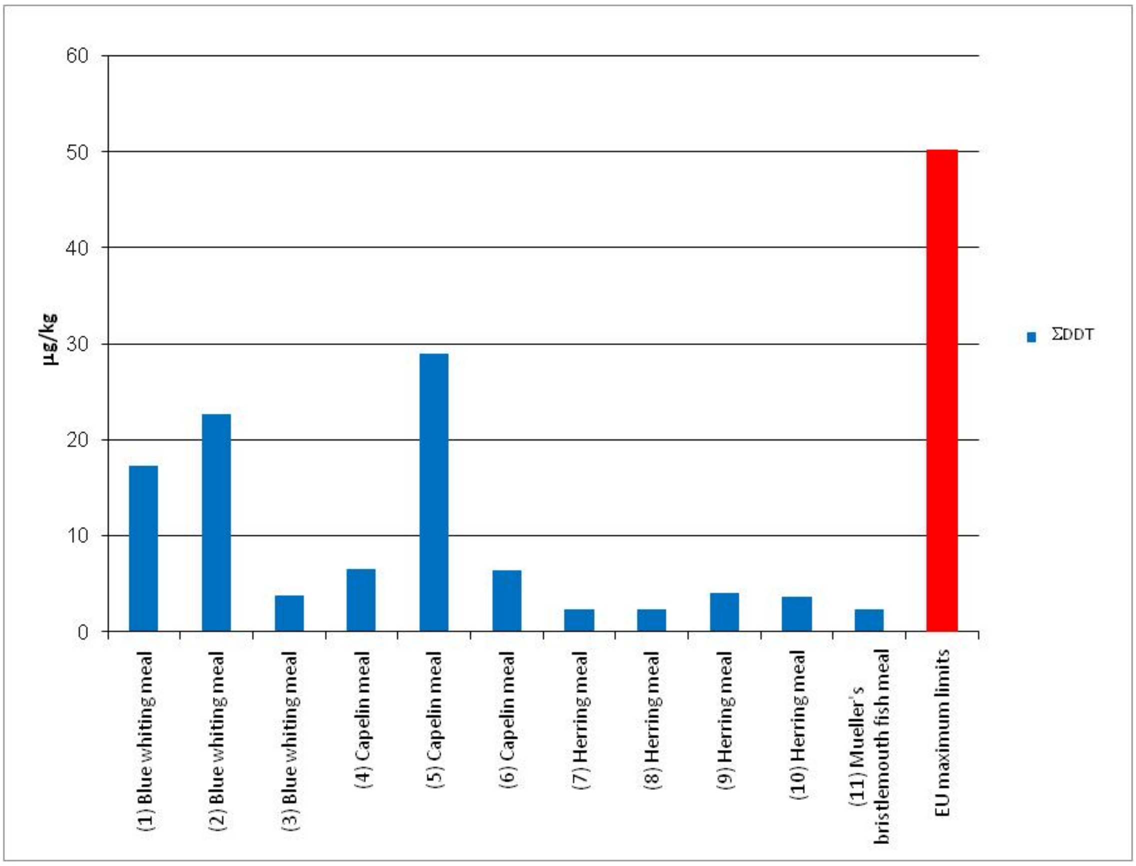

Figure 13: ΣDDT in fish meal from Icelandic fishing grounds in 2010 in µg/kg wet weight.

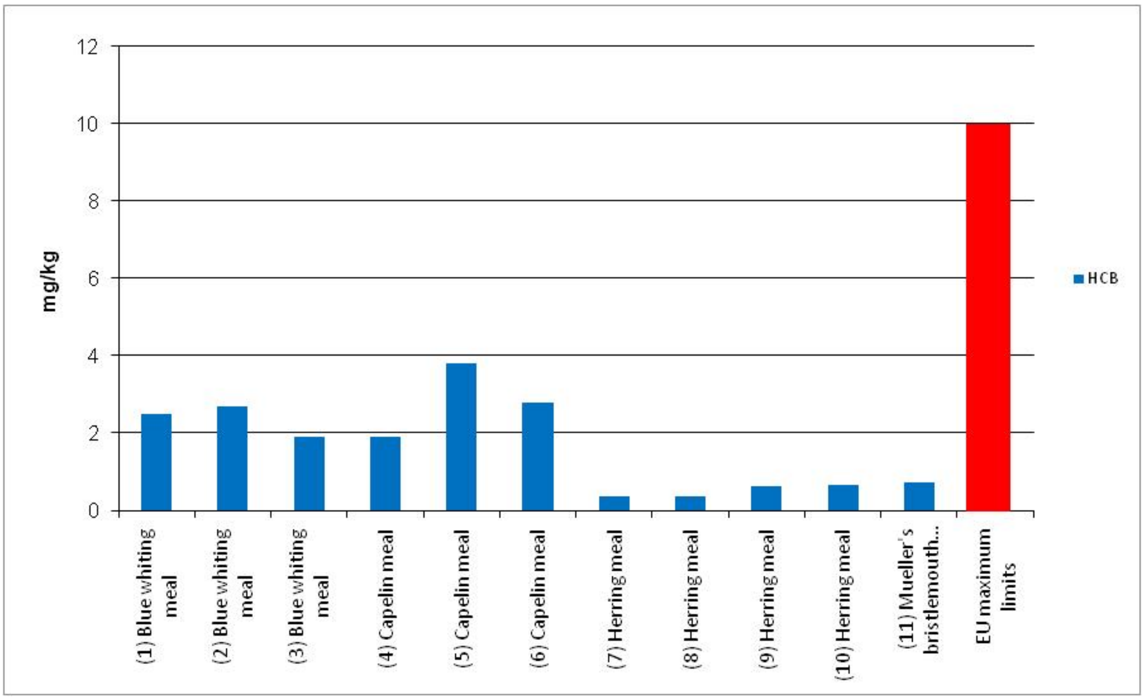

Figure 14: HCB in fish meal from Icelandic fishing grounds in 2010 in µg/kg wet weight.

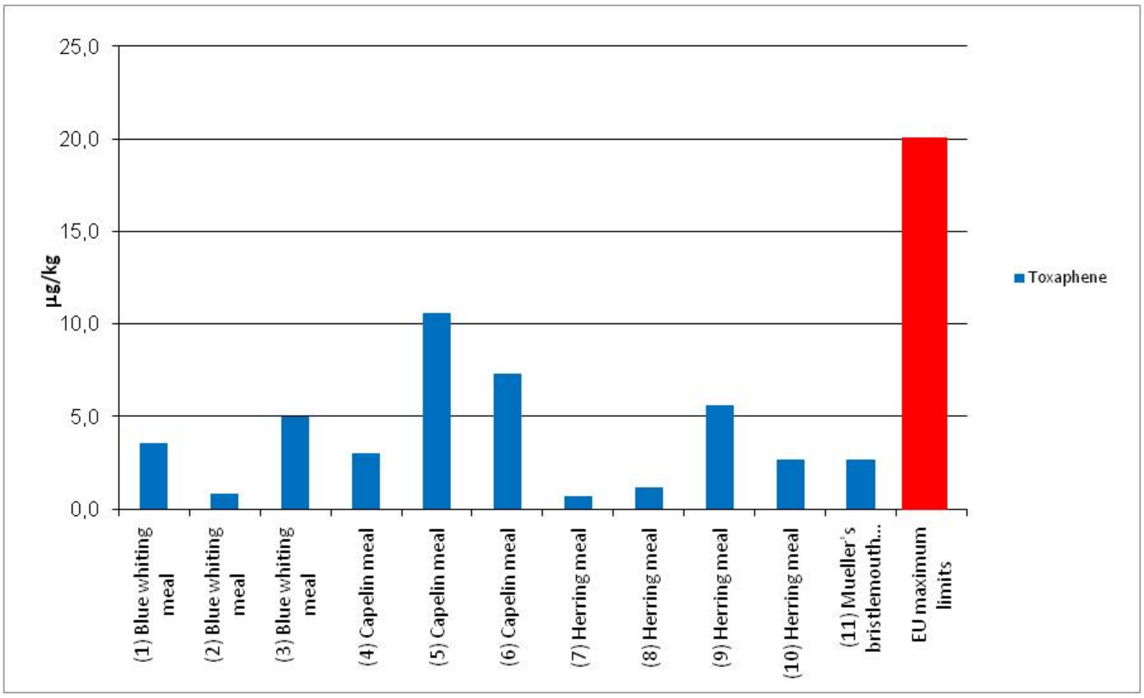

Figure 15: Toxaphene in fish meal from Icelandic fishing grounds in 2010 in µg/kg wet weight.

Concentration of pesticides in fish oil were below EU maximum limits in most cases (Commission Directive 2006/77/EC). The exception was the concentration of toxaphene and chlordane in the blue whiting oil that exceeds the EU maximum limits as illustrated in Figure 16 and Figure 17.

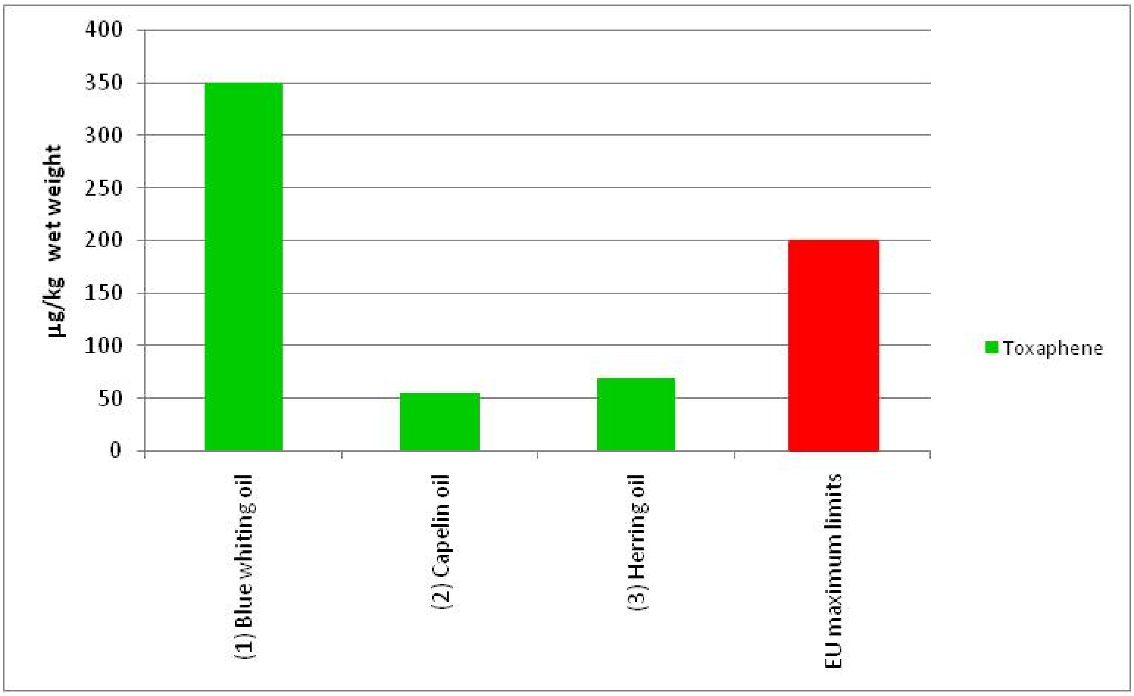

Figure 16: Toxaphene in fish oil from Icelandic fishing grounds in 2010 in µg/kg oil.

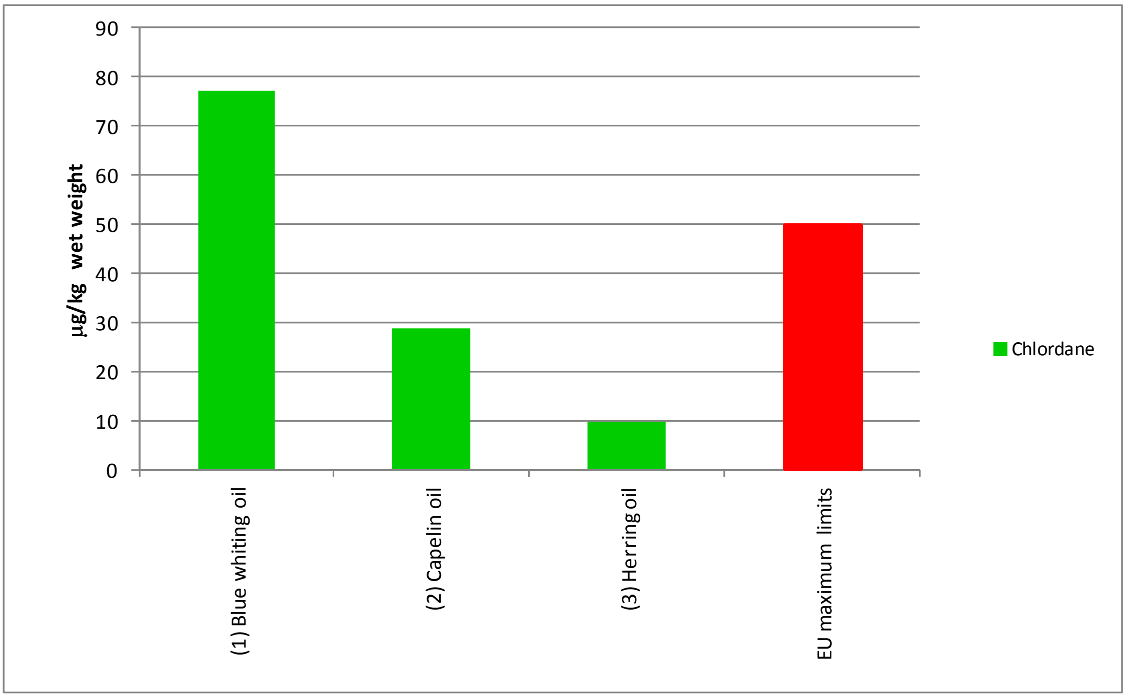

Figure 17: Chlordane in fish oil from Icelandic fishing grounds in 2010 in µg/kg oil.

5.6 Inorganic trace elements

Year 2010 most of the fish samples (twenty six in total) were measured for the following inorganic trace elements; Hg (mercury), Cd (cadmium), Pb (lead), As (arsenic), Se (selenium), Zn (zinc), Cu (copper) and Fe (iron). Some of the elements like Se, Zn, Cu and Fe are essential minerals and thus do not fall into the category undesirable substances, however, the ICP-MS technology used to measure the trace elements enables us to measure these elements as well for relatively little extra cost. Therefore, all the previously mentioned trace elements are reported in Table 7-9 in Appendix.

5.6.1 Inorganic trace elements in seafood

In short, the concentration of heavy metals like Hg, Pb and Cd in all the samples of the edible part of fish muscle was well below the maximum limits set by EU (Commission regulation 1881/2006, Commission Regulation (EC) No 629/2008). The concentration of Mercury (Hg) in the fish samples is shown in Figure 18 and in Figure 19, the results are presented in two Figures as the maximum limits for the fish species presented in Figure 19 are higher according to the above mentioned regulation.

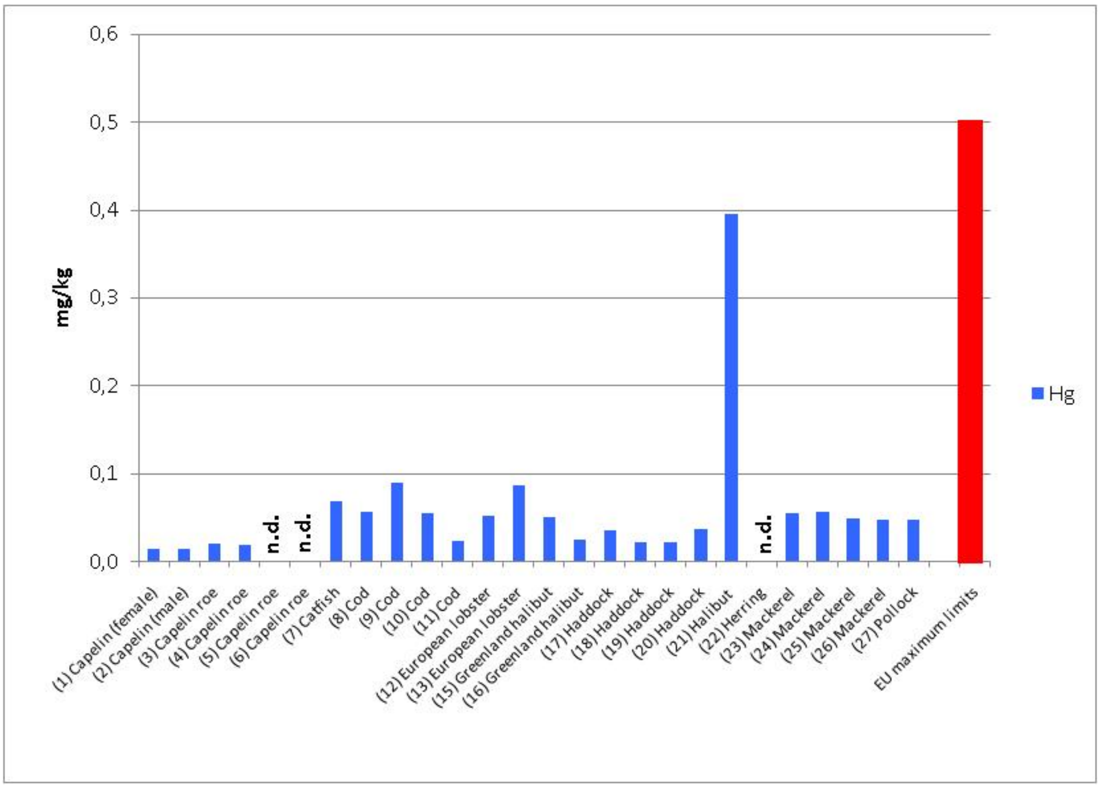

Figure 18: Hg in fish muscle from Icelandic fishing grounds in 2010 in mg/kg wet weight.

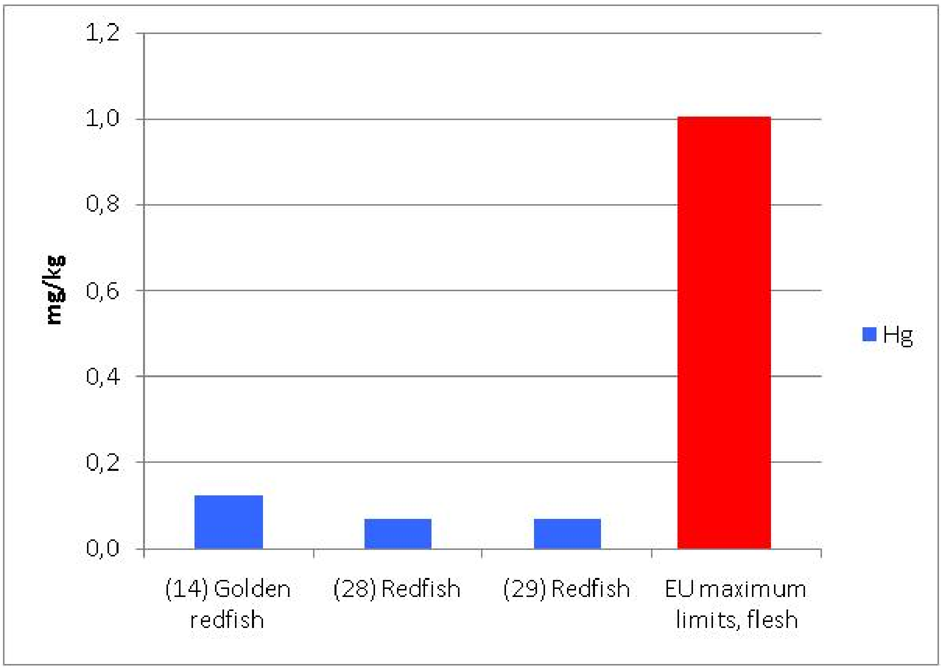

Figure 19: Hg in fish muscle from Icelandic fishing grounds in 2010 in mg/kg wet weight. Different EU maximum level compared to Figure 18.

The concentration of lead (Pb) in fish muscle was very low for fish muscle as can be seen in Table 7 in the Appendix.

No limits have yet been set for arsenic, but results from the monitoring in 2010, which are shown in Figure 20 were in agreement with earlier measurements (Auðunsson, 2004, Ásmundsdóttir et al. 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Jörundsdóttir et al., 2009). The results obtained this year showed that the level of arsenic was well below 25 mg/kg and in all cases below 4 mg/kg except for haddock with concentrations around 8-15 mg/kg and one of the European lobster samples 5,8 mg/kg (Table 7). The total arsenic concentration was measured in the samples, but not the concentration of the toxic form i.e. inorganic arsenic.

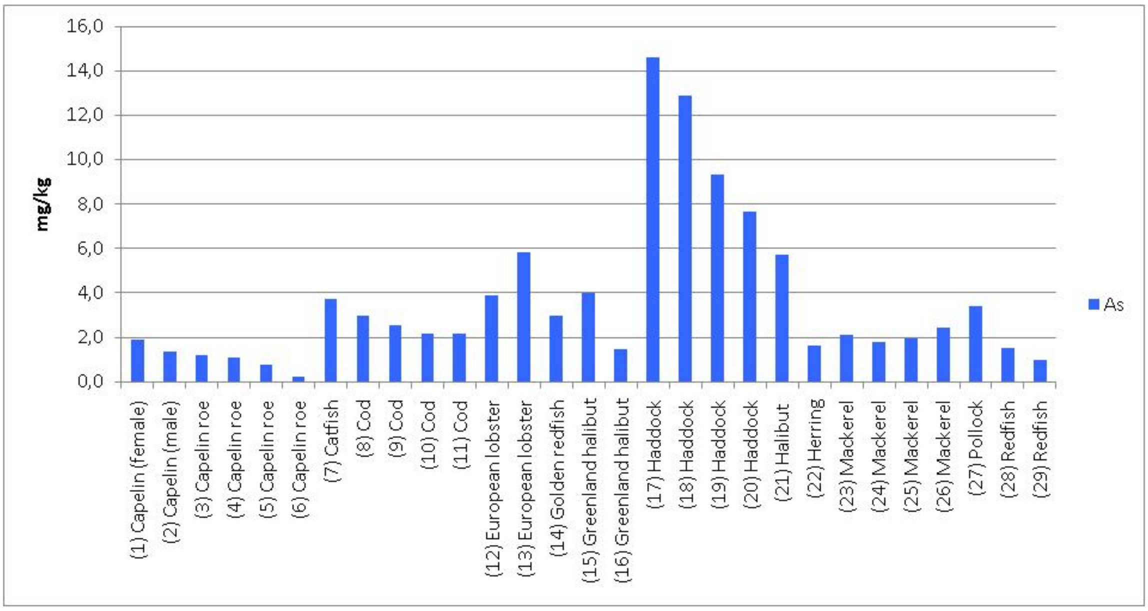

Figure 20: As in fish muscle from Icelandic fishing grounds in 2010 in mg/kg wet weight.

5.6.2 Inorganic trace elements in fish oil and fish meal

Inorganic trace elements were analysed in fish oil and fish meal as shown in Table 8 and 9. Both undesirable and essential metals and metalloids were analysed. Maximum limits exist for arsenic, cadmium, mercury and lead in fish meal and oil (Directive 2002/32/EC, Commission Directive 2003/100/EC, Commission Directive 2005/87/EC, Commission Directive 2009/141/EC). Levels of these metals were low in both meal and oil samples and were always below the EU maximum level. Cadmium and lead was in most cases just above detection limits.

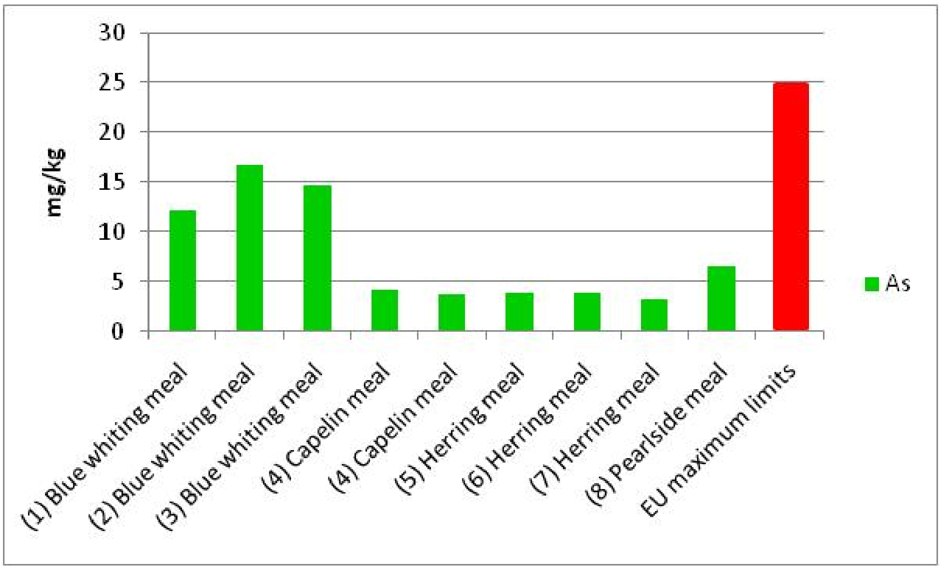

Figure 21: As in fish meal from Icelandic fishing grounds in 2010 in mg/kg wet weight.

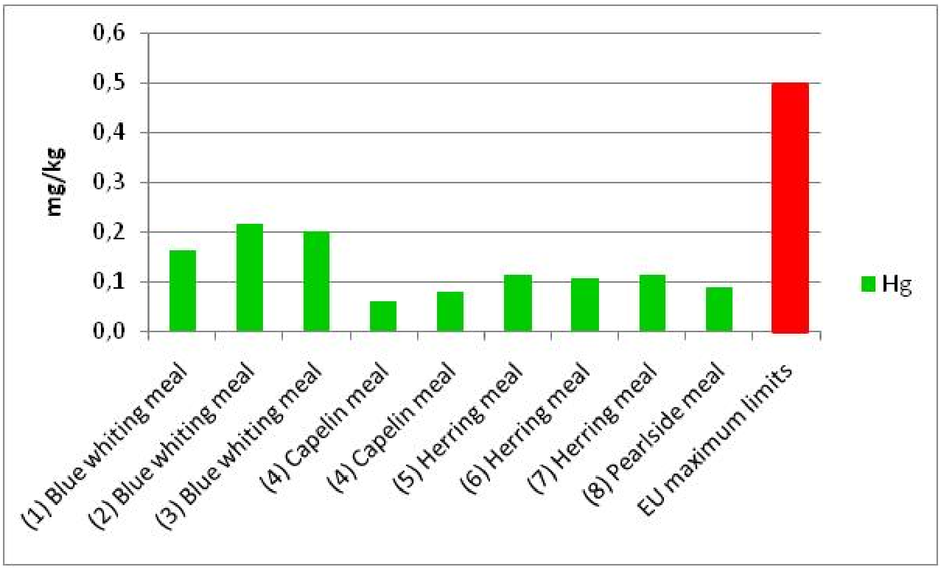

Figure 22: Hg in fish meal from Icelandic fishing grounds in 2010 in mg/kg wet weight.

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Commission Directive 2005/87/EC of 5th December 2005

Commission Directive 2006/13/EC of 3th February 2006

Commission Directive 2006/77/EC of 29th September 2006

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Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002

Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 of February 2005

Reglugerð um gildistöku reglugerðar framkvæmdastjórnarinnar (EB) nr. 1881/2006 um hámarksgildi fyrir tiltekin aðskotaefni í matvælum. Nr 265/2010.

7 Appendix

7.1 Table 1: Dioxin, PCBs and PBDEs in fish muscle

7.2 Table 2: Dioxin, PCBs and PBDEs in fish meal for feed

7.3 Table 3: Dioxin, PCBs and PBDEs in fish oil for feed

7.4 Table 4: Pesticides in fish muscle

7.5 Table 5: Pesticides in fish meal for feed

7.6 Table 6: Pesticides in fish oil for feed

7.7 Table 7: Trace elements in fish muscle

7.8 Table 8: Trace elements in fish meal for feed

7.9 Table 9: Trace elements in fish oil for feed

Table 1: Dioxins PCBs and PBDE in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fishing ground	Size [cm]	Lipid content %	PCDD/PCDFs pg/g WHO-TEQ	Dioxin like PCBs pg/g WHO-TEQ	Sum of Dioxins and DL-PCBs pg/g WHO-TEQ	Marker PCBs µg/kg	PBDEs µg/kg
R10-2599-1	1	Atlantic catfish	*Anarhichas lupus*	*NW*	28-38	0,65	0,024	0,018	0,042	0,32	0,11
R10-880-1	2	Atlantic catfish	*Anarhichas lupus*	*NW*	35-47	0,95	0,008	0,0066	0,015	0,30	0,12
R-10-1016-1	3	Capelin - female	*Mallotus villosus*	*S*		8,4	0,26	0,22	0,48	2,7	1,9
R-10-1016-2	4	Capelin - male	*Mallotus villosus*	*S*		5,8	0,23	0,19	0,42	2,4	1,3
R10-945-1	5	Capelin roes	*Mallotus villosus*	*SW*		2,6	0,069	0,084	0,15	0,91	0,16
R10-945-2	6	Capelin roes	*Mallotus villosus*			2,4	0,068	0,050	0,12	0,56	0,11
R10-945-3	7	Capelin roes	*Mallotus villosus*	*NW*		2,1	0,075	0,074	0,15	0,74	0,14
R10-945-4	8	Capelin roes	*Mallotus villosus*	*SW*		1,9	0,043	0,044	0,087	0,54	0,10
R10-794-1	9	Cod	*Gadus morhua*	*N*	70-85	0,57	0,020	0,041	0,061	0,36	0,15
R10-815-1	10	Cod	*Gadus morhua*	*N*	41-50	0,61	0,0058	0,028	0,033	0,26	0,14
R10-851-1	11	Cod	*Gadus morhua*	*SW*	74-97	0,51	0,0052	0,021	0,026	0,21	0,12
R10-926-1	12	Cod	*Gadus morhua*	*SE*	60-68	0,55	0,0031	0,0086	0,012	0,32	0,11
R10-2716-1	13	Deepwater Redfish	*Sebastes mentella*	*S*	38-45	0,52	0,092	0,17	0,26	2,1	0,23
R10-1343-2	14	European lobster	*Homarus gammarus*	*SE*		0,48	0,027	0,016	0,043	0,10	0,11
R10-1409-1	15	European lobster	*Homarus gammarus*			0,61	0,029	0,03	0,06	0,31	0,11
R10-2599-2	16	European plaice	*Pleuronectes platessa*	*NW*	38-45	0,87	0,03	0,04	0,07	0,48	0,12
R10-909-1	17	Greenland halibut	*Reinhardtius hippoglossoides*	*E /SE*	44-58	12	0,61	0,66	1,3	8,2	0,74
R10-912-1	18	Greenland halibut	*Reinhardtius hippoglossoides*	*N*	53-61	12	0,76	0,73	1,5	6,8	0,66
R10-1343-1	19	Halibut	*Hippoglossus hippoglossus*			7,9	1,0	2,6	3,7	33	2,1
R10-1184-1	20	Herring	*Clupea harengus*	*NE*		4,6	0,60	0,54	1,1	6,3	0,88
R10-2716-2	21	Ling	*Molva molva*	*E/SE*	60-87	0,44	0,022	0,026	0,048	0,35	0,12
R10-1981-1	22	Mackerel	*Scomber scombrus*	*NE*	36-43	20	0,13	0,25	0,38	3,3	0,65
R10-1981-2	23	Mackerel	*Scomber scombrus*	*NE*	34-43	19	0,11	0,28	0,39	3,6	0,70
R10-1981-3	24	Mackerel	*Scomber scombrus*	*NE*	32-42	20	0,10	0,24	0,35	3,0	0,57
R10-1981-4	25	Mackerel	*Scomber scombrus*		25-45	27	0,14	0,31	0,45	4,2	0,71
R10-893-1	26	Pollock	*Pollachius virens*	*S*	59-65	0,87	0,0065	0,0092	0,016	0,34	0,13
R10-794-4	27	Redfish	*Sebastes marinus*	*N*	25-30	2,6	0,045	0,078	0,12	0,86	0,17
R10-794-5	28	Redfish	*Sebastes marinus*	*N*	35-45	2,5	0,043	0,17	0,21	1,7	0,29
R10-866-1	29	Redfish	*Sebastes marinus*	*S*	39-43	2,2	0,067	0,17	0,23	2,1	0,31
		EU action level					3,00	3,00	*	*	*
		EU maximum limits					4,00	*	8,00	*	*

*No maxinmum limits exist in the EU for the substances

Table 2: Dioxins and PCBs in fish meal for feed calculated in relation to 12% moisture and PBDEs on wet weight

Sample code	Meal sample no.	Sample name	Latin name	PCDD/PCDF pg/g WHO-TEQ	Dioxin like PCBs pg/g WHO-TEQ	Sum of Dioxins and DL-PCBs pg/g WHO-TEQ	Marker-PCBs µg/kg	PBDEs µg/kg (ww)
R10-648-1	1	Blue whiting meal	*Micromesistius poutassou*	0,51	1,4	1,9	14	2,7
R10-904-1	2	Blue whiting meal	*Micromesistius poutassou*	0,63	2,9	3,6	28	3,7
R10-2248-3	3	Blue whiting meal	*Micromesistius poutassou*	0,80	2,2	3,0	23	4,2
R10-677-1	4	Capelin meal	*Mallotus villosus*	0,32	0,33	0,65	3,1	1,1
R10-2248-1	5	Capelin meal	*Mallotus villosus*	0,20	0,18	0,38	1,7	1,1
R10-2405-3	6	Capelin meal	*Mallotus villosus*	0,36	0,29	0,65	3,3	1,5
R10-1529-1	7	Herring meal	*Clupea harengus*	0,16	0,23	0,39	3,3	1,3
R10-2008-1	8	Herring meal	*Clupea harengus*	0,19	0,19	0,38	2,3	1,1
R10-2311-1	9	Herring meal	*Clupea harengus*	0,31	0,34	0,65	3,6	1,6
R10-2405-1	10	Herring meal	*Clupea harengus*	0,30	0,27	0,57	3,3	1,9
R10-187-1	11	Mueller's bristlemouth fish meal	*Maurolicus muelleri*	0,25	0,08	0,33	1,2	1,0
		EU action level		1,00	2,50	3,50	*	*
		EU maximum limits		1,25		4,50	*	*

* No maximum limits exist in the EU for substances

Table 3: Dioxin, PCB and PBDE in fish oil for feed

Sample code	Fish oil sample no.	Sample name	Latin name	PCDD/PCDF pg/g WHO-TEQ	dioxin like PCBs pg/g WHO-TEQ	Sum of Dioxins and DL-PCBs pg/g WHO-TEQ	Marker-PCBs µg/kg	PBDEs µg/kg
R10-2248-4	1	Blue whiting oil	*Micromesistius poutassou*	8,8	24	33	291	45
R10-2248-2	2	Capelin oil	*Mallotus villosus*	1,6	1,3	2,9	17	3,8
R10-2405-2	3	Herring oil	*Clupea harengus*	2,4	2,8	5,2	34	6,1
		EU action level		5,0	14		*	*
		EU maximum limits		6,0		24	*	*

* No maxinum limits exist in the EU for the substances.

Table 4: Pesticides in fish mucle on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fishing ground	Size [cm]	Lipid content %	β-HCH µg/kg	α-HCH µg/kg	γ-HCH µg/kg	δ-HCH µg/kg	Σ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R10-2599-1	1	Atlantic catfish	*Anarhichas lupus*	*NW*	*28-38*	0,65	0,003	0,01	0,003	<0,0008	0,17	0,005	0,049	0,018
R10-880-1	2	Atlantic catfish	*Anarhichas lupus*	*NW*	35-47	0,95	0,0092	<0,008	<0,02	<0,006	0,26	0,019	0,087	0,052
R-10-1016-1	3	Capelin - female	*Mallotus villosus*	*S*		8,4	0,073	0,13	0,032	<0,009	5,7	0,064	2,2	0,52
R-10-1016-2	4	Capelin - male	*Mallotus villosus*	*S*		5,8	0,050	0,098	0,023	<0,006	4,9	0,12	2,3	0,37
R10-945-1	5	Capelin roes	*Mallotus villosus*	*SW*		2,6	0,037	0,11	0,076	<0,03	0,57	0,10	0,55	0,17
R10-945-2	6	Capelin roes	*Mallotus villosus*			2,4	0,052	0,071	0,047	<0,04	0,19	0,13	0,38	0,11
R10-945-3	7	Capelin roes	*Mallotus villosus*	*NW*		2,1	0,027	0,048	0,050	<0,02	0,30	0,079	0,33	0,11
R10-945-4	8	Capelin roes	*Mallotus villosus*	*SW*		1,9	0,046	0,090	0,086	<0,03	0,41	0,11	0,44	0,14
R10-794-1	9	Cod	*Gadus morhua*	*N*	70-85	0,57	0,0080	0,011	<0,02	<0,006	0,48	0,018	0,46	0,065
R10-815-1	10	Cod	*Gadus morhua*	*N*	41-50	0,61	0,010	0,018	<0,02	<0,005	0,31	0,026	0,37	0,064
R10-851-1	11	Cod	*Gadus morhua*	*SW*	74-97	0,51	0,0071	0,013	0,034	<0,006	0,44	0,032	0,35	0,063
R10-926-1	12	Cod	*Gadus morhua*	*SE*	60-68	0,55	<0,01	0,011	<0,02	<0,01	0,34	0,013	0,21	0,063
R10-2716-1	13	Deepwater Redfish	*Sebastes mentella*	*S*	*38-45*	0,52	0,01	0,004	0,01	<0,002	3,1	0,012	0,17	0,062
R10-1343-2	14	European lobster	*Homarus gammarus*	*SE*		0,48	<0,002	0,004	<0,003	<0,002	0,062	0,004	0,035	0,028
R10-1409-1	15	European lobster	*Homarus gammarus*			0,61	0,003	<0,002	0,01	<0,002	0,12	0,005	0,046	0,031
R10-2599-2	16	European plaice	*Pleuronectes platessa*	*NW*	*38-45*	0,87	0,005	0,01	0,003	<0,002	0,29	0,01	0,071	0,032
R10-909-1	17	Greenland halibut	*Reinhardtius hippoglossoides*	*E /SE*	44-58	12	0,15	0,73	0,24	<0,01	14	0,36	3,6	0,87
R10-912-1	18	Greenland halibut	*Reinhardtius hippoglossoides*	*N*	53-61	12	0,16	0,64	0,20	<0,009	12,23	0,39	3,7	0,81
R10-1343-1	19	Halibut	*Hippoglossus hippoglossus*			7,9	0,07	0,17	0,047	<0,003	55	0,05	1,5	0,56
R10-1184-1	20	Herring	*Clupea harengus*	*NE*		4,6	0,050	0,15	0,044	<0,02	9,0	0,13	1,3	0,33
R10-2716-2	21	Ling	*Molva molva*	*E/SE*	*60-87*	0,44	0,002	0,0029	<0,002	<0,002	0,23	0,003	0,037	0,023
R10-1981-1	22	Mackerel	*Scomber scombrus*	*NE*	*36-43*	20	0,12	0,44	0,14	<0,009	3,7	0,12	1,1	0,40
R10-1981-2	23	Mackerel	*Scomber scombrus*	*NE*	*34-43*	19	0,11	0,32	0,10	<0,007	3,8	0,09	1,2	0,33
R10-1981-3	24	Mackerel	*Scomber scombrus*	*NE*	*32-42*	20	0,11	0,37	0,11	<0,011	2,7	0,091	1,2	0,38
R10-1981-4	25	Mackerel	*Scomber scombrus*		*25-45*	27	0,15	0,45	0,12	0,02	3,7	0,14	1,4	0,44
R10-893-1	26	Pollock	*Pollachius virens*	*S*	59-65	0,87	0,0082	<0,008	<0,02	<0,006	0,43	0,016	0,24	0,062
R10-794-4	27	Redfish	*Sebastes marinus*	*N*	25-30	2,6	0,024	0,078	0,036	<0,005	1,6	0,060	0,65	0,13
R10-794-5	28	Redfish	*Sebastes marinus*	*N*	35-45	2,5	0,022	0,052	<0,02	<0,005	2,8	0,050	0,62	0,12
R10-866-1	29	Redfish	*Sebastes marinus*	*S*	39-43	2,2	0,012	0,035	0,022	<0,006	3,7	0,037	0,52	0,14
		EU maximum limits					50	50	50		500		50	50

Table 4 (cont): Pesticides in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	Date of catch	Fishing ground	Size [cm]	Lipid content %	Aldrin/ dieldrin µg/kg	Toxaphene µg/kg	Octachloro styrene µg/kg	Endrin µg/kg	Endo-sulfane µg/kg	Chlordane µg/kg	*trans*-Nonachlor µg/kg	Mirex µg/kg
R10-2599-1	1	Atlantic catfish	*Anarhichas lupus*	*NW*	28-38	0,65	0,069	0,25	0,0025	0,005	0,025	0,039	0,062	0,015
R10-880-1	2	Atlantic catfish	*Anarhichas lupus*	*NW*	35-47	0,95	0,13	0,27	<0,006	<0,02	0,60	0,10	0,25	0,027
R-10-1016-1	3	Capelin - female	*Mallotus villosus*	*S*		8,4	3,0	7,3	0,065	0,69	0,37	2,0	1,3	0,024
R-10-1016-2	4	Capelin - male	*Mallotus villosus*	*S*		5,8	2,7	7,3	0,040	0,46	0,38	1,8	1,2	0,028
R10-945-1	5	Capelin roes	*Mallotus villosus*	*SW*		2,6	0,62	0,89	<0,007	0,13	1,8	0,31	0,20	<0,004
R10-945-2	6	Capelin roes	*Mallotus villosus*			2,4	0,24	0,26	<0,007	<0,05	1,5	0,14	0,07	<0,004
R10-945-3	7	Capelin roes	*Mallotus villosus*	*NW*		2,1	0,33	0,40	<0,005	0,089	1,4	0,19	0,11	<0,004
R10-945-4	8	Capelin roes	*Mallotus villosus*	*SW*		1,9	0,48	0,57	<0,006	0,078	1,9	0,25	0,15	0,008
R10-794-1	9	Cod	*Gadus morhua*	*N*	70-85	0,57	0,19	0,34	0,009	<0,01	1,2	0,20	0,19	0,011
R10-815-1	10	Cod	*Gadus morhua*	*N*	41-50	0,61	0,17	0,17	0,006	<0,01	0,78	0,15	0,13	0,005
R10-851-1	11	Cod	*Gadus morhua*	*SW*	74-97	0,51	0,16	0,32	0,007	0,016	0,75	0,15	0,14	0,010
R10-926-1	12	Cod	*Gadus morhua*	*SE*	60-68	0,55	0,11	0,27	<0,006	<0,03	1,2	0,11	0,12	0,008
R10-2716-1	13	Deepwater Redfish	*Sebastes mentella*	*S*	38-45	0,52	0,31	2,5	0,014	0,026	0,11	0,56	0,80	0,036
R10-1343-2	14	European lobster	*Homarus gammarus*	*SE*		0,48	0,14	0,062	<0,002	0,0064	0,067	0,036	0,020	<0,002
R10-1409-1	15	European lobster	*Homarus gammarus*			0,61	0,14	0,06	0,003	0,0042	0,12	0,042	0,023	0,0046
R10-2599-2	16	European plaice	*Pleuronectes platessa*	*NW*	38-45	0,87	0,08	0,17	0,003	0,0091	0,060	0,072	0,12	0,007
R10-909-1	17	Greenland halibut	*Reinhardtius hippoglossoides*	*E /SE*	44-58	12	4,3	15	0,11	0,71	0,76	5,6	5,5	0,12
R10-912-1	18	Greenland halibut	*Reinhardtius hippoglossoides*	*N*	53-61	12	4,0	13	0,087	0,71	1,0	5,1	5,4	0,12
R10-1343-1	19	Halibut	*Hippoglossus hippoglossus*			7,9	4,0	38	0,3	0,48	0,21	9,3	15	0,57
R10-1184-1	20	Herring	*Clupea harengus*	*NE*		4,6	1,9	12	0,064	0,15	1,4	2,6	3,7	0,078
R10-2716-2	21	Ling	*Molva molva*	*E/SE*	60-87	0,44	0,046	0,19	0,0027	0,0058	0,076	0,052	0,07	0,004
R10-1981-1	22	Mackerel	*Scomber scombrus*	*NE*	36-43	20	1,5	5,1	0,031	0,28	1,1	1,3	1,2	0,024
R10-1981-2	23	Mackerel	*Scomber scombrus*	*NE*	34-43	19	1,6	5,0	0,034	0,26	0,55	1,5	1,3	0,021
R10-1981-3	24	Mackerel	*Scomber scombrus*	*NE*	32-42	20	1,4	4,3	0,026	0,22	0,80	1,1	0,91	0,013
R10-1981-4	25	Mackerel	*Scomber scombrus*		25-45	27	2,1	4,4	0,032	0,39	1,1	1,7	1,4	0,017
R10-893-1	26	Pollock	*Pollachius virens*	*S*	59-65	0,87	0,14	0,33	0,008	0,017	0,74	0,18	0,16	0,009
R10-794-4	27	Redfish	*Sebastes marinus*	*N*	25-30	2,6	0,70	2,5	0,013	0,034	0,84	0,75	0,73	0,026
R10-794-5	28	Redfish	*Sebastes marinus*	*N*	35-45	2,5	0,59	3,2	0,023	0,025	0,68	1,1	1,4	0,042
R10-866-1	29	Redfish	*Sebastes marinus*	*S*	39-43	2,2	0,54	2,7	0,028	0,022	0,73	0,98	1,4	0,050
		EU maximum limits					50			50		100		

Table 5: Pesticides in fish meal for feed on wet weight

Sample code	Meal sample no.	Sample name	β-HCH µg/kg	α-HCH µg/kg	γ-HCH µg/kg	δ-HCH µg/kg	Σ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R10-648-1	1	Blue whiting meal	0,041	0,052	0,015	<0,013	17	0,10	2,5	0,49
R10-904-1	2	Blue whiting meal	0,016	<0,013	<0,013	<0,013	23	0,072	2,7	0,43
R10-2248-3	3	Blue whiting meal	0,12	0,063	0,077	<0,013	3,8	0,24	1,9	0,61
R10-677-1	4	Capelin meal	0,078	0,05	0,026	<0,013	6,5	0,18	1,9	0,61
R10-2248-1	5	Capelin meal	0,034	0,031	<0,013	<0,013	29	0,13	3,8	0,63
R10-2405-3	6	Capelin meal	0,072	0,035	0,035	<0,013	6,4	0,24	2,8	0,69
R10-1529-1	7	Herring meal	<0,037	<0,037	<0,045	<0,037	2,3	0,051	0,35	0,44
R10-2008-1	8	Herring meal	<0,039	<0,039	<0,049	<0,039	2,4	0,054	0,37	0,51
R10-2311-1	9	Herring meal	0,079	0,11	<0,048	<0,039	4,0	0,044	0,61	0,57
R10-2405-1	10	Herring meal	0,058	0,12	0,039	<0,013	3,7	0,082	0,65	0,32
R10-187-1	11	Mueller's bristlemouth fish	0,068	0,087	0,024	<0,013	2,3	0,091	0,73	0,41
		EU maximum limits	10	20	200		50		10	

Table 5 (cont.): Pesticides in fish meal for feed on wet weight.

Sample code	Meal sample no.	Sample name	Aldrin/ dieldrin µg/kg	Toxaphene µg/kg	Octachloro styrene µg/kg	Endrin µg/kg	Endo-sulfane µg/kg	Chlordane µg/kg	*trans*-Nonachlor µg/kg	Mirex µg/kg
R10-648-1	1	Blue whiting meal	2,6	3,6	0,26	0,32	0,49	3,5	3,9	0,23
R10-904-1	2	Blue whiting meal	2,6	0,8	0,39	0,18	0,46	4,6	5,0	0,27
R10-2248-3	3	Blue whiting meal	2,9	5,0	0,033	0,64	0,43	1,8	1,0	0,023
R10-677-1	4	Capelin meal	3,2	3,0	0,13	0,58	0,67	2,2	1,3	0,03
R10-2248-1	5	Capelin meal	3,3	11	0,48	0,38	0,43	5,9	6,9	0,43
R10-2405-3	6	Capelin meal	3,8	7,3	0,058	0,76	0,85	3,0	1,8	0,035
R10-1529-1	7	Herring meal	0,92	0,7	<0,037	<0,037	1,3	0,63	0,51	<0,037
R10-2008-1	8	Herring meal	1,0	1,2	<0,039	<0,039	1,4	0,71	0,77	<0,039
R10-2311-1	9	Herring meal	1,7	5,6	0,044	0,16	1,3	1,3	2,0	0,043
R10-2405-1	10	Herring meal	1,3	2,7	0,038	0,11	0,47	0,95	1,0	0,036
R10-187-1	11	Mueller's bristlemouth fish	1,6	2,7	0,017	0,36	0,44	0,75	0,47	0,018
		EU maximum limits	10	20		10	100	20		

Table 6: Pesticides in fish oil for feed

Sample code	**Fish oil no.**	**Sample name**	**β-HCH** µg/kg	**α-HCH** µg/kg	**γ-HCH** µg/kg	**δ-HCH** µg/kg	**Σ DDT** µg/kg	**Pentachlor benzene** µg/kg	**HCB** µg/kg	**Σ Heptachlores** µg/kg
R10-2248-4	1	Blue whiting oil	0,60	1,4	0,25	<0,1	398	2,5	62	8,3
R10-2248-2	2	Capelin oil	1,2	3,7	1,1	<0,1	36	2,7	20	5,5
R10-2405-2	3	Herring oil	0,65	2,7	0,64	<0,1	40	1,3	7,7	3,3
		EU maximum limits	100	200	2000		500		200	

Table 6 (cont): Pesticides in fish oil for feed

Sample code	**Fish oil no.**	**Sample name**	**Aldrin/ dieldrin** µg/kg	**Toxaphene** µg/kg	**Octachloro styrene** µg/kg	**Endrin** µg/kg	**Endo-sulfane** µg/kg	**Chlordane** µg/kg	***trans*-Nonachlor** µg/kg	**Mirex** µg/kg
R10-2248-4	1	Blue whiting oil	49	350	6,2	7,3	6	77	87	6,1
R10-2248-2	2	Capelin oil	28	55	0,32	6,3	7,4	29	23	0,26
R10-2405-2	3	Herring oil	14	69	0,39	1,7	5,2	10	10	0,51
		EU maximum limits	100	200		50	100	50		

Table 7: Trace elements in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fe mg/kg	Cu mg/kg	Zn mg/kg	As mg/kg	Se mg/kg	Cd mg/kg	Hg mg/kg	Pb mg/kg
R10-1016-1	1	Capelin (female)	*Mallotus villosus*	27	0,39	15	1,9	0,33	0,026	0,014	<0,04
R10-1016-2	2	Capelin (male)	*Mallotus villosus*	28	0,36	12	1,4	0,24	0,02	0,014	<0,03
R10-945-1	3	Capelin roe	*Mallotus villosus*	35	1,3	41	1,2	0,96	0,065	0,021	<0,05
R10-945-2	4	Capelin roe	*Mallotus villosus*	37	1,2	35	1,1	0,83	0,060	0,019	<0,04
R10-945-3	5	Capelin roe	*Mallotus villosus*	14	0,85	22	0,8	0,55	0,046	<0,01	<0,03
R10-945-4	6	Capelin roe	*Mallotus villosus*	4,7	0,28	8,6	0,24	0,19	<0,003	<0,008	<0,02
R10-880-1	7	Catfish	*Anarhichas lupus*	3,9	0,14	5,3	3,7	0,57	<0,02	0,069	<0,01
R10-926-1	8	Cod	*Gadus morhua*	2,3	0,23	3,4	3,0	0,32	<0,03	0,06	<0,01
R10-851-1	9	Cod	*Gadus morhua*	3,4	0,28	4,7	2,5	0,45	0,00084	0,090	<0,02
R10-794-1	10	Cod	*Gadus morhua*	2,9	0,25	3,6	2,2	0,26	0,013	0,055	<0,01
R10-815-1	11	Cod	*Gadus morhua*	3,2	0,24	3,6	2,2	0,25	0,014	0,024	<0,01
R10-1343-2	12	European lobster	*Homarus gammarus*	7,5	3,0	9,5	3,9	0,43	0,032	0,052	NA
R10-1409-1	13	European lobster	*Homarus gammarus*	12	1,4	6,5	5,8	0,34	0,026	0,087	<0,001
R10-866-1	14	Golden redfish	*Sebastes marinus*	4,9	0,29	3,9	3,0	1,01	0,0015	0,12	<0,02
R10-912-1	15	Greenland halibut	*Reinhardtius hippoglossoides*	1,8	0,18	3,0	4,0	0,44	<0,04	0,050	<0,02
R10-909-1	16	Greenland halibut	*Reinhardtius hippoglossoides*	1,0	0,054	1,3	1,5	0,18	0,0093	0,025	<0,01
R10-851-2	17	Haddock	*Melanogrammus aeglefinus*	3,3	0,21	3,6	15	0,55	<0,04	0,036	<0,02
R10-816-1	18	Haddock	*Melanogrammus aeglefinus*	5,4	0,26	3,9	13	0,55	0,00091	0,022	<0,02
R10-794-2	19	Haddock	*Melanogrammus aeglefinus*	3,7	0,14	2,8	9,3	0,42	0,01	0,022	<0,01
R10-794-3	20	Haddock	*Melanogrammus aeglefinus*	3,6	0,22	2,8	7,7	0,40	0,015	0,037	<0,01
R10-1343-1	21	Halibut	*Hippoglossus hippoglossus*	0,82	0,13	2,7	5,7	0,42	<0,0005	0,40	NA
R10-1184-1	22	Herring	*Clupea harengus*	14	0,87	14	1,7	0,59	0,071	<0,1	0,029
R10-1981-1	23	Mackerel	*Scomber scombrus*	10	0,88	6,3	2,1	0,47	0,002	0,055	0,007
R10-1981-2	24	Mackerel	*Scomber scombrus*	9,7	0,71	5,3	1,8	0,46	0,001	0,056	0,006
R10-1981-3	25	Mackerel	*Scomber scombrus*	9,4	0,62	4,8	2,0	0,43	0,002	0,049	0,004
R10-1981-4	26	Mackerel	*Scomber scombrus*	8,1	0,61	5,4	2,4	0,45	0,002	0,048	0,002
R10-893-1	27	Pollock	*Pollachius virens*	4,0	0,46	4,0	3,4	0,33	<0,03	0,048	<0,01
R10-794-4	28	Redfish	*Sebastes marinus*	5,2	0,32	3,9	1,5	0,62	<0,002	<0,07	<0,07
R10-794-5	29	Redfish	*Sebastes marinus*	4,5	0,23	3,3	1,0	0,59	<0,002	<0,07	<0,07
		EU maximum limits, flesh							0,05	0,5*	0,3

* EU maximum limit for Hg in Anglerfish and Redfish is 1 mg/kg

Table 8: Trace elements in fish meal for feed on wet weight.

Sample code	**Meal sample no.**	**Sample name**	**Fe mg/kg**	**Cu mg/kg**	**Zn mg/kg**	**As mg/kg**	**Se mg/kg**	**Cd mg/kg**	**Hg mg/kg**	**Pb mg/kg**
R10-648-1	1	Blue whiting meal	310	1,8	47	12	2,1	0,07	0,16	0,000
R10-904-1	2	Blue whiting meal	305	2,3	57	17	2,6	0,14	0,22	0,004
R10-2248-3	3	Blue whiting meal	410	2,0	50	15	2,1	0,17	0,20	0,021
R10-2248-1	4	Capelin meal	320	2,0	64	4,1	1,3	0,16	0,06	0,024
R10-677-1	5	Capelin meal*	211	2,0	75	3,7	1,3	0,07	0,08	0,009
R10-1529-1	6	Herring meal	293	3,2	73	3,9	4,4	0,74	0,11	0,022
R10-1927-1	7	Herring meal	340	2,8	77	3,9	3,0	0,32	0,11	0,010
R10-2311-1	8	Herring meal	326	2,3	77	3,2	2,7	0,20	0,11	0,007
R10-187-1	9	Pearlside meal	293	6,7	48	6,5	1,8	0,17	0,09	0,002
		EU maximum limits				25		2	0,5	10

Table 9: Trace elements in fish oil for feed

Sample code	Fish oil sample no.	Sample name	Fe mg/kg	Cu mg/kg	Zn mg/kg	As mg/kg	Se mg/kg	Cd mg/kg	Hg mg/kg	Pb mg/kg
R10-2248-4	1	Blue whiting oil	2,7	0,17	2,1	2,4	0,15	0,027	0,015	0,020
R10-2248-2	2	Capelin oil	1,8	0,21	1,2	10	0,038	0,033	0,014	0,13
		EU maximum limits				25		2	0,5	10