VKM
Vitenskapskomiteen for mat og miljø
Norwegian Scientific Committee for Food and Environment

VKM Report 2019:3

Scenario calculations of mercury exposure from fish and overview of species with high mercury concentrations

Opinion of the Panel on Contaminants of the Norwegian Scientific Committee for Food and Environment

Report from the Norwegian Scientific Committee for Food and Environment (VKM) 2019:3
Scenario calculations of mercury exposure from fish and overview of species with high mercury concentrations

Opinion of the Panel on Contaminants of the Norwegian Scientific Committee for Food and Environment 05.04.2019

ISBN: 978-82-8259-319-9
ISSN: 2535-4019
Norwegian Scientific Committee for Food and Environment (VKM)
Po 4404 Nydalen
N – 0403 Oslo
Norway

Phone: +47 21 62 28 00
Email: vkm@vkm.no

vkm.no
vkm.no/english

Cover photo: Colourbox

Suggested citation: VKM, Heidi Amlund, Kirsten Eline Rakkestad, Anders Ruus, Jostein Starrfelt, Jonny Beyer, Anne Lise Brantsæter, Sara Bremer, Gunnar Sundstøl Eriksen, Espen Mariussen, Ingunn Anita Samdal, Cathrine Thomsen and Helle Katrine Knutsen (2019). Scenario calculations of mercury exposure from fish and overview of species with high mercury concentrations. Opinion of the Panel on Contaminants of the Norwegian Scientific Committee for Food and Environment. VKM report 2019:3, ISBN: 978-82-8259-319-9, ISSN: 2535-4019. Norwegian Scientific Committee for Food and Environment (VKM), Oslo, Norway.

Scenario calculations of mercury exposure from fish and overview of species with high mercury concentrations

Preparation of the opinion

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to answer the request from the Norwegian Food Safety Authority. The project group consisted of three VKM-members, and three employees, including a project leader, from the VKM secretariat. Two external referees reviewed and commented on the manuscript. The VKM Panel on Contaminants evaluated and approved the final opinion drafted by the project group.

Authors of the opinion

Members of the project group that contributed to the drafting of the opinion (in alphabetical order after chair of the project group):

Heidi Amlund – Chair of the project group and member of the Panel on Contaminants in VKM. Affiliation: 1) VKM; 2) National Food Institute, Technical University of Denmark

Helle Katrine Knutsen – Member of the project group and chair of the Panel on Contaminants in VKM. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health

Kirsten Eline Rakkestad – VKM secretariat. Affiliation: VKM

Anders Ruus – Member of the project group and member of the Panel on Plant Protection Products. Affiliation: 1) VKM; 2) Norwegian Institute for Water Research

Jostein Starrfelt – VKM secretariat. Affiliation: 1) VKM; 2) University of Oslo

Members of the VKM Panel on Contaminants that assessed and approved the manuscript: In addition to Heidi Amlund and Helle Katrine Knutsen these were (in alphabetical order):

Jonny Beyer. Affiliation: 1) VKM; 2) Norwegian Institute for Water Research

Anne Lise Brantsæter. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health

Sara Bremer. Affiliation: 1) VKM; 2) Apokus, National Centre for Development of Pharmacy Practice

Gunnar Sundstøl Eriksen. Affiliation: 1) VKM; 2) Norwegian Veterinary Institute

Espen Mariussen. Affiliation: 1) VKM; 2) Norwegian Institute for Air Research

Ingunn Anita Samdal. Affiliation: 1) VKM; 2) Norwegian Veterinary Institute

Cathrine Thomsen. Affiliation: 1) VKM; 2) Norwegian Institute of Public Health

Acknowledgment

VKM would like to thank Emma Halldin Ankarberg (National Food Agency, Sweden) and Amund Måge (University of Bergen, Norway) for their valuable comments through critical review of the draft opinion. VKM emphasises that the two referees are not responsible for the content of the final opinion. In accordance with VKM's routines for approval of a risk assessment (VKM 2018), VKM received their comments before evaluation and approval by the Panel and before the opinion was finalised for publication.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

Table of Contents

Summary

Request from the Norwegian Food Safety Authority

The Norwegian Food Safety Authority (NFSA) requested the Norwegian Scientific Committee for Food and Environment (VKM) to evaluate human exposure to mercury (Hg) from fish, with focus on fish with elevated mercury concentrations and vulnerable groups of the population. VKM was asked to estimate the exposure to mercury from fish clarifying which mercury concentrations in fish leads to an exposure exceeding the tolerable weekly intake (TWI) for methylmercury. VKM was also asked to give an overview of fish species in Norway with high concentrations of mercury.

How VKM addressed the request

VKM appointed a working group consisting of three VKM members and a statistician and a project manager from the VKM secretariat, to answer the request. The Panel on Contaminants reviewed and revised the draft prepared by the working group and finally approved the opinion. The draft was also reviewed by two external reviewers prior to the final adoption of the opinion.

Dietary mercury exposure and TWI

Mercury is released to the environment from both natural and anthropogenic sources. Mercury is methylated to methylmercury by microorganisms both in the water columns and in sediments. Methylmercury is readily bioavailable and bioaccumulates in aquatic food chains, leading to elevated mercury concentrations in predatory fish.

Human exposure to methylmercury is mainly dietary and fish and other seafood is the main dietary source. VKM applied a conservative approach, based on two assumptions: 1) all mercury found in fish is methylmercury; 2) there is no other dietary source of mercury than fish.

The European Food Safety Authority (EFSA) has established a tolerable weekly intake (TWI) for methylmercury of 1.3 μg/kg body weight per week (expressed as mercury) based on human neurodevelopmental outcomes after prenatal exposure. Pregnant women and their foetuses are therefore the population group most vulnerable to dietary methylmercury exposure. Therefore, VKM focused on mercury exposure in the adult population, including pregnant women, in the scenarios estimating methylmercury exposure from consumption of fish.

Occurrence data

VKM received from NFSA 26 361 measurements of total mercury in 36 different fish species from 305 locations. VKM excluded data obtained from fish caught in the open sea, data from

before 2008 and species with less than 20 observations. The final dataset used in the present opinion consisted of 8 906 measurements of total mercury in 21 fish species commonly consumed in Norway. For each species mean and 95-percentile concentrations were predicted based on estimated log-normal distribution.

Exposure to mercury from fish

VKM chose a six-by-four set of scenarios for the estimation of exposure to methylmercury from fish consumption. The six-by-four matrices were based on six levels of consumption (ranging from 150 to 1000 g fish per week) and four different compositions of the diet (varying from a diet consisting of only fish with low mercury concentrations to a diet of only fish with high concentrations).

The 'low' mercury concentration was set at 0.051 mg/kg wet weight (ww), which equals to 60% Atlantic cod (coastal and open sea) with 0.075 mg/kg ww and 40% farmed Atlantic salmon with 0.014 mg/kg ww. The 'high' mercury concentration was the estimated 95-percentile concentration in coastal Atlantic cod, 0.33 mg/kg ww.

The scenario exposures to mercury were compared with the TWI.

Eating fish with a low mercury concentration will not lead to an exposure exceeding the TWI, even at a high weekly intake of fish (1000 g).

Eating a diet consisting of 2/3 of fish with a low mercury concentration and 1/3 fish with a high mercury concentration will lead to a methylmercury exposure exceeding the TWI when having a high weekly intake of fish (1000 g).

Increasing the proportion of fish with a high mercury concentration (1/3 low concentration and 2/3 high concentration) leads to an exposure equal to the TWI at a weekly intake of two portions of fish (300 g).

Eating only fish with a high mercury concentration leads to an exposure exceeding the TWI when consuming more than one portion of fish per week (150 g).

The mean weekly intake of fish in pregnant women (217 g) therefore leads to an exposure exceeding the TWI if only fish with a high mercury concentration is consumed.

Mercury concentrations in fish leading to an exposure reaching the TWI

VKM used inverse modelling to estimate the concentration of mercury in fish leading to an exposure reaching the TWI given different compositions of fish in the diet and number of portions of fish consumed.

The estimated concentrations were compared to the estimated mean or 95-percentile concentrations of mercury in fish.

When eating three weekly portions of fish consisting of only fish with an assumed high concentration of mercury, the fish can contain up to 0.28 mg/kg ww before the TWI is reached.

Three portions of fish per week is in line with the current upper recommendations of fish consumption from the Norwegian Directorate of Health.

Fish species in Norway with a high concentration of mercury

VKM identified species with estimated mean and 95-percentile concentrations of mercury above 0.28 mg/kg ww.

The marine species blue ling and tusk, and the freshwater species burbot, Northern pike, and European perch, have an estimated mean mercury concentration higher than 0.28 mg/kg ww.

Species with an estimated mercury concentration above 0.28 mg/kg at the 95-percentile were the marine species Atlantic cod, tusk, blue ling, common ling, rosefish, European hake, and Atlantic halibut, and the freshwater species burbot, brown trout, Northern pike, European perch, and Arctic charr.

Atlantic cod is a species commonly caught by recreational fishing. The estimated mercury concentration in Atlantic cod rarely exceeds 0.28 mg/kg ww, i.e. the estimated mean concentration and the estimated 95-percentile concentration are 0.12 and 0.33 mg/kg ww, respectively.

The concentration of mercury increased with fish length in several species. This was in particular evident for Atlantic cod, tusk, haddock, saithe, Atlantic halibut and brown trout.

Uncertainty

VKM considers the contribution of the uncertainties in the scenario exposure estimates as moderate to low, and in the inverse modelling as low.

Key words: Dietary exposure, fish, inverse modelling, mercury, methylmercury, Norwegian Scientific Committee for Food and Environment, VKM

Sammendrag på norsk

Oppdrag fra Mattilsynet

Mattilsynet ba Vitenskapskomiteen for mat og miljø (VKM) om å vurdere inntaket av kvikksølv fra fisk, med fokus på fisk med høye kvikksølvkonsentrasjoner og sårbare grupper av befolkningen. VKM ble bedt om å estimere kvikksølveksponeringen fra fisk, og å avklare hvilke kvikksølvkonsentrasjoner i fisk som vil føre til en eksponering som overskrider tolerabelt ukentlig inntak (TWI) for metylkvikksølv. VKM ble også bedt om å gi en oversikt over fisk i Norge med høye konsentrasjoner av kvikksølv.

Slik har VKM besvart bestillingen

VKM nedsatte en arbeidsgruppe som bestod av tre VKM-medlemmer og en statistiker og en prosjektleder fra sekretariatet i VKM for å svare på bestillingen. Faggruppen for forurensninger, naturlige toksiner og medisinrester har gjennomgått og revidert utkastet utarbeidet av arbeidsgruppen, og har godkjent vurderingen. Utkastet ble også evaluert av to eksterne fagpersoner innen vurderingen ble godkjent.

Inntak av kvikksølv via kosten og TWI

Kvikksølv tilføres miljøet fra naturlige og antropogene kilder. Mikroorganismer i vann og sedimenter metylerer kvikksølv til metylkvikksølv. Metylkvikksølv er biotilgjengelig og bioakkumuleres i akvatiske næringskjeder. Dette fører til forhøyede kvikksølvkonsentrasjoner i rovfisk.

Mennesker er i hovedsak eksponert for metylkvikksølv via kosten, der fisk og annen sjømat er hovedkilden. VKM gjorde en konservativ tilnærming og forutsatte: 1) at all kvikksølv i fisk forekommer som metylkvikksølv, og 2) at fisk var den eneste kilden til kvikksølv i kosten.

EFSA, den europeiske myndighet for næringsmiddeltrygghet, har fastsatt TWI for metylkvikksølv til 1,3 µg/kg kroppsvekt/uke (uttrykt som kvikksølv) basert på hemmet utvikling av nervesystemet etter eksponering via mor før fødsel. Gravide kvinner og deres foster er derfor ansett som den mest sårbare gruppen for metylkvikksølveksponering. I scenarioberegningene av metylkvikksølveksponering fra fisk har VKM derfor fokusert på kvikksølveksponeringen i den voksne befolkningen, som inkluderer gravide kvinner.

Forekomstdata

VKM mottok 26 361 målinger av totalkvikksølv i 36 ulike fiskearter fra 305 lokaliteter fra Mattilsynet. VKM ekskluderte data fra fisk som ikke var fanget i kystnære områder, data som var eldre enn 2008 og data fra arter der det var færre enn 20 målinger. Det endelige datasettet som ble benyttet i rapporten besto av 8 906 målinger at totalkvikksølv i 21 fiskearter som det er vanlig å spise i Norge. For hver art ble gjennomsnittet og 95-persentilkonsentrasjonen predikert basert på den estimerte lognormalfordelingen.

Inntak av kvikksølv fra fisk

VKM valgte et seks-ganger-fire sett av scenarier for estimeringen av metylkvikksølveksponering fra fisk. Matrisen var basert på seks nivåer for inntak (fra 150 til 1000 g fisk per uke) og fire ulike sammensetninger av fisk i kosten (varierende fra en kost bestående av kun fisk med lave kvikksølvkonsentrasjoner til en kost bestående av fisk med kun høye kvikksølvkonsentrasjoner).

Den «lave» kvikksølvkonsentrasjonen ble satt til 0,051 mg/kg våtvekt (v.v.), som tilsvarer 60% torsk (kystnær og fra havet, 0.075 mg/kg v.v.) og 40% oppdrettslaks (0,014 mg/kg v.v.). Den «høye» konsentrasjonen ble satt til den estimerte 95-persentilkonsentrasjonen for kystnær torsk, som var 0,33 mg/kg v.v.

De estimerte kvikksølveksponeringene ble sammenlignet med TWI-en som er satt av EFSA.

Å spise fisk med lave kvikksølvkonsentrasjoner vil ikke føre til en eksponering som overskrider TWI, selv ikke med at høyt ukentlig konsum av fisk (1000 g).

En fiskekost som består av 2/3 fisk med en lav kvikksølvkonsentrasjon og 1/3 fisk med en høy kvikksølvkonsentrasjon fører til en metylkvikksølveksponering som overskrider TWI hvis man har et høyt ukentlig konsum av fisk (1000 g).

Dersom man øker man andelen av fisk med høy kvikksølvkonsentrasjon (1/3 lav konsentrasjon og 2/3 høy konsentrasjon) vil eksponeringen være lik TWI ved et ukentlig konsum av to porsjoner fisk (300 g).

Spiser man kun fisk med høy kvikksølvkonsentrasjon vil eksponeringen overskride TWI hvis man spiser mer enn en porsjon fisk i uken (150 g).

Det gjennomsnittlige ukentlige inntak av fisk blant gravide kvinner (217 g) fører derfor til en eksponering som overskrider TWI hvis man kun spiser fisk med høy kvikksølvkonsentrasjon.

Kvikksølvkonsentrasjoner i fisk som fører til et inntak lik TWI

VKM brukte omvendt modellering til å estimere hvilke kvikksølvkonsentrasjoner i fisk som vil føre til en eksponering lik TWI gitt forskjellig sammensetning av fisk i kosten og antall porsjoner fisk spist.

De estimerte konsentrasjonene ble sammenlignet med de estimerte gjennomsnitts- og 95-persentilkonsentrasjonene av kvikksølv i fisk.

Spiser man tre porsjoner per uke av fisk med høy kvikksølvkonsentrasjon kan fisken inneholde opptil 0,28 mg/kg v.v. kvikksølv før TWI er nådd.

Tre porsjoner fisk per uke tilsvarer nåværende øvre anbefalinger fra Helsedirektoratet.

Fiskearter med høye konsentrasjoner av kvikksølv

VKM har identifisert fisk med estimerte gjennomsnitts- og 95-persentilkonsentrasjoner av kvikksølv over 0,28 mg/kg v.v.

Saltvannsartene blålange og brosme, samt ferskvannsartene lake, gjedde og abbor, har estimerte gjennomsnittskonsentrasjoner over 0,28 mg/kg v.v.

Arter med en estimert kvikksølvkonsentrasjon over 0.28 mg/kg v.v. ved 95-persentilen er saltvannsartene torsk, brosme, blålange, lange, uer, lysing og kveite, samt ferskvannsartene lake, ørret, gjedde, abbor og røye.

Torsk er en art som ofte fanges av fritidsfiskere. Den estimerte kvikksølvkonsentrasjonen i torsk overskrider sjelden 0,28 mg/kg v.v. De estimerte gjennomsnitts- og 95-persentilkonsentrasjonene av kvikksølv er henholdsvis 0,12 og 0,33 mg/kg v.v.

Konsentrasjonen av kvikksølv økte med lengden på fisken for enkelte arter. Dette gjaldt særlig for torsk, brosme, hyse, sei, kveite og ørret.

Usikkerhet

VKM anser usikkerhetene i scenarioberegningene som moderate til lave, og usikkerheten i den omvendte modelleringen som lav.

Nøkkelord: Fisk, Eksponering, kost, kvikksølv, metylkvikksølv, omvendt modellering, VKM

Abbreviations

BMDL – Benchmark Dose Lower Confidence Limit

bw – body weight

CONTAM Panel – EFSA Panel on Contaminants in the Food Chain

DRV – Dietary reference value

EEA – European Economic Area

EFSA – The European Food Safety Authority

FAO – The Food and Agriculture Organization of the United Nations

Hg – Mercury

HI – Institute of Marine Research (Havforskningsinstiuttet)

JECFA – Joint FAO/WHO Expert Committee on Food Additives

LCPUFA – Long chained polyunsaturated fatty acids

ML – Maximum limits

MoBa – the Norwegian mother and child cohort study

NDA Panel – EFSA Panel on Dietetic Products, Nutrition, and Allergies

NFSA – The Norwegian Food Safety Authority

NIVA – Norwegian Institute for Water Research

NOAEL – No observed adverse effect level

PTWI – Provisional tolerable weekly intake

SC – EFSA Scientific Committee

TOR – Terms of reference

TWI – Tolerable weekly intake

VKM – Vitenskapskomiteen for mat og miljø / The Norwegian Scientific Committee for Food and Environment

v.v. – Våtvekt

WHO – World Health Organization

ww – Wet weight

Background as provided by the Norwegian Food Safety Authority

Mercury can be found in both organic and inorganic chemical forms. Usually only total mercury is measured in fish and other seafood. The most common organic form, methylmercury, make up the main part of the total mercury in seafood (up to 100% in fish fillets). Mercury is found in all fish and seafood, but the concentration depends on the fish species, fish size and geographical area where the fish are caught. In most agricultural products the inorganic mercury constitute up to 100% of the total mercury.

The European Food Safety Authority (EFSA) have set a tolerable weekly intake (TWI) for methylmercury of 1.3 µg/ kg body weight/ week and a TWI for inorganic mercury of 4 µg /kg body weight/ week (ESFA, 2012) (Chain, 2012). The contribution of inorganic mercury from fish in the diet is uncertain, but even in estimates where the inorganic mercury is set to high levels in fish (20%) and other seafood (50%), EFSA concluded that the possibility of exceeding the TWI for inorganic mercury was low. For methylmercury, the consumption of certain types of seafood could lead to exceedance of the TWI.

The most vulnerable population groups for methylmercury are foetuses and infants since methylmercury can affect the development of the central nervous system.

In the European economic area (EEA), maximum levels (ML) for mercury allowed in fish fillets (muscle meat) to be legally placed on the marked for human consumption have been established. The general ML is 0.5 mg/kg wet weight, but for certain predatory fish species the ML is 1.0 mg/kg wet weight. Fishermen, fish landing facilities and all parts involved in processing, distributing and marketing fishery products are responsible to assure that the regulations are met. When it comes to recreational fishing or harvesting of seafood, the person catching the fish or seafood is responsible for the quality and safety of the food.

MLs for mercury were established to stop trade with highly polluted fish, and does not directly protect people against exceeding the TWI. With background in a report by EFSA 2014 (EFSA Dietetic Products and Allergies, 2014), the EU commission recommends that consumption advice should be refined at national/regional level, based on knowledge about local consumption patterns and the mercury concentration in the fish species consumed .

The Norwegian Scientific Committee for Food and Environment (VKM) made a benefit and risks evaluation of fish and seafood consumption in Norway in 2006, with a revision in 2014 (VKM, 2006; VKM, 2014). In this evaluation VKM concluded that the with the average concentration of methylmercury in fish and the current fish consumption level in Norway, the exposure to methylmercury from fish was under the TWI of 1.3 micrograms/kg bodyweight/week for more than 95% of 2-years-olds, adults and pregnant women. The mercury concentration in fish from different areas varies considerably and it is known that consumption of certain species can cause exceedance of the TWI. This is especially applicable for the part of the population that obtain most of the fish or seafood they consume from polluted areas.

Terms of reference as provided by the Norwegian Food Safety Authority

Recreational fishing and consumption of self-caught fish is substantial in parts of the population. The Norwegian Food Safety Authority wants a risk evaluation of mercury concentration in fish with background in local variations in mercury concentrations. Focus shall be on fish caught in areas with elevated mercury concentrations, and vulnerable groups of the population. We want in particular:

- Scenario calculations of mercury exposure from fish. Clarification of which mercury concentration levels in fish that can cause exceedance of the TWI for methylmercury with intake of different amounts, and species of fish
- An overview of which fish species in Norway that is known to have a high concentration of mercury

Clarification of the terms of reference (TOR)

During discussions of the mandate with VKM, the Norwegian Food Safety Authority (NFSA) made it clear that identification of geographical areas with high mercury concentrations was not part of the TOR. Therefore, VKM focused on identification of fish species with possibly elevated mercury concentrations.

Assessment

1.Introduction

1.1 Background

The VKM Panel on Contaminants published in 2006 a risk assessment on mercury exposure from cod filets, with focus on pregnant women (VKM, 2006; in Norwegian only). In the exposure scenarios, the mercury in cod filet varied, while the mercury concentrations in other fish and seafood were kept constant. The estimated exposures were compared with the provisional tolerable weekly intake (PTWI) for methylmercury of 1.6 µg/kg body weight (bw) as mercury set by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) (FAO/WHO, 2004).

Since then, the European Food Safety Authority (EFSA) has established a new tolerable weekly intake (TWI) for methylmercury of 1.3 µg/kg bw, given as mercury (EFSA, 2012) (Chain, 2012). Furthermore, more data on the occurrence of mercury and methylmercury in Norwegian fish (fresh- and seawater species) are available.

1.2 Mercury in food

Mercury is released to the environment from both natural and anthropogenic sources, and occurs in three chemical forms; 1. Elemental mercury, 2. Inorganic mercury, and 3. Organic mercury. Organic mercury is mercury methylated to methylmercury by microorganisms both in the water columns and in sediments. Methylmercury is readily bioavailable and bioaccumulates in aquatic food chains leading to elevated mercury concentrations in predatory fish.

Human exposure to inorganic mercury and methylmercury are mainly dietary, and fish and other seafood is the main dietary source of both forms (Chain, 2012).The food category "Fish and other seafood" is the food category with the highest concentrations of mercury, and in fish most mercury is present as methylmercury (Chain, 2012). In this opinion, VKM assumes, as a conservative approach, that all mercury found in fish is methylmercury. VKM also assumes that there is no other exposure to mercury than through fish in the diet.

1.3 Legislation

The European Union (EU) Commission Regulation (EC) 1881/2006, and later amendments, sets maximum levels for certain contaminants in foodstuffs . The legislation is of relevance to European Economic Area (EEA), and is implemented in Norway trough regulation FOR-2015-

07-03-870 Forskrift om visse forurensende stoffer i næringsmidler, last changed by FOR-2018-07-09-1164 . The current maximum levels are summarised in table 1.3-1.

Table 1.3-1 Current maximum levels for mercury in foodstuffs set in European Union (EU) Commission Regulation (EC) 1881/2006, and later amendments .

Foodstuff	**Maximum level (mg/kg ww)**
Fish products and muscle meat of fish excluding species listed below. The maximum level for crustaceans applies to muscle meat of appendages and abdomen. In case of crabs and crab-like crustaceans (*Brachyura* and *Anomura*) it applies to muscle meat from appendages.	0.5
Excluded fish, meat of the following fish Anglerfish (*Lophius* species) Atlantic catfish (*Anarhichas lupus*) Bonito (*Sarda* species) Eel (*Anguilla* species) Emperor, orange roughy, rosy soldierfish (*Hoplostethus* species) Grenadier (*Coryphaenoides* species) Halibut (*Hippoglossus hippoglossus*) Kingklip (*Genypterus capsensis*) Marlin (*Makaira* species) Megrim (*Lepidorhombus* species) Mullet (*Mullus* species) Pink cusk eel (*Genypterus blacodes*) Pike (*Esox lucius*) Plain bonito (*Orcynopsis unicolor*) Poor cod (*Tricopterus minutes*) Portuguese dogfish (*Centroscymnus coelelepis*) Rays (*Raja* species) Redfish (*Sebastes marinus, S. mentella, S. viviparus*) Sail fish (*Istiophorus platypterus*) Scabbard fish (*Lepidopus caudatus, Aphanopus carbo*) Seabream, pandora (*Pagellus* species) Shark (all species) Snake mackerel or butterfish (*Lepidocybium flavobrunneum, Revettus pretiosus, Gempylus serpens*) Sturgeon (*Acipenser* species) Swordfish (*Xiphias gladius*) Tuna (*Thunnus* species, *Euthynnus* species, *Katsuwonus pelamis*)	1.0
Food supplements (as sold)	0.1

1.4 Previous risk assessments

1.4.1 EFSA 2012

In 2012, the EFSA Panel on Contaminants in the Food Chain (CONTAM Panel) published a Scientific Opinion on the risk for public health related to the presence of inorganic mercury and methylmercury in food (Chain, 2012). The CONTAM Panel established TWIs for inorganic mercury and methylmercury and assessed the dietary exposure to mercury. The opinion focused only on the risk related to dietary exposure to mercury, and not the benefits associated with consumption of specific foods, i.e. fish and other seafood. The TWI for methylmercury was established at 1.3 µg/kg bw per week (expressed as mercury) which is lower than the PTWI of 1.6 µg/kg bw per week set by JECFA (FAO/WHO, 2004). For inorganic mercury, EFSA established a TWI at 4 µg/kg bw per week (expressed as mercury), in line with the one set by JECFA (2004). The following summary focuses on methylmercury.

Critical effect and TWI

Both animal studies and epidemiological studies were evaluated, and the CONTAM Panel concluded that the best endpoint for the derivation of a TWI was neurodevelopmental outcomes in children. The association between methylmercury exposure and neurodevelopmental outcomes after prenatal exposure was chosen as a basis for the derivation of a TWI. Results from two cohort studies, the Faroe Island study and the Seychelles study, respectively, were used.

The TWI was derived as follows; A mean (11.5 mg/kg maternal hair) of the apparent no observed effect level (NOEL) from the Seychelles cohort (11 mg/kg maternal hair) and the Benchmark Dose Lower Confidence Limit ($BMDL_{01}$) from the Faroe Island cohort (12 mg/kg maternal hair) was determined. The mercury concentration in hair was converted to a concentration in maternal blood using a hair to blood ratio of 250, and then the mercury concentration in maternal blood (46 µg/L) was converted to a daily dietary mercury intake (1.2 µg/kg bw) using a one-compartment model. Two assessment factors were then applied, a factor of 2 for variation in the hair to blood ratio, and a factor of 3.2 for interindividual variation in the one-compartment model. The established TWI for methylmercury was 1.3 µg/kg bw expressed as mercury.

Risk characterisation

The exposure to methylmercury through the consumption of fish and other seafood was calculated for the European population. In general, the mean dietary exposure did not exceed the TWI for all age groups. However, in some surveys, the TWI was exceeded, indicating that the mean methylmercury exposure in some children may exceed the TWI. The 95-percentile exposures for all age groups were close to or above the TWI, and for high consumers of fish, the exposure may be approximately six times higher than the TWI. The CONTAM Panel noted that TWI was based on neurodevelopmental outcomes, and that pregnant women may be present in the group of high consumers of fish. The CONTAM Panel concluded that dietary exposure to methylmercury above the TWI is of concern. They also stated that if measures to reduce the dietary exposure to methylmercury are considered, the potential benefits of consuming fish should be taken into consideration.

1.4.2 EFSA Risk benefit 2014

In 2014, the EFSA Panel on Dietetic Products, Nutrition, and Allergies (the NDA Panel) addressed the risks and benefits of seafood (fish and shellfish) consumption with regards to the intake of nutrients and exposure to methylmercury. The NDA Panel evaluated the health benefits of seafood consumption and concluded that the consumption of one to two servings of seafood per week, and up three to four servings per week during pregnancy, was associated with better neurodevelopmental outcomes in children compared to no consumption of seafood. In adults, similar weekly serving sizes were associated with a lower risk of coronary heart disease mortality. The NDA Panel noted that these associations refer to the consumption of seafood as such, i.e. they include beneficial effects of nutrients and adverse effects of contaminants (e.g. methylmercury).

1.4.3 EFSA Risk benefit 2015

Following the EFSA Scientific Opinions of 2012 and 2014, the EFSA Scientific Committee (SC) published, in 2015, a Scientific Opinion on the benefits of fish/seafood consumption compared to the risks of methylmercury in fish/seafood (Committee, 2015). Considering the TWI for methylmercury (EFSA, 2012) (Chain, 2012) and the dietary reference value (DRV) for n-3 long chained polyunsaturated fatty acids (LCPUFA) (EFSA, 2010) (EFSA Panel on Dietetic Products and Allergies, 2010), the SC used scenarios to calculate the number of servings per week needed to reach the TWI and DRV, respectively. If fish species with high concentrations of methylmercury was consumed the TWI for mercury was reached before the DRV for n-3 LCPUFA. The TWI was reached when consuming one to two servings of fish species with a high mercury content per week. The SC concluded that the consumption of fish species with a high concentration of methylmercury should be limited. They stated that due to regional variation in the type of fish consumed, it is not possible to give a general recommendation for the European population on the consumption of fish. Each country needs to assess benefits and risks associated with consumption of fish considering national consumption patterns.

1.4.4 VKM Benefit-risk fish 2014

In 2014, the Scientific Steering Committee of the VKM published an Opinion on the Benefit-risk assessment of fish and fish products in the Norwegian diet (VKM, 2014). This was an update of the benefit-risk assessment published by VKM in 2006 (VKM, 2006). The assessment consisted of three parts; a benefit assessment, a risk assessment, and a benefit-risk assessment. Several nutrients and contaminants were included in the assessment, but the following summary focuses only on methylmercury.

Exposure

The exposure to mercury through the consumption of fish and fish products were estimated for 2-year-olds, adults and pregnant women. For 2-year-olds, the mean lower bound exposure to mercury was 0.50 μg/kg bw/week, while the mean upper bound exposure was 0.51 μg/kg bw/week. The 95-percentile exposures were 1.1 and 1.2 μg/kg bw/week for lower and upper bound, respectively. The mean and 95-percentile fish consumption by 2-year-old were 16 g/day (corresponding to 112 g/week) and 36 g/day (252 g/week), respectively. For adults, the mean lower bound exposure to mercury was 0.29 μg/kg bw/week, and the upper bound exposure was 0.30 μg/kg bw/week. The 95-percentile exposure was 1.2 μg/kg bw/week for both lower and upper bound. The mean and 95-percentile fish consumption by adults were 51 g/day (corresponding to 357 g/week) and 201 g/day (1407 g/week), respectively. The exposure to mercury in pregnant women were lower than for adults, so was also the fish consumption. For pregnant women, the mean lower bound and upper bound exposures to mercury were both 0.17 μg/kg bw/week, while the 95-percentile exposures were 0.38 and 0.39 μg/kg bw/week for lower and upper bound, respectively. The mean and 95-percentile fish consumption by pregnant women were 31 g/day (corresponding to 217 g/week) and 68 g/day (476 g/week), respectively. The upper bound 95-percentile exposure represents high exposure to mercury.

Risk characterisation

The upper bound exposures were compared to the TWI of 1.3 μg/kg bw. For all groups (2-year-olds, adults, and pregnant women) both mean and high upper bound exposures were below the TWI. VKM concluded that for more than 95% of the population of 2-year-olds, adults, and pregnant women, the exposure to methylmercury was below the TWI, and that "this exposure represents a negligible risk and is of no concern".

Changes in fish consumption pattern and amounts were evaluated through scenarios. The scenarios included the current mean fish intake with a consumption of two-thirds lean fish and one-third fatty fish, the current mean fish intake with different consumption patterns, and increased fish intake with different consumption patterns. All scenarios, except one, gave estimated exposure below the TWI. For 2-year-olds eating a high amount of fish (225 g), and only cod, the estimated exposure was 1.3 μg/kg bw/week. This is equal to the TWI. VKM concluded that fish consumption in line with the food-based dietary guideline of 300-450 g fish, hereof 200 g fatty fish per week was of no concern.

Benefit-risk assessment

VKM compared the benefits and the risks of eating fish and fish products and concluded that "the benefits clearly outweigh the negligible risk presented by current levels of contaminants and other undesirable substances in fish". They stated that adults, including pregnant women, may miss the beneficial effects if they consume less than one serving of fish per week. The beneficial effects were on cardiovascular diseases, particular cardiac mortality, and optimal neurodevelopment.

1.5 Definition of vulnerable groups

The TWI set by EFSA was set based on neurodevelopmental outcomes after prenatal exposure. Pregnant women and their foetuses are therefore the population group most vulnerable to dietary methylmercury exposure. VKM decided to focus on the adult population, including pregnant women, in the later scenarios estimating methylmercury exposure from consumption of fish.

1.6 Regional factors affecting concentrations in fish

In their Scientific Opinion in 2015, the EFSA SC concluded that the consumption of fish with a high concentration of methylmercury should be limited. They did not give a general recommendation for the European population on the consumption of fish due to regional differences in consumption pattern. In addition to the variation in the type of fish consumed, other regional factors may affect the dietary exposure to mercury.

Mercury is released to the environment from both natural and anthropogenic sources. Natural sources are mainly geological, i.e. volcanic activities or weathering of rocks. Anthropogenic sources include industry, batteries, sewage, incineration of waste, deforestation and forest fires, and emissions from coal, oil and gas burning. In Norway, past time pollution from industrial sources are the main cause of elevated mercury levels in soil and sediments. Local pollution may lead to elevated mercury concentrations in the environment and in fish found in the area.

Recreational fishing, i.e. fishing for non-commercial purposes, is a popular activity in many countries. In Norway, recreational fishing includes fishing in lakes, rivers and along the coast. The frequency of recreational fishing, location and the types of fish caught will affect the fish consumption pattern.

A recent large study on mercury in fish in Norwegian waters reported factors affecting the mercury concentration in fish (Azad et al., 2019). The study included 17 species of fish caught in the North Atlantic Ocean, including coastal areas and fjords, and a total of 8459 samples. The mercury concentration was higher in demersal fish than in pelagic fish, and fish caught in fjords and coastal areas had higher mercury concentrations than fish caught offshore. Furthermore, the mercury concentration was higher in fish caught in the south than in fish caught in the north, i.e. the mercury concentration increased from the north to the south of the North Atlantic Ocean.

2. Occurrence data

2.1 Data collection

The NFSA provided data in April - June 2018. The NFSA collected data from the Norwegian Environment Agency, the Institute of Marine Research (HI), the Norwegian Institute for Water Research (NIVA), Vannområde Øyeren and Vannområdet Hurdalsvassdraget/Vorma. VKM also received some additional data from NIVA in October 2018. The raw dataset consisted of 26 361 measurements of total mercury in 36 different fish species across 305 locations. Data were then checked for duplicates manually. In order to identify fish with possible higher mercury concentrations than background level, which could reflect local variations, observations from the open sea were removed. Furthermore, all observations prior to 2008 were removed in case concentrations have changed over time. Finally, removing cartilaginous fish and species not normally consumed, as well as requiring 20 or more observations for any set of analyses left 21 species with 8 906 mercury measurements of which 7 198 also had length measurements to be used for testing for a correlation between mercury concentrations and length.

2.2 Mercury concentrations in fish

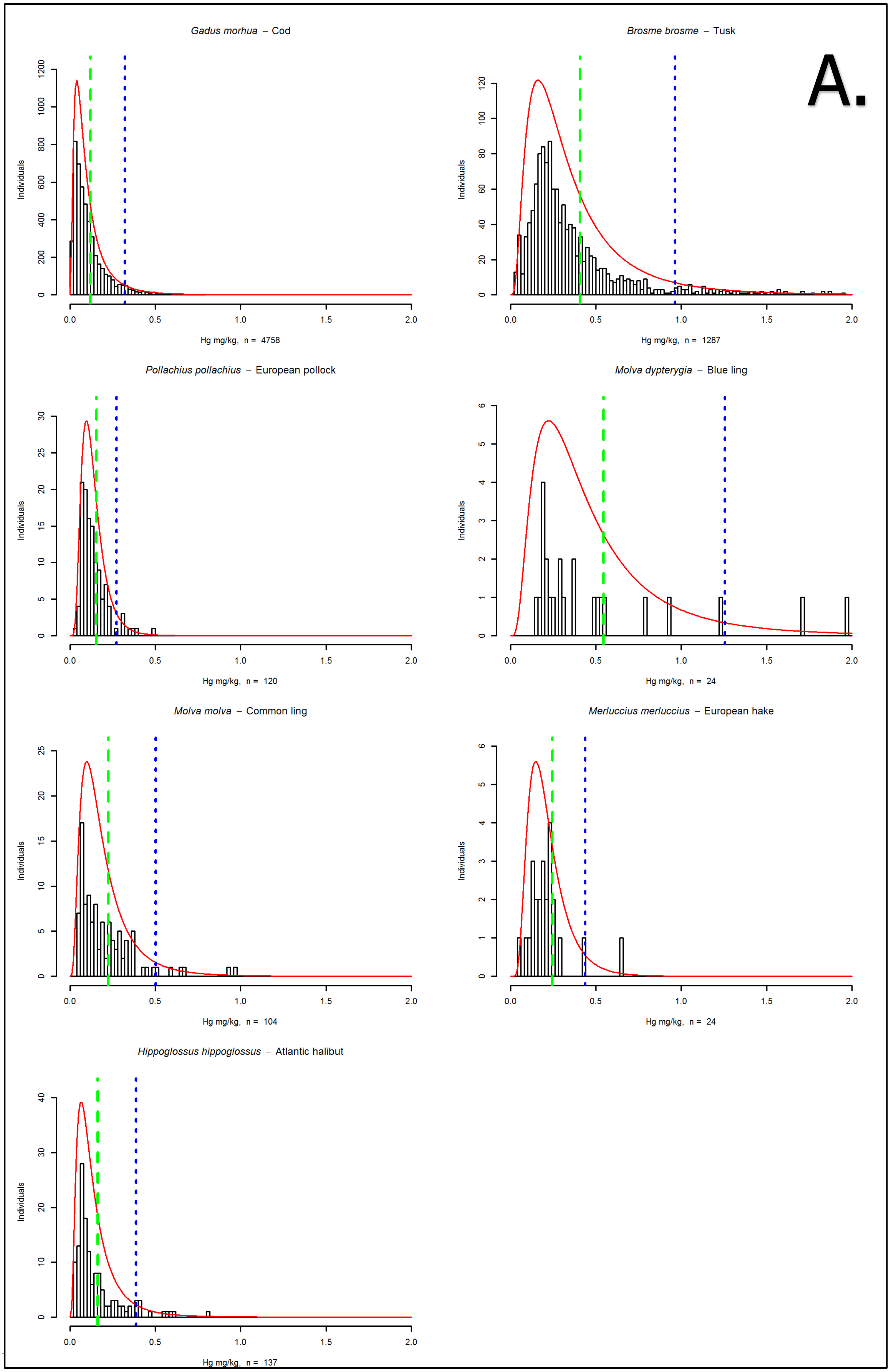
Two basic analyses were performed on the concentration data, both including fitting a log-normal distribution to a set of observations. Firstly, species were lumped from all locations to get an impression of the overall concentration levels in different species (shown in Figure 2.2-1 and summarized in Table 2.2-1). Secondly, to investigate how mercury levels in fish vary across space, a log-normal distribution for each species in each location was performed, if enough data (>19 observations) were available.

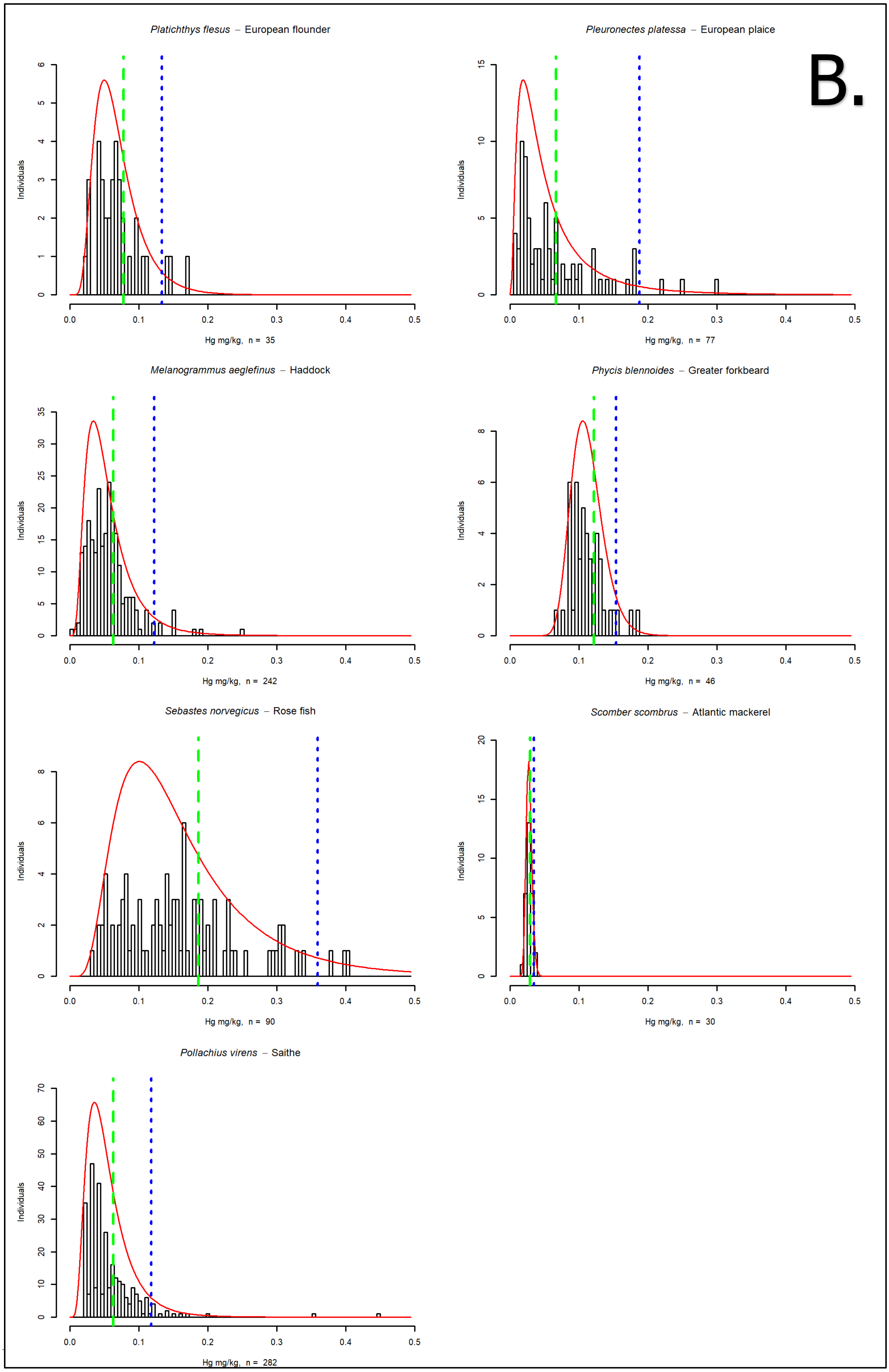
A log-normal distribution has the maximum likelihood estimators (given a set of *n* concentrations *C*);

$$\hat{\mu} = \frac{\sum_{i=1..n}(\log C_i)}{n} \qquad \text{(Equation 1)}$$

$$\hat{\sigma}^2 = \frac{\sum_{i=1..n}(\log C_i - \hat{\mu})^2}{n} \qquad \text{(Equation 2)}$$

As measure of the central tendency of concentrations, we utilized the mean of the log-normal distribution ($e^{\mu+\sigma^2/2}$), and as an indication of extreme levels of mercury concentrations we used the 95 percentile of the log-normal with the parameters estimated using equations 1 & 2.


A.
Gadus morhua – Cod
Individuals
Hg mg/kg, n = 4758
Brosme brosme – Tusk
Individuals
Hg mg/kg, n = 1287
Pollachius pollachius – European pollock
Individuals
Hg mg/kg, n = 120
Molva dypterygia – Blue ling
Individuals
Hg mg/kg, n = 24
Molva molva – Common ling
Individuals
Hg mg/kg, n = 104
Merluccius merluccius – European hake
Individuals
Hg mg/kg, n = 24
Hippoglossus hippoglossus – Atlantic halibut
Individuals
Hg mg/kg, n = 137


B.
Platichthys flesus – European flounder
Hg mg/kg, n = 35
Pleuronectes platessa – European plaice
Hg mg/kg, n = 77
Melanogrammus aeglefinus – Haddock
Hg mg/kg, n = 242
Phycis blennoides – Greater forkbeard
Hg mg/kg, n = 46
Sebastes norvegicus – Rose fish
Hg mg/kg, n = 90
Scomber scombrus – Atlantic mackerel
Hg mg/kg, n = 30
Pollachius virens – Saithe
Hg mg/kg, n = 282
Individuals

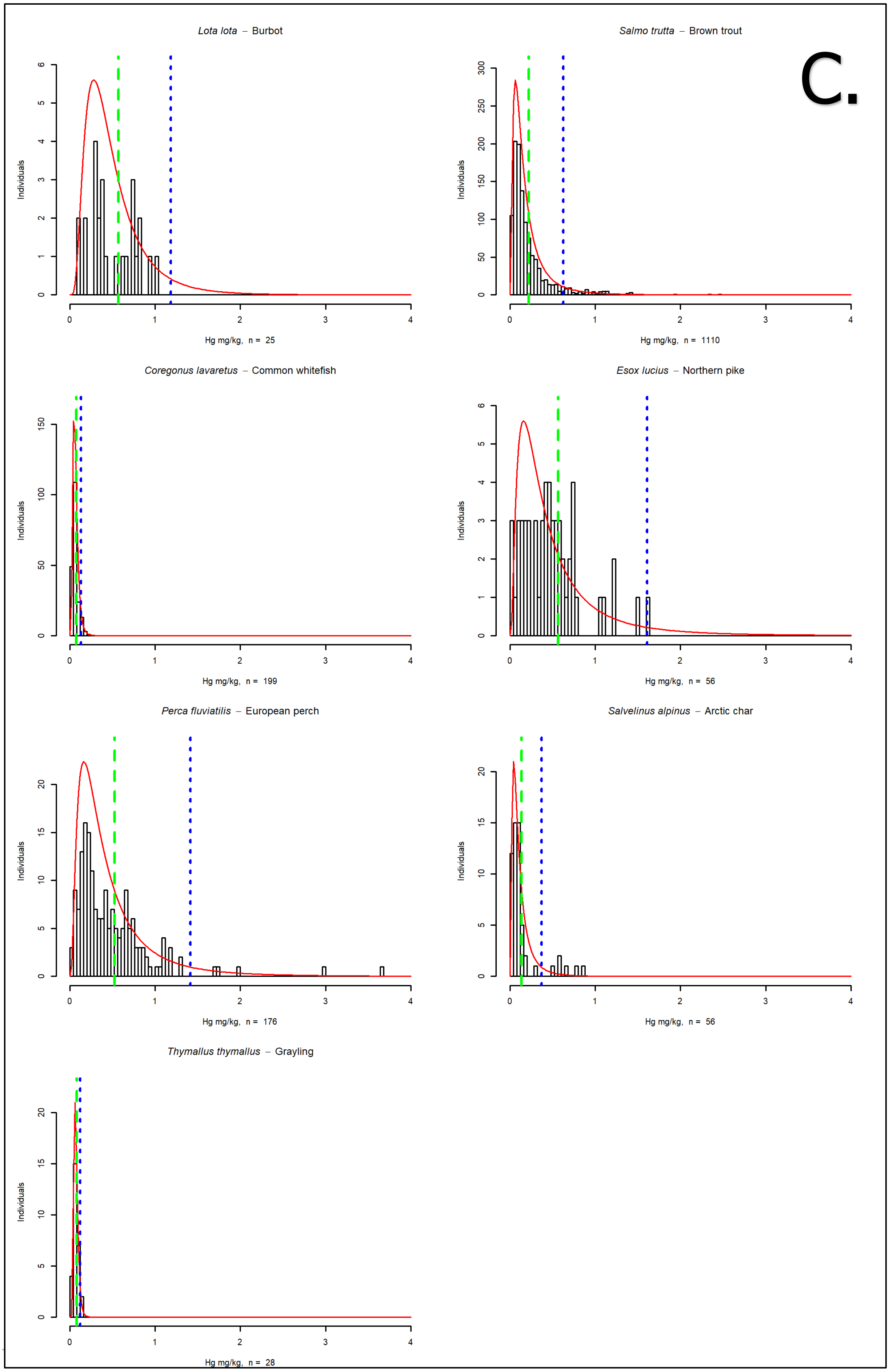

C.
Lota lota – Burbot
Individuals
Hg mg/kg, n = 25
Salmo trutta – Brown trout
Individuals
Hg mg/kg, n = 1110
Coregonus lavaretus – Common whitefish
Individuals
Hg mg/kg, n = 199
Esox lucius – Northern pike
Individuals
Hg mg/kg, n = 56
Perca fluviatilis – European perch
Individuals
Hg mg/kg, n = 176
Salvelinus alpinus – Arctic char
Individuals
Hg mg/kg, n = 56
Thymallus thymallus – Grayling
Individuals
Hg mg/kg, n = 28

Figure 2.2-1 Histograms of all mercury concentrations (mg/kg ww) per fish species from the years 2008 – 2018. The red line is the estimated log-normal distribution, the green stripped line is the predicted mean concentration and the blue dotted line is the predicted 95-percentile concentration. **A**: Marine species, set 1. Note: 10 samples of tusk are outside the x-axis range and not shown. **B**: Marine species, set 2. Note: different x-axis from A. **C**: Freshwater species. Note: different x-axis from A and B.

The highest estimated mercury concentrations (0.53 – 0.57 mg/kg ww) were found in the marine species blue ling, and in the freshwater species burbot, Northern pike, and European perch. High estimated mercury concentrations (0.22 – 0.41 mg/kg ww) were also found for the marine fish tusk, European hake, and common ling, and for the freshwater species brown trout. Elevated (0.12 – 0.19 mg/kg ww) mercury concentrations were estimated for the marine species Rosefish, Atlantic halibut, European pollock, Atlantic cod and Greater forkbeard, and for the freshwater fish Arctic charr. The estimated mercury concentrations were low (0.029 – 0.079 mg/kg ww) for the marine species flounder, saithe, European plaice, haddock, and Atlantic mackerel, and for the freshwater species grayling, common whitefish, and vendace.

Table 2.2-1 Estimated mercury concentrations (mg/kg ww) of the 21 main coastal and fresh water fish. Mean and 95th percentile are predicted from the log-normal distribution fitted to all n measurements from each species (i.e. all locations lumped). The last two columns indicate number of locations, and the number of locations in which there was a significant positive correlation between mercury concentration and length of fish.

Latin name	English name	Estimated mean concentration	Estimated 95-percentile concentration	Total number of measurements (n)	Total number of locations	Number of locations with significant positive correlation between length and concentration/total number of locations where associations could be evaluated
Gadus morhua	Atlantic cod	0.12	0.33	4758	99	38/43 (88%)
Platichthys flesus	European flounder	0.078	0.13	35	1	1/1 (100%)
Brosme brosme	Tusk	0.41	0.96	1287	21	13/15 (87%)
Pollachius pollachius	European pollock	0.16	0.27	120	8	2/2 (100%)

Pleuronectes platessa	European plaice	0.067	0.19	77	12	1/1 (100%)
Molva dypterygia	Blue ling	0.54	1.3	24	5	NA*
Melanogrammus aeglefinus	Haddock	0.063	0.12	242	13	5/8 (63%)
Molva molva	Common ling	0.23	0.50	104	9	1/1 (100%)
Phycis blennoides	Greater forkbeard	0.12	0.15	46	2	0/1 (0%)
Sebastes norvegicus	Rose fish	0.19	0.36	90	3	0/2 (0%)
Merluccius merluccius	European hake	0.24	0.44	24	1	1/1 (100%)
Scomber scombrus	Atlantic mackerel	0.029	0.035	30	1	NA
Pollachius virens	Saithe	0.063	0.12	282	9	6/9 (67%)
Hippoglossus hippoglossus	Atlantic halibut	0.16	0.39	137	16	3/3 (100%)
Lota lota	Burbot	0.57	1.2	25	7	NA
Salmo trutta	Brown trout	0.22	0.63	1110	76	12/21 (57%)
Coregonus lavaretus	Common whitefish	0.075	0.13	199	8	NA
Esox lucius	Northern pike	0.57	1.6	56	13	NA
Thymallus thymallus	Grayling	0.079	0.12	28	4	NA

Perca fluviatilis	European perch	0.53	1.4	176	15	2/2 (100%)
Salvelinus alpinus	Arctic charr	0.14	0.37	56	12	NA

*) NA denotes 'not applicable'

2.3 Relationship between mercury concentration and length of fish

It is well known that mercury, i.e. methylmercury, accumulates in fish over time, and that fish length is related to age more than fish weight for most species. The relationship between mercury concentration and length of the fish was investigated in order to see to what extent this relationship could be used to predict increased mercury concentrations in different fish species. The relationship was investigated for those species where information about length were available and the samples size was n>19. Table 2.2-1 shows the number of locations for each investigated fish species that showed a positive correlation between mercury concentration and fish length.

For most species there was a positive relationship between mercury concentration and length of the fish, i.e. the mercury concentration was higher in longer fish, at most of the locations (Table 2.2-1). For Atlantic cod there was a positive correlation between mercury concentration and length at 88% of the location where association could be evaluated (38 of 43 locations, Table 2.2-1). For tusk, haddock and saithe the percentage of locations with a positive correlation was 87%, 63%, and 67%, respectively (Table 2.2-1). For Atlantic halibut there was a positive correlation between mercury concentration and length at all locations (Table 2). For brown trout there was a positive correlation at 57% of the locations (Table 2.2-1).

2.4 Other fish species with high concentrations of mercury

The available dataset did not cover all fish species regularly consumed in Norway, such as tuna (*Thunnus* sp.). A recent study looked at the mercury concentrations in yellowfin tuna (*Thunnus albacore*) caught at twelve locations in the world's oceans (Nicklisch et al., 2017). The mercury concentration ranged from 0.03 to 0.82 mg/kg ww (n = 8 -10 depending on location, n = 117 in total) (Table 2.4-1), and the concentrations varied significantly between locations. The highest concentrations were found in yellowfin tuna caught in the North

Pacific Ocean, the North East Atlantic Ocean and the South East Atlantic Ocean. They also found a weak association between mercury concentration and the length of the tuna. In a later study, the mercury concentration in two species of tuna were compared (Vazzana et al., 2018). The mean mercury concentration was higher in bluefin tuna (*Thunnus thynnus*) than in yellowfin tuna. The concentrations were 0.84 ± 0.2 mg/kg ww (n = 95) and 0.16 ± 0.3 mg/kg ww (n = 110), respectively (Table 2.4-1). Mercury concentration in canned tuna available on the Norwegian market has been reported (Nilsen and Maage, 2016). The mean mercury concentration was 0.076 ± 0.074 mg/kg ww (n = 50), however the concentrations ranged from 0.008 to 0.34 mg/kg ww (Table 2.4-1). Data on the concentration of mercury in tuna caught in Norwegian waters over the latest years were not available. Also Greenland halibut (*Reinhardtius hippoglossoides*) has been reported to contain relatively high concentrations of mercury (Julshamn et al., 2011). The mercury concentration ranged from 0.03 to 1.1 mg/kg ww depending on size, and the mean concentration was 0.23 ± 0.22 mg/kg ww (n = 320).

Table 2.4-1 Mercury concentrations (mg/kg ww) in tuna. Data are presented as range or mean ± standard deviation.

Species	Mercury concentration (mg/kg ww)	Sample size	Reference
Yellowfin tuna	0.03 – 0.82	117	12
Yellowfin tuna	0.16 ± 0.3	110	13
Bluefin tuna	0.84 ± 0.2	95	13
Canned tuna	0.008 – 0.34	50	14

3. Scenario exposure assessment

3.1 Scenarios for the exposure to methylmercury from fish

A six-by-four set of scenarios were chosen for the estimation of the exposure to methylmercury from fish consumption. The six-by-four matrices are based on six levels of fish consumption and four different diet compositions.

The six fish consumption levels for adults in the scenarios are;

- 150 g fish per week. VKM assume that one portion corresponds to 150 g of fish.
- 217 g fish per week. This is the mean consumption in the Norwegian mother and child cohort study (MoBa).
- 300 g fish per week, corresponding to two portions.
- 364 g fish per week. This is the mean consumption in the Norkost 3 survey (Norwegian dietary survey for adults 2010-2011).
- 450 g fish per week. This is the recommendation of two to three portions of fish per week made by the Norwegian Directorate of Health.
- 1000 g fish per week. VKM considers this a high intake. In comparison, the 95 percentile consumption in Norkost 3 is 1407 g.

The methylmercury exposure will be affected by both the origin of the fish (e.g. obtained from recreational fishing in polluted areas vs. store-bought fish, which is primarily fish from open waters) and the preference for certain fish species with generally higher mercury concentrations.

To represent background mercury concentrations, VKM used a combination of 60% lean fish and 40% fatty fish, as this was the mean composition in Norkost 3 (VKM, 2014). The lean fish mostly consumed was Atlantic cod, while the fatty fish mostly consumed was farmed Atlantic salmon. In the report "Benefit and risk assessment of fish in the Norwegian diet - an update of the report from 2006 based on new knowledge" (2014) from VKM, the mean concentration of mercury in farmed Atlantic salmon was 0.014 mg/kg ww. The mean concentration of mercury in Atlantic cod was 0.075 mg/kg ww. Assuming that 'low' concentrations of mercury in fish is a combination of 60% lean (approximated by the mean for Atlantic cod (from both coastal areas and open sea), at 0.075 mg/kg ww) and 40% fatty fish (approximated by mean for farmed Atlantic salmon, at 0.014 mg/kg ww), this leads to an assumed mercury concentration for the 'low' condition at 0.051 mg/kg ww. Since coastal Atlantic cod is a common catch by recreational or local fishing, the upper 95 percentile of the distribution for Atlantic cod, 0.33 mg/kg ww, was used as the 'high' concentration for the scenario calculations (Figure 2.2-1 and Table 2.2-1).

To evaluate the impact of varying composition of fish in the diet with respect to mercury content, the following four different compositions of fish in the diet are used:

- Only fish with low mercury concentrations (Diet A)
- 2/3 low mercury concentrations + 1/3 high concentrations (Diet B)
- 1/3 low mercury concentrations + 2/3 high concentrations (Diet C)
- Only fish with high concentrations (Diet D)

Combining the six dietary fish consumption levels and the four different compositions of fish with the assumed high and low mercury concentrations (Diet A-D), and a body weight of 70 kg, result in weekly methylmercury exposure in adults as shown in Table 3.1-1.

Exposure (Y) was calculated using Equation 3. Letting C_h and C_l denote high and low concentrations (mg/kg ww), f_h and f_l denoting the fraction of high/low in the diet, A the amount of fish consumed per week (kg/week) and the average person body weight at bw = 70 kg. Mercury exposures are given in µg/kg bw/week.

$$Y = A \times (C_h f_h + C_l f_l)/bw \qquad \text{(Equation 3)}$$

Table 3.1-1. Estimates of weekly exposure to mercury in adults (µg/kg bw/week) based on a six-by-four set of scenarios of fish consumption and composition of fish with low and high mercury concentrations (Diet A – D). Green colour indicates exposure below the TWI.

	One weekly portion (150 g)	MoBa mean (217 g)	Two weekly portions (300 g)	Norkost3 mean (364 g)	Three weekly portions (450 g)	High weekly consumption (1000 g)
Diet A Only low Hg concentration	0.082	0.12	0.16	0.20	0.25	0.55
Diet B 2/3 low + 1/3 high Hg	0.36	0.51	0.71	0.85	1.1	2.4
Diet C 1/3 low + 2/3 high Hg	0.63	0.91	1.3	1.5	1.9	4.2
Diet D Only high Hg concentration	0.90	1.3	1.8	2.1	2.7	6.0

The scenarios of methylmercury exposures in Table 3.1-1 are compared with the TWI set by EFSA (2012) at 1.3 µg/kg bw/week. The TWI is exceeded in several of the scenarios (indicated by red in Table 3.1-1). Eating fish with a low mercury concentration (Diet A) will not lead to an exposure exceeding the TWI, even at a high weekly intake of fish. Eating a diet consisting of 2/3 of fish with a low mercury concentration and 1/3 fish with a high mercury concentration (Diet B) will lead to a methylmercury exposure exceeding the TWI only for those having the highest weekly intake of fish. Increasing the consumption of fish with a high mercury concentration (Diet C; 1/3 low concentration and 2/3 high concentration) leads to an exposure equal to the TWI at a weekly consumption of two portions of fish. Eating only fish with a high mercury concentration (Diet D) leads to an exposure exceeding the TWI when eating more than one portion of fish per week. The mean weekly intake of fish by pregnant women was in the MoBa cohort study 217 g, i.e. between one and two portions of fish per week. This consumption level leads to an exposure equal to the TWI if only fish with a high mercury concentration is consumed.

3.2 Inverse modelling

Using inverse modelling, one can derive which concentration of mercury in fish with 'high' concentrations that will lead to an exposure equal to the TWI of 1.3 µg/kg bw/week (Table 3.2-1). The same assumptions as above was made.

Rearranging equation 3 yields;

$$C_h = \frac{\frac{TWI \times bw}{A} - C_l f_l}{f_h} \qquad \text{(Equation 4)}$$

for the high concentration that leads to an exposure equal to the TWI.

Table 3.2-1. Concentrations of mercury (mg/kg ww) in fish derived using inverse modelling. The concentrations are concentrations of mercury in fish with 'high' concentrations that will lead to an exposure equal to the TWI of 1.3 µg/kg bw/week.

	One weekly portion (150 g)	MoBa mean (217 g)	Two weekly portions (300 g)	Norkost3 mean (364 g)	Three weekly portions (450 g)	High weekly consumption (1000 g)
Diet A Only low Hg concentration	NA*	NA	NA	NA	NA	NA
Diet B 2/3 low + 1/3 high Hg	2.4	1.7	1.3	1.0	0.82	0.38

Diet C 1/3 low + 2/3 high Hg	1.2	0.85	0.62	0.52	0.42	0.20
Diet D Only high Hg concentration	0.82	0.57	0.42	0.35	0.28	0.14

*) NA denotes 'not applicable'

Table 3.2-1 shows the concentrations of mercury in fish at which the combined diet and portions of fish consumed will lead to a methylmercury exposure equal to the TWI. The estimated concentrations can be compared to the estimated mean or 95-percentile of mercury concentrations in any fish and location (Figure 2.2-1 and Appendix II). Three portions of fish per week is in line with the current recommendations of fish consumption from the Norwegian Directorate of Health. Eating only fish with an assumed high concentration of mercury (Diet D), the fish can contain up to 0.28 mg/kg ww before the exposure is similar to the TWI (Table 3.2-1). Of the fish included in the opinion the marine species blue ling and tusk, and the freshwater species burbot, Northern pike, and European perch, have an estimated mean mercury concentration higher than 0.28 mg/kg ww. (Figure 2.2-1 and Table 2.2-1). The following fish have an estimated 95-percentile mercury concentration above 0.28 mg/kg; the marine species Atlantic cod, tusk, blue ling, common ling, rosefish, European hake, and Atlantic halibut, and the freshwater species brown trout, burbot, Northern pike, European perch and Arctic charr (Figure 2.2-1 and Table 2.2-1). The estimated mean concentrations are ranging from 0.41 to 0.57 mg/kg ww (Figure 2.2-1 and Table 2.1-1). Atlantic cod is a species commonly caught by recreational fishing. However, the estimated mercury concentration in Atlantic cod rarely exceeds 0.28 mg/kg ww, i.e. the estimated mean concentration and the estimated 95-percentile concentration are 0.12 and 0.33 mg/kg ww, respectively (Figure 2.2-1 and Table 2.2-1).

4. Uncertainties

The uncertainties associated with the TWI for methylmercury described by EFSA (2012) are also applicable to this opinion.

VKM decided to estimate the exposure to methylmercury from consumption of fish by scenario calculations. The uncertainties associated with the scenarios are discussed below.

The estimated mercury concentrations in fish species with few data points are uncertain; this could result in over- or underestimation of the estimated concentrations. For these, the categorisation into species with possible high or low concentrations is uncertain.

Furthermore, the fish samples in the dataset may not represent the size of geographic sub-populations. If data from polluted areas are overrepresented in the dataset, then the predicted concentrations will be higher, leading to an overestimation of the dietary exposure to methylmercury.

The length of fish included in the environmental monitoring programmes may not represent the length of the fish actually eaten. This may lead to an over- or underestimation of the estimated mercury concentrations.

The composition of the fish consumption was set as 40% fatty fish and 60% lean fish based on Norkost 3 (VKM, 2014). The Norkost 3 survey was conducted in 2010 – 2011. Since then the composition may have changed, thus the estimated methylmercury exposure from the background diet may have been under- or overestimated.

The contribution to the methylmercury exposure from other seafood, such as crab, lobster and blue mussels, is not included. This could result in an underestimation of the dietary methylmercury exposure.

The contribution to the methylmercury exposure from other food is not included. This could result in a small underestimation of the dietary methylmercury exposure, as it is known that other food than seafood contains low concentrations of methylmercury.

Total mercury in fish is regarded as methylmercury; this represents an overestimate of the methylmercury exposure.

Table 4-1. Qualitative evaluation of the main uncertainties (+ overestimation, - underestimation of exposure or risk).

Source of uncertainty	Direction
Estimated mercury concentrations for categorisation of species	+/-

Source of uncertainty	Direction
Samples not representative for relative importance of sub-populations	+/-
Sample size not representative of fish size consumed	+/-
Composition of background diet	+/-
Contribution from other seafood	-
Contribution from other food	-
Total mercury in fish set as methylmercury	+

VKM considers the contribution of the uncertainties in the scenario exposure estimates as moderate to low, and in the inverse modelling as low.

5. Conclusions

The estimated exposures to mercury were compared with the TWI of 1.3 µg/kg bw/week.

The scenarios included background ('low') and 'high' concentrations of mercury in fish. The 'low' concentration was 0.051 mg/kg ww and was composed of 60% Atlantic cod (coastal and open sea) with 0.075 mg/kg ww and 40% farmed Atlantic salmon with 0.014 mg/kg ww. The 'high' concentration was the estimated 95-percentile concentration in coastal Atlantic cod, 0.33 mg/kg ww.

- Eating fish with a low mercury concentration will not lead to an exposure exceeding the TWI, even at a high weekly intake of fish (1000 g).
- Eating a diet consisting of 2/3 of fish with a low mercury concentration and 1/3 fish with a high mercury concentration will lead to a methylmercury exposure exceeding the TWI when having a high weekly intake of fish (1000 g).
- Increasing the proportion of fish with a high mercury concentration (1/3 low concentration and 2/3 high concentration) leads to an exposure equal to the TWI at a weekly intake of two portions of fish (300 g).
- Eating only fish with a high mercury concentration leads to an exposure exceeding the TWI when consuming more than one portion of fish per week (150 g).
- The mean weekly intake for fish in pregnant women (217 g) leads to an exposure exceeding the TWI when only fish with a high mercury concentration is consumed.

Inverse modelling was used to estimate the concentration of mercury in fish (corresponding to high) leading to an exposure reaching the TWI of 1.3 µg/kg bw/week given different compositions of fish in the diet and number of portions of fish consumed.

- Eating three portions per week of only fish with an assumed high concentration of mercury, the fish can contain up to 0.28 mg/kg ww before the TWI is reached.

VKM identified species with estimated mean and 95-percentile concentrations of mercury above 0.28 mg/kg ww.

- Of the fish included in the opinion, the marine species blue ling and tusk, and the freshwater species burbot, Northern pike, and European perch, have an estimated mean mercury concentration higher than 0.28 mg/kg ww.
- Species with an estimated mercury concentration above 0.28 mg/kg at the 95-percentile were the marine species Atlantic cod, tusk, blue ling, common ling, rosefish, European hake, and Atlantic halibut, and the freshwater species burbot, brown trout, Northern pike, European perch, and Arctic charr.
- Atlantic cod is a species commonly caught by recreational fishing. The estimated mercury concentration in Atlantic cod rarely exceeds 0.28 mg/kg ww, i.e. the estimated mean concentration and the estimated 95-percentile concentrations are 0.12 and 0.33 mg/kg ww, respectively.

- The concentration of mercury increased with fish length in several species. This was in particular evident for Atlantic cod, tusk, haddock, saithe, Atlantic halibut and brown trout.

6. Data gaps

There is a lack of occurrence data for mercury concentrations in some of the fish species that are consumed, such as tuna caught in Norwegian waters. There is also a lack of data for mercury concentrations in other fish species commonly caught by recreational fishing, e.g. the marine fish anglerfish (*Lophius piscatorius*; breiflabb in Norwegian) and wolfish (*Anarhichas lupus*; steinbit in Norwegian), and the freshwater fish perch-pike (*Sander lucioperca*; gjørs in Norwegian).

There is little data available on recreational fishing, i.e. volumes fished, species caught and consumed, and areas of fishing.

7. References

Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs (Text with EEA relevance), EUR-Lex.

EU Commission Policies, information and services. Food. Mercury.

FOR-2015-07-03-870 Forskrift om visse forurensende stoffer i næringsmidler, LOVDATA.

Azad A.M., Frantzen S., Bank M.S., Nilsen B.M., Duinker A., Madsen L., Maage A. (2019) Effects of geography and species variation on selenium and mercury molar ratios in Northeast Atlantic marine fish communities. Science of The Total Environment 652:1482-1496. DOI: https://doi.org/10.1016/j.scitotenv.2018.10.405.

Chain E.P.o.C.i.t.F. (2012) Scientific Opinion on the risk for public health related to the presence of mercury and methylmercury in food. EFSA Journal 10:2985. DOI: doi:10.2903/j.efsa.2012.2985.

Committee E.S. (2015) Statement on the benefits of fish/seafood consumption compared to the risks of methylmercury in fish/seafood. EFSA Journal 13:3982. DOI: doi:10.2903/j.efsa.2015.3982.

EFSA Dietetic Products N., Allergies. (2014) Scientific Opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury. EFSA Journal 12:3761. DOI: doi:10.2903/j.efsa.2014.3761.

EFSA Panel on Dietetic Products N., Allergies. (2010) Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol. EFSA Journal 8:1461. DOI: doi:10.2903/j.efsa.2010.1461.

FAO/WHO (2004) Evaluation of certain food additives and contaminants: sixty-first report of the Joint FAO/WHO Expert Committee on Food Additives, World Health Organization.

Julshamn K., Frantzen S., Valdersnes S., Nilsen B., Maage A., Nedreaas K. (2011) Concentrations of mercury, arsenic, cadmium and lead in Greenland halibut (Reinhardtius hippoglossoides) caught off the coast of northern Norway.

Nicklisch S.C.T., Bonito L.T., Sandin S., Hamdoun A. (2017) Mercury levels of yellowfin tuna (Thunnus albacares) are associated with capture location. Environmental pollution (Barking, Essex : 1987) 229:87-93. DOI: 10.1016/j.envpol.2017.05.070.

Nilsen B.M., Maage A. (2016) Kvikksølv i hermetisert tunfisk, Nasjonalt institutt for ernærings- og sjømatforskning NIFES. pp. 16.

Vazzana M., Arizza V., Giunta F., Vella A., Lo Dico G., Giaccone V., Giofrè S.V., Giangrosso G., Cicero N., Ferrantelli V. (2018) Mercury in fish products: what's the best for consumers between bluefin tuna and yellowfin tuna? AU - Cammilleri, Gaetano. Natural Product Research 32:457-462. DOI: 10.1080/14786419.2017.1309538.

VKM (2006) A comprehensive assessment of fish and other seafood in the Norwegian diet. The Norwegian Scientific Committee for Food Safety. pp. 171.

VKM (2014) Benefit-risk assessment of fish and fish products in the Norwegian diet – an update. The Norwegian Scientific Committee for Food Safety. pp. 293.

8. Appendix I

Alphabetical lists of fish names in Latin, Norwegian and English

Table 8-1 Fish species listed in the alphabetical order of their Latin names with Norwegian and English translation

Latin	Norwegian	English
Brosme brosme	Brosme	Tusk
Coregonus lavaretus	Sik	Common whitefish
Esox lucius	Gjedde	Northern pike
Gadus morhua	Torsk	Cod
Hippoglossus hippoglossus	Kveite	Atlantic halibut
Lota lota	Lake	Burbot
Melanogrammus aeglefinus	Hyse	Haddock
Merluccius merluccius	Lysing	European hake
Molva dypterygia	Blålange	Blue ling
Molva molva	Lange	Common ling
Perca fluviatilis	Abbor	European perch
Phycis blennoides	Skjellbrosme	Greater forkbeard
Platichthys flesus	Skrubbe	European flounder
Pleuronectes platessa	Rødspette	European plaice
Pollachius pollachius	Lyr	European pollock
Pollachius virens	Sei	Saithe
Salmo trutta	Ørret	Brown trout
Salvelinus alpinus	Røye	Arctic char
Scomber scombrus	Makrell	Atlantic mackerel
Sebastes norvegicus	Uer	Rose fish
Thymallus thymallus	Harr	Grayling

Table 8-2 Fish species listed in the alphabetical order of their English names with Norwegian and Latin translation

English	Norwegian	Latin
Arctic char	Røye	*Salvelinus alpinus*
Atlantic halibut	Kveite	*Hippoglossus hippoglossus*
Atlantic mackerel	Makrell	*Scomber scombrus*
Blue ling	Blålange	*Molva dypterygia*
Brown trout	Ørret	*Salmo trutta*
Burbot	Lake	*Lota lota*
Cod	Torsk	*Gadus morhua*

English	Norwegian	Latin
Common ling	Lange	*Molva molva*
Common whitefish	Sik	*Coregonus lavaretus*
European flounder	Skrubbe	*Platichthys flesus*
European hake	Lysing	*Merluccius merluccius*
European perch	Abbor	*Perca fluviatilis*
European plaice	Rødspette	*Pleuronectes platessa*
European pollock	Lyr	*Pollachius pollachius*
Grayling	Harr	*Thymallus thymallus*
Greater forkbeard	Skjellbrosme	*Phycis blennoides*
Haddock	Hyse	*Melanogrammus aeglefinus*
Northern pike	Gjedde	*Esox lucius*
Rose fish	Uer	*Sebastes norvegicus*
Saithe	Sei	*Pollachius virens*
Tusk	Brosme	*Brosme brosme*

Table 8-3 Fish species listed in the alphabetical order of their Norwegian names with Latin and English translation

Norwegian	Latin	English
Abbor	*Perca fluviatilis*	European perch
Blålange	*Molva dypterygia*	Blue ling
Brosme	*Brosme brosme*	Tusk
Gjedde	*Esox lucius*	Northern pike
Harr	*Thymallus thymallus*	Grayling
Hyse	*Melanogrammus aeglefinus*	Haddock
Kveite	*Hippoglossus hippoglossus*	Atlantic halibut
Lake	*Lota lota*	Burbot
Lange	*Molva molva*	Common ling
Lyr	*Pollachius pollachius*	European pollock
Lysing	*Merluccius merluccius*	European hake
Makrell	*Scomber scombrus*	Atlantic mackerel
Rødspette	*Pleuronectes platessa*	European plaice
Røye	*Salvelinus alpinus*	Arctic char
Sei	*Pollachius virens*	Saithe
Sik	*Coregonus lavaretus*	Common whitefish
Skjellbrosme	*Phycis blennoides*	Greater forkbeard
Skrubbe	*Platichthys flesus*	European flounder
Torsk	*Gadus morhua*	Cod
Uer	*Sebastes norvegicus*	Rose fish
Ørret	*Salmo trutta*	Brown trout

9. Appendix II

Mercury concentrations in fish

Table 9-1 Predicted mercury concentrations (mg/kg ww) in fish per location. Location name as provided by NFAS. Mean and P95 is the mean and 95 percentile of the fitted log-normal distribution for each species in each location, using n samples. If lengths for individual samples were also available, the correlation between log(length) and log(concentrations) were also tested, presented as Corr.coef (correlation coefficient) and p-value. Rightmost column gives the source of the data.

Species	Location	Mean	P95	Corr. coef	p-value	n	source
B. brosme	Boknafjorden	0.5472744	0.8533665	0.6993584	0.0002044	23	HI
B. brosme	Sørfjorden (ved Osterøy)	0.3185683	0.4455135	0.2645987	0.2114898	24	HI
B. brosme	Porsangerfjorden	0.1150154	0.1848478	0.6302111	0.0028970	20	HI
B. brosme	Ullsfjorden	0.1193416	0.1313664	0.6759672	0.0002082	25	HI
B. brosme	Laksefjorden	0.0455637	0.0502726	0.8307375	0.0000005	24	HI
B. brosme	Bømlafjorden	0.3896387	0.5491325	0.6468983	0.0004747	25	HI
B. brosme	Kongsfjorden	0.0531007	0.0554262	0.5949122	0.0017084	25	HI
B. brosme	Fensfjorden	0.3520692	0.5319689	0.6321213	0.0006992	25	HI
B. brosme	Førdefjorden	0.3849231	0.6774265	0.5207975	0.0000235	59	HI
G. morhua	Varangerfjord	0.0225378	0.0331299	0.6663371	0.0000000	190	Niva
G. morhua	Farsund area	0.0811246	0.1452002	0.7297084	0.0000000	186	Niva
G. morhua	Bømlo north	0.1223054	0.2206602	0.6625333	0.0000000	192	Niva
G. morhua	Inner Oslofjord	0.2590177	0.3451077	0.5366487	0.0000000	189	Niva
G. morhua	Færder area	0.1096187	0.1758338	0.6706238	0.0000000	185	Niva
G. morhua	Inner Sørfjord	0.2107606	0.3800336	0.4694183	0.0000000	184	Niva
G. morhua	Lofoten, Skrova	0.0644046	0.1239227	0.4179887	0.0000000	189	Niva
G. morhua	Kristiansand harbour	0.0783228	0.1623737	0.7488652	0.0000000	165	Niva
G. morhua	Tromsø harbour	0.0438526	0.0655922	0.2616515	0.0006869	165	Niva
G. morhua	Munkholmen	0.1066479	0.1873002	0.5299600	0.0000000	127	Niva
G. morhua	Kirkøy (north)	0.1109326	0.1406891	0.5839389	0.0000000	77	Niva
G. morhua	Hammerfest (havn)	0.0492965	0.0807005	0.2613892	0.0234996	75	Niva
G. morhua	Grenlandsfjorden Breviks area	0.2235196	0.3570738	0.7941843	0.0000000	90	Niva
G. morhua	Helgelandskysten area by Sandnessjøen	0.0589196	0.0831441	0.2351501	0.0422724	75	Niva
G. morhua	Bergen havn	0.1754281	0.3864494	0.5328650	0.0001643	45	Niva
G. morhua	Hardangerfjorden	0.2034351	0.3132853	0.5654732	0.0009165	31	HI
G. morhua	Ullsfjorden	0.0437604	0.0659918	0.0248469	0.9061531	25	HI
G. morhua	Borgundfjorden	0.1751938	0.2330089	0.4288808	0.0324166	25	HI
G. morhua	Balsfjorden	0.0307489	0.0412389	0.2543522	0.0276574	75	HI
G. morhua	Porsangerfjorden	0.0396743	0.0552937	0.4687679	0.0005957	50	HI

G. morhua	Austfjorden	0.0698164	0.1124755	0.6179217	0.0009963	25	HI
G. morhua	Vestfjorden	0.0652221	0.0954075	0.3994613	0.0040547	50	HI
G. morhua	Boknafjorden	0.1136533	0.1716895	0.5573059	0.0038021	25	HI
G. morhua	Sognefjorden	0.2086024	0.4294157	0.6401005	0.0004287	26	HI
G. morhua	Oslofjorden	0.1056678	0.1768742	0.6218274	0.0000000	166	HI
G. morhua	Bergensområdet	0.0913772	0.2020408	0.7005557	0.0000331	30	HI
G. morhua	Salten	0.0872912	0.1249381	0.0576139	0.6407317	88	HI
G. morhua	Skjerstadfjorden	0.0523744	0.0802413	0.8549938	0.0000016	20	HI
G. morhua	Førdefjorden	0.1040486	0.1472757	0.5194226	0.0000249	59	HI
G. morhua	Honningsvåg	0.0325939	0.0451961	0.5364676	0.0022425	30	HI
G. morhua	Narvik	0.1134609	0.2838889	0.7333114	0.0000135	27	HI
G. morhua	Stavanger	0.1830612	0.2922880	0.6325662	0.0001345	31	HI
G. morhua	Tønsberg/Vrengen	0.0982091	0.1297501	0.6991835	0.0000000	54	HI
H. hippoglossus	Vestfjorden	0.1577998	0.3239556	0.6879601	0.0000000	51	HI
H. hippoglossus	Andfjorden	0.1618678	0.4310693	0.7769576	0.0000559	20	HI
H. hippoglossus	Lofoten	0.1055258	0.1837030	0.7930837	0.0000180	21	HI
M. aeglefinus	Boknafjorden	0.0583009	0.0762244	-0.0727461	0.7605286	20	HI
M. aeglefinus	Sørfjorden (ved Osterøy)	0.0514251	0.0714395	-0.0630603	0.7595770	26	HI
M. aeglefinus	Hardangerfjorden	0.0723212	0.0987603	0.4738356	0.0108611	28	HI
M. aeglefinus	Lauvøyfjorden	0.0425897	0.0686040	0.5002493	0.0127936	24	HI
M. aeglefinus	Vestfjorden	0.0723094	0.0930369	0.6332282	0.0006797	25	HI
M. aeglefinus	Varangerfjorden	0.0280892	0.0322921	0.5662192	0.0031721	25	HI
M. aeglefinus	Oslofjorden	0.0678664	0.0864476	0.0006657	0.9975367	24	HI
M. aeglefinus	Altafjorden	0.0398290	0.0820559	0.7413190	0.0000518	23	HI
M. merluccius	Bjørnefjorden	0.1962707	0.2896567	0.7458211	0.0000287	24	HI
P. flesus	Sande	0.0634177	0.0886044	0.4728389	0.0041249	35	Niva
P. latessa	Vestfjorden	0.0345234	0.0841388	0.4503213	0.0238885	25	HI
P. pollachius	Bjørnefjorden	0.1667537	0.2018573	0.6739331	0.0003055	25	HI
P. virens	Fensfjorden/Austfjorden	0.0521583	0.0701852	0.7486902	0.0000167	25	HI
P. virens	Ryfylke	0.0482203	0.0728376	0.4280047	0.0328109	25	HI
P. virens	Hardangerfjord	0.0582475	0.0821087	0.3381807	0.0982359	25	HI
P. virens	Florø	0.0530367	0.0880010	0.2924180	0.1866393	22	HI
P. virens	Oslofjord øst	0.0687315	0.0852306	0.6528618	0.0004037	25	HI

P. virens	Oslofjord Øst	0.0848313	0.0950213	0.3671371	0.0710201	25	HI
S. trutta	Bekk øvre Rautjønn	0.1189246	0.1454664	0.4878346	0.0248696	21	ICP
S. trutta	Djupetjønnbekken	0.1190138	0.3393749	0.0899787	0.5660970	43	ICP
S. trutta	Dybingsvatnet	0.1712133	0.2668499	-0.1302061	0.5842800	20	ICP
S. trutta	Dyrdalsåi	0.2649138	0.4293547	0.4255368	0.0239701	28	ICP
S. trutta	Hovinbekken	0.0662202	0.1588791	0.1261285	0.4146021	44	ICP
S. trutta	Jordtjenn	0.1390040	0.1808463	0.2338885	0.1177143	46	ICP
S. trutta	Lystjerbekken	0.1278168	0.3328830	0.2208085	0.1599527	42	ICP
S. trutta	Møsvatn	0.1396983	0.2189620	0.8621496	0.0000010	20	ICP
S. trutta	Norsjø	0.2489612	0.7529609	0.7636163	0.0000000	51	ICP
S. trutta	Overnbekken	0.1939814	0.5430604	-0.3912890	0.0086284	44	ICP
S. trutta	Rossåna	0.2416690	0.5827026	0.2798665	0.2071440	22	ICP
S. ,utta	Rysjøen	0.1131974	0.1585828	0.7936169	0.0000297	20	ICP
S. trutta	Saudlandsvatnet	0.1867107	0.2417840	0.8121423	0.0000137	20	ICP
S. trutta	Songa	0.0834594	0.1518249	0.6387272	0.0024352	20	ICP
S. trutta	Tandrebekk	0.1605040	0.1923195	0.3057064	0.0584096	39	ICP
S. trutta	Tinnsjøen	0.2197867	0.2772280	0.5987673	0.0032373	22	ICP
S. trutta	Totak	0.1594226	0.2246259	0.7996148	0.0000233	20	ICP
S. trutta	Veumbekken	0.3724174	0.5007405	0.7244973	0.0000001	42	ICP
S. trutta	Ørntjern	0.1079371	0.1228889	0.3932279	0.0863039	20	ICP
S. trutta	Øvre Heimdalsvatn	0.0522454	0.0717768	0.3847183	0.0024048	60	ICP
S. trutta	Øvre Rautjønnbekken	0.5564379	0.6830479	0.4779607	0.0284184	21	ICP
S. scombrus	Oslofjorden	0.0272653	0.0282915	NA	NA	30	HI
S. norvegicus	Vestfjorden	0.0985243	0.1557506	0.3658908	0.0720574	25	HI