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Environmental Contaminants in an Urban Fjord, 2020

Photo: Anders Ruus

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REPORT

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Summary

This programme, “Environmental Contaminants in an Urban Fjord” has covered sampling and analyses of sediment and organisms in a marine food web of the Inner Oslofjord, in addition to samples of blood and eggs from herring gull. The programme also included inputs of pollutants via surface water (stormwater), and effluent water and sludge from a wastewater treatment plant. The bioaccumulation potential of the contaminants in the Oslo fjord food web was evaluated. The exposure to/accumulation of the contaminants was also assessed in birds. A vast number of chemical parameters have been quantified, in addition to some biological effect parameters in cod, and the report serves as a status description of the concentrations of these chemicals in different compartments of the Inner Oslofjord marine ecosystem.

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Environmental Contaminants in an Urban Fjord, 2020

Preface

The programme covers sampling and analyses of organisms in a marine food web of the Inner Oslofjord in 2020 in addition to samples of blood and eggs of herring gull. The programme also includes inputs of pollutants via surface water (stormwater), and wastewater treatment plant discharges. This monitoring programme adds to results from other monitoring programmes such as "Contaminants in coastal waters" (MILKYS) and "the Norwegian river monitoring programme". These programmes are referred to, when relevant. 2020 represents the eighth year of the Urban Fjord programme. As such, the programme has begun to produce unique time series valuable for capturing developments in the environmental concentrations of a vast number of contaminants.

The study was carried out by NIVA, with a majority of the chemical analyses performed by the Norwegian Institute for Air Research, NILU. Collection of herring gull samples was conducted by the University of Oslo (Morten Helberg).

Besides the authors of this report, several persons are acknowledged for their contribution in sample collection, sample preparation, data treatment and analysis: Ingar Johansen, Merete Schøyen, Gunhild Borgersen, Alfhild Kringstad, Camilla With Fagerli, Tânia Gomes, Marthe Torunn Solhaug Jenssen, Pawel Rostowski, Mikael Harju, Hilde Uggerud, Marit Vadset, Inger-Christin Steen, Linda Hanssen, Carsten Lome, Dag Hjermann.

The report has been quality assured by Marianne Olsen.

Oslo, 24.11.2021

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1 Summary

In 2020, the programme, “Environmental Contaminants in an Urban Fjord” has covered sampling and analyses of sediment and organisms in a marine food web of the Inner Oslofjord, samples of blood and eggs from herring gull, as well as inputs of pollutants via surface water (stormwater), and wastewater treatment plant discharges.

The objective of the programme was to monitor the presence of chemicals in a densely populated area and to study how this contaminant input affects a fjord system. The present study adds to previous surveys and provides knowledge to answer the Norwegian Environment Agency’s objectives to:

- Estimate the degree of bioaccumulation of selected contaminants at several trophic levels in marine food chains.
- Connect pollutant exposure of marine organisms to toxic effects at different biological levels, including endocrine disruption and contaminant interactions ("cocktail effects").
- Identify sources and sinks (i.e. the fate) of environmental contaminants in fjord systems and design targeted actions.

Furthermore, there is an intention that data will be used in international chemical regulation, such as REACH and the Stockholm Convention. The programme was also meant to provide data from governmental monitoring in Norway to comply with the requirements of The Water Framework Directive (The Water Regulation/ “Vannforskriften”). 2020 represents the eighth year of the Urban Fjord programme.

The bioaccumulation potential of the contaminants in the Oslo fjord food web was evaluated. The exposure to/accumulation of the contaminants was also assessed in herring gull, as an indicator of an urban fjord inhabitant. A vast number of chemical parameters have been quantified, and the report serves as valuable documentation of the concentrations of these chemicals in different compartments of the Inner Oslofjord marine ecosystem.

Analyses of stable isotopes of carbon and nitrogen showed the same results/trophic interactions as in 2015-2019, reflecting the expected trophic relationship in the marine food web: Trophic position in increasing order with mean $\delta^{15}N$ levels in brackets: blue mussels (7.9) < krill (11.8) < polychaetes (11.9) < herring (13.3) < prawns (13.8) < cod (15.9). Cod has a higher $\delta^{13}C$ level (mean -18.3) than herring (mean -21.1), also according to previous studies. The biomagnifying potential of contaminants is described by trophic magnification factors (TMFs) calculated from the relationship between log_{10}-concentrations of contaminants and trophic position derived from $\delta^{15}N$ levels. The PCB congener CB-180 ($p<0.0001$), the PBDE congener BDE-100 ($p=0.0006$), mercury (Hg; $p<0.0001$)), silver (Ag; $p<0.0001$) and PFOS ($p=0.0003$) all displayed biomagnification in this marine food web by a positive, significant relationship with trophic position.

The sediments of the inner Oslofjord is a potential source of environmental contaminants to sediment dwelling organisms and the contaminants may thus enter the food chain. Several of the target compounds of this study were detected in sediment. Inputs of several compounds to the fjord via stormwater and effluent water from a wastewater treatment plant (WWTP) is also shown. Concentrations of some compounds exceeded environmental quality standards (EQS) in sediment (D5, PCB_7, Zn, As, Ni, Hg and PFOS). Concentrations in stormwater (Bisphenol A, Cu, PCB_7, Zn, As and PFOS)

and WWTP effluent water (PFOS) also exceeded the EQS, however these water types are outside the scope of EQS comparisons. The BPA analogue, BPS (bisphenol S) was detected at 1300 ng/L in stormwater from Alna 136X Alnabru.

As previously reported, concentrations of PBDEs and D5 in eggs of herring gull from the Oslo area in 2020 were higher than concentrations in herring gull eggs from more remote marine colonies (Sklinna and Røst, 2012), suggesting urban influence on the Oslo gulls.

UV-compounds, such as octocrylene (OC), UV-327 and UV-328 were found in WWTP sludge and in the stormwater particle fraction, reflecting the use of UV-chemicals in sunscreens and other cosmetics, as well as in other products.

PFAS, especially PFOS, were found in samples of effluent water from the WWTP, exceeding the EQS. PFAS were also found in a higher proportion in herring gull blood compared to eggs.

Sammendrag

Tittel: Environmental Contaminants in an Urban Fjord, 2020
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I 2020 har overvåkingsprogrammet "Miljøgifter i en Urban Fjord" omfattet prøvetaking og analyse av sediment og organismer i en marin næringskjede i Indre Oslofjord, analyser av prøver av blod og egg fra gråmåke, samt undersøkelser av tilførsler av miljøgifter via overvann og kloakkrenseanlegg.

Målet med programmet var å undersøke tilstedeværelsen av miljøgifter i et tett befolket område og studere hvordan disse påvirker et fjordsystem. Denne undersøkelsen bygger på tilsvarende tidligere undersøkelser og utgjør ytterligere ett skritt mot Miljødirektoratets generelle mål om å:

- Anslå graden av bioakkumulering av utvalgte miljøgifter på flere trofiske nivåer i marine næringskjeder.
- Koble eksponeringen av miljøgifter på marine organismer til toksiske effekter på ulike biologiske nivåer, inkludert hormonforstyrrende effekter og interaksjonseffekter ("cocktaileffekter").
- Identifisere kilder og sluk for miljøgifter i fjordsystemer ("skjebnen" til miljøgifter i en fjord), og utforme målrettede tiltak.

Intensjonen er videre at data skal brukes i internasjonale miljøgiftreguleringer, som REACH og Stockholmkonvensjonen. Dessuten skal programmet frembringe data som vil være til hjelp i å gjennomføre kravene i Vanndirektivet ("Vannforskriften") i forbindelse med statlig basisovervåking. 2020 er det åttende året "Miljøgifter i en Urban Fjord" har vært gjennomført. Det er gjort noen forandringer/forbedringer i design/innhold av programmet fra starten i 2013, frem til 2020.

Analyser av stabile isotoper av karbon og nitrogen viste resultater som for perioden 2015-2019, noe som gjenspeiler det forventede trofiske forholdet i det marine næringsnettet: Trofisk posisjon i stigende rekkefølge med gjennomsnittlige δ^{15}N-nivåer i parentes: blåskjell (7,9) < krill (11,8) < polychaetes (11,9) < sild (13,3) < reker (13,8) < torsk (15,9). Torsk har et høyere δ^{13}C-nivå (gjennomsnittlig -18,3) enn sild (gjennomsnittlig -21,1), dette også i samsvar med tidligere studier. Biomagnifiseringspotensialet til utvalgte miljøgifter er beskrevet av trofisk magnifiseringsfaktor (TMF) beregnet ut fra forholdet mellom $\log_{10}$-konsentrasjoner av miljøgifter og trofisk posisjon avledet fra δ^{15}N-nivåer. PCB-kongeneren CB-180 ($p<0,0001$), PBDE-kongeneren BDE-100 ($p=0,0006$), kvikksølv (Hg; $p<0,0001$)), sølv (Ag; $p<0,0001$) og PFOS ($p=0,0003$) viste alle biomagnifisering i dette marine næringsnettet ved en positiv, signifikant sammenheng med trofisk posisjon.

Sedimentene i Indre Oslofjord er i utgangspunktet en potensiell kilde til miljøgifter i bunnlevende organismer og dermed også en kilde til miljøgifter opp i den marine næringskjeden. Flere av stoffene i denne undersøkelsen ble funnet i sediment. Tilførsel til fjorden via overvann og utslippsvann fra kloakkrenseanlegg ble også vist for flere av stoffene. Konsentrasjoner av enkelte stoffer overskred miljøkvalitetsstandarder i sediment (D5, PCB_7, Zn, As, Ni, Hg og PFOS). For vannprøver ble EQS

overskredet i prøver av overvann (Bisphenol A, Cu, PCB_7, Zn og PFOS) og utslippsvann fra kloakkrenseanlegg (PFOS), men vi presiserer at EQS ikke er ment for disse vanntypene. Bisfenol S ble påvist i prøver av overvann (Alna 136X Alnabru) (1300 ng/L).

Som rapportert tidligere var konsentrasjonene av PBDE-forbindelser og D5 funnet i gråmåkeegg fra Oslofjordområdet i 2020 høyere enn konsentrasjoner funnet i gråmåkeegg fra mer fjerntliggende marine kolonier (Sklinna og Røst, 2012), som kan tyde på urban påvirkning av måkene fra Oslofjorden.

UV-stoffer, bl.a. oktokrylen (OC), UV-327 og UV-328, ble funnet i slam fra renseanlegg og i partikkelfraksjonen til overvannsprøvene, noe som gjenspeiler bruken av UV-kjemikalier i solkremer og annen kosmetikk, så vel som i andre produkter. Disse stoffene ble også gjenfunnet i blod fra gråmåke og i krill.

PFAS ble påvist i avløpsvann fra Bekkelaget, med PFOS som den dominerende forbindelsen (over EQS). PFAS ble også funnet i prøver av blod fra gråmåke.

2 Introduction

"Environmental contaminants in an urban fjord" is a programme designed to monitor discharges of anthropogenic chemicals in a densely populated area and to study how this contaminant input affects a fjord system. The programme addresses inputs of pollutants from potential sources, measurements of contaminant concentrations in different marine species, assessment of bioaccumulation patterns within a food web and estimation of effect risks in organisms. The programme contributes to the Norwegian Environment Agency's ongoing monitoring activity in coastal areas and supplements two other monitoring programmes: "the Norwegian river monitoring programme " and "MILKYS - Environmental contaminants in coastal waters".

2.1 Objectives

The environmental monitoring activity in the present programme contributes to the Norwegian Environment Agency's general aim to:

- Estimate the bioaccumulation of selected contaminants at several trophic levels in marine food chains.
- Connect pollutant exposure of marine organisms to toxic effects at different levels of biological organisation, including endocrine disruption and contaminant interactions ("cocktail effects").
- Identify sources and sinks of environmental contaminants in fjord systems ("the fate of the contaminants in a fjord") and designing targeted actions.

The programme will also provide data that will aid to implement the requirements of The Water Framework Directive (The Water Regulation/"Vannforskriften") regarding governmental basic monitoring as well as used in international chemical regulation. The present report (2020) represents the eighth year of the Urban Fjord project. As such, the programme has begun to produce unique time series valuable for capturing developments in the environmental concentrations of a vast number of contaminants.

3 Material and Methods

3.1 Sample Collection

Polychaetes, zooplankton (krill), prawns, blue mussel, herring and cod were collected as representatives of a food chain in the inner Oslo Fjord. In addition, sediment was collected. The samples were collected in an area within 4.7 km from Steilene (**Figure 1**), in the autumn of 2020. Herring gull samples (blood and eggs) were also collected within the programme (spring 2020), as a representative of an urban fjord inhabitant. **Table 1** shows the sampling plan of the programme. The programme also included samples of stormwater (water and particle fraction), and effluent water and sludge from a wastewater treatment plant.

3.1.1 Sediment

Sediment was collected at the station Ildjernet, just west of the northern tip of Nesoddtangen (Station Cm21, **Figure 1**) by means of a van Veen grab (0.15 m^2) from Research Vessel Trygve Braarud. Four grabs of the top layer (0-2 cm in grab samples with undisturbed surface) were prepared[1] for one sample.

3.1.2 Food web of the Inner Oslofjord

Polychaetes, zooplankton (krill), prawns, blue mussel, herring and cod were collected as representatives of a food chain in the inner Oslo Fjord.

Polychaetes were collected at station Cm21 (**Figure 1**) using a van Veen grab (0.15 m^2) from RV Trygve Braaarud. When possible (dependent on species and mechanical damage), the worms were held in a container of clean seawater for 6-8 hours prior to freezing and analysis. This was done in order to allow the worms to purge any residual sediment from the gut. Some gut content (sediment particles and/or organic matter) may still have been included in the polychaete samples, possibly having some influence on the chemical analysis, but the amount of gut content was minor relative to the polychaete tissue. Material for three pooled samples was collected. The samples consisted of the species listed in **Table 2**.

Krill (*Euphausiacea*) were collected at Midtmeie, southwest of Steilene (**Figure 1**), as representatives of the zooplankton. A fry trawl was operated from RV Trygve Braarud for this purpose. Material for three pooled samples was collected.

Prawns (*Pandalus borealis*) were caught with benthic trawl from RV Trygve Braarud in the same area as zooplankton (krill); Midtmeie, southwest of Steilene (**Figure 1**). Material for three pooled samples (of 50 individuals each; size: 92-146 mm) was collected.

Mussels were collected at Steilene (**Figure 1**) by standard procedures (handpicked, using rake, or snorkelling; as done in the project "Contaminants in coastal waters", MILKYS; Green et al. 2019; The Norwegian Environment Agency M-1515). Three pooled samples (each of 15-16 shells; shell length 56 to 79 mm) was prepared. The method for collecting and preparing blue mussels was based on the National Standard for mussel collection (NS 9434:2017).

[1] According to the Norwegian Environment Agency guidelines for risk assessment of contaminated sediment (M-409/2015).

Herring (*Clupea harengus*) were caught with trawl from RV Trygve Braarud at Midtmeie, southwest of Steilene (**Figure 1**). Material (muscle tissue) for three pooled samples (of 5 individuals in each; length: 21.5-27 cm, weight: 111-199 g) was collected.

Cod (*Gadus morhua*) were caught with trawl (n=40) from RV Trygve Braarud at Alterdypet, southwest of Steilene (**Figure 1**). Samples of muscle tissue, liver and bile were taken. Biometric data for the fish are given in Appendix. Note that for several individual specimens, the livers were not sufficiently large for all chemical analyses, thus each liver sample was pooled with livers from up to 5-6 individuals (see Appendix).

3.1.3 Herring gull

Herring Gull (*Larus argentatus*) blood samples (from adult breeding individuals trapped at nest) and eggs (14 egg samples and 15 blood samples) were sampled at Søndre Skjælholmen (Nesodden municipality; 59.85317 N, 10.7281 E; **Figure 1**). Biometric data for the birds are given in Appendix. Adult birds were trapped by walk-in trap placed at the nest. Blood samples (~5 ml) were taken from a vein under the wing. Adult female and egg were sampled from the same nest.

3.1.4 Stormwater

Stormwater samples were collected at one occasion at two specific sampling points (Bryn Ring 3/E6, and Breivoll E6, downstream terminal; **Figure 1**). The samples were collected from manholes by filling bottles directly in the stormwater. Subsequently, the stormwater samples were separated into a filtered fraction (hereafter referred to as “dissolved fraction”) and a particulate fraction by filtering (polyethylene (PE) frit, 20 µm porosity prior to analysis of per-and polyfluorinated substances (at NIVA) and Whatman Glass Microfilters GF, pore size 1.2 µm, prior to analysis of other chemical parameters (at NILU)).

3.1.5 Wastewater treatment plant

Sludge and treated effluent water were collected from Bekkelaget Wastewater Treatment Plant (WWTP; **Figure 1**) at two occasions (August 26th and August 27th). Samples of effluent water were collected using the WWTPs fixed equipment for collection of 24h-samples (according to rules for accredited sampling). Aliquots were transferred to appropriate flasks for the different analytes.

Table 1. Overview of samples collected for the «Urban Fjord" programme 2020.

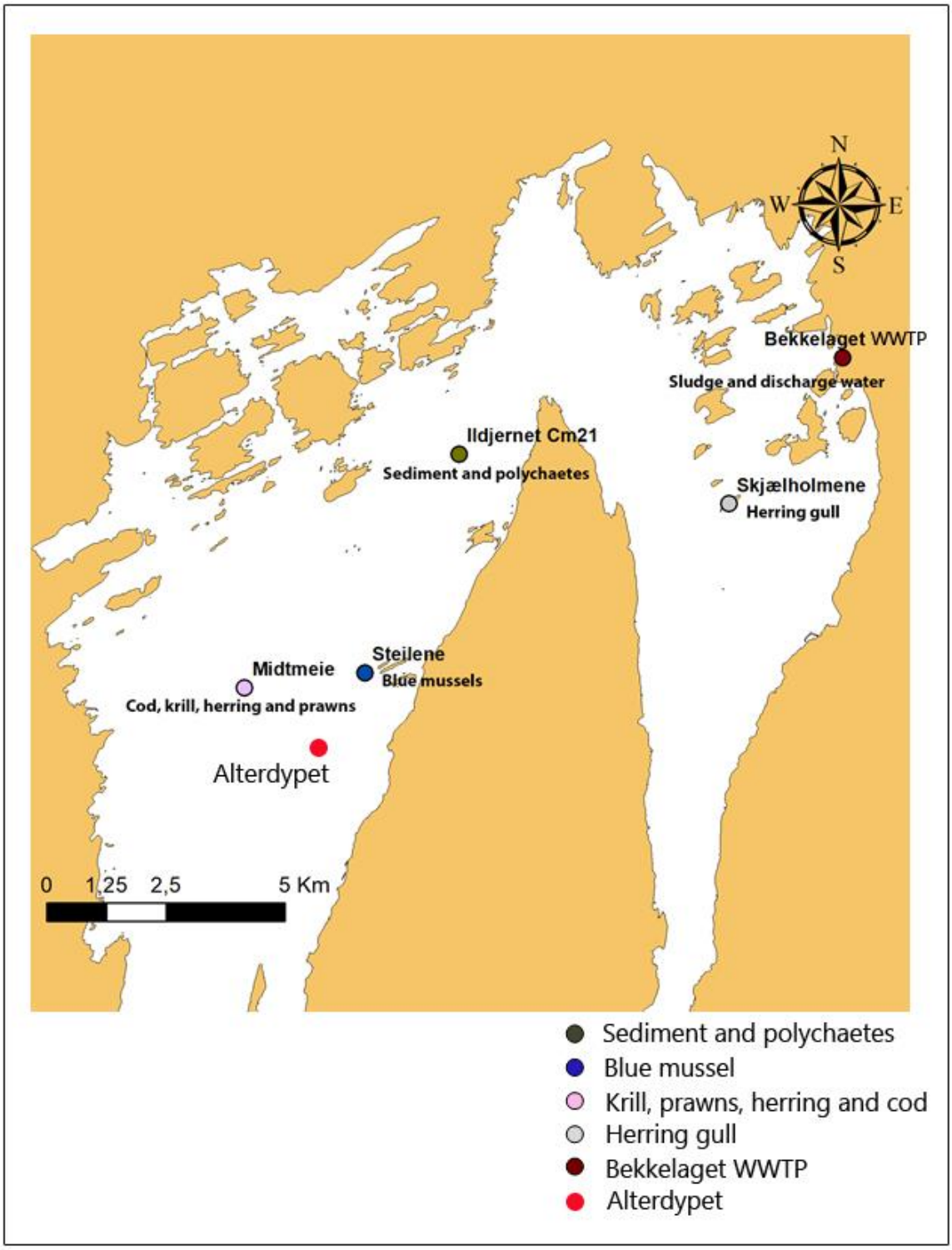
Species/sample	Matrix	Locality	Frequency	No. for analysis
Sediment	Whole sediment	Ildjernet (Cm21)	Once per year	1
Polychaetes	Pooled samples, whole individuals	Ildjernet (Cm21)	Once per year	3 pooled samples
Zooplankton (krill)	Pooled samples, whole individuals	Midtmeie	Once per year	3 pooled samples
Prawns	Pooled samples, soft tissue tails	Midtmeie	Once per year	3 pooled samples
Blue mussel	Pooled samples, soft body	Steilene	Once per year	3 pooled samples
Herring	Muscle	Midtmeie	Once per year	3 pooled samples
Cod	Muscle, liver, bile	Alterdypet	Once per year	40 individuals (15 pooled liver samples)
Herring gull (blood)	Blood	Søndre skjælholmen	Once per year	15 individuals
Herring gull (egg)	Egg	Søndre skjælholmen	Once per year	15 eggs
Inputs stormwater	Water (dissolved) and particulate fraction	See **Figure 1**	Once per year	4 samples (2 samples of dissolved fraction plus 2 of particulate fraction)
Inputs from Wastewater Treatment Plant	Effluent water and sludge	Bekkelaget	Twice per year	4 samples (2 samples of discharge water and 2 samples of sludge)

Table 2. Species constituting polychaete samples (grams of each species).

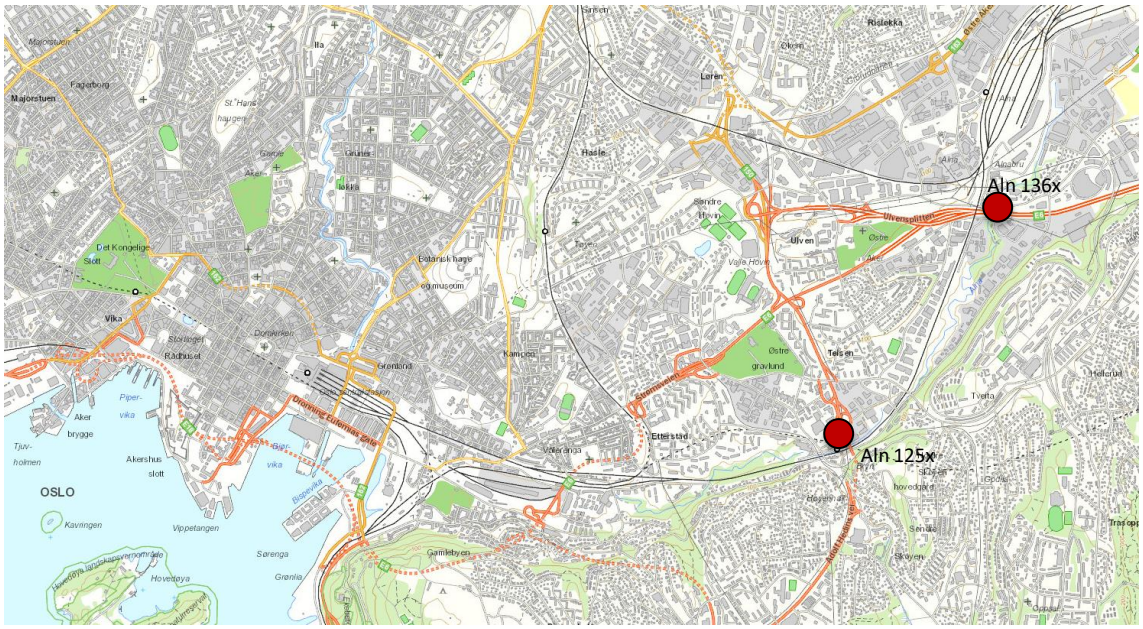
	Inner Oslofjord (Ildjernet, Cm21)		
	Repl. 1	**Repl. 2**	**Repl. 3**
P.crassa	300	0	0
Lumbrineridae	0	137	0
Terbellidae	0	0	102
Aphrodita aculeata	0	0	55
*Misc. **	0	0	105
Total (grams)	**300**	**137**	**262**

* *Inter alia*: *Nephtys, Glycera, Goniadidae, Ophelina, Ophiodromus flexuosus, Skoloplos, Spiophanes kroyeri, Scalibregma inflatum.*

A.


N
W
E
S
Bekkelaget WWTP
Sludge and discharge water
Ildjernet Cm21
Sediment and polychaetes
Skjælholmene
Herring gull
Steilene
Blue mussels
Midtmeie
Cod, krill, herring and prawns
Alterdypet
0 1,25 2,5 5 Km
Sediment and polychaetes
Blue mussel
Krill, prawns, herring and cod
Herring gull
Bekkelaget WWTP
Alterdypet

B.



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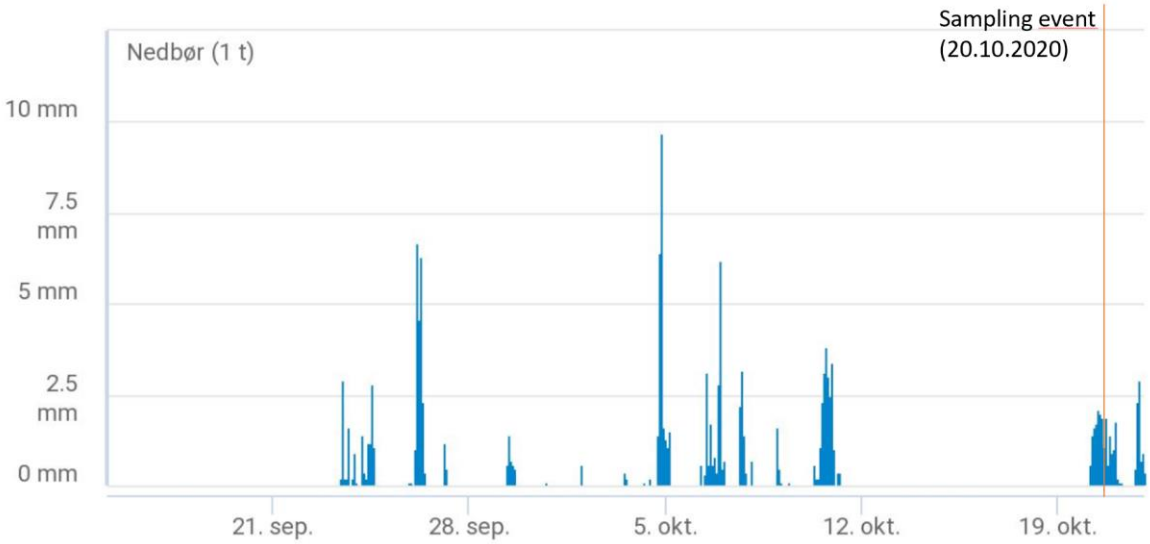


Figure 1. A.: (previous page) Map depicting stations for collection of sediment and polychaetes, blue mussel, and krill, prawns, herring and cod in the Inner Oslofjord, as well as collection of herring gull eggs and blood in the inner Oslofjord. The map also shows the location of Bekkelaget WWTP. B.: Map depicting sites (125x Bryn and 136x Alnabru) for collection of stormwater/surface water samples. C.: Overview of time of sampling of stormwater/surface water in relation to rainfall (mm/d).

3.2 Chemical analysis, support parameters and biological effect parameters

Table 3 to **Table 6** provide a detailed overview of the compounds/parameters analysed in the different samples in 2020. The samples were analysed at NIVA and NILU. Stable isotopes of carbon and nitrogen were analysed at IFE.

Table 3. Overview: Analyses in different matrices from the different localities in 2020.

Species/matrix	Locality	Analytes
Sediment	Ildjernet Cm21 (Inner Oslofjord)	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes
Polychaetes	Ildjernet Cm21 (Inner Oslofjord)	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, stable isotopes of C and N.
Zooplankton (krill)	Midtmeie	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, stable isotopes of C and N.
Prawns	Midtmeie	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, stable isotopes of C and N.
Blue mussel	Steilene	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, stable isotopes of C and N.
Herring	Midtmeie	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, stable isotopes of C and N.
Cod [1]	Alterdypet	Metals, PCB, PFAS, bisphenols, brominated flame retardants, octylphenol, nonylphenol, chlorinated paraffins, UV-chemicals, siloxanes, stable isotopes of C and N.
Herring gull (blood)	Søndre Skjælholmen	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, antioxidant MB1, stable isotopes of C and N.
Herring gull (eggs)	Søndre Skjælholmen	Metals, PCB, PFAS, brominated flame retardants, chlorinated paraffins, UV-chemicals, siloxanes, antioxidant MB1, stable isotopes of C and N.
Inputs stormwater [2]	See **Figure 1**	Metals, PCB, PFAS, bisphenols, brominated flame retardants, octylphenol, nonylphenol, chlorinated paraffins, UV-chemicals.
Wastewater Treatment Plant [3]	Bekkelaget	Silver (Ag), PFAS, bisphenols, brominated flame retardants, octylphenol, nonylphenol, chlorinated paraffins, UV-chemicals, siloxanes, antioxidant MB1.

[1] Liver. Mercury in fillet. Bisphenols, octylphenol and nonylphenol in bile.
[2] Dissolved and particulate fractions. [3] Sludge and discharge/effluent water.

Table 4. Overview: Additional analyses performed in 2020.

Analytes	Description
M3T(Ph)	M3T(Ph) was analysed in all samples of which were analysed for siloxanes.

Table 5. Analytes included in the programme (see the electronic Appendix for CAS-no.). Additional compounds are indicated.

Parameter	Single compounds
Metals	Hg, Pb, Cd, Ni, Ag, Cu (plus Cr, Zn, Fe, As, Sb)
PCB	CB-28, -52, -101, -118, -138, -153, -180 (plus -18, -31, -33, -37, -47, -66, -74, -99, -105, -114, -122, -123, -128, -141, -149, -156, -157, -167, -170, -183, -187, -189, -194, -206, -209)
PFAS	PFPA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUdA, PFDoA, PFTrDA, PFTeDA, PFPeDA, PFBS, PFPS, PFHxS, PFHpS, PFOS, 8Cl-PFOS, PFNS, PFDS, PFDoS, PFOSA, meFOSA, etFOSA, meFOSE, etFOSE, 4:2 FTS, 6:2 FTS, 8:2 FTS, 10:2 FTS, meFOSAA, etFOSAA
Brominated flame retardants	PBDEs [1]: BDE-47, -99, -100, -126, -153, -154, -183, -196, -202, -206, -207, and -209. Tetrabromobisphenol A (TBBPA), decabromodiphenyl ethane (DBDPE), bis(2-ethylhexyl) tetrabromophtalate (TBPH/BEH-TBP), hexabromobenzene (HBB), pentabromotoluene (PBT) (plus tribromoanisole, TBA)
Bisphenols	Bisphenol A, bisphenol S, bisphenol F (plus bisphenol AF, AP, B, E, FL, M, Z) (Bisphenol F is also separated in 2,2'- and 4,4'-)
Octyl-/nonylphenol	Octyl-/nonylphenol (isomer-spesific, i.e. we separate 4- and 4-tert)
UV-chemicals	Octocrylene, benzophenone-3, ethylhexylmethoxycinnamate (plus UV-327, -328 and -329)
Chlorinated paraffins	SCCP (C10-C13) and MCCP (C14-C17)
Siloxanes	Octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), dodecamethylcyclohexasiloxane (D6), Tris(trimethylsiloxy) Phenylsilane (M3T(Ph))
Antioxidant MB1	4,4'-methylenebis[2,6- bis (1,1 dimethylethyl)-phenol]

[1] Plus: BDE-17, -28, -49, -66, -71, -77, -85, -119, -138, -156, -184, -191, -197.

Table 6. Support parameters included in the programme.

Parameter	Specific single parameters	Comment
Stable isotopes	$\delta^{15}N$ and $\delta^{13}C$	In biological matrices
Lipid content (%) in biota		In biological matrices
Weight and length		Fish
Age		Cod
Grain size distribution	Fraction <63 µm	Sediment
TOC		Sediment

3.2.1 Background, target compounds

Chemical elements (including metals) are occurring naturally in our environment. Human activities have, however, through history led to increasing amounts of several of them in different environmental compartments such as biota, water or sediments. In the aquatic environment, inorganic mercury (Hg) may be transformed to the organic form methylmercury, mainly by bacterial activity. In fish, most of the mercury is in the form of methylmercury, which is more bioaccumulative and toxic than inorganic mercury (Wolfe et al., 1998). Cadmium (Cd) has been used e.g. in various industrial processes, such as protecting steel against corrosion. Other applications have been e.g. batteries, pigments, ceramic glaze and surface treatments, but the element is also a contaminant in products, including some types of fertilizer. Cadmium can enter fish by passive diffusion across the gills or by entering the marine food chain at the plankton and microorganism level and thereby being transferred to fish through the diet. Cadmium is highly toxic to humans and its bioaccumulative properties prevents the reduction of the accumulated body burden (Bosch et al., 2016). Lead (Pb) has a great number of industrial applications, both in its elemental form and in the form of alloys and compounds. The major use of lead has been the manufacture of lead accumulators. Furthermore, tetraalkyl lead, R_4Pb, mostly tetraethyl lead is an organic lead species that was previously used as anti-knocking agents in leaded gasoline. This application has declined dramatically due to restrictions imposed through environmental legislation. Pb infers with the biosynthesis of porphyrins and heme, eventually leading to anemia.

Polychlorinated biphenyls (PCBs) are a group of industrial chemicals (209 theoretical congeners), that are also formed as by-product in different industrial processes and combustion processes. The PCBs have unique physical and chemical properties, such as high thermal and chemical stability and high electrical resistance, hence their application in many industrial applications, such as hydraulic fluids, cooling liquids in transformers and dielectric liquids in capacitors. They have also been applied in plasticizers, lubricants, inks and paints. In Norway, the production and use of PCBs was restricted since the 1970s and later banned by law. Immunosuppressive effects, endocrine disrupting effects and impairment of reproduction are some toxic effects expressed by PCBs (Safe, 1994).

PFAS compounds have been applied in both industrial processes and consumer products since the 1950s. They may for instance give products water and dirt repellent properties, and they have been used to impregnate textiles and in food packaging. Some of the PFAS compounds have properties that prevent fire and evaporation of volatile compounds, and have therefore been used in firefighting, such as PFOS. Firefighting foam was previously the largest source of PFOS emissions in Norway, before PFOS containing foams were banned in 2007.

The brominated flame retardants have been applied in products to prevent fire. In Norway, brominated flame retardants can mainly be found in electrical/electronic products. Brominated flame retardants can also be found in cars, plastic insulation materials (polystyrene), and in textiles, such as furniture and workwear.

There are many different bisphenols available, and bisphenol A is the most known substance. It is used e.g. as raw material for plastics and paints and may be found in imported plastic products. There is less knowledge regarding other bisphenols, such as bisphenol AF, bisphenol B, bisphenol BP, bisphenol F, bisphenol M and bisphenol S. These substances can be used as a replacement for bisphenol A. Bisphenol S is a substitute for bisphenol A in heat-sensitive paper. Furthermore, bisphenol F and bisphenol B may possibly replace bisphenol A in products made of epoxy resin and polycarbonate, such as epoxy paint and plastic cutlery.

Alkylphenols have been/are used in textiles, plastic products, paints and lubricants. Nonyl- and octylphenol ethoxylates have been widely used in products such as detergents and cosmetics. Emissions of nonyl- and octylphenols have been substantially reduced the last couple of decades. The decrease is mainly due to reduced application in detergents following regulations.

Short-chained chlorinated paraffins (SCCPs) are banned in Norway, but the compounds may still be found in several imported plastic products and in adhesives and sealants in old windows and building materials. Medium-chained chlorinated paraffins (MCCPs) may also be found in imported products. These substances are primarily applied as softeners and flame retardants and can be found in rubber and PVC used for the production of e.g. cables and floor coverings.

Octocrylene, benzophenone-3 and ethylhexylmethoxycinnamate are used is in sunscreens and other cosmetics to absorb UV rays from the sun, protecting the skin from damage. UV-327, UV-238 and UV-329 are benzotriazol based compounds used as stabilizers in paints, rubber and clear plastics to protect materials from sun light.

Siloxanes have properties that affect the consistency of products such as shampoo and creams to facilitate their use. Siloxanes can otherwise be found in e.g. car wax, paint, insulation materials and cement. Cosmetic products such as soap, skin care products, deodorants and makeup are likely the largest source of siloxane emissions in Norway.

4,4'-methylenebis[2,6-bis(1,1-dimethylethyl)-phenol (MB1) is used as an industrial anti-oxidant and additive to plastics.

3.2.2 Analysis of metals

Metal analyses were performed by NILU.

Sample Preparation

Sediment-/sludge- and biota-samples were added supra pure acid and digested at high pressure and temperature in a microwave- based digestion unit (UltraClave). A minimum of two blanks were included with each digestion. Furthermore, reference material (traceable to NIST) was digested with the samples.

Water samples were preserved in original bottles with 1% (v/v) nitric acid.

Instrumental Analysis

Concentrations of nickel (Ni), cadmium (Cd), mercury (Hg), lead (Pb), silver (Ag) and copper (Cu) were determined using inductively coupled plasma mass spectrometer (ICP-MS). All samples, standards and blanks were added internal standard prior to analysis. In addition, Chromium (Cr), zinc (Zn), iron (Fe), arsenic (As) and antimony (Sb) were determined.

Limits of Detection

Detection limits (LoD) and Quantification limits (LoQ) were calculated from 3 times and 10 times the standard deviation of blanks, respectively.

Quality assurance and accreditation

NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. Silver (Ag) is not included in NILUs accredited method for determination of metals. However, analysis of Ag follows all principles in the accredited method.

3.2.3 Analysis of PCBs, brominated flame retardants and S/MCCP

Polychlorinated biphenyls (PCBs), brominated flame retardants (TBBPA analysed with phenolic compounds; see Chapter 3.2.5), and short- and medium chained chlorinated paraffins (S/MCCP) were analysed by NILU.

Extraction

Prior to extraction, the samples were added a mixture of isotope labelled PCBs for quantification purposes.

The water-, sludge-/sediment- and biota-samples were extracted with organic solvents and concentrated under nitrogen flow, followed by a clean-up procedure using concentrated sulphuric acid and a silica column to remove lipids and other interferences prior to analysis.

Analysis

The compounds were quantified on GC-HRMS (Waters Autospec) and/or BG-QToF (Agilent 7200B).

Limits of Detection

The limits of detection (LoD) and quantification (LoQ) were calculated for each sample, using the accepted standard method, i.e. the average of blanks plus 3 and 10 times the standard deviation for blanks, for LoD and LoQ, respectively.

Quality assurance and accreditation

NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. NILU is accredited for the analysis of PCBs. For the other compounds, the same quality assurance procedures (as for the accredited compounds) were applied.

3.2.4 Analysis of PFAS

Per- and polyfluorinated substances (PFAS) were analysed by NIVA

Extraction

Prior to extraction, the samples were added a mixture of isotope labelled PFAS, for quantification purposes. Sediment-/sludge-, water- and biota-samples were extracted with organic solvents and use of buffers for pH control. The extracts were cleaned using solid phase extraction (SPE) and active coal if needed (the latter for lipid rich biota samples). Water samples were concentrated and cleaned up using an SPE column. All samples were concentrated under nitrogen flow.

Analysis

PFAS compounds were analysed using LC-qTOF-MS.

Limits of Detection

The limits of detection (LoD) and quantification (LoQ) were calculated for each sample, using the accepted standard method; 3 times the signal/noise ratio (z/n) and 9 times z/n, respectively.

Quality assurance and accreditation

NIVA's laboratory is accredited by Norwegian Accreditation for ISO/IEC 17025. NIVA is not accredited for these particular compounds, but to the extent possible, documentation, preparation, analysis and calculations are performed in accordance with accredited methods.

Samples were analysed in groups with at least one additive standard sample and a blank control.

3.2.5 Analysis of alkylphenols and bisphenols

Alkylphenols and bisphenols (octylphenol, nonylphenol, bisphenol A, S, F, AF, AP, B, E, FL, M og Z, as well as TBBPA) were analysed by NILU.

Extraction

Prior to extraction, the samples were added a mixture of isotope labelled phenols for quantification purposes.

The particulate- and biota-samples were extracted with organic solvents and concentrated under nitrogen flow. Then they were further cleaned with an SPE column to remove interferences prior to analysis. In addition, prior to the extraction and clean-up procedure for biota, liver and bile samples were subjected to an enzyme digestion procedure in order to convert possible Phase II metabolites of phenolic compounds into their respective free forms. Water samples were concentrated and purified on a SPE column. After elution from the SPE column, the water sample extracts were further concentrated under nitrogen and subjected to instrumental analysis.

Analysis

All samples were analysed by LC-QToF (Agilent 65/50), or LC-ToF (Waters Premier).

Limits of Detection

The limits of detection (LoD) and quantification (LoQ) were calculated for each sample, using the accepted standard method, i.e. the average of blanks plus 3 and 10 times the standard deviation for blanks, for LoD and LoQ, respectively.

Quality assurance and accreditation
NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. NILU is not accredited for the analysis of alkylphenols and bisphenols, but as far as possible, the documentation, sample preparation, analysis and calculation procedures were conducted according to the accredited methods.

3.2.6 Analysis of UV-chemicals

UV-chemicals were analysed by NIVA. The methods are modified from earlier validated and published methods developed at NIVA (Langford et al. 2008; 2009; 2011; 2015; Thomas et al. 2014).

Extraction of UV-chemicals
Homogenized biota samples were added isotope labelled internal standards for quantification purposes. Then they were extracted twice with a combination of solvents. Extracts were concentrated under nitrogen flow and cleaned up using gel permeation chromatography (GPC) and/or SPE, dependent on complexity of matrix.

Analysis of UV-chemicals
UV-chemicals were analysed using GC-MS/MS (Agilent).

Limits of Detection
The limits of detection (LoD) and quantification (LoQ) were calculated for each sample, using the accepted standard method; three times the signal/noise ratio (z/n) and 9 times z/n, respectively.

Quality assurance and accreditation
NIVA's laboratory is accredited by Norwegian Accreditation for ISO/IEC 17025. NIVA is not accredited for these particular compounds, but to the extent possible, documentation, preparation, analysis and calculations are performed in accordance with accredited methods. Samples were analysed in groups with at least one additive standard sample and a blank control.

3.2.7 Analysis of siloxanes

Siloxanes, i.e. octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), dodecamethylcyclohexasiloxane (D6) and M3T(Ph) were analysed by NILU. Already established methods based on liquid/liquid extraction (Warner et al., 2010; Warner et al., 2012) were used to extract and quantify siloxanes, in addition to headspace extraction techniques to analyze siloxanes in water and sediments.

Extraction
Sediment and biota tissues were extracted using solid-liquid extraction with a biphasic solvent system of acetonitrile and hexane. Extraction of water samples was performed using headspace extraction.

Analysis
Collected extracts from sediment-/sludge- and biota tissues were analysed using Concurrent solvent recondensation large volume injection gas chromatography mass spectrometry (CSR-LVI-GCMS; Companioni-Damas et al., 2012). For water analysis, 2 ml of extracted headspace was directly injected onto a GCMS (Sparham et al., 2008).

Limits of Detection

The limits of detection (LoD) and quantification (LoQ) were calculated for each sample using the accepted standard method, i.e. the average of blanks plus 3 and 10 times the standard deviation for blanks, for LoD and LoQ, respectively.

Quality assurance and accreditation
NILU has extensive experience with analysis of siloxanes. The greatest risk in the analysis is background contamination, as these chemicals (D4, D5 and D6) are applied in e.g. skin care products. Using a state-of-the-art cleanroom and clean bench technologies, NILU is capable of performing trace analysis of these compounds in matrices even from pristine environments, including the Arctic (Krogseth et al., 2013; Warner et al., 2013).

NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. NILU is not accredited for the analysis of siloxanes. However, to the extent possible, documentation, preparation, analysis and calculations were performed in accordance with accredited methods. NILU has previously participated in a laboratory intercalibration of siloxanes (McGoldrick et al. 2011) and has also worked closely with the industry in Artic monitoring programmes to develop methods to enhance result accuracy and limit reporting of false positives (Warner et al., 2013).

Samples were extracted and analysed in batches with a minimum of 3 procedural blanks to assess background contamination and calculate LOD and LOQ per extraction batch. As the sample matrix can contribute to the overall background response, procedural blanks were run both before and after samples to ensure results were above detection limits and not an artefact of background variation.

Field blanks were used to assess any potential contamination that occurred during sample collection and preparation. Each field blank consisted of approximately 3 grams of XAD-2 sorbent in filter bags of polypropylene/cellulose. XAD-2 sorbent was cleaned using a 1:1 mixture of hexane:dichloromethane and dried overnight in a clean cabinet equipped with a HEPA- and charcoal filter to prevent contamination from indoor air. Filter bags were cleaned by ultrasonic treatment in hexane for 30 min. Subsequently, hexane was removed and substituted with clean dichloromethane and the field blanks were sonicated once more for 30 min. After ultrasonic treatment, filter bags were placed in a clean cabinet to dry under similar conditions as the XAD-2 sorbent. Once dry, XAD-2 sorbent was transferred to filter bags and sealed in polypropylene containers to be sent for sampling purposes. Several field-blanks were stored at NILU’s laboratories (hereafter called reference blanks) and analysed to determine reference concentrations before sampling. The field blanks for sampling purposes were exposed and handled in the field during sampling and during preparation of samples.

3.2.8 Analysis of M3T(Ph)

M3T(Ph) was analysed by NILU. This compound was extracted and analysed with the siloxanes (D4, D5 and D6), as described above (Chapter 3.2.7).

Extraction

Already established methods based on liquid/liquid extraction (Warner et al., 2010; Warner et al., 2012) was used to extract M3T(Ph) with the siloxanes (see above; Chapter 3.2.7).

Analysis

Samples were analysed using Concurrent solvent recondensation large volume injection gas chromatography mass spectrometry (CSR-LVI-GCMS; Companioni-Damas et al., 2012).

Limits of Detection
The limit of detection (LoD) and quantification (LoQ) were calculated for each sample using the accepted standard method, i.e. the average of blanks plus 3 and 10 times the standard deviation for blanks, for LoD and LoQ, respectively.

Quality assurance and accreditation
NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. NILU is not accredited for the analysis of M3T(Ph). However, to the extent possible, documentation, preparation, analysis and calculations were performed in accordance with accredited methods.

3.2.9 Analysis of antioxidant MB1

Antioxidant MB1 was analysed by NILU, with the same extraction methods as described for PCBs, brominated flame retardants and S/MCCP.

Extraction
The water-, sludge- and biota-samples were extracted with organic solvents and concentrated under nitrogen flow, followed by a clean-up procedure using concentrated sulphuric acid and a silica column to remove lipids and other interferences prior to analysis.

Analysis
Antioxidant MB1 was analysed using GC-MS.

Limits of Detection
The limits of detection (LoD) and quantification (LoQ) were calculated for each sample, using the accepted standard method, i.e. the average of blanks plus 3 and 10 times the standard deviation for blanks, for LoD and LoQ, respectively.

Quality assurance and accreditation
NILU's laboratories are accredited by Norwegian Accreditation for ISO/IEC 17025. NILU is not accredited for the analysis of antioxidant MB1, but as far as possible, the documentation, sample preparation, analysis and calculation procedures were conducted according to the accredited methods.

3.2.10 Support parameters

Stable isotopes of nitrogen and carbon were analysed by IFE. Analysis of nitrogen and carbon isotopes was done by combustion in an element analyser, reduction of NOx in Cu-oven, separation of N_2 and CO_2 on a GC-column and determination of $\delta^{13}C$ and $\delta^{15}N$ at IRMS (Isotope Ratio Mass Spectrometer).

Trophic level was calculated as follows (assuming a 3.8 increase per full trophic level; Hobson and Welch, 1992; and that blue mussel inhabit trophic level 2, filtrating algal particles on trophic level 1):

$$TL_{consumer} = 2 + (\delta^{15}N_{consumer} - \delta^{15}N_{blue\ mussel})/3.8$$

Captive-rearing studies on piscivorous birds indicate that the $\delta^{15}N$ isotopic fractionation factor between bird diet and tissue is less than that derived for other trophic steps, most likely linked to the fact that birds produce uric acid (Mizutani et al., 1991). According to Mizutani et al (1991) an isotopic fractionation factor of +2.4 ‰ is appropriate. Thus, the following equation was used to calculate the trophic level of herring gulls and eider ducks:

$TL_{herring\ gull} = 3 + (\delta^{15}N_{herring\ gull} - (\delta^{15}N_{blue\ mussel} + 2.4))/3.8$

Lipid content in biological samples was determined gravimetrically during extraction for chemical analyses.

Weight and length of fish were determined before dissection.

The age of the cod was read from otoliths. The age was read by counting the number of opaque zones (summer zones) and hyaline zones (winter zones).

Grain size distribution (fraction of particles <63 µm) in sediment was determined according to procedures described by Krumbein and Petttijohn (1938).

Total organic carbon content (TOC) in sediment was determined by catalytic combustion in an element analyzer.

3.3 Data treatment

Statistical analyses (linear regressions; general linear models) were performed with the use of JMP software (JMP 16.0.0). A significance level of $\alpha = 0.05$ was chosen. When appropriate, data were log_{10}-transformed. When results are below LoD (especially when this occurs in many samples), the value of the information is reduced, and there are challenges regarding presentations and statistical evaluation. For the purpose of calculating mean concentrations, we have assigned these samples/parameters a value of LoD/2. In regression models, we have omitted samples with non-detects from processing ("case-wise deletion").

Pooled samples of cod were necessary to be able to perform all the chemical analyses. Due to very small cod size this year, a total of 40 individual cods were pooled. Altogether 40 cods were used to constitute the 15 cod samples. The 15 cod samples were analysed individually for contaminants and isotopes, while for the estimation of trophic biomagnification, 3 statistical samples were constituted in order to have a statistically balanced design. The means of the isotopes and contaminants were used in calculation of the TMF. The samples/pooled cod samples that constituted the statistical samples were:

- Statistical sample 1: cod samples 2, 3, 5, 7, 11
- Statistical sample 2: cod samples 1, 4, 10, 12, 15
- Statistical sample 3: cod samples 6, 8, 9, 13, 14

When exploring correlations between contaminant concentrations and trophic position, concentrations of the following contaminants were expressed on a wet weight basis: Metals and PFASs. The concentrations of the following contaminants were expressed on a lipid weight basis: PCBs and other organochlorine compounds, chlorinated paraffins, brominated flame retardants, siloxanes (including M3T(Ph)) and UV-filters. Biomagnification potential was evaluated by comparing contaminant concentrations (as given above) with trophic position, calculated from $\delta^{15}N$ levels. Trophic Magnification Factors (TMFs) were calculated from statistically significant relationships:
$Log_{10}[Contaminant] = a + b(Trophic\ position)$
as $TMF = 10^b$.

4 Results and discussion

The results of the chemical analyses (and lipid content of biological samples) are given in the electronic Appendix, where also analyses below LoD are indicated together with the values of the LoDs.

4.1 Stable isotopes

The results of the individual stable isotope-analysis of C and N are given in Appendix (Tables A3-A6).

Stable isotopes of carbon and nitrogen are useful indicators of food origin and trophic levels. $\delta^{13}C$ gives an indication of carbon source in the diet or a food web. For instance, it is in principle possible to detect differences in the importance of autochthonous (native marine) and allochthonous (watershed/origin on land) carbon sources in the food web, since the $\delta^{13}C$ signature of the land-based energy sources is lower (greater negative number). Also $\delta^{15}N$ (although to a lesser extent than $\delta^{13}C$) may be lower in allochthonous as compared to autochthonous organic matter (Helland et al., 2002), but more important, it increases in organisms with higher trophic level because of a greater retention of the heavier isotope (^{15}N). The relative increase of ^{15}N over ^{14}N is 3-5‰ per trophic level (Layman et al. 2012; Post 2002) and provides a continuous descriptor of trophic position. It is also the basis for trophic magnification factors (TMFs) that quantify the increase in concentrations of contaminants in the foodweb. TMFs have been amended to Annex XIII of the European Community Regulation on chemicals and their safe use (REACH) for possible use in weight of evidence assessments of the bioaccumulative potential of chemicals as contaminants of concern.

In the present report, the stable isotope data have been reviewed partly to indicate possible different energy sources for the organisms/individuals in question. Secondly, trophic level is calculated from $\delta^{15}N$ for the organisms to assess possible biomagnification of the compounds/contaminants in question in the Inner Oslofjord food web.

It has previously been noted (Ruus et al., 2014; Ruus et al., 2015a; Ruus et al., 2016; Ruus et al., 2017; Ruus et al., 2019a; Ruus et al., 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-205, M-375, M-601, M-812, M-1131, M-1441 and M-1766) that herring gull sampled in the Inner Oslofjord display low $\delta^{15}N$ and low $\delta^{13}C$, relative to the marine species sampled in the programme. This indicates that important food items for the gull are not related to the marine food web sampled. Herring gull is therefore treated separately (not as part of the food web) in the present study (as in the "Urban fjord" programme in 2015 to 2019; Ruus et al. 2016; Ruus et al. 2017; Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-601, M-812, M-1131, M-1441 and M-1766).

The aquatic food web sampled in 2020 was identical to that in 2015-2019, and the results of the stable isotope analysis (**Figure 2**) continue to suggest that the species sampled in 2015-2020 well represent members of the marine food web of the Inner Oslofjord. The differences in $\delta^{15}N$ seem to reflect expected trophic relationships; blue mussel (filters particulate organic matter from the water) < zooplankton (herbivore) < polychaetes (different modes of living, largely detritivorous) < prawns (some scavenging behaviour) < herring (pelagic fish feeding on zooplankton) < cod (mesopelagic fish, predator on fish and benthic organisms). The food web spans over approximately 2 (~2.2) trophic levels with blue mussel defined at trophic level 2 (see Chapter 3.2.10), zooplankton (krill) at trophic level 3.0, polychaetes at trophic level 3.1, prawns and herring at trophic level 3.6 and 3.4, respectively, and cod at trophic level 4.1 in average (assuming an increase in $\delta^{15}N$ of 3.8‰ per integer trophic level).

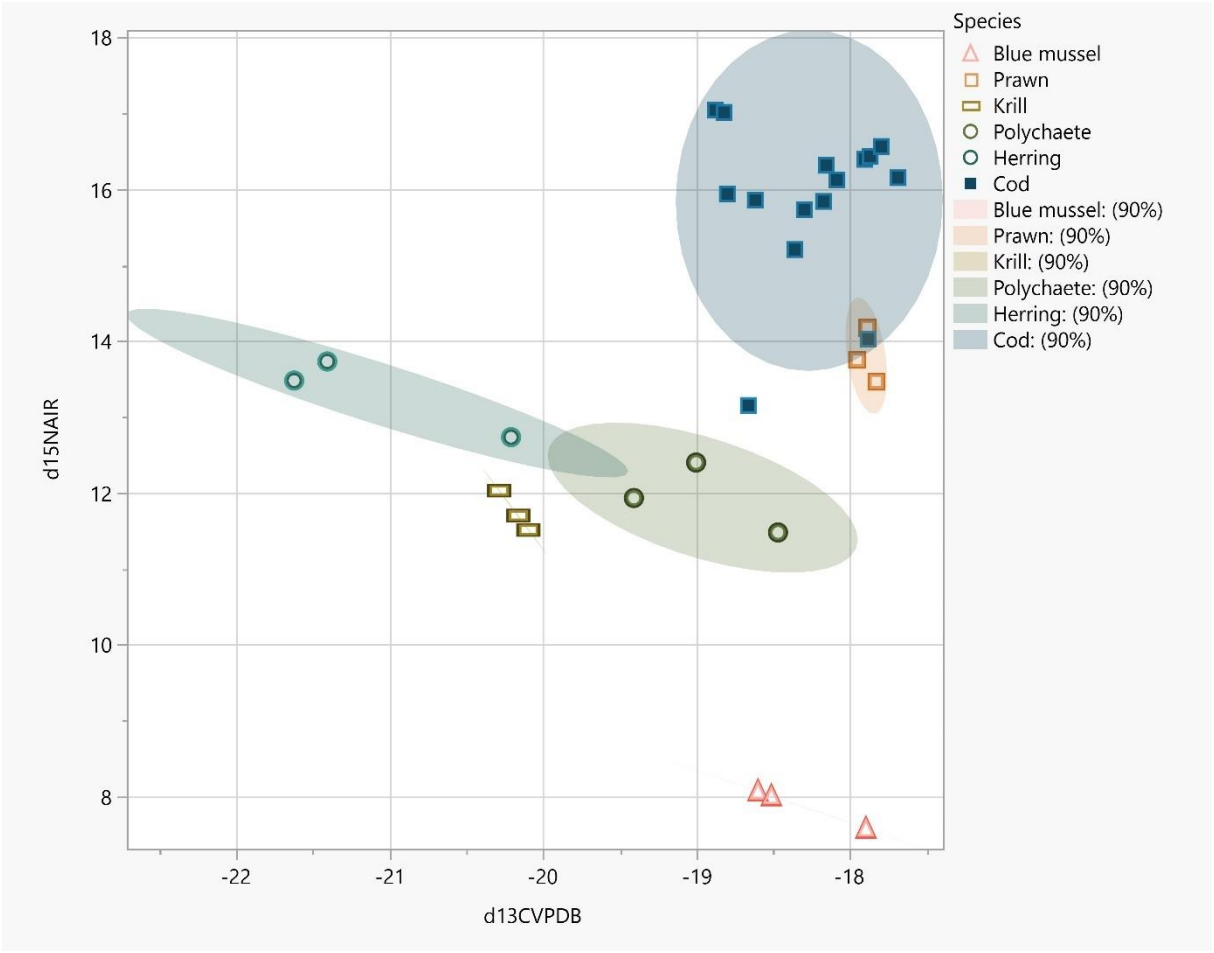


Figure 2. $\delta^{15}N$ plotted against $\delta^{13}C$ in organisms from the inner Oslofjord marine food web. The 90% confidence areas are indicated by the shaded areas or indicated with a line (for linear correlations).

The isotopic signatures of the herring gulls showed the same patterns as previously (Ruus et al. 2016; Ruus et al. 2017; Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-205, M-375, M-601, M-812, M-1131, M-1441 and M-1766). When herring gull matrices (blood and eggs) are evaluated (**Figure 4**), it can be seen that the matrices show fairly similar $\delta^{15}N$, but the eggs had on average a higher $\delta^{15}N$ than the blood (but not statistically significant (t-test p=0.088). The $\delta^{13}C$ ratio is, however, higher in blood than in eggs. The difference is likely related to different lipid content. It should be noted that samples were not treated to remove carbonates or lipid before stable isotope analysis. The C:N ratio was measured (Appendix, Tables A3 and A4) and a C:N ratio of >3.5 implies the presence of lipids, which may somewhat confound $\delta^{13}C$ interpretation, since lipids are ^{13}C -depleted relative to proteins (Sweeting et al., 2006). Eggs showed a higher C:N ratio than blood (Appendix, Tables A3 and A4).

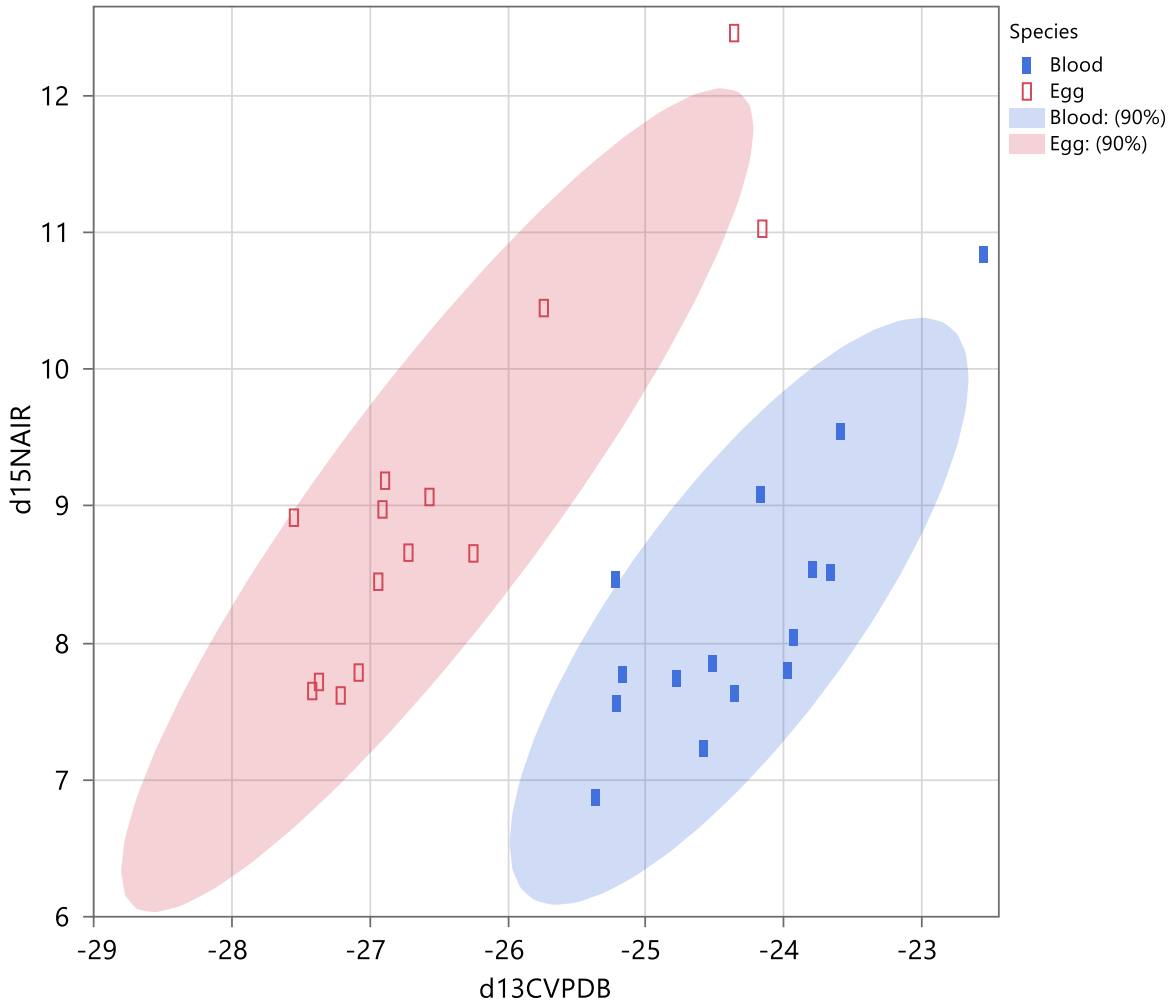


Figure 3 $\delta^{15}N$ plotted against $\delta^{13}C$ in blood and eggs of herring gull from the Inner Oslofjord. The 90% confidence area are indicated with by the shaded areas

Regarding the herring gulls, adult female and egg were sampled from the same nest (i.e. mother and future offspring). In **Figure 4** the individual pairs of female and egg are indicated by a line. The egg of one female was not analysed for isotopes (JNA37), leaving 14 pairs of adult females and eggs. By comparing the females (blood) and eggs as matched pairs for $\delta^{15}N$ and $\delta^{13}C$ (see **Figure 5**) the difference for both isotopes were statistically significant (p=0.019 and <0.0001 respectively). The eggs had on average 0.78 higher $\delta^{15}N$ than the females, and only two pairs had lower $\delta^{15}N$ in eggs than in blood (JNA34 and JNA36). The eggs had on average of 2.2 lower $\delta^{13}C$ than the females, and only one egg had higher $\delta^{13}C$ than the female (JNA26). As stated previously, the difference in $\delta^{13}C$ is caused by higher lipids in the eggs. We are unsure of the cause to the small but statistically significant difference in $\delta^{15}N$ between females and eggs.

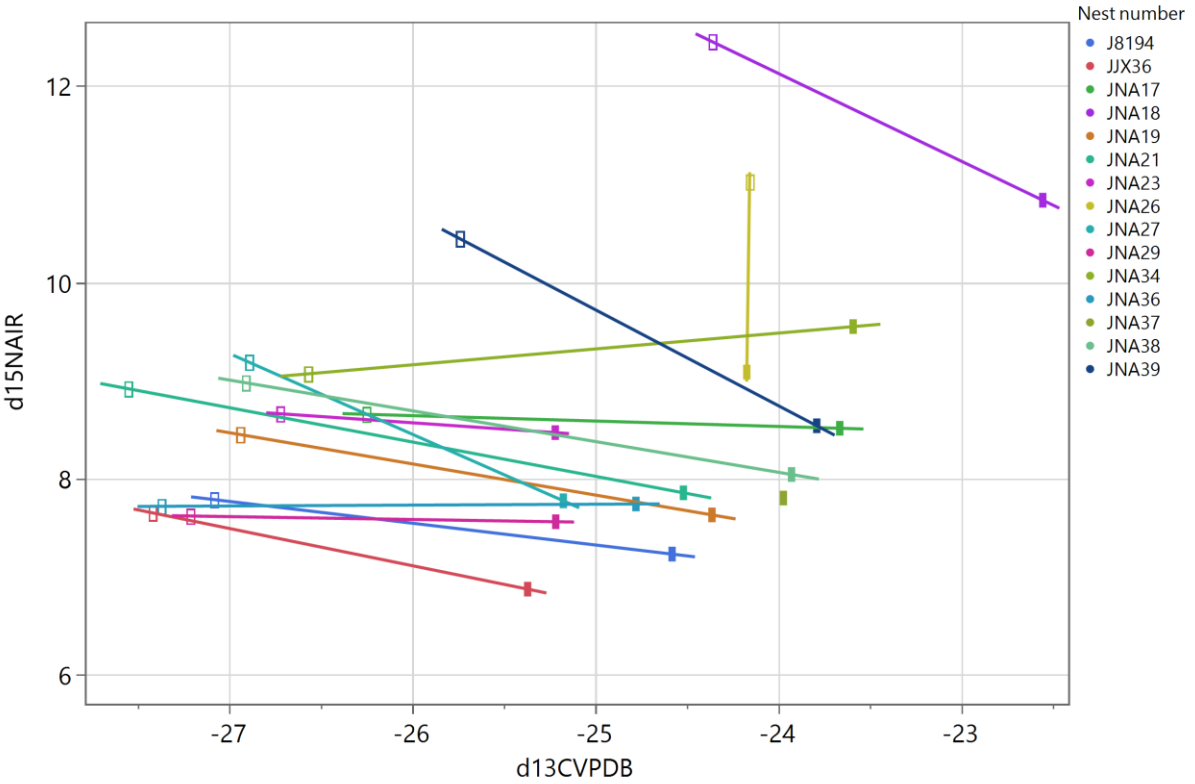


Figure 4. $\delta^{15}N$ plotted against $\delta^{13}C$ in blood and eggs of herring gull from the Inner Oslofjord. The eggs with open squares and the blood with closed squares. The egg and female are connected with a line to identify the bird pairs.

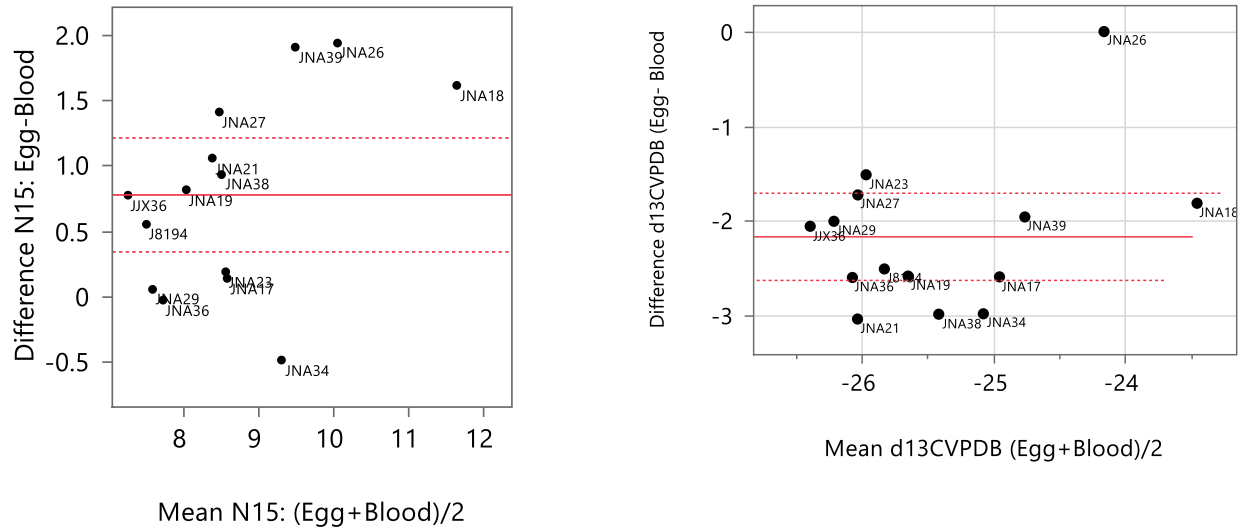
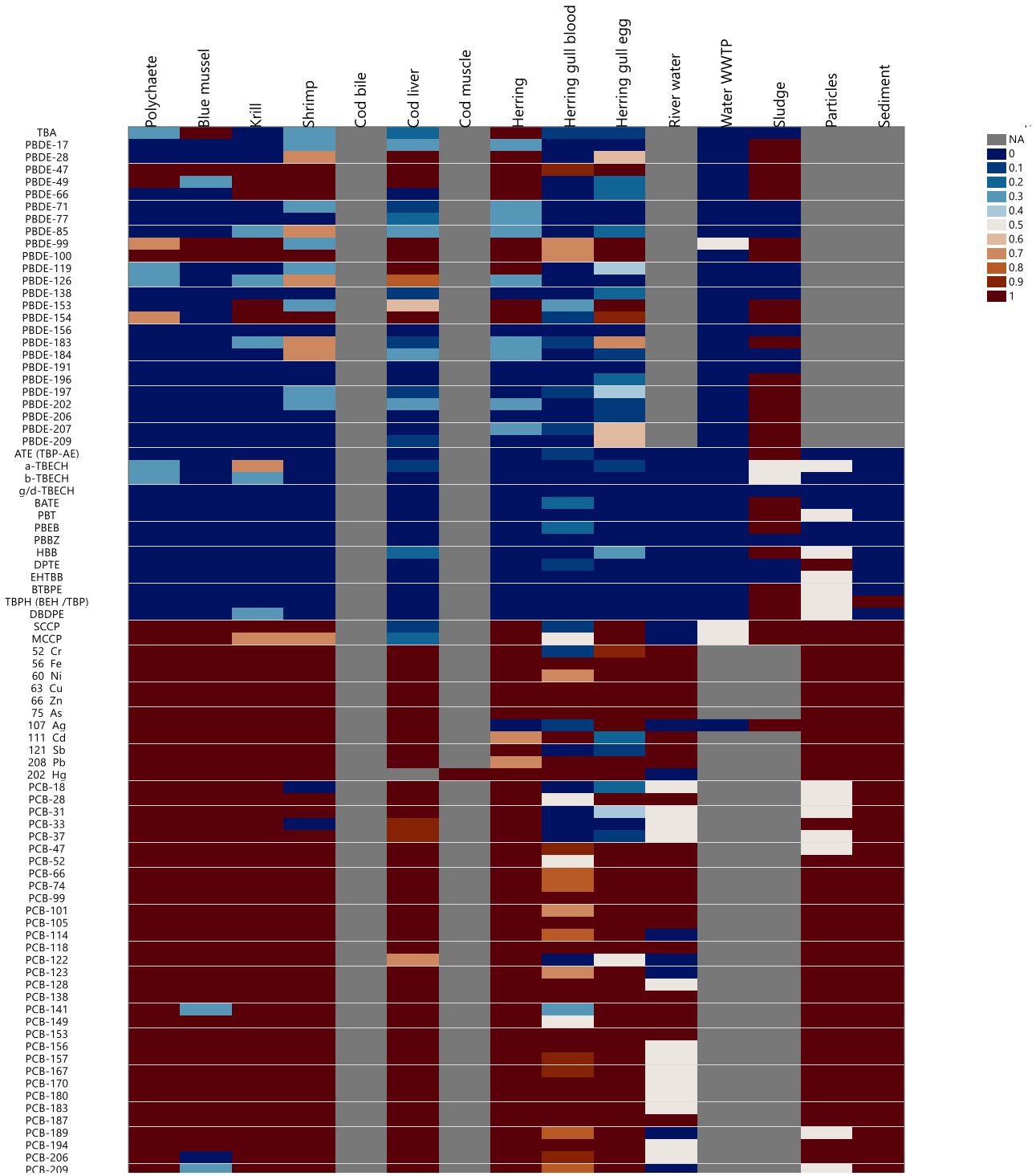


Figure 5. Difference between eggs and females (blood) for isotopic ratios of $\delta^{15}N$ (left) and $\delta^{13}C$ (right). The mean of the isotope ratios for individual pairs (egg/blood) form the x-axis, while the difference between the pairs (egg-blood) are shown at the y-axis. The mean difference is indicated by a red line, while the 90% confidence limits are indicated with dotted red lines. Each female/egg pair is indicated with the given name.

4.2 Detection frequencies of contaminants

A total of 174 single compounds/isomers were analysed in this study (not all compounds were analysed in all samples; see electronic Appendix). **Figure 6** gives the detection frequency (in %) of the various compounds in the different samples.


Polychaete
Blue mussel
Krill
Shrimp
Cod bile
Cod liver
Cod muscle
Herring
Herring gull blood
Herring gull egg
River water
Water WWTP
Sludge
Particles
Sediment
TBA
PBDE-17
PBDE-28
PBDE-47
PBDE-49
PBDE-66
PBDE-71
PBDE-77
PBDE-85
PBDE-99
PBDE-100
PBDE-119
PBDE-126
PBDE-138
PBDE-153
PBDE-154
PBDE-156
PBDE-183
PBDE-184
PBDE-191
PBDE-196
PBDE-197
PBDE-202
PBDE-206
PBDE-207
PBDE-209
ATE (TBP-AE)
a-TBECH
b-TBECH
g/d-TBECH
BATE
PBT
PBEB
PBBZ
HBB
DPTE
EHTBB
BTBPE
TBPH (BEH /TBP)
DBDPE
SCCP
MCCP
52 Cr
56 Fe
60 Ni
63 Cu
66 Zn
75 As
107 Ag
111 Cd
121 Sb
208 Pb
202 Hg
PCB-18
PCB-28
PCB-31
PCB-33
PCB-37
PCB-47
PCB-52
PCB-66
PCB-74
PCB-99
PCB-101
PCB-105
PCB-114
PCB-118
PCB-122
PCB-123
PCB-128
PCB-138
PCB-141
PCB-149
PCB-153
PCB-156
PCB-157
PCB-167
PCB-170
PCB-180
PCB-183
PCB-187
PCB-189
PCB-194
PCB-206
PCB-209
NA
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

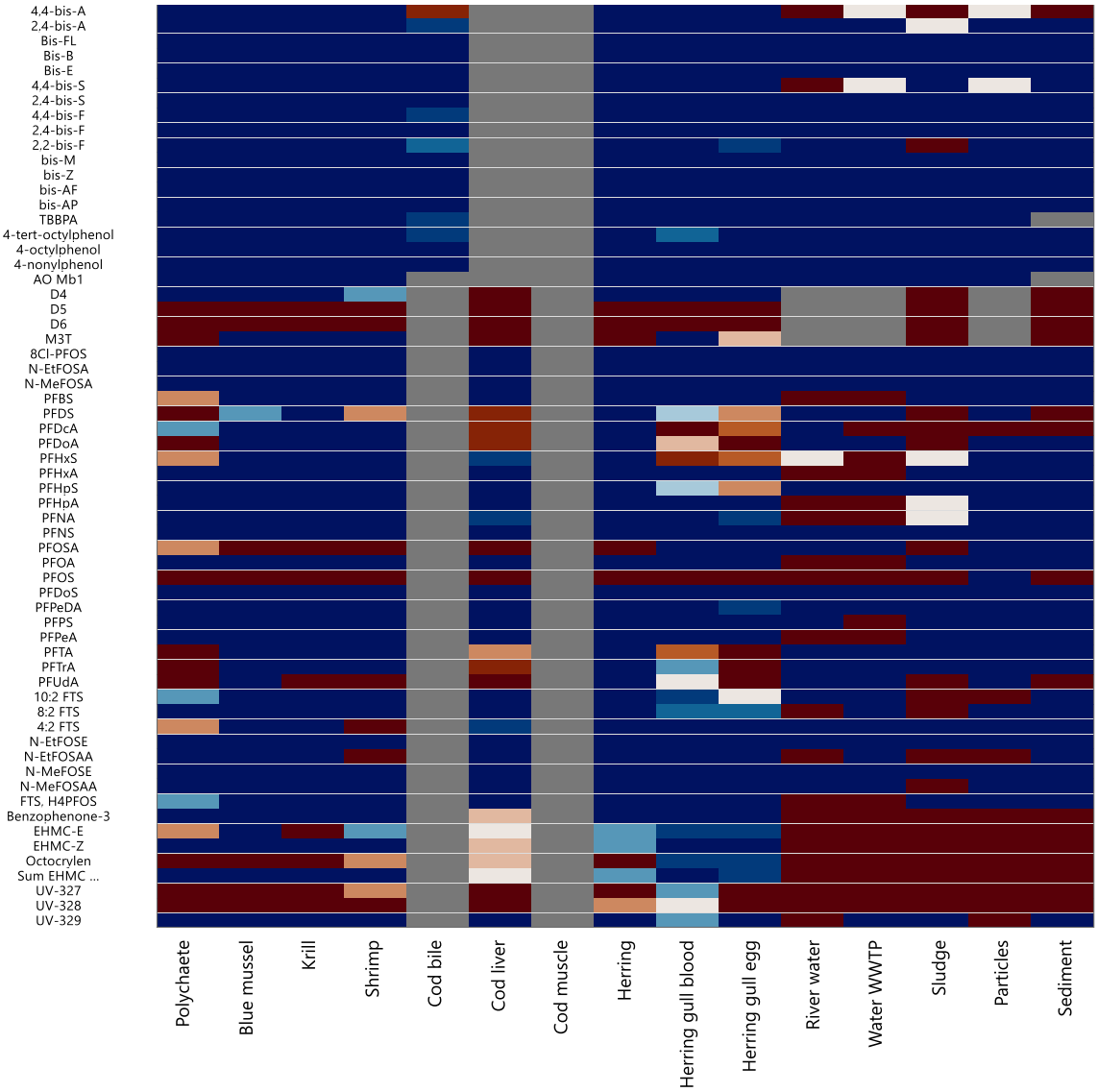


Figure 6. Detection frequency (%) of all the analysed compounds in the different environmental samples in this study.

4.3 Abiotic matrices

Marine sediments are an important sink, or end station, for particles entering the recipient from various sources, such as urban runoff and WWTPs. The sediments of the inner Oslofjord is thus a potential source of environmental contaminants to sediment dwelling organisms and the contaminants may thus enter the food chain. Several of the target compounds of this study were detected in the sediment sample (**Figure 6**). Inputs to the fjord via stormwater, and effluent water and sludge from a wastewater treatment plant (see Chapters 4.3.9 and 0) for several of the compounds are also shown.

4.3.1 Siloxanes

Siloxanes were only analysed in sediment and sludge from WWTP due to instrument problems. Of the siloxanes, D5 constituted the highest proportion of the sum in sediment, followed by D6 (**Figure 7** and **Table 7**). Both D4 and M3T(ph) were also detected (**Figure 7**).The composition of sediment is similar to that observed in sludge, but the levels of siloxanes in sludge is very much higher.

D5-concentrations observed in samples from other WWTPs include mean concentrations of D5 in sludge from HIAS WWTP and Rambekk WWTP of 7900 ng/g and 6059 ng/g, respectively (van Bavel et al. 2016; The Norwegian Environment Agency M-596). M3T(Ph) was not detected in effluent water from HIAS and Rambekk WWTPs, while mean concentrations in sludge were 93 ng/g and 62 ng/g, respectively (van Bavel et al. 2016; The Norwegian Environment Agency M-596).

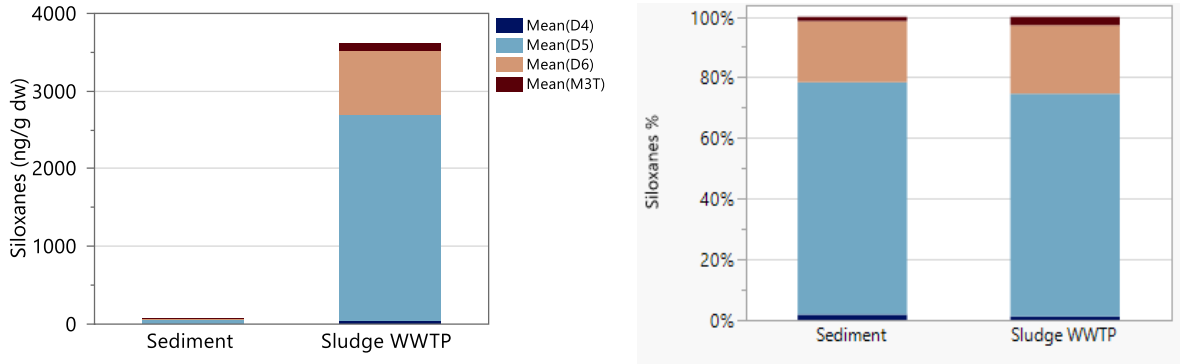


Figure 7. Concentrations (ng/g dry wt.) of siloxanes in sediment from the Inner Oslofjord (station Cm21) and sludge from Bekkelaget (mean of 2 samples).

Table 7. Overview of abiotic concentrations of siloxanes (ng/g dw)

	D4	D5	D6	M3T(ph)
Sediment	1.2	53	14	0.96
Sludge WWTP	43	2700	820	100

4.3.2 PCBs

PCB-concentrations were highest in the particulate fraction. PCBs were detected in stormwater, but in much lower concentrations (**Figure 8**, **Table 8**). Given the hydrophobic nature of PCBs, they have a high affinity for the particulate phase and are usually associated with particles.

The concentration of PCB_7 in the sediment was similar to what has been observed previously (Ruus et al. 2020; The Norwegian Environment Agency M-1766). PCB_7 constituted roughly half of the PCB-load in sediments of the Oslofjord. The composition of the river water and stormwater is similar to that observed in sediments, but some variance is observed. However, the levels of PCBs in stormwater particles is very different between the two locations in Alna (125x Bryn and 136x Alnabru), and the sediment concentrations are a roughly a third of the highest observed in particles from Alna. The PCBs were not measured in WWTP.

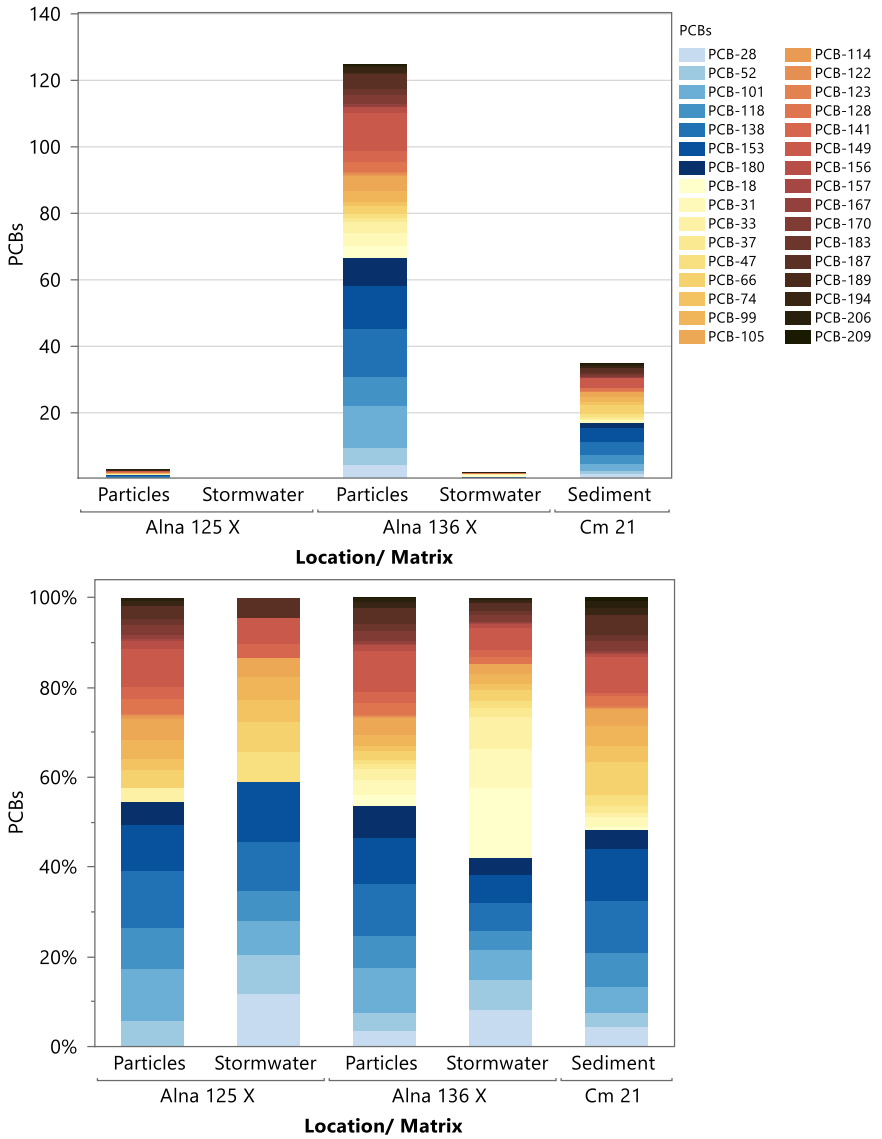


Figure 8. Concentrations (ng/g dry wt.) of PCB-congeners in sediment from the Inner Oslofjord (Ildjernet, station Cm21). Also, the abiotic matrices of stormwater (ng/L) and particles (ng/g dw) are given for comparison from station Alna 125x Bryn and Alna 136x Alnabru.

Table 8 Overview of PCBs in abiotic samples (ng/g dw for particles and sediment, ng/L for stormwater). The data are given with 2 significant digits. Blank cells represent concentrations <LOD.

	Location	Alna 125 X		Alna 136 X		Cm 21
	matrix	Particles	Stormwater	Particles	Stormwater	Sediment
PCB_7	PCB-18			3.3	0.34	0.19
	PCB-28		0.018	4.4	0.18	1.5
	PCB-52	0.16	0.014	5.1	0.15	1.1
	PCB-101	0.32	0.012	13	0.15	2.1
	PCB-118	0.25	0.011	9	0.093	2.7
	PCB-138	0.36	0.017	15	0.14	4
	PCB-180	0.15		8.7	0.085	1.5
Other PCBs	PCB-31			4.1	0.19	0.78
	PCB-33	0.087		3.1	0.16	0.39
	PCB-37			1.4	0.041	0.49
	PCB-47		0.01	1.1	0.036	0.85
	PCB-66	0.11	0.01	2.3	0.052	2.6
	PCB-74	0.073	0.0075	1.4	0.031	1.2
	PCB-99	0.11	0.0078	3.3	0.047	1.6
	PCB-105	0.14	0.0065	4.7	0.053	1.3
	PCB-114	0.013		0.31		0.059
	PCB-122	0.011		0.33		0.07
	PCB-123	0.0087		0.22		0.087
	PCB-128	0.089		3.3	0.031	0.84
	PCB-141	0.073	0.0047	3.2	0.036	0.26
	PCB-149	0.24	0.0092	11	0.11	2.8
	PCB-153	0.29	0.02	13	0.14	4.1
	PCB-156	0.049		1.8	0.017	0.26
	PCB-157	0.014		0.29	0.0047	0.07
	PCB-167	0.021		0.64	0.0074	0.18
	PCB-170	0.067		2.9	0.035	0.75
	PCB-183	0.038		1.9	0.017	0.45
	PCB-187	0.078	0.0068	4.5	0.04	1.6
	PCB-189			0.13		0.034
	PCB-194	0.035		1.7	0.016	0.53
	PCB-206	0.017		0.9	0.0086	0.56

4.3.3 PBDEs and other brominated compounds

The PBDEs were only analysed in WWTP sludge and water (from Bekkelaget) (**Figure 9**, **Table 9**). In sludge, the majority of the PBDEs measured were not among the BDE_6. BDE_6 constituted less than 10% of the total load of PBDEs. Of the PBDEs, BDE-209 showed, by far, the highest concentration in the sludge (**Figure 10**). Given the hydrophobic nature of these compounds, they have a high affinity for the particulate phase, thus they were detected here. Finding BDE-209 in the highest concentrations in sludge corresponds with other recent findings (Aigars et al. 2017; Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-1131; M-1441 and M-1766) and with the historic market demand for deca-BDE mixtures (McGrath et al. 2017). As the main component of these mixtures, BDE-209 has been the most prevalent congener in a large majority of soil samples (McGrath et al. 2017).

The other brominated compounds were measured in all abiotic matrices but were only detected in substantial concentrations in particles from Alna 136 X and sludge from Bekkelaget. A notable result of the analysis of the sludge was that the alternative/"new" brominated flame retardants TBPH (BEH/TBP) and DBDPE were found in equally conspicuous concentrations as BDE-209 (**Figure 10**, **Table 10**). DBDPE was found in the highest concentrations, while in sludge also TBPH was found in 82 ng/g dw. Other brominated compounds were detected in particles from Alna (136X Alnabru) and Bekkelaget sludge, but in lower concentrations.

High concentrations of these compounds correspond with earlier findings (Ruus et al. 2019a; The Norwegian Environment Agency M-1131).

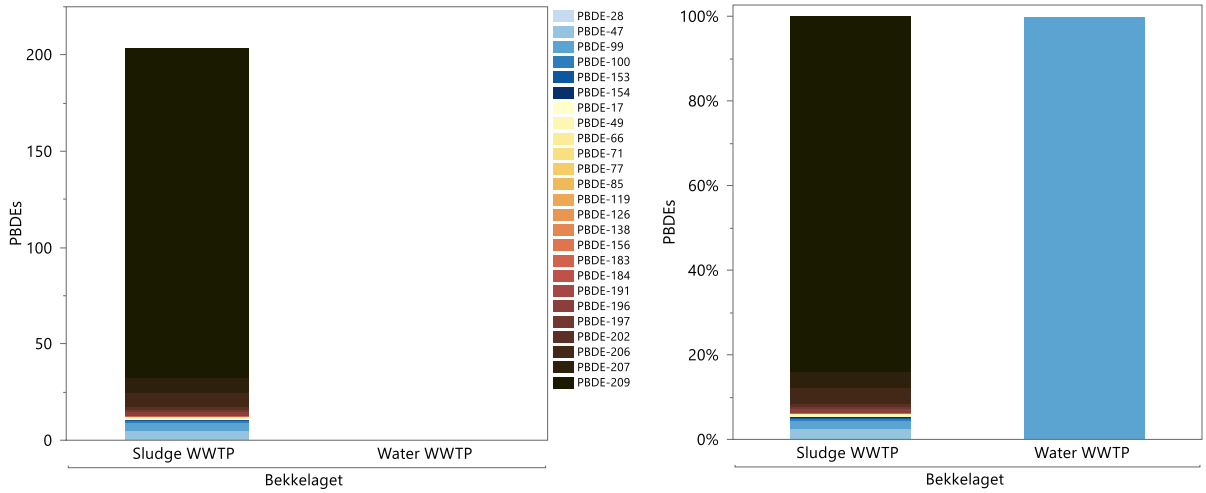


Figure 9 PBDEs in WWTP (sludge (ng/g dw) and water ng/L)) in Bekkelaget from 2020. To the left the concentrations in sludge and water, and to the right the % composition in the two matrices. The presented data are the mean of two analyses for each matrix.

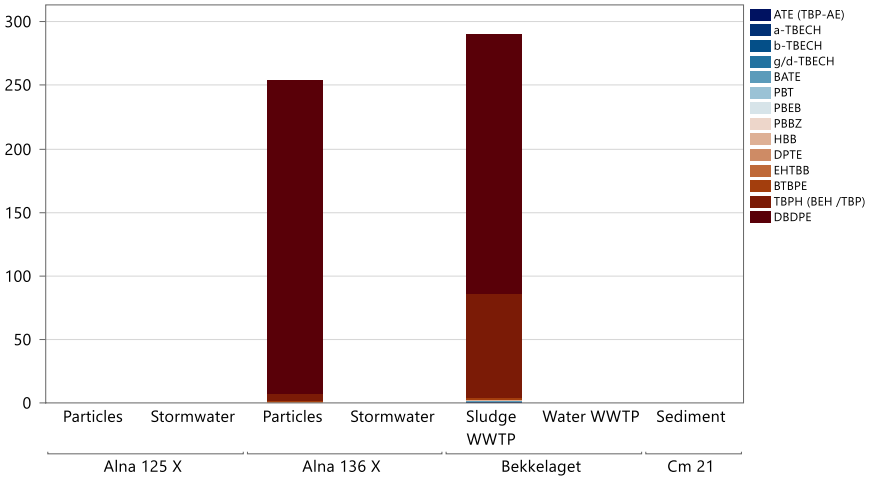


Figure 10 Other brominated compounds in all abiotic matrices in 2020. The concentrations are given in ng/g dw. Stormwater (water and particles) from Station Alna 125x Bryn and Alna 136x Alnabru, effluent water and sludge from Bekkelaget WWTP and sediments from Ildjernet in Inner Oslofjord (station Cm21).

Table 9 Mean concentrations of PBDEs in Bekkelaget matrices (ng/g dw for sludge and ng/L for water). Blank cells represent concentrations <LOD.

	Analysis Columns	Sludge WWTP	Water WWTP
BDE_6	BDE-28	0.18	
	BDE-47	4.7	
	BDE-99	4.2	0.026
	BDE-100	0.93	
	BDE-153	0.52	
	BDE-154	0.31	
Other BDEs	BDE-17	0.2	
	BDE-49	1.1	
	BDE-66	0.13	
	BDE-71		
	BDE-77		
	BDE-85		
	BDE-119		
	BDE-126		
	BDE-138		
	BDE-156		
	BDE-183	0.49	
	BDE-184		
	BDE-191		
	BDE-196	2.1	
	BDE-197	1.1	
	BDE-202	1.1	
	BDE-206	7.7	
	BDE-207	7.9	
	BDE-209	170	

Table 10 Overview of mean concentrations of other brominated compounds in abiotic matrices (2020). No detections were found in stormwater, which are therefore not included in the table.

	Alna 125 X Bryn	Alna 136 X Alnabru	Ildjernet, Cm 21	Bekkelaget
	Particles	Particles	Sediment	Sludge WWTP
ATE (TBP-AE)				0.44
a-TBECH		0.24		0.48
b-TBECH				0.31
g/d-TBECH				
BATE				0.22
PBT		0.15		0.22
PBEB				0.19
PBBZ				
HBB		0.19		0.67
DPTE	0.058	0.08		
EHTBB		0.4		
BTBPE		0.93		1.2
TBPH (BEH /TBP)		5.2	0.11	82
DBDPE		250		200

4.3.4 Chlorinated paraffins

As observed for many other abiotic matrices, the concentrations of the sum of SCCPs and MCCPs in the particles from Alna 136X at Alnabru were much higher (6000 ng/g dw) than from Alna 125 X at Bryn (<500 ng/g dw) (**Figure 11**). The WWTP sludge contained lower concentrations than the highest concentrations found in stormwater particles (3000 ng/g dw), while the fjord sediments had concentrations of approx. 1000 ng/g dw. The concentrations in water was very low compared with the particles/sludge/sediment. Regarding the composition of the chlorinated paraffins, the SCCP varied between 20% (sludge) and almost 65% (sediment sample from the fjord).

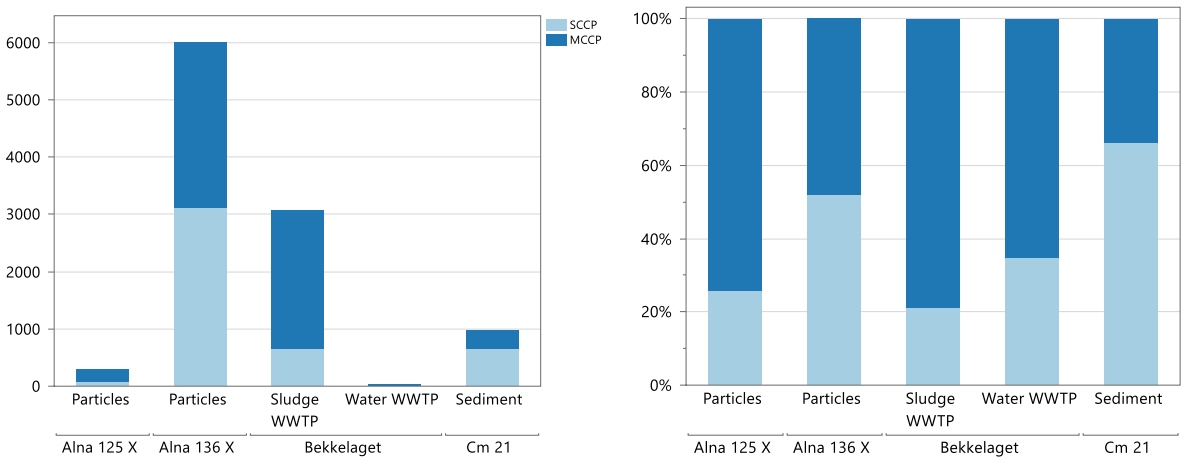


Figure 11 Chlorinated paraffins in abiotic matrices (ng/g dw and ng/L for water). To the left, the concentrations, to the right, the % composition.

4.3.5 PFAS

The PFAS composition varied among the abiotic matrices, both in concentrations and in composition (**Figure 12, Table 11**). All four groups of the PFAS investigated was observed in one or more of the matrices investigated. PFCAs were detected in all matrices, shorter chains in water phases and longer chains in particulate phases. PFSAs were not observed in particles from Alna, but in all other matrices with PFOS as the main PFAS among this group. Among the fluoramides (PFASA), N-EtFOSAA was detected most matrices, but was not in water from Bekkelaget or sediment from the Oslofjord. The FTSs were detected in all matrices but the sediment from Oslofjord.

PFAS compounds were detected in higher concentrations (sum) in the dissolved fraction of stormwater. Likewise, higher concentrations of sum PFAS was found in the water from WWTP. Inputs of several of the target compounds to the fjord via river inputs and WWTPs are thus found.

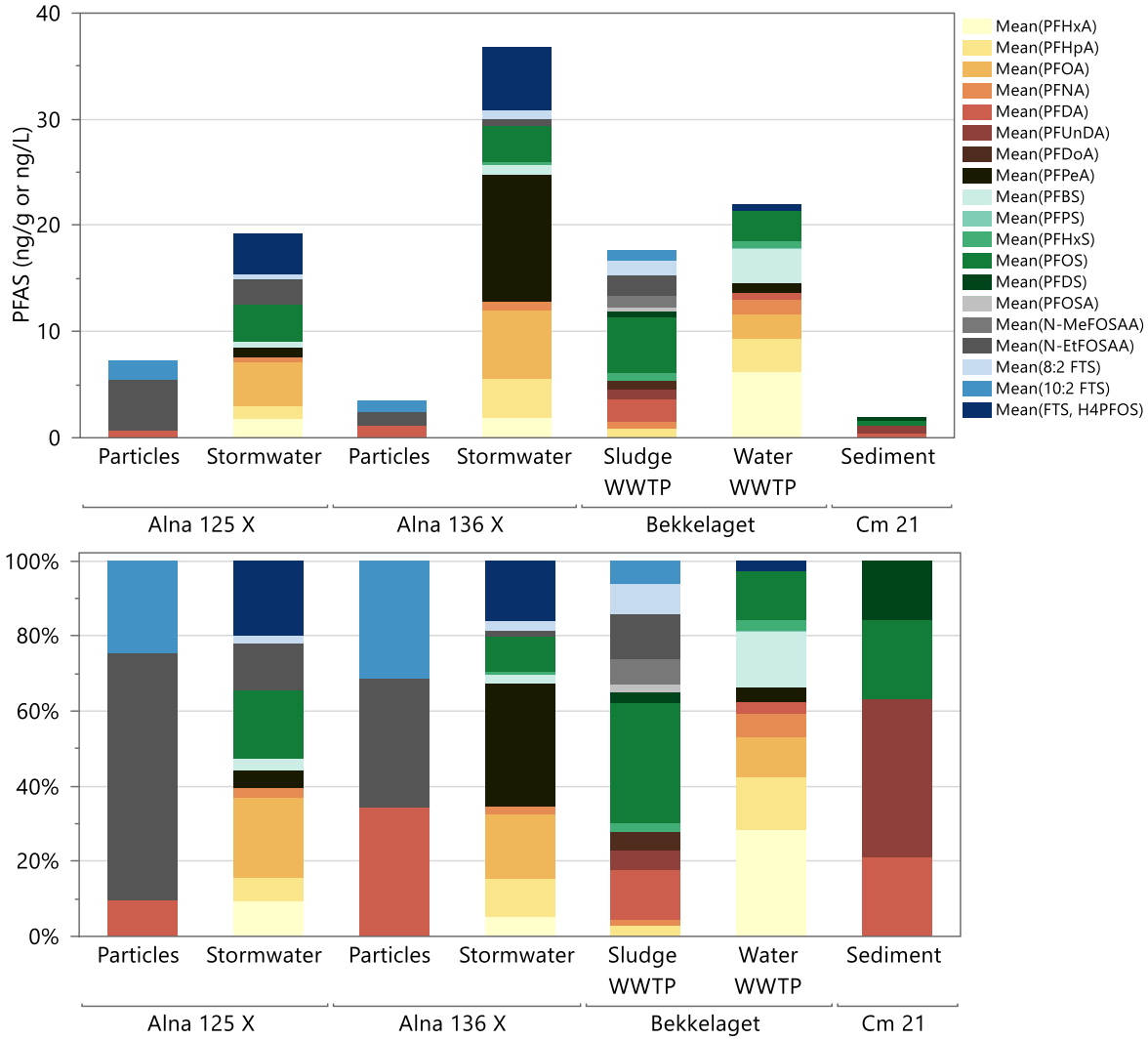


Figure 12 PFAS in abiotic matrices (ng/g dw and ng/L for water). Upper panel: the concentrations, lower panel: the % compositions. Stormwater (water and particles) from Station Alna 125x Bryn and Alna 136x Alnabru, effluent water and sludge from Bekkelaget WWTP and sediments from Ildjernet in Inner Oslofjord (station Cm21).

Table 11 Overview of PFAS detected in abiotic matrices. Mean concentrations are given in ng/g dw for particles, sludge and sediment, and in ng/L for stormwater and water. Blank cells indicate concentrations <LOQ.

		Alna 125 X		Alna 136 X		Bekkelaget WWTP		Cm 21,
		Particles	Stormwater	Particles	Stormwater	Sludge	Water	Sediment
PFCA	PFHxA		1.8		1.9		6.3	
	PFHpA		1.2		3.7	0.9	3.1	
	PFOA		4.1		6.4		2.4	
	PFNA		0.5		0.8	0.6	1.4	
	PFDA	0.7		1.2		2.2	0.65	0.4
	PFUnDA					0.9		0.8
	PFDoA					0.8		
	PFPeA		0.9		12		0.85	
PFSA	PFBS		0.6		0.9		3.3	
	PFPS						0.1	
	PFHxS				0.3	0.8	0.65	
	PFOS		3.5		3.4	5.3	2.8	0.4
	PFDS					0.5		0.3
PFASA	PFOSA					0.35		
	N-MeFOSAA					1.1		
	N-EtFOSAA	4.8	2.4	1.2	0.6	2		
FTS	8:2 FTS		0.4		0.9	1.3		
	10:2 FTS	1.8		1.1		1		
	FTS, H4PFOS		3.8		5.9		0.6	

4.3.6 Bisphenols

Bisphenols were analysed for all abiotic matrices and were detected in all matrices except particles from Alna 125X Bryn. 4,4-bisphenol A was in general detected in the highest concentrations, apart from 4,4 bisphenol S which was detected at 1300 ng/L in stormwater from Alna 136X Alnabru. 4,4-Bisphenol A was also detected in sediments of the inner Oslofjord as an indication that the bisphenol load to the fjord from rivers and WWTPs, see **Table 12** and **Figure 13**.

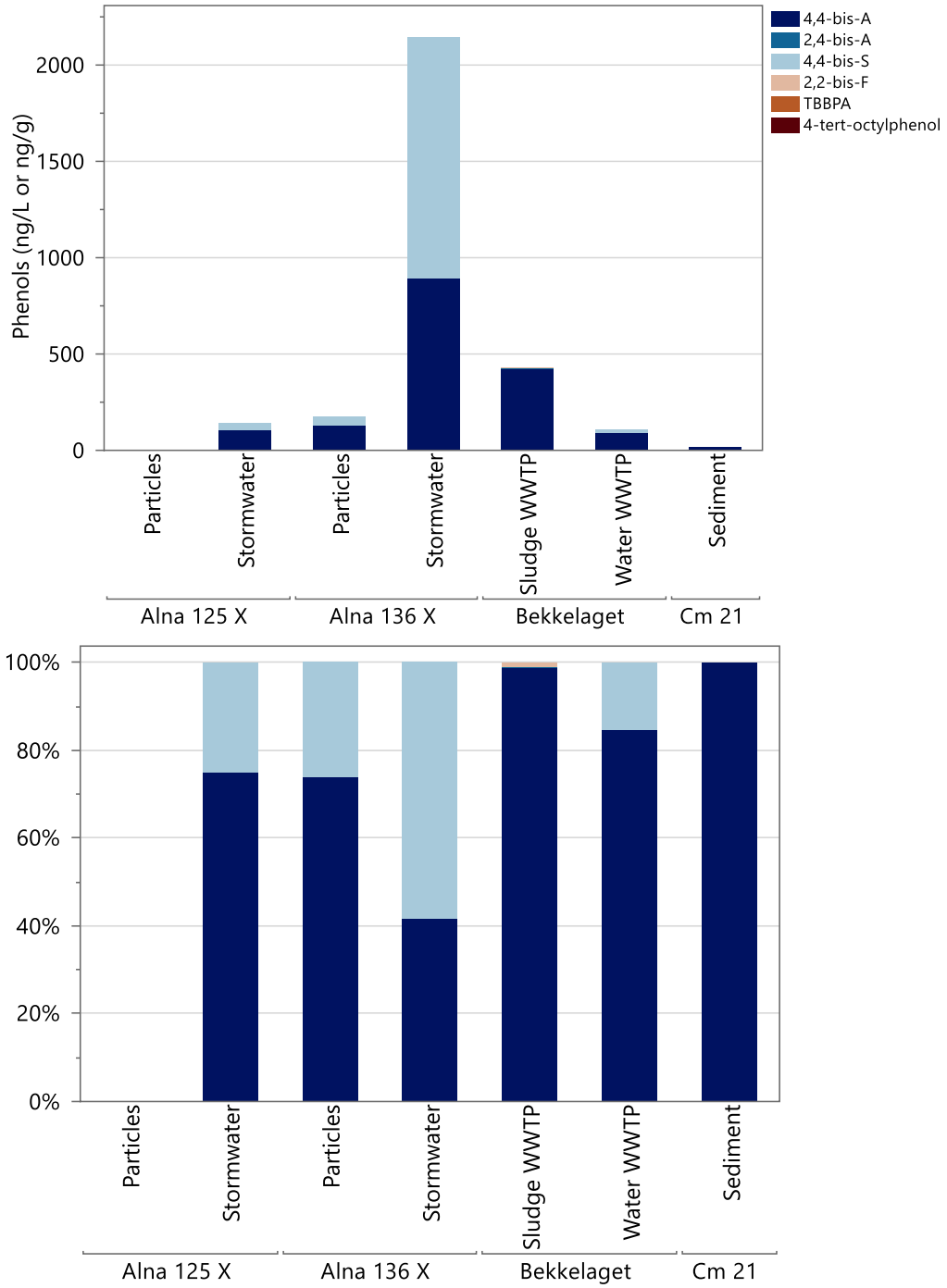


Figure 13 Concentrations and composition of bisphenols in abiotic matrices. Stormwater (water and particles) from Station Alna 125x Bryn and Alna 136x Alnabru, effluent water and sludge from Bekkelaget WWTP and sediments from Ildjernet in Inner Oslofjord (station Cm21).

Table 12 Mean concentrations of bisphenols in abiotic matrices, in storm- and effluent wastewater (ng/L) and the particle fraction of stormwater, sludge from WWTP and sediment from Inner Oslofjord (ng/g dw). Blank cells represent results <LOD.

	Alna 125 X Bryn		Alna 136 X Alnabru		Bekkelaget WWTP		Cm 21
	Particles	Stormwater	Particles	Stormwater	Sludge	Water	Sediment
4,4-bis-A		110	130	890	430	89	15
2,4-bis-A					1.8		
4,4-bis-S		35	46	1300		16	
2,2-bis-F					4.2		
TBBPA							
4-tert-octylphenol							

4.3.7 UV chemicals

UV-chemicals (benzophenone, ethylhexylmethoxycinnamate and especially octocrylene, as well as UV-327, UV-328 and UV-329) were detected in notable concentrations in samples of particles in stormwater from Alna 136X Alnabru and Bekkelaget wastewater treatment plant (**Figure 14**, **Table 13**). Octocrylen was the dominant compound with 370 and 6.1 ng/L in these two samples, respectively. This corresponds with findings from previous years (Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-1131; M-1441 and M-1766). These findings reflect the use of UV-chemicals in sunscreens and other cosmetics, as well as in other products.

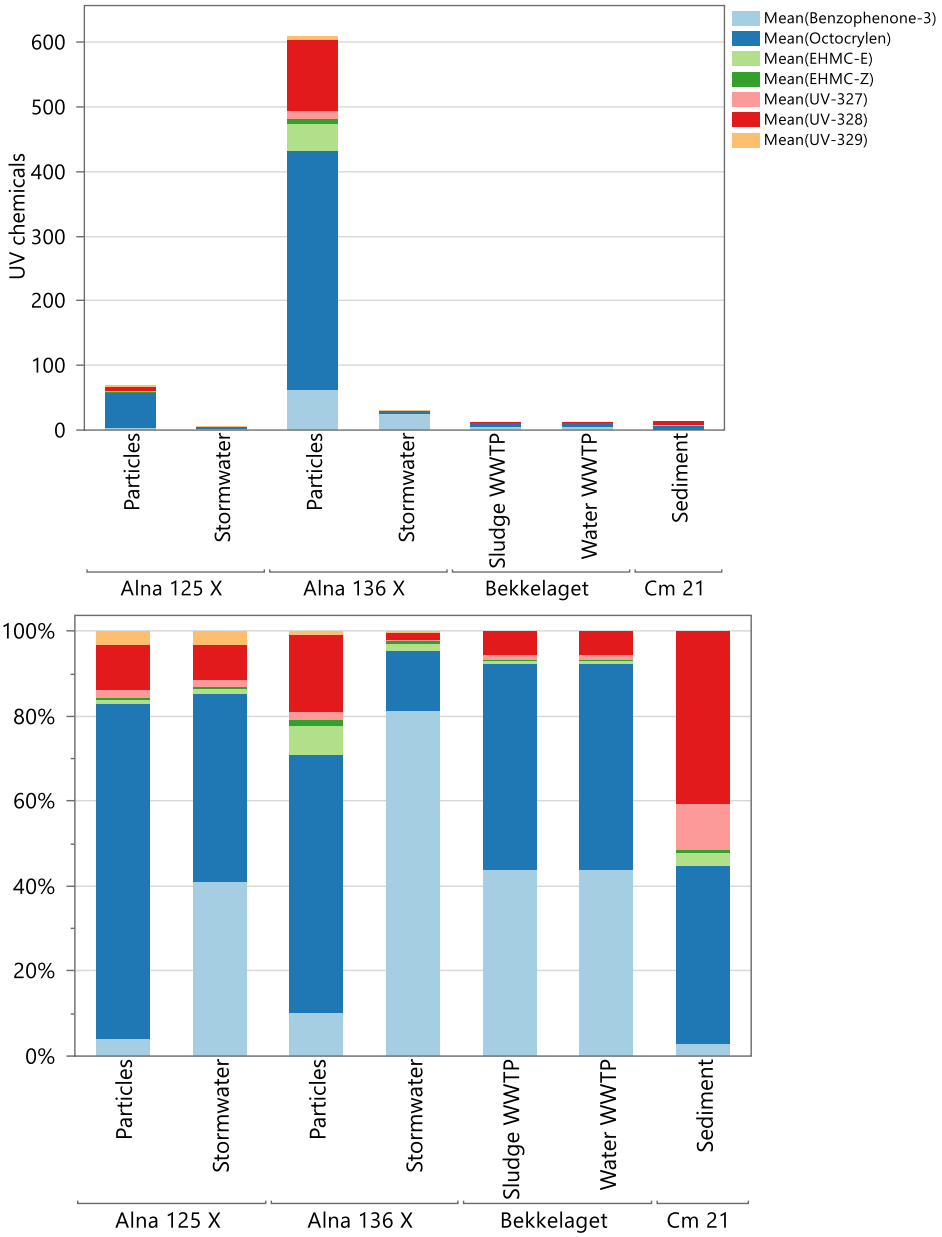


Figure 14 UV chemicals in abiotic matrices. Stormwater (water and particles) from Station Alna 125x Bryn and Alna 136x Alnabru, effluent water and sludge from Bekkelaget WWTP and sediments from Ildjernet in Inner Oslofjord (station Cm21).

Table 13 Mean concentrations of UV chemicals in abiotic matrices measured (ng/L) Blank cells represent results <LOD.

	Alna 125 X Bryn		Alna 136 X Alnabru		Bekkelaget WWTP		Cm 21,
	Particles	Stormwater	Particles	Stormwater	Sludge	Water	Sediment
Benzophenone-3	2.8	2.5	62	25	5.5	5.5	0.4
EHMC-E	0.8	0.08	42	0.5	0.1	0.1	0.4
EHMC-Z	0.2	0.02	7.9	0.2	0.03	0.03	0.1
Octocrylen	55	2.7	370	4.4	6.1	6.1	5.8
UV-327	1.4	0.1	12	0.1	0.13	0.13	1.5

UV-328	7.4	0.5	110	0.5	0.7	0.7	5.6
UV-329	2.2	0.2	5.1	0.1			
Benzophenone-3	2.8	2.5	62	25	5.5	5.5	0.4

4.3.8 Sediments EQS

For several compounds, environmental quality standards (EQS) for sediment are given through Norwegian law (The Water Regulation/"Vannforskriften"), according to the requirements of the Water Framework Directive. Furthermore, quality standards are given for even more compounds (Direktoratsgruppen vanndirektivet 2018). For the target compounds of this study of which quality standards exist, the sediment concentrations and EQSs are compared in **Table 14**. D5, PCB_7, Zn, As, Ni, Hg and PFOS exceeded the quality standards. Regarding inputs to the fjord (apart from the stormwater and WWTP effluent, according to Gundersen et al. (2019; The Norwegian Environment Agency M-1508), River Alna also brings some contaminants to the fjord (see Chapter 4.3.9), such as As, Pb, Cu, Zn, Ni, Cr and Hg.

Table 14. Concentrations of contaminants (mg/kg dry wt) of which Norwegian quality standards (Direktoratsgruppen vanndirektivet 2018) exist in sediment from the inner Oslofjord. Red numbers indicate concentrations exceeding the quality standard (annual average, AA-EQS).

River basin specific compounds	EQS (mg/kg dry wt.)	Sediment conc. (mg/kg dry wt.)
Bisphenol A	0.0011	-
Decamethylcyclopentasiloxane (D5)	0.044	0.053
Medium chained chloroparafins (MCCPs)	4.6	0.33
Copper (Cu)	84	80
PCB_7	0.0041	0.016
PFOA	0.071	<0.0005
Zinc (Zn)	139	313
TBBPA	0.108	-
Arsenic (As)	18	52
Chromium (Cr)	660	144
TCEP	0.0716	-
EU priority substances		
Cadmium (Cd)	2.5	0.2
Lead (Pb)	150	115
Nickel (Ni)	42	66
Mercury (Hg)	0.52	0.95
Brominated diphenyl ethers *	0.062	-
Hexachlorobenzene	0.017	0.0005
C10-13 chloroalkanes **	0.8	0.65

River basin specific compounds	EQS (mg/kg dry wt.)	Sediment conc. (mg/kg dry wt.)
Pentachlorobenzene	0.4	0.0004
Nonylphenol (4-)	0.016	-
Octylphenol (4-*tert*-)	0.0003	-
PFOS	0.00023	0.00040
* Sum of BDE-28, -47, -99, -100, -153 and -154. ** Short chained chlorinated paraffins (SCCPs)		

4.3.9 Stormwater EQS

For several compounds, environmental quality standards for water are given through Norwegian law (The Water Regulation/"Vannforskriften"), according to the requirements of the Water Framework Directive. Furthermore, quality standards are given for even more compounds (Direktoratsgruppen vanndirektivet 2018). For the target compounds of this study of which quality standards exist, the water concentrations (dissolved fraction) and EQSs are compared in **Table 15** (EQSs for coastal water used, to elucidate the potential of surface water as source of contaminants to parts of the fjord).

Concentrations of bisphenol A, MCCPs, copper, PCB_7, zinc, 4-*tert*-octylphenol and PFOS exceeded the quality standards, reflecting runoff from the surrounding (urban) area. Copper, PCB_7, zinc and PFOS also exceeded the quality standards for sediment from station Cm21 (see chapter 4.3). It should be mentioned that for copper and zinc, the concentrations in the dissolved fraction of stormwater did not only exceed the Annual Average (AA-)EQS, but also the Maximum Allowable Concentration (MAC-)EQS. Furthermore, for several compounds, the concentrations were higher in the particulate phase that in the dissolved fraction (see Appendix).

Gundersen et al. (2019; The Norwegian Environment Agency M-1508) estimated the input of contaminants to the fjord from River Alna in 2018: 0.01 ton/yr As, 0.02 ton/yr Pb, 0.10 ton/yr Cu, 0.37 ton/yr Zn, 0.03 ton/yr Ni, 0.02 ton/yr Cr and 0.03 kg/yr Hg. Annual mean concentrations of As, Pb, Cd, Cu, Zn, Cr and Ni in the river water were 0.35 µg/L, 0.39 µg/L, 0.032 µg/L, 2.72 µg/L, 9.47 µg/L, 0.35 µg/L and 0.80µg/L, respectively. In 2018, annual discharges of organic contaminants were not estimated in the river monitoring programme (Allan et al. 2019; The Norwegian Environment Agency M-1509). In 2017, however, the following discharges were estimated from river Alna: 9.6 g/yr HCB, 10.7 g/yr ΣPBDE, 1.8 kg/yr SCCPs and 1.7 kg/yr MCCPs (Allan et al. 2018; The Norwegian Environment Agency M-1166).

As such, there are several pathways, including stormwater runoff, effluent from WWTPs and riverine inpout of these studied contaminants to the Inner Oslofjord.

Table 15. Concentrations of contaminants (µg/L) in stormwater (dissolved fraction) and WWTP effluent water of which Norwegian quality standards (Direktoratsgruppen vanndirektivet 2018) exist in coastal water. Red numbers indicate concentrations exceeding the quality standard.

River basin specific compounds	AA-EQS (µg/L)	Stormwater conc. (dissolved; µg/L)	Effluent water (WWTP) conc. (µg/L),
Bisphenol A	0.15	0.9	0.09
Decamethylcyclopentasiloxane (D5)	0.17	n.a.	n.a.
Medium chained chlorinated paraffins (MCCPs)	0.05	<0.004	0.02
Copper (Cu)	2.6	6.6	n.a.
PCB_7	0.0000024	<0.0009	n.a.
PFOA	9.1	0.0036	0.0061
Zinc (Zn)	3.38	24.4	n.a.
TBBPA	0.254	<0.0035	<0.013
Arsenic (As)	0.6	1.4	n.a.
Chromium (Cr)	3.4	1.5	n.a.
TCEP	6.5	n.a.	n.a.
EU priority substances			
Cadmium (Cd)	0.2	0.02	n.a.
Lead (Pb)	1.3	0.14	n.a.
Nickel (Ni)	8.6	1.6	n.a.
Mercury (Hg)	0.07 ***	<0.002	n.a.
Brominated diphenyl ethers *	0.014 ***	n.a.	<0.0012
Hexachlorobenzene	0.05 ***	<0.00033	n.a.
C10-13 chloroalkanes **	0.4	<0.15	0.01
Pentachlorobenzene	0.0007	<0.00022	n.a.
Nonylphenol (4-)	0.3	<0.004	<0.045
Octylphenol (4-*tert*-)	0.01	<0.003	<0.027
PFOS	0.00013	0.0035	0.0045

* Sum of BDE-28, -47, -99, -100, -153 and -154.
** Short chained chlorinated paraffins (SCCPs)
*** No AA-EQS for these substances, thus this is the MAC-EQS

4.3.10 Wastewater treatment plant (WWTP) EQS

The last annual discharge data from VEAS wastewater treatment plant (WWTP) is from 2019, published in Norske utslipp in 2020. Data include a reported discharge of 53 kg As, 72 kg Pb, 6.5 kg Cd, 642 kg Cu, 0.31 kg Hg, 236 kg Ni and 2184 kg Zn that year (more than 90% of the measurements were below the limit of detection for Cd, Cr and Hg, and half of the LoD was reported for these; VEAS 2020). In 2018, the discharges were 46 kg As, 39 kg Pb, 4.5 kg Cd, 434 kg Cu, 48 kg Cr, 0.33 kg Hg, 247 kg Ni and 1857 kg Zn that year (more than 90% of the measurements were below the limit of detection for Cd, Cr and Hg, and half of the LoD was reported for these; VEAS 2019; VEAS 2020).

Effluent water from the sewer of the population in the urban environment of Oslo is also a pathway of several compounds to the Inner Oslofjord marine environment, even though treatment technologies improve every year. The concentrations measured in WWTP effluent water in this study represent 1-day averages and are merely "snap shots" of what can be observed in this matrix. The above mentioned yearly discharges of metals from VEAS WWTP show slightly higher (a factor 2-5) amounts for several elements (such as As, Pb, Cu and Cr) as those transported by river Alna (see chapter 4.3.9 and Gundersen et al. 2019; The Norwegian Environment Agency M-1508).

As mentioned, for several compounds, environmental quality standards (EQS) for water are given through Norwegian law (The Water Regulation/"Vannforskriften"), according to the requirements of the Water Framework Directive. Furthermore, quality standards are given for even more compounds (Direktoratsgruppen vanndirektivet 2018). For the target compounds of this study of which quality standards exist, the concentrations in effluent water from Bekkelaget WWTP and the EQSs are also compared in **Table 15** (EQSs for coastal water used, to elucidate the potential of effluent water as source of contaminants to parts of the fjord). Only PFOS exceeded AA-EQS for effluent water. In previous years, MCCPs and 4-*tert*-octylphenol have also been above EQS (Ruus et al., 2020), but in 2020 there were higher LOD/LOQ for 4-*tert*-ocylphenol specifically.

4.4 Inner Oslofjord Food Web

4.4.1 Data from 2020

Several legacy contaminants with well-known biomagnifying properties displayed a positive significant relationship between log10 concentrations and trophic position (deduced from the d15N isotopic ratio) in the studied Inner Oslofjord marine food web. Previously, some of the PCB congeners have showed significant biomagnification ($p \leq 0.0403$): PCB-114 (TMF=2.69), -141 (TMF=4.46), -170 (TMF=8.60), -180 (TMF=5.28) and -194 (TMF=6.09). Thus, PCBs have shown to display an expected behaviour in the Inner Oslofjord food web, supporting again that the studied food web is appropriate for assessing biomagnifying behaviour of contaminants, where PCBs may serve as "benchmark".

In 2020, biomagnifying potential of contaminants was observed by calculating trophic magnification factors (TMFs) by studying the relationship between log10-concentrations of contaminants and trophic position derived from δ15N levels. The PCB congener CB-180 (TMF=6.9, $p<0.0001$), the PBDE congener BDE-100 (TMF=4.7, $p=0.0006$), mercury (Hg; TMF=3.1, $p<0.0001$)), silver (Ag; TMF=25, $p<0.0001$) and PFOS (TMF= 4.2, $p=0.0003$) all displayed biomagnification in this marine food web by a positive, significant relationship with trophic position.

PCBs

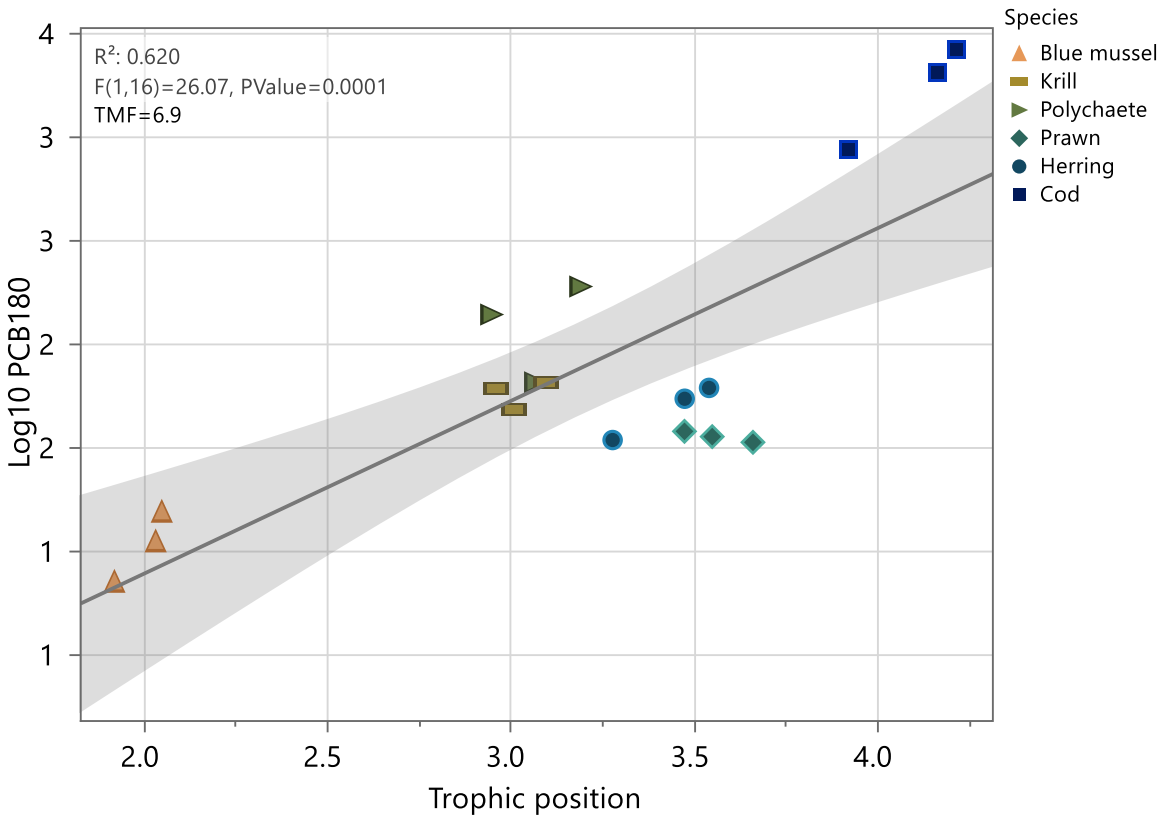


Figure 15. Trophic position against concentrations (ng/g lipid wt.; log-transformed) of PCB-180 in the studied Inner Oslofjord food web. The confidence region of the fitted line is indicated with grey shading.

The relative contribution of PCB-congeners to the sum of PCB_7 was similar among the species of the Inner Oslofjord food web, with PCB-153 constituting the highest percentage (**Figure 16**, **Table 16**). The other PCBs than PCB_7 measured in biota is also included in the figure, showing that in e.g. krill these congeners constitute ca. 50% to the total PCB burden. Also, for the other organisms these other PCBs constitute a significant contaminant burden. The pattern for the PCB_7 was very similar to that observed the previous year (Ruus et al. 2020; The Norwegian Environment Agency M-1766).

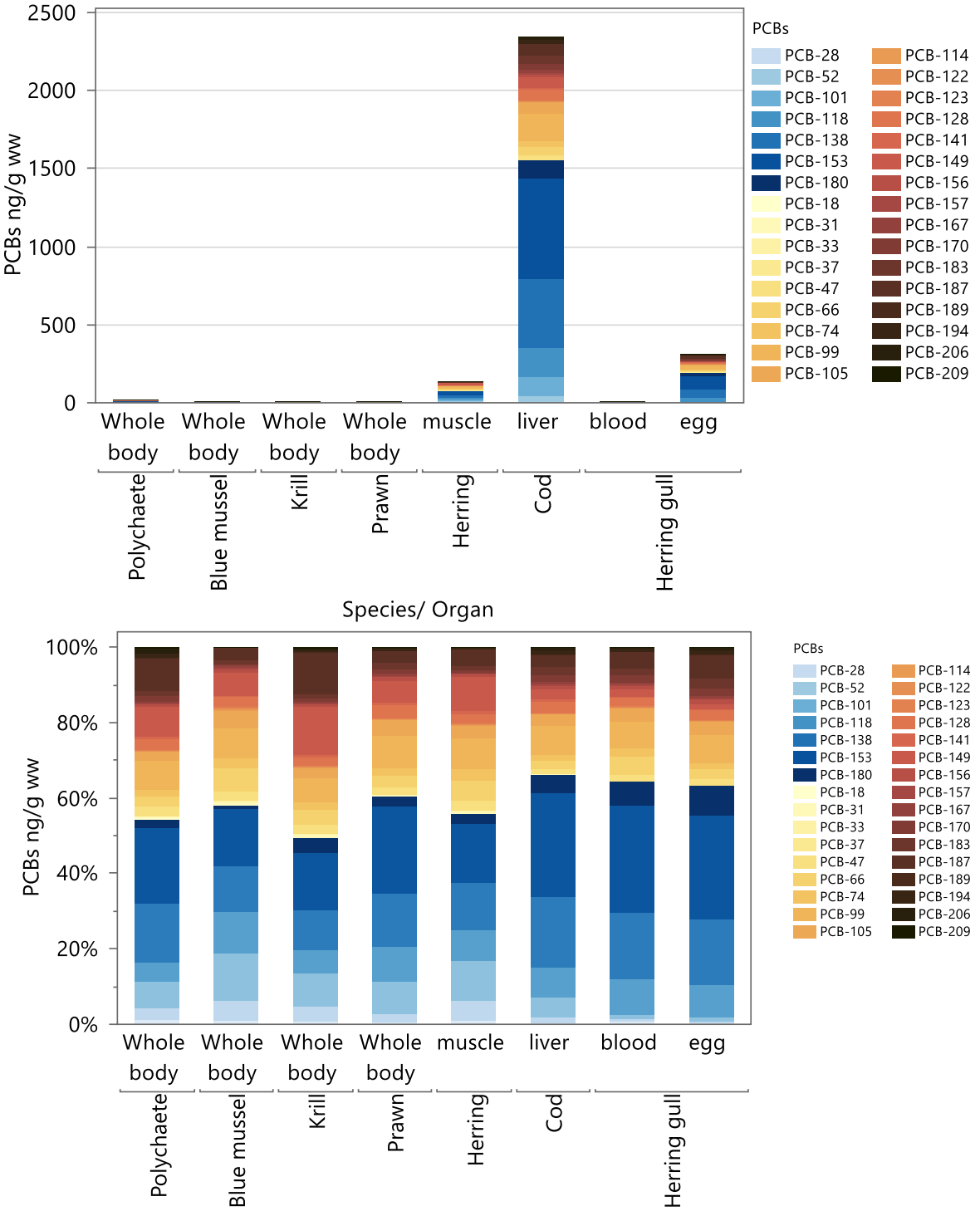


Figure 16. Concentrations (ng/g wet wt.; mean) of PCB-congeners in the species of the inner Oslofjord food web and herring gull. The PCB_7 are shown in colours in blue with congeners with higher numbers in darker blue. Other PCBs analysed are shown in colours from yellow to black, with darker colours for congeners with higher numbers. On the top are the concentrations (ng/g ww) shown, while at the bottom the % distribution of congeners within each species/matrix measured are depicted.

Table 16 Overview of mean concentration of each of PCB_7 in the organisms in the food web and herring gulls.

	CB-28	CB-52	CB-101	CB-118	CB-138	CB-153	CB-180
Polychaete	0.23	0.64	1.5	1.1	3.3	4.1	0.48
Blue mussel	0.094	0.50	1.2	1.0	1.2	1.5	0.083
Krill	0.061	0.33	0.74	0.54	0.88	1.3	0.32
Prawn	0.040	0.16	0.61	0.68	1.0	1.7	0.21
Herring	1.3	7.4	15	11	17	22	3.5
Cod	6.6	36	120	190	440	650	120
Herring gull, blood	0.064	0.074	0.10	0.92	1.7	2.7	0.62
Herring gull, egg	0.87	1.5	3.6	26	54	85	25

PBDEs

Biomagnification of PBDEs has previously been shown in marine systems (e.g. Hallanger et al., 2011), and biomagnifying potential was indicated for BDE-100 in the 2019 data from Oslofjorden (Ruus et al. 2020).

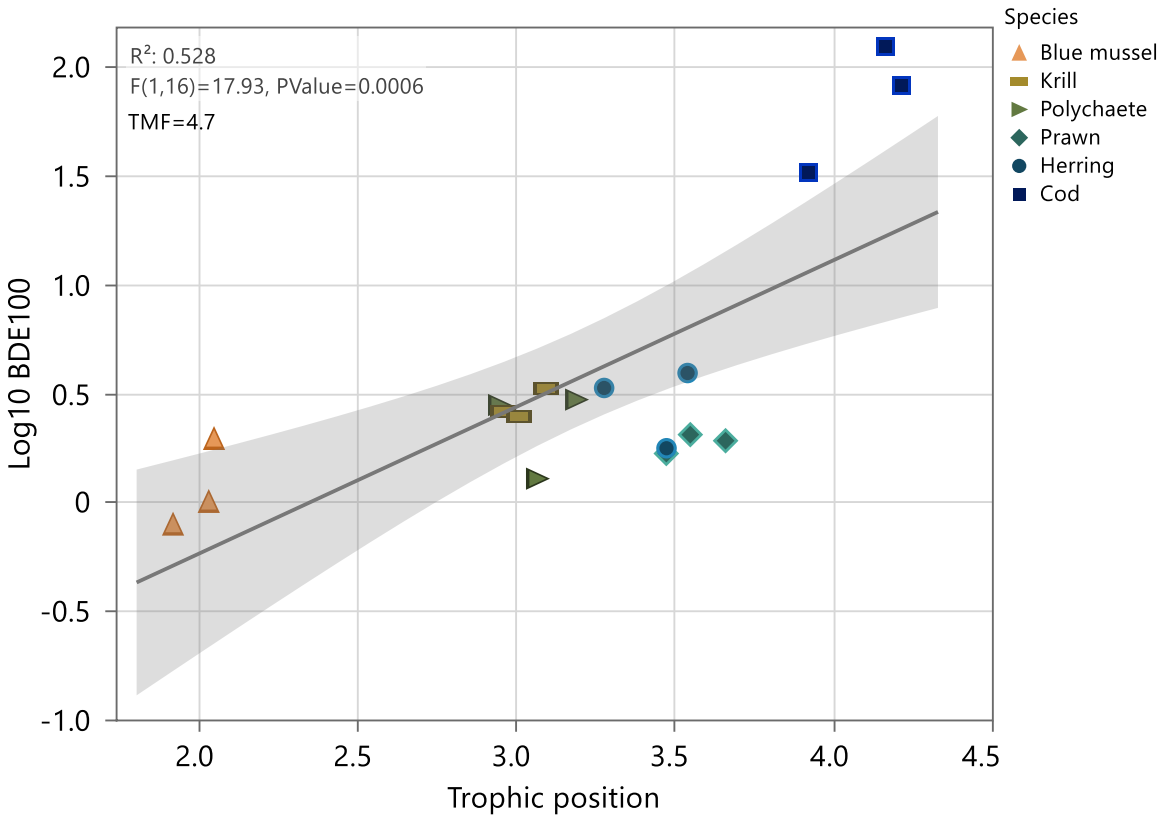


Figure 17 Trophic position against concentrations (ng/g lipid wt.; log-transformed) of BDE-100 in the studied Inner Oslofjord food web. The confidence region of the fitted line is indicated with grey shading.

The relative contribution of PBDE-congeners to the sum of PBDEs appeared somewhat different among the species of the Inner Oslofjord food web (**Figure 18**, **Table 17**). BDE-47 constituted the highest proportion in prawns, herring and cod (**Figure 18**). BDE-99 was a major constituent in krill (together with BDE-47) and in blue mussel (**Figure 18**). Dominating proportions of BDE-47 and -99 in some species correspond with previous observations (Ruus et al. 2019b; The Norwegian Environment Agency M-1441). BDE-47 is bioaccumulative and recalcitrant against degradation and is a major constituent of the penta-BDE mixture (De Wit, 2002). Furthermore, BDE-47 is a degradation product from the debromination of higher brominated PBDEs (including BDE-209), and Roberts et al. (2011) describe species-specific differences in debromination of PBDEs. The proportion of BDE_6 vs the other PBDEs varied between the species, and herring gull eggs and prawns had the highest proportion of PBDEs other than BDE_6.

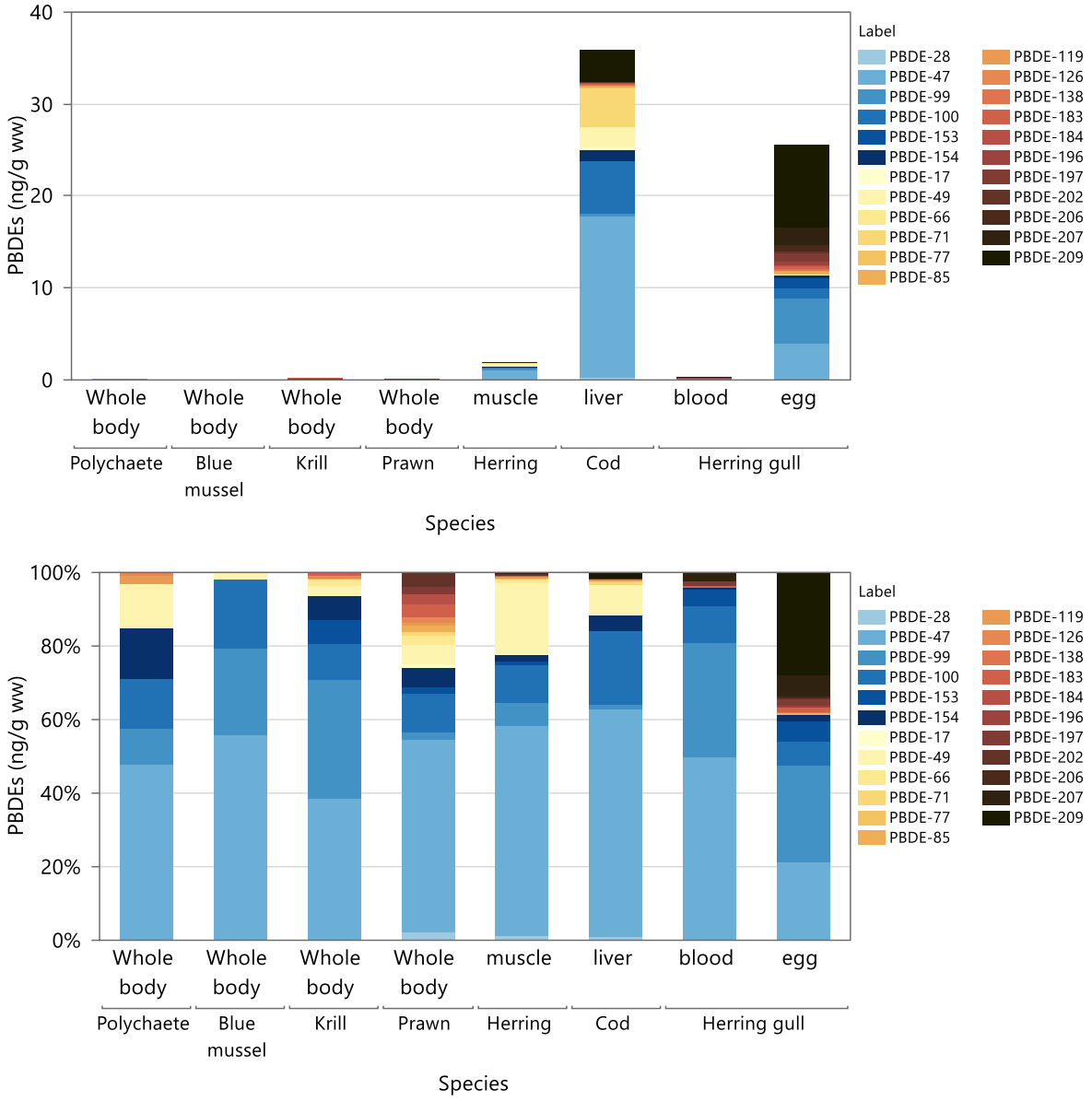


Figure 18. Concentrations (ng/g wet wt.; mean; non-detected components were assigned a value of zero) of PBDE-congeners in the marine food web and herring gull (see **Table 5**). The BDE_6 are shown in colours in blue with congeners with higher numbers in darker blue. Other PBDEs analysed are shown in colours from yellow to black, with darker colours for congeners with higher numbers. On the top are the concentrations (ng/g ww) shown, while at the bottom the % distribution of congeners within each species/matrix measured are depicted.

Table 17 Mean of concentrations (ng/g ww) of PBDEs in the marine food web and herring gull. Data are given with two significant digits. Blank cells represent results <LOD.

		Polychaete	Blue mussel	Krill	Prawn	Herring	Cod	Herring gull blood	Herring gull egg
BDE6	BDE-28				0.0034	0.021	0.25		0.011
	BDE-47	0.031	0.027	0.061	0.054	1.1	18	0.077	3.9
	BDE-99	0.0095	0.011	0.051	0.006	0.12	0.37	0.058	4.9
	BDE-100	0.0086	0.0089	0.016	0.011	0.19	5.6	0.02	1.2
	BDE-153			0.01	0.0057	0.017	0.086	0.023	1.1
	BDE-154	0.013		0.011	0.0055	0.036	1.2	0.0097	0.33
Other BDEs	BDE-17				0.0031	0.013	0.24		
	BDE-49	0.0077	0.0029	0.0044	0.0055	0.36	2.3		0.059
	BDE-66			0.0026	0.0026	0.019			0.061
	BDE-71				0.0025	0.011	4.3		
	BDE-77					0.0069	0.035		
	BDE-85			0.0021	0.0029	0.0044	0.1		0.32
	BDE-119	0.004			0.002	0.0087	0.074		0.024
	BDE-126	0.0019		0.0027	0.0026	0.0054	0.052		
	BDE-138						0.13		0.27
	BDE-183			0.0042	0.0052	0.0078	0.055	0.0099	0.29
	BDE-184				0.0041	0.0054	0.055		0.041
	BDE-196								0.45
	BDE-197				0.0068		0.055	0.028	0.9
	BDE-202				0.012	0.022	0.13		0.22
	BDE-206								0.64
	BDE-207					0.022		0.046	1.9
	BDE-209						3.5		9

Siloxanes (D4, D5, D6, M3T(Ph))

The concentrations of siloxanes (D4, D5, D6 and M3T(Ph)) displayed no significant positive relationship with trophic position. (M3T(Ph) was only detected in polychaetes, herring and cod). There have previously been some divergences in reports of the biomagnifying properties of siloxanes in different systems (e.g. Borgå et al. 2012 and references therein). By compiling data from different surveys from the period 2010-2019, Jartun et al. (2020) demonstrated biomagnification of D5 in lake Mjøsa (freshwater) with a TMF of 2.13, and biomagnification of D6 with a common TMF of 1.29 (data from 2010 to 2019). D5 appeared in the highest concentrations (Jartun et al. 2020). On the other hand, Powel et al. (2018) found no biomagnification of D4, D5 and D6 across demersal and pelagic food webs in the Oslofjord (marine food web).

Of the siloxanes analysed in the present study, D5 also appeared in the highest concentrations in all species of the food web (**Figure 19**, **Table 18**).

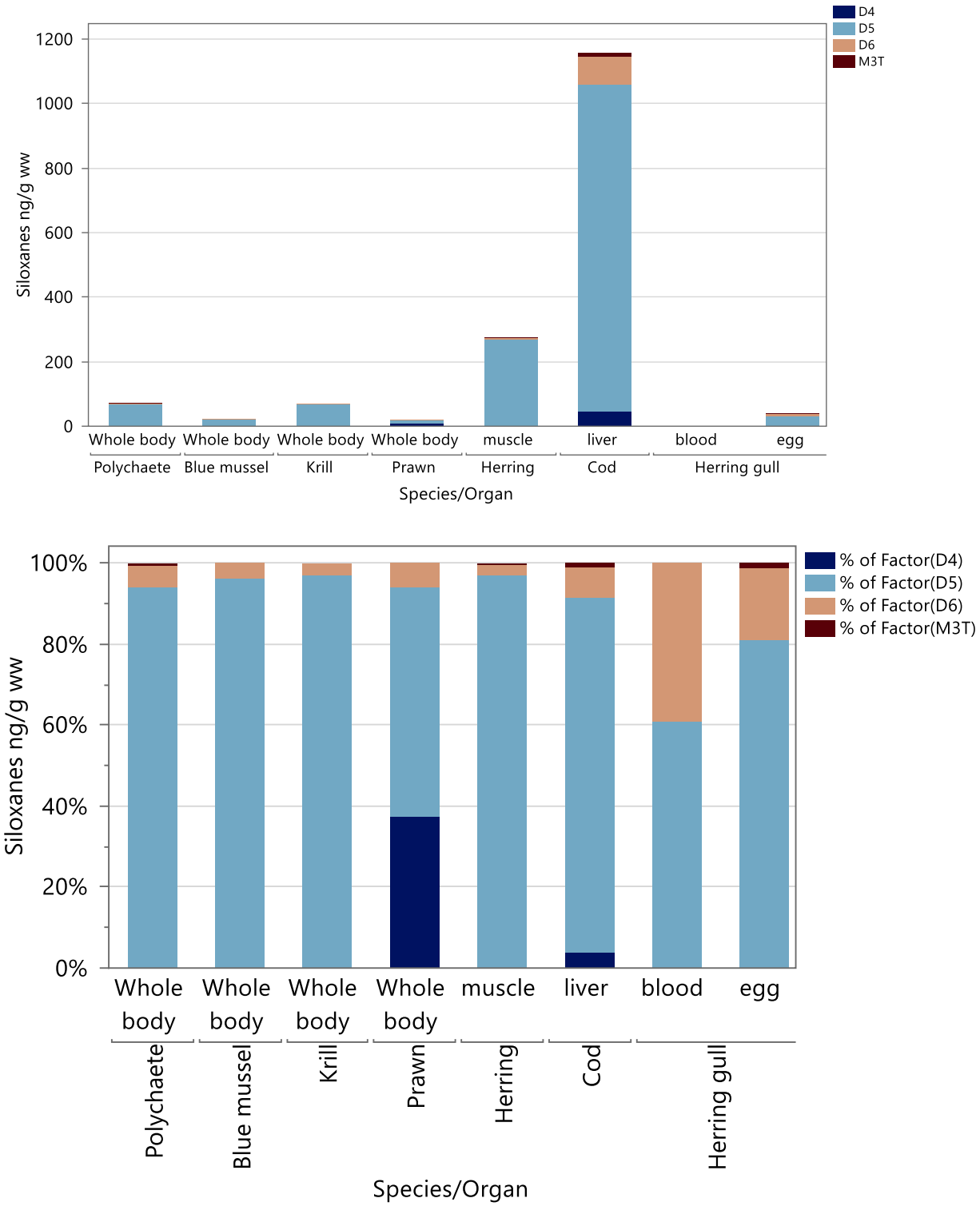


Figure 19. Concentrations (top figure; ng/g wet wt.; mean) and percentage (bottom figure) of D4, D5, D6 and M3T(Ph) in the species of the Inner Oslofjord food web.

Table 18 Mean concentrations of siloxanes (ng/g ww, mean) in inner Oslofjord food web and herring gulls. The data are given with 2 significant digits. Data below quantification limits are indicated by an empty cell.

	D4	D5	D6	M3T(Ph)
Polychaete		68	3.9	0.42
Blue mussel		21	0.83	
Krill		67	2	
Prawn	7.9	12	1.3	
Herring		270	7.2	1
Cod	46	1000	87	12
Herring gull blood		1	0.65	
Herring gull eggs		31	6.8	0.46

Mercury (Hg)

Hg was determined in muscle tissue of individuals of the top predator cod in 2020, and thus qualified for calculation of TMF. Total Hg displayed statistically significant biomagnification (TMF=3.1; **Figure 20**) in the Inner Oslofjord food web, as previously observed in the "Urban fjord" programme (Ruus et al., 2016; Ruus et al., 2017; Ruus et al., 2019a; Ruus et al., 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-601, M-812, M-1131, M-1441, M-1766). The biomagnifying properties of Hg (particularly methylmercury, MeHg) are well known (e.g. Jaeger et al., 2009; Ruus et al., 2015b). It should be noted that the proportion of total Hg that is MeHg in the different organism is not known and likely differs.

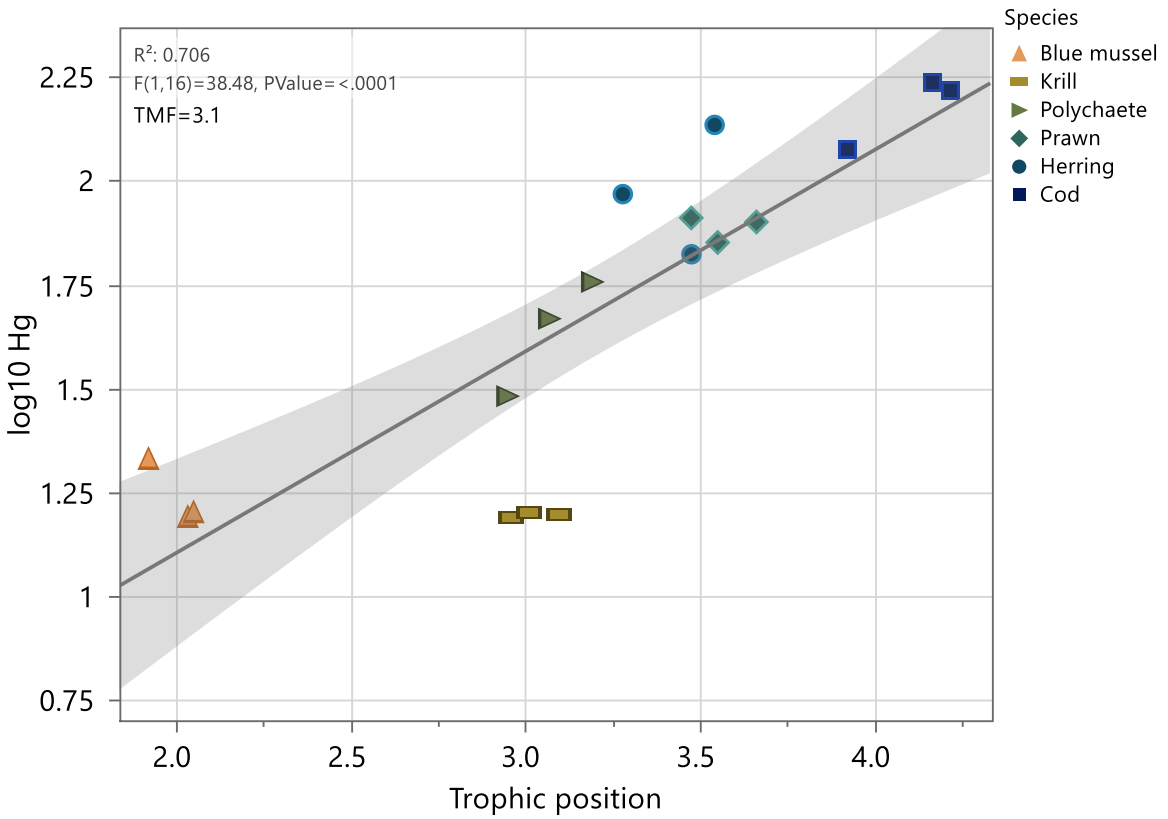


Figure 20. Trophic position against concentrations (ng/g wet wt.; log-transformed) of mercury (Hg) in the studied Inner Oslofjord food web. The confidence region of the fitted line is indicated with grey shading.

Silver (Ag)

There is little evidence of biomagnification of Ag in marine systems, and according to a review by Fisher and Wang (1998), trophic transfer of Ag has been shown to be insignificant in several aquatic animals but more important in others. Maneekarn et al. (2014) studied bioaccumulation and biomagnification of nano Ag^0 particles (AgNPs) in a model food chain containing green algae (*Chlorella sp.*), water flea (*Moina macroscopa*), blood worm (*Chironomus spp.*) and silver barb *(Barbonys gonionotus*). They found that food chain transfer of AgNPs occurred only from *Chlorella sp.* to *M. macroscopa*. Furthermore, Ag has previously displayed statistically significant positive relationships between (log) concentrations and trophic position (in 2015-2019; Ruus et al., 2020).

Hg and Ag were detected in sediment from the Inner Oslofjord, as well as in stormwater (only in the particulate phase) entering the fjord (see electronic Appendix). Ag (the only element analysed) was not detected in effluent water from Bekkelaget WWTP (<0.006 ng/ml). Silver nanoparticles (AgNP) are used in several consumer products (*inter alia* textiles) for their antimicrobial properties, however, their possible influence on the observed results is unknown. Wang et al (2014) showed that the marine polychaete *Nereis virens* accumulated Ag in the forms of AgNP-citrate, AgNP-polyvinylpyrrolidone and as a salt ($AgNO_3$).

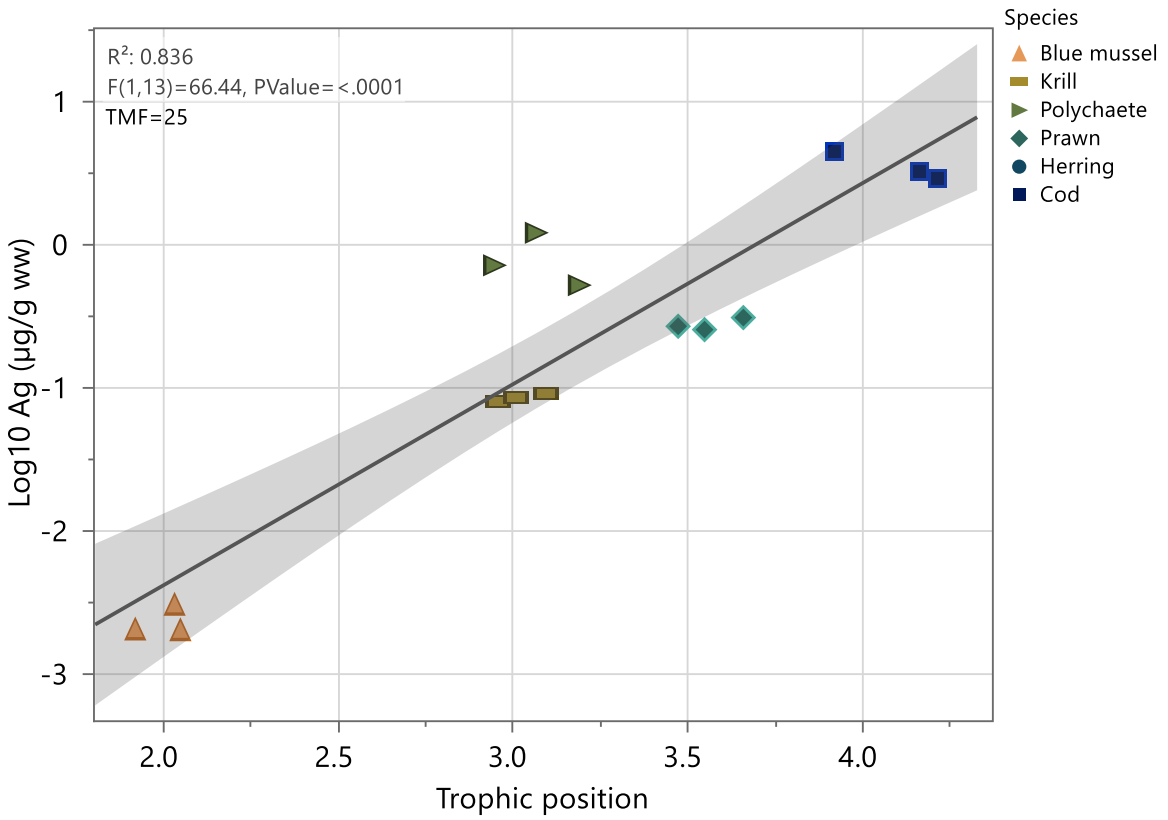


Figure 21 Trophic position against concentrations (ng/g wet wt.; log-transformed) of silver (Ag) in the studied Inner Oslofjord food web. The confidence region of the fitted line is indicated with grey shading.

PFAS

Regarding PFAS compounds, there were many non-detects for most compounds. PFOS and PFOSA had high detection frequencies in all organisms, and were detected in all species, although not in all samples (see electronic Appendix). Previously, PFOS has shown significant biomagnification in the Inner Oslofjord marine food web (e.g. Ruus et al. 2017; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-812, M-1441 and M-1766). Biomagnification of PFOS has previously been shown in marine food webs (e.g. Kelly et al. 2009; Houde et al. 2011), However, Franklin (2015), points to the great variability in field derived biomagnification estimates of PFAS compounds.

PFOSA constituted a high proportion (of sum PFAS) in blue mussel, krill, herring and cod (**Figure 23**, **Table 19**), as previously observed Ruus et al. 2017; Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-812, M-1131, M-1441 and M-1766). PFOS was also an important constituent in cod and prawn (**Figure 23**). PFCAs were detected in all organisms but blue mussels and herring, while FTS were detected in most organisms, but not blue mussels, krill and herring.

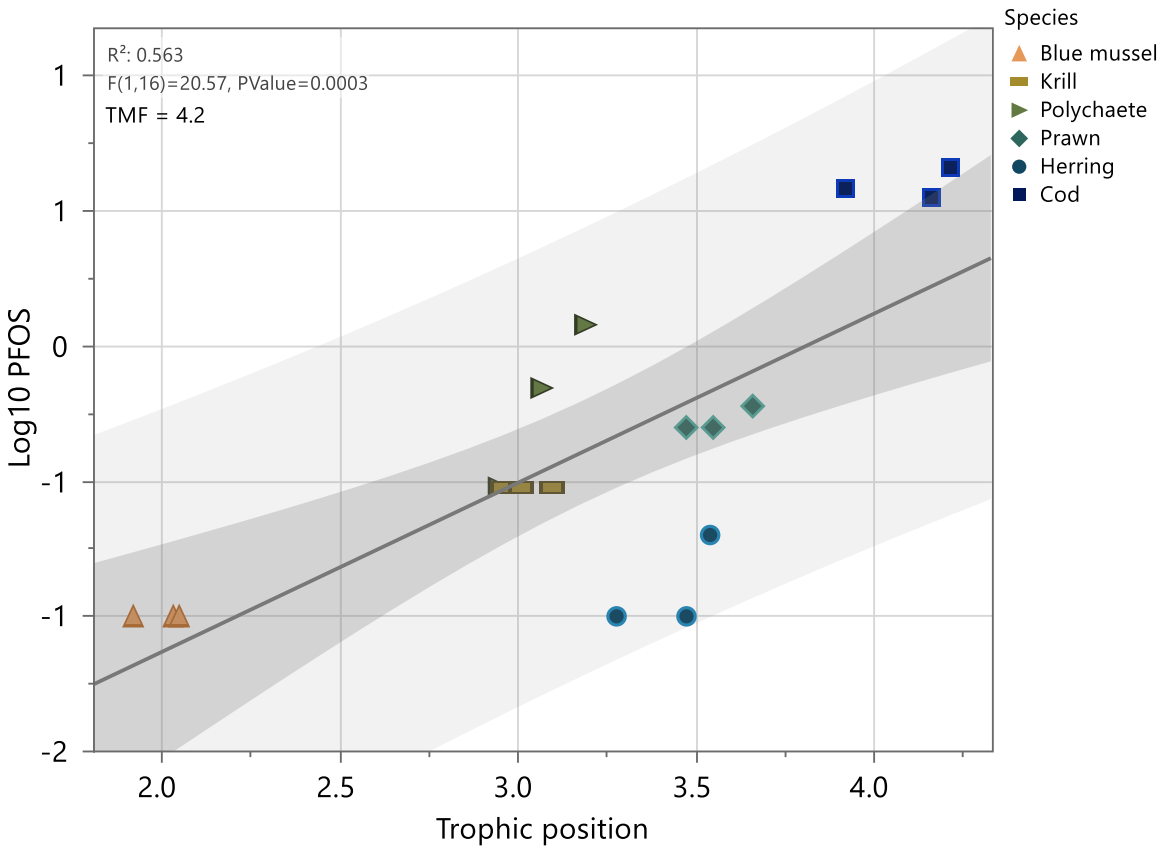


Figure 22 Trophic position against concentrations (ng/g wet wt.; log-transformed) of PFOS in the studied Inner Oslofjord marine food web. The confidence region of the fitted line is indicated with grey shading.

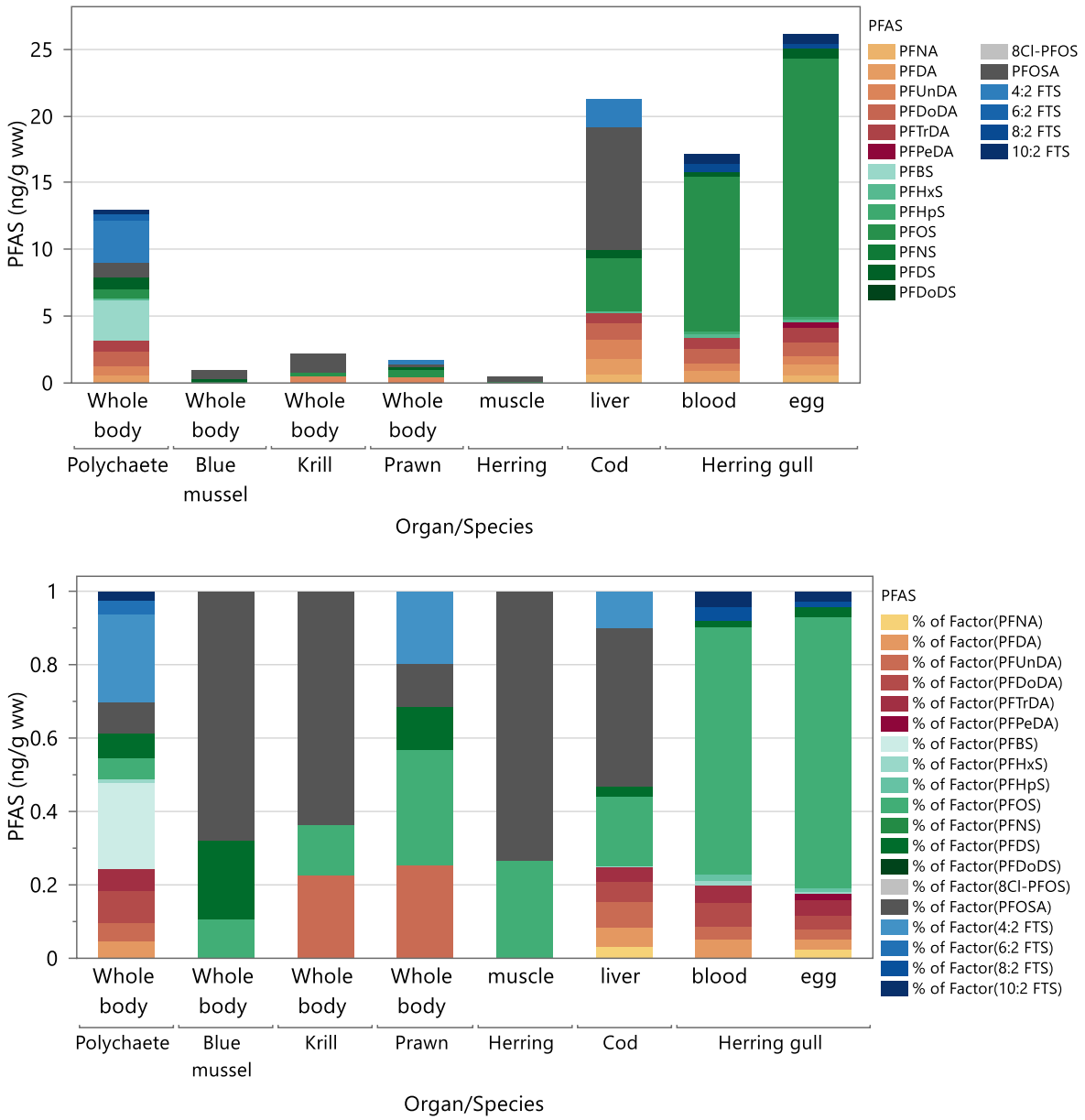


Figure 23. Concentrations (ng/g wet wt.; mean; non-detected components were assigned a value of LoD/2) of (detected) PFAS compounds in the species of the Inner Oslofjord food web, Herring gull data are also shown for comparison. The different groups of PFAS are shown in different colours, PFCAs in yellow/red, PFSAs in green, pre-PFOS in grey and FTS in blue. In general, higher fluorinated compounds have a darker colour.

Table 19 Table showing concentrations of PFAS (ng/g ww) in inner Oslofjord food web and herring gulls. The data are given with 2 significant digits. Data below quantification limits are indicated by an empty cell.

		Polychaete	Blue mussel	Krill	Prawn	Herring	Cod	Herring gull	Herring gull
PFCA	PFNA						0.65		0.6
	PFDA	0.6					1.2	0.88	0.75
	PFUnDA	0.67		0.5	0.43		1.5	0.61	0.69
	PFDoDA	1.1					1.2	1.1	1
	PFTrDA	0.8					0.8	0.8	1.1
	PFPeDA								0.45
PFASA	PFBS	3.1							
	PFHxS	0.1					0.1	0.25	0.16
	PFHpS							0.27	0.22
	PFOS	0.73	0.1	0.3	0.53	0.13	4	12	19
	PFNS								
	PFDS	0.9	0.2		0.2		0.61	0.28	0.69
	PFDoDS								
PFASA	8Cl-PFOS								
	PFOSA	1.1	0.63	1.4	0.2	0.37	9.2		
	N-EtFOSAA				0.18				
FTS	4:2 FTS	3.1			0.33		2.1		
	6:2 FTS	0.5							
	8:2 FTS							0.67	0.4
	10:2 FTS	0.3						0.7	0.71

4.4.2 TMF historical data (2017-2020)

In this section, we provide data for the biomagnification potential of selected contaminants within the marine food web of the Inner Oslofjord based on all collected data from 2017-2020. Previous chapters discussed the TMFs of PCB congener CB-180, PBDE congener BDE-100, Hg, Ag and PFOS for the specific year 2020, but here we present the biomagnification potential based on accumulated data from 2017-2020 in the Urban fjord monitoring program, see **Figure 24** to **Figure 28**.

Based on comparable data from the past four years, TMFs for all these contaminants found to be significant and above 1, indicating a positive relationship between $\delta^{15}N$ levels and concentrations found in the marine food web of Inner Oslofjord. The same figures but grouped by years are shown in Appendix.

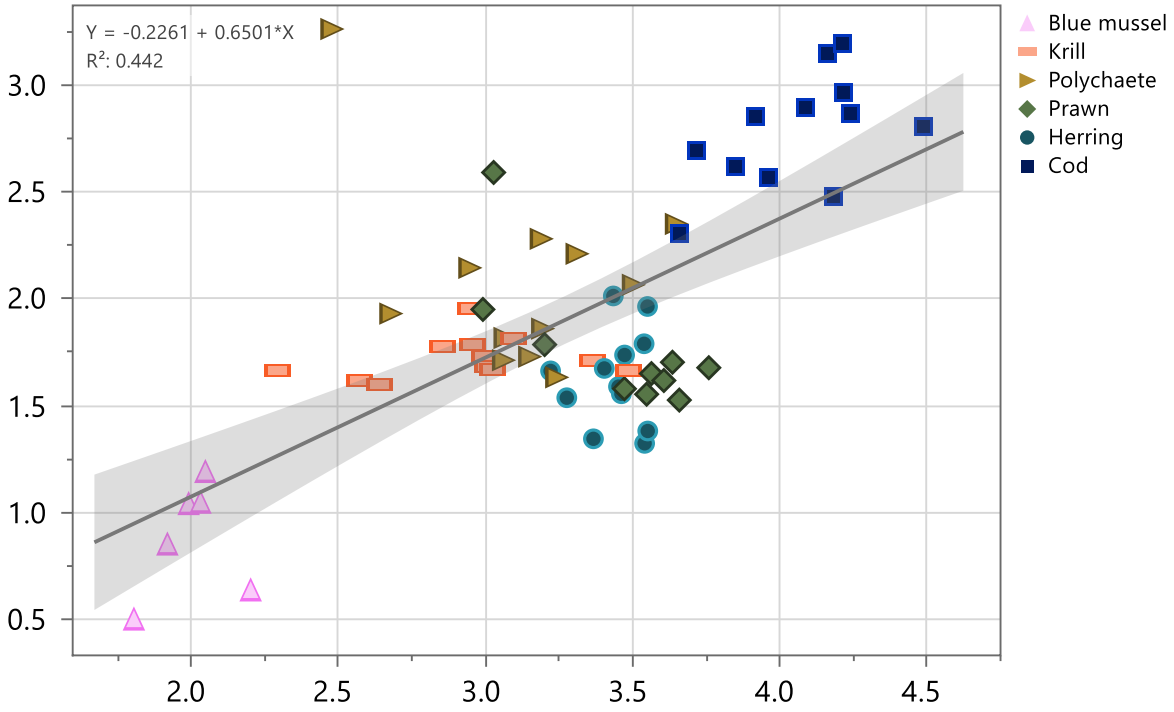


Figure 24 $\log_{10}$ CB-180 lipid normalized against trophic position for all years (2017-2020). TMF=4.5.

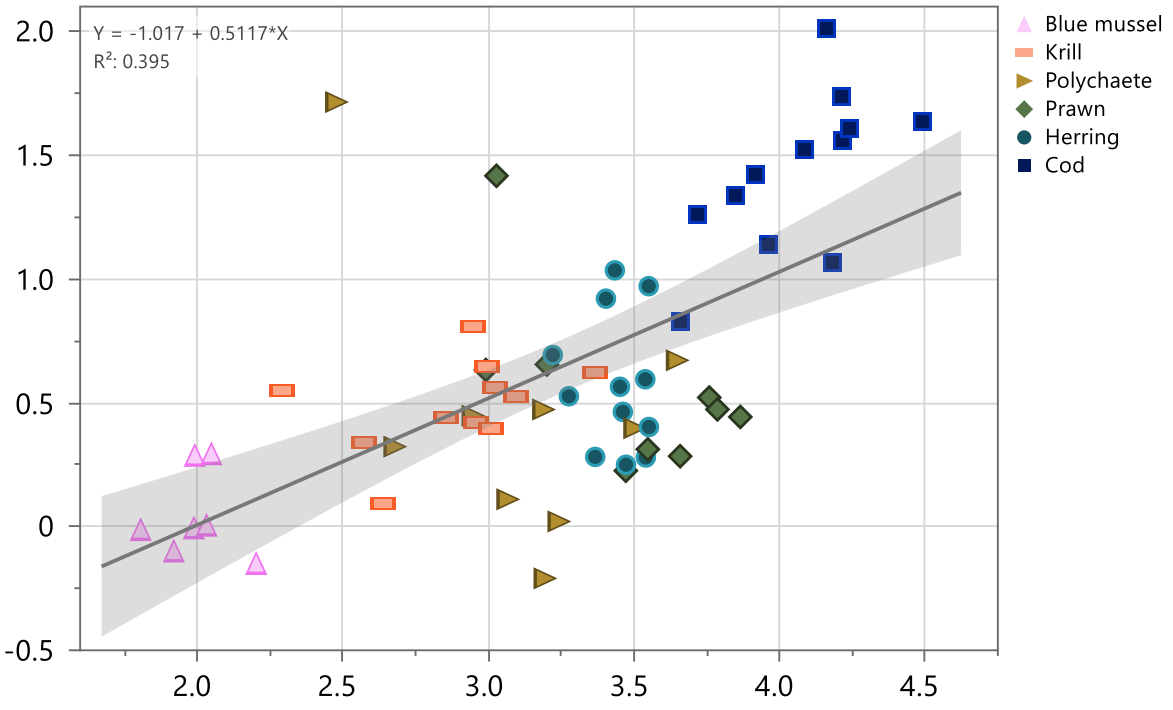


Figure 25 $\log_{10}$ BDE-100 lipid normalized against trophic position for all years (2017-2020). TMF=3.2.

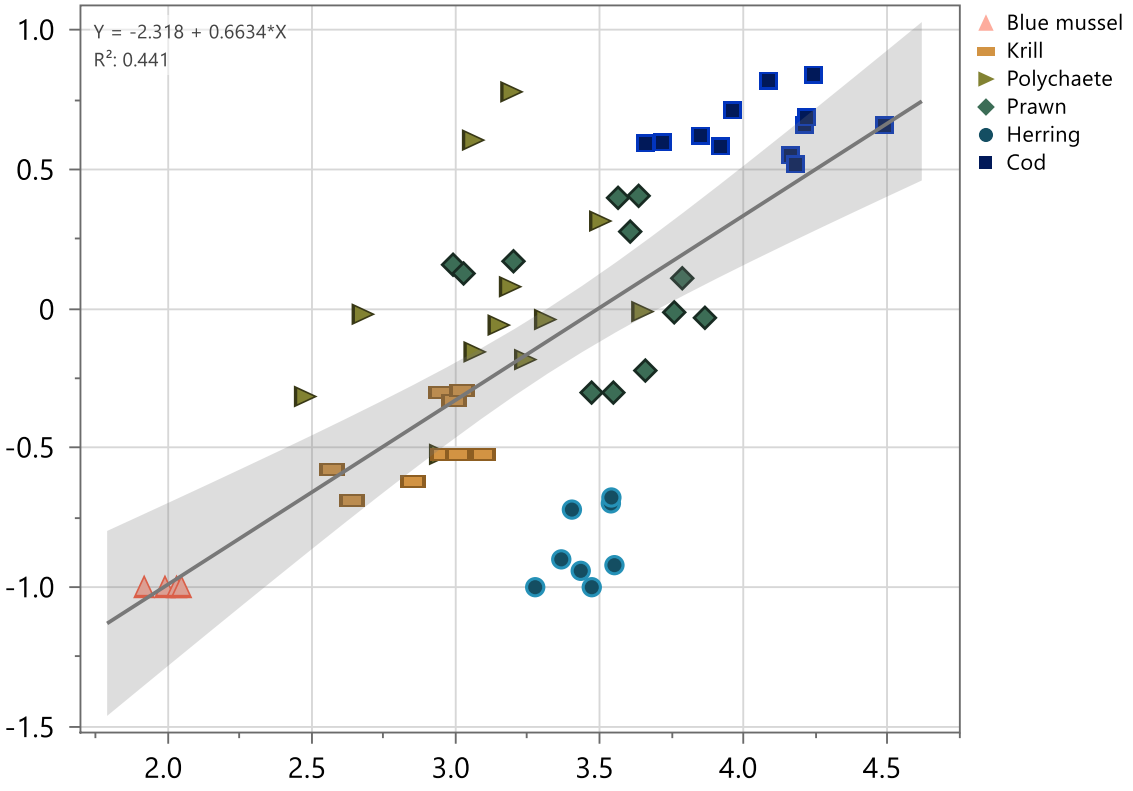


Figure 26 $\log_{10}$ PFOS (ww) against trophic position for all years (2017-2020). TMF =4.6.

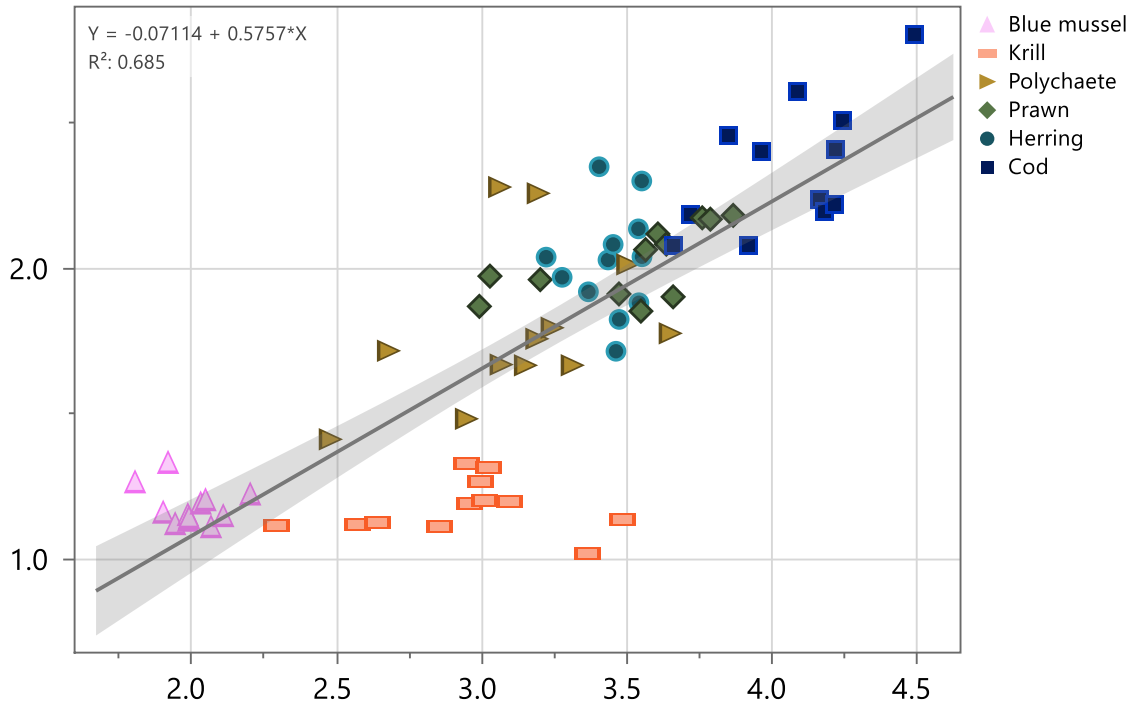


Figure 27 $\log_{10}$ Hg (ww) against trophic position for all years (2017-2020). TMF=3.8.

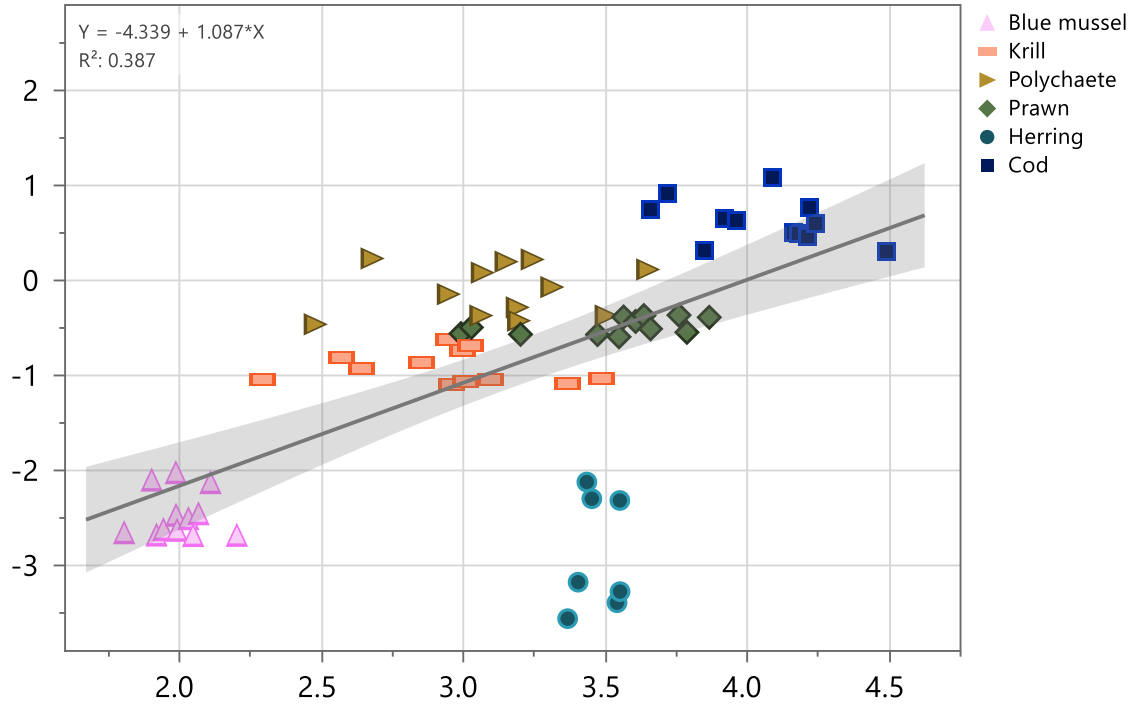


Figure 28 $\log_{10}$ Ag (ww) against trophic position for all years (2017-2020). TMF=12.

4.5 Cod

Environmental contaminants were analysed in 15 cod samples. A total of 40 individuals were sampled. Most of the environmental contaminants were determined in liver samples, however because of limited liver size, these samples had to be pooled according to table A5 in the Appendix. Hg and stable isotopes were determined in muscle tissue from individuals (table A5).

Here we present the data for environmental contaminants in cod liver (Hg in muscle) with boxplots (**Figure 29** to **Figure 37**) showing the median (mid box), standard error (box) and standard deviation (whiskers) together with the individual concentrations (points). Statistical data for the concentrations of environmental contaminants in cod liver (lipids, PCBs, PBDEs, nBFRs, siloxanes, phenolic compounds (n=3), chlorinated paraffins, metals (Hg in muscle), PFAS and UV compounds) and bile (phenolic compounds) from the Inner Oslo fjord are presented in Appendix (Tables A7 and A8, respectively).

No individual D5 concentration exceeded the EQS of 15000 ng/g ww (Direktoratsgruppen, 2018), Figure 29. Mean concentration of D5 in cod liver in 2020 was 1000 ng/g ww and 12000 ng/g lipid. These concentrations are higher than those found in brown trout from Lake Mjøsa (Jartun et al., 2020). In previous studies of cod from the Inner Oslofjord (e.g. Powell et al. 2018; Schlabach et al. 2007), D5 was, as in the present study, detected as the dominating siloxane compound. M3T(Ph) was found in cod liver, however, not in equally high concentrations as D4, D5 and D6. No significant change in the concentration of D5 could be detected in all the years siloxanes have been quantified in cod liver in the Urban fjord programme (Kruskal-Wallis test), and the variation has been high, see Ruus et al., 2020.

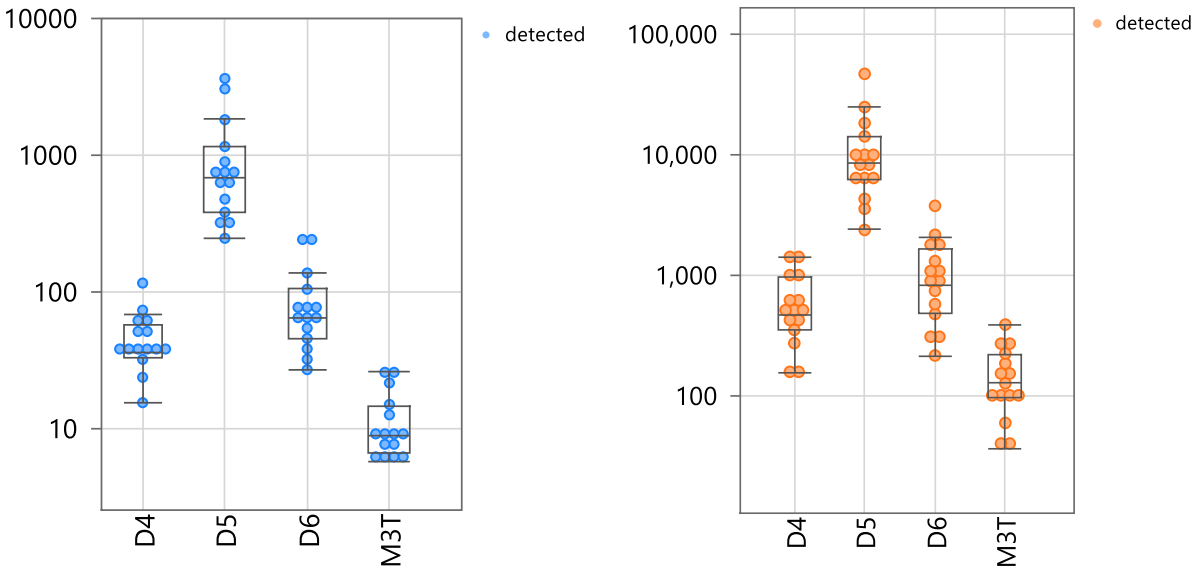


Figure 29 Boxplots of siloxanes in samples of cod liver in 2020; ng/g ww left (blue), ng/g lipid right (orange).

Concentrations of PBDEs in samples of cod liver are presented in **Figure 30**. Dominating PBDE congeners are BDE-47 and BDE-100, in accordance with previous studies (Ruus et al., 2020). EQS for BDE_6 (BDEs 28, 47, 99, 100, 153, 154) is 0.0085 ng/g ww, and all samples of cod liver exceed this concentration, with a mean BDE_6 concentration of 25 ng/g ww.

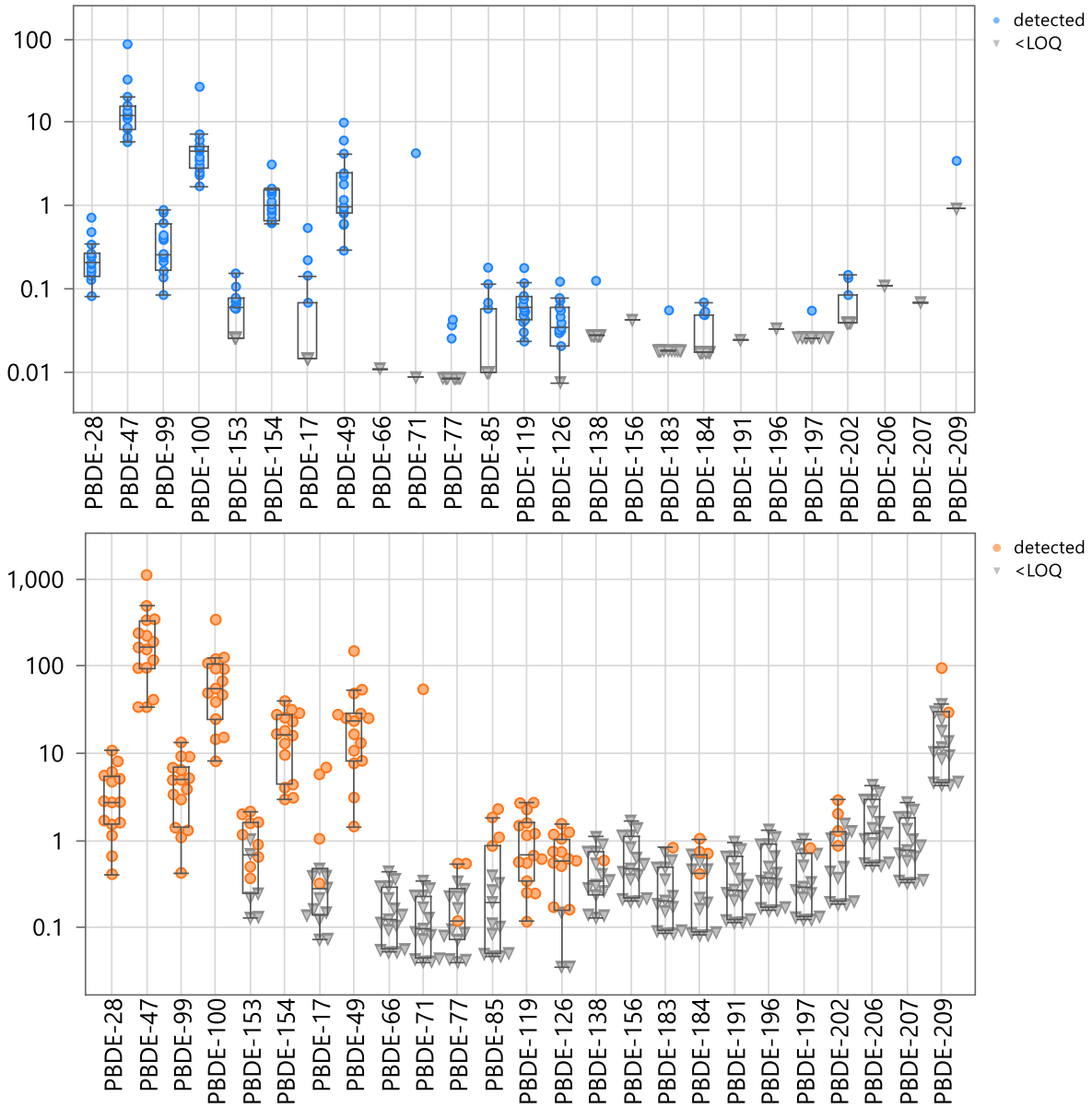


Figure 30 Concentrations of PBDEs in samples of cod liver in 2020 (ng/g ww top, ng/g lipid bottom) sorted according to median concentration on a ww basis. The BDE6 are to the left. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

Concentrations of PCBs in samples of cod liver in 2020 are presented in **Figure 31**. Dominating congeners are PCB 153 and 138 with mean ww concentrations of 645 and 440 ng/g ww, respectively. EQS in biota for PCB_7 is 0.6 ng/g ww, and all cod liver samples exceeded this value with concentrations ranging from 700 – 3580 ng/g ww.

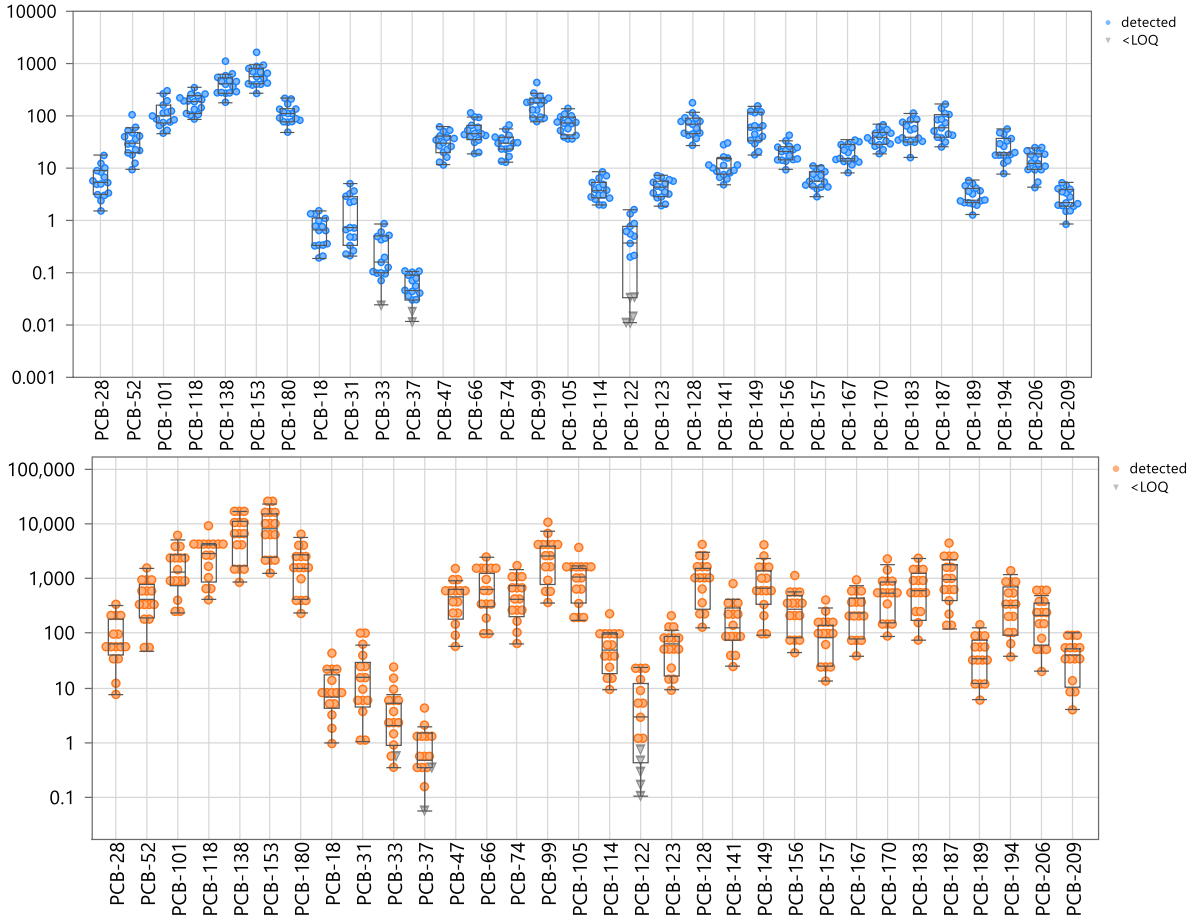


Figure 31 Concentrations of PCBs in samples of cod liver in 2020 in ng/g ww top, ng/g lipid bottom. The PCB7 are to the left. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

Concentrations of dominating PFAS compounds are presented in **Figure 32**. The precursor compound PFOSA and PFOS are dominating the PFAS pattern profile, with mean concentrations of 9.2 and 4.0 ng/g ww, respectively. These concentrations are lower than those observed in samples of brown trout liver in Lake Mjøsa (Jartun et al., 2019 and 2020). No individual samples of cod liver exceed the EQS for PFOS (9.1 ng/g ww).

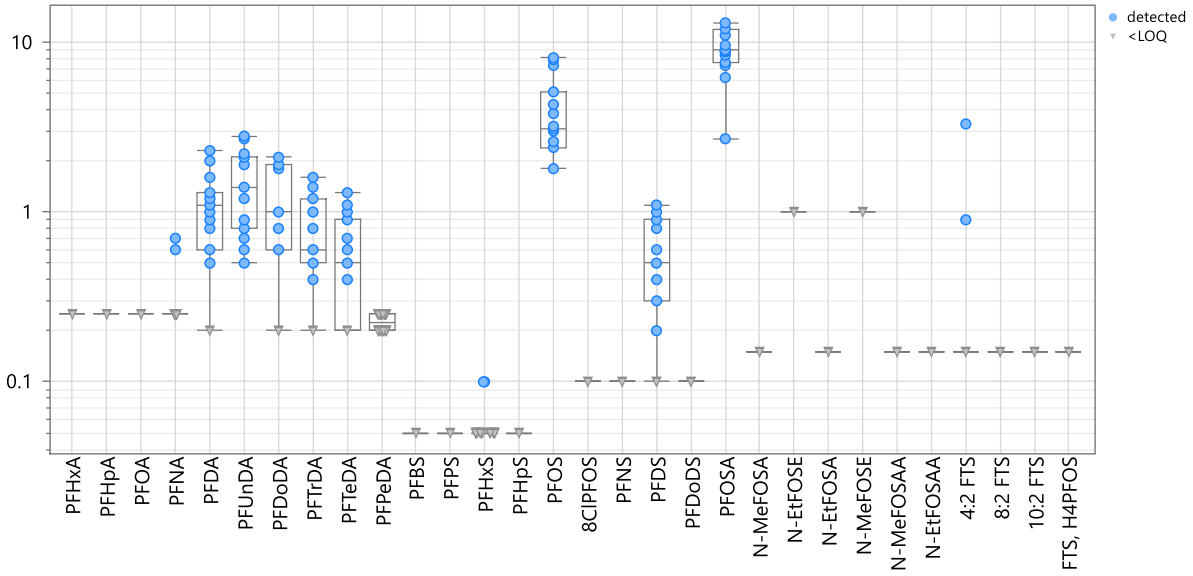


Figure 32 Concentrations of dominating PFAS compounds in cod liver in 2020 (ng/g ww). Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure. PFAS are ordered by group (PFCAs, PFSAs, PFASAs and FTSs) then in general by increasing fluorination.

Concentrations of UV compounds are presented in **Figure 33**. Dominating compounds are UV-328 and octocrylene with a detection frequency of 100 and 60 %, respectively. Mean concentrations for these two compounds were 10.3 and 5.2 ng/g ww, respectively. UV compounds are found in higher frequencies and concentrations in cod liver compared to e.g. brown trout from Lake Mjøsa (Jartun et al., 2020).

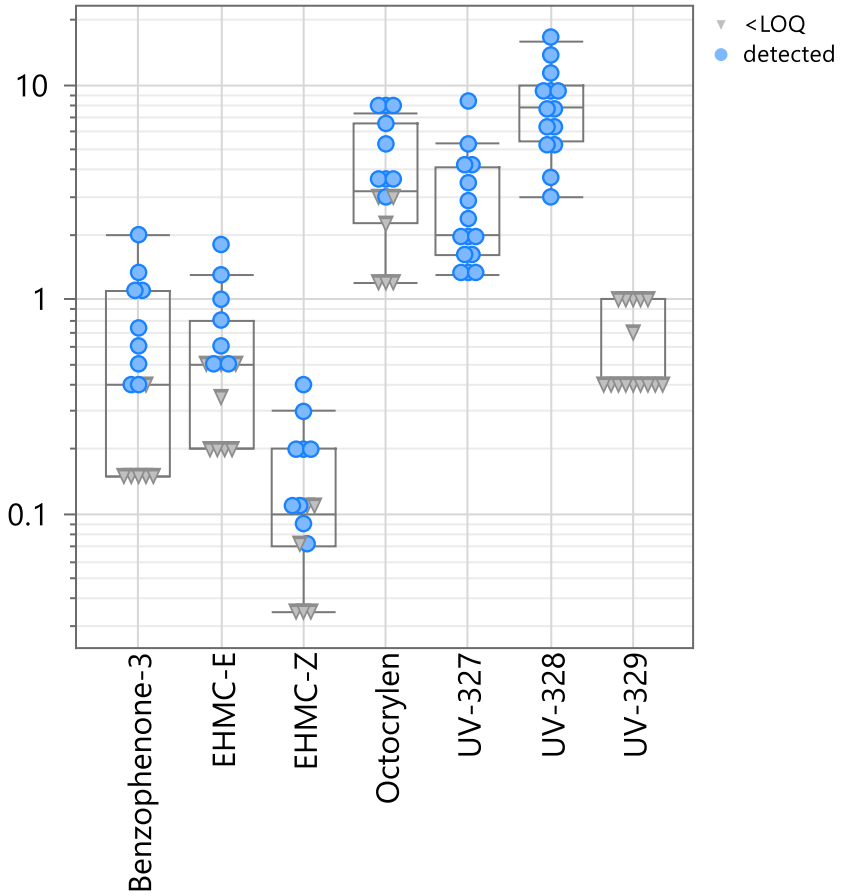


Figure 33 Concentrations of UV compounds in samples of cod liver (ng/g ww). Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

Concentrations of the elements Hg, Fe, Zn, As, Cu, Ag, Ni, Cd, Cr, Pb and Sb (µg/g ww) in samples of cod liver (Hg in muscle) in 2020 are presented in **Figure 34**. EQS is only defined for Hg of these metals (20 ng/g ww) and all samples of cod muscle exceeded this value.

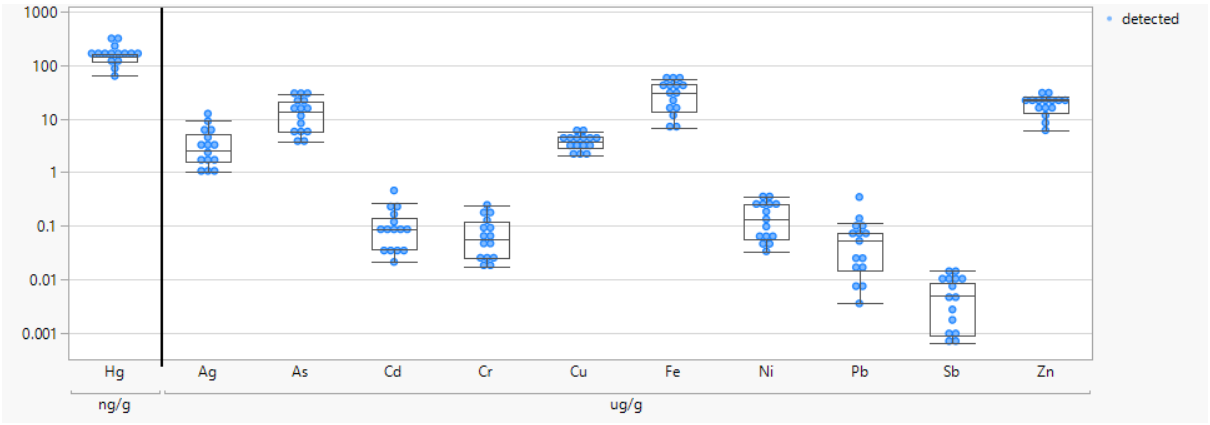


Figure 34 Concentration of metals in samples of cod liver in 2020 (Hg in muscle and ng/g; see figure for measurement units). Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

A statistically significant relationship (p=0.02) was found between log Hg in cod muscle and fish length (log cm), as presented in **Figure 35**. Similar positive relationship has previously been found in the Urban fjord program (Ruus et al., 2020). Co-variation between fish length and Hg-concentrations is well known (e.g. Eikenberry et al. 2015; Green and Knutzen, 2003; Jones et al. 2013; Julshamn et al. 2013; Sackett et al. 2013), and Jones et al. (2013) have also argued that detecting the influence of changes in Hg exposure will depend on how well fish biometrics (length, age and growth rates) are considered.

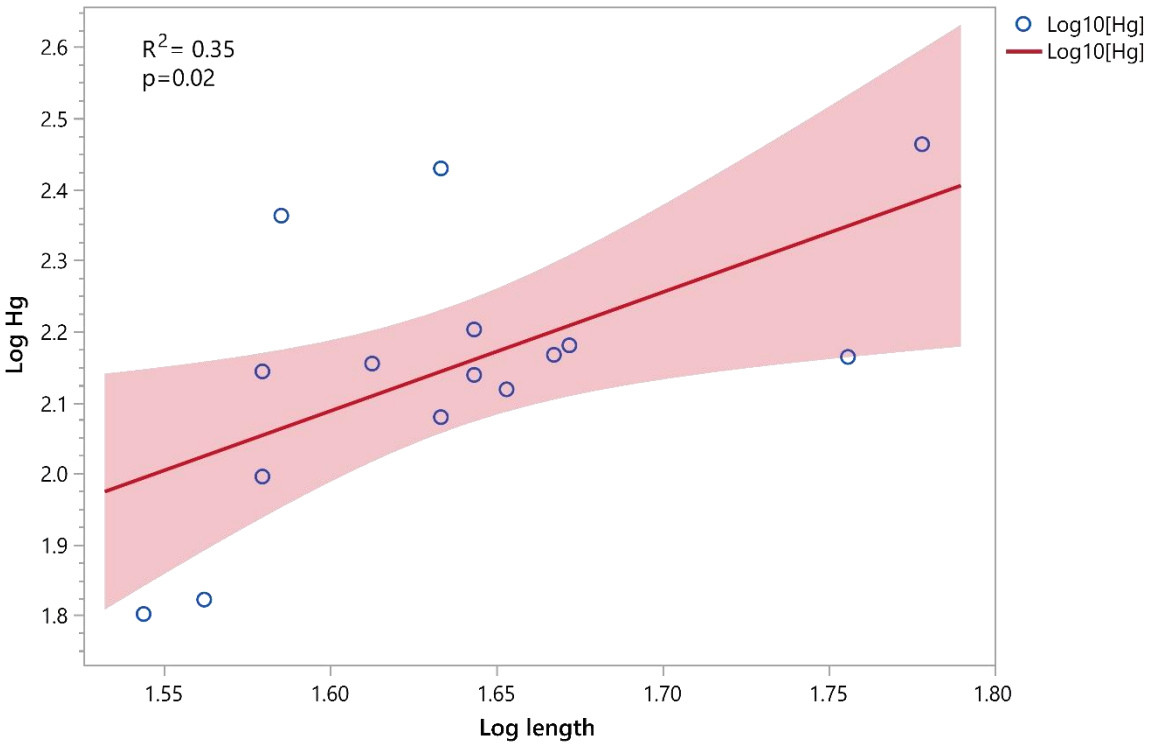


Figure 35 Concentration of Hg (ng/g ww; log transformed) in samples of cod muscle against length (cm; log transformed).

Phenolic compounds were determined in samples of cod bile, and concentrations are presented in **Figure 36**. 4,4-bisphenol-A was the dominant compound with a mean concentration of 78 ng/g ww. EQS for 4-tert-octylphenol was exceeded in two samples.

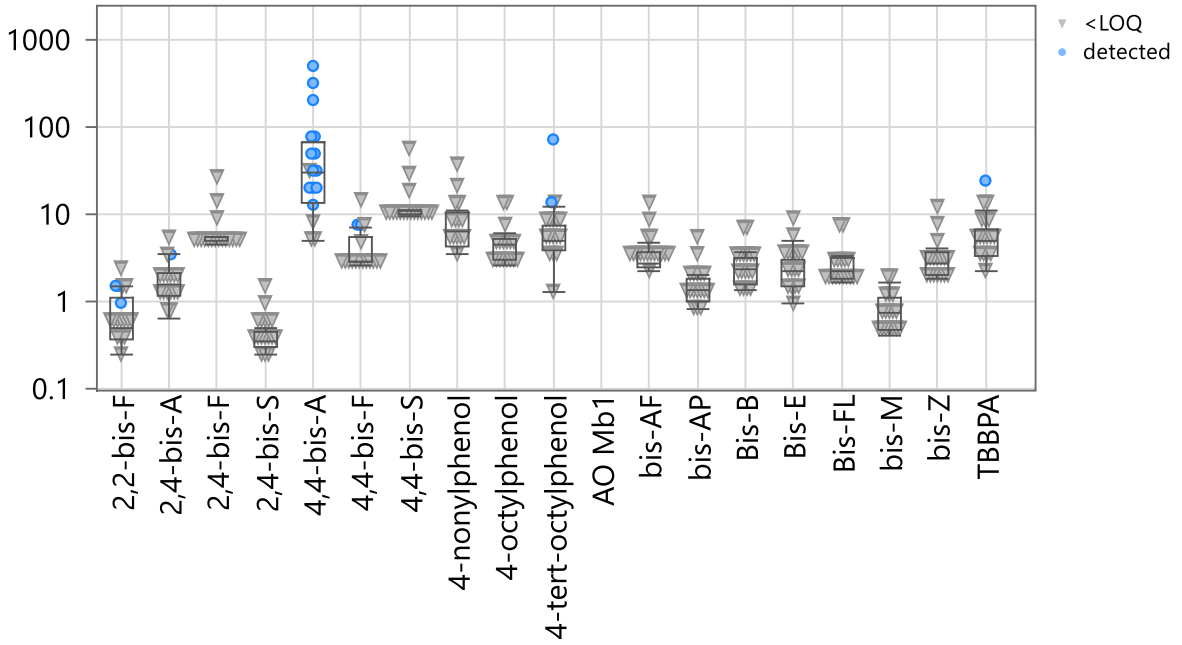


Figure 36 Concentrations (ng/g ww) of bisphenols in samples of cod liver in 2020. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

Concentrations (ng/g ww) of chlorinated paraffins in samples of cod liver are presented in **Figure 37**. MCCP is the dominant compound, although with a detection frequency of 2/15. One of the samples (370 ng/g ww) exceeded the EQS biota for MCCP.

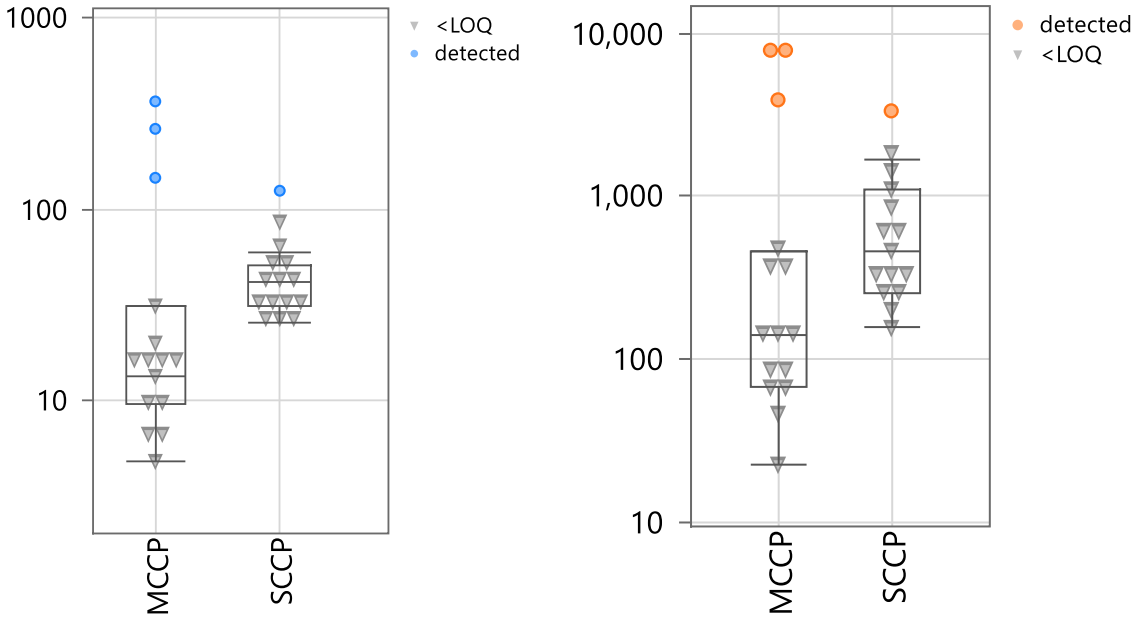


Figure 37 Concentration of chlorinated paraffins (ng/g ww left and ng/g lipid) in samples of cod liver in 2020. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.6 Herring gull

Concentrations of environmental contaminants in herring gull were determined in eggs (n=14) and blood (n=15), and all results are presented with mean, range and number of detections in table A9 in the Appendix.

4.6.1 Lipid content

Both blood and egg were sampled from herring gull, n=15 and N=14, respectively. Adult female blood and egg was sampled from the same nest (i.e. mother and future offspring). The lipid content of blood was 1.0 %, while that of eggs was significantly higher (8.4%). The mean difference between the female/egg pairs was 7.4 (%). The matched pairs analysis is shown in **Figure 38**.

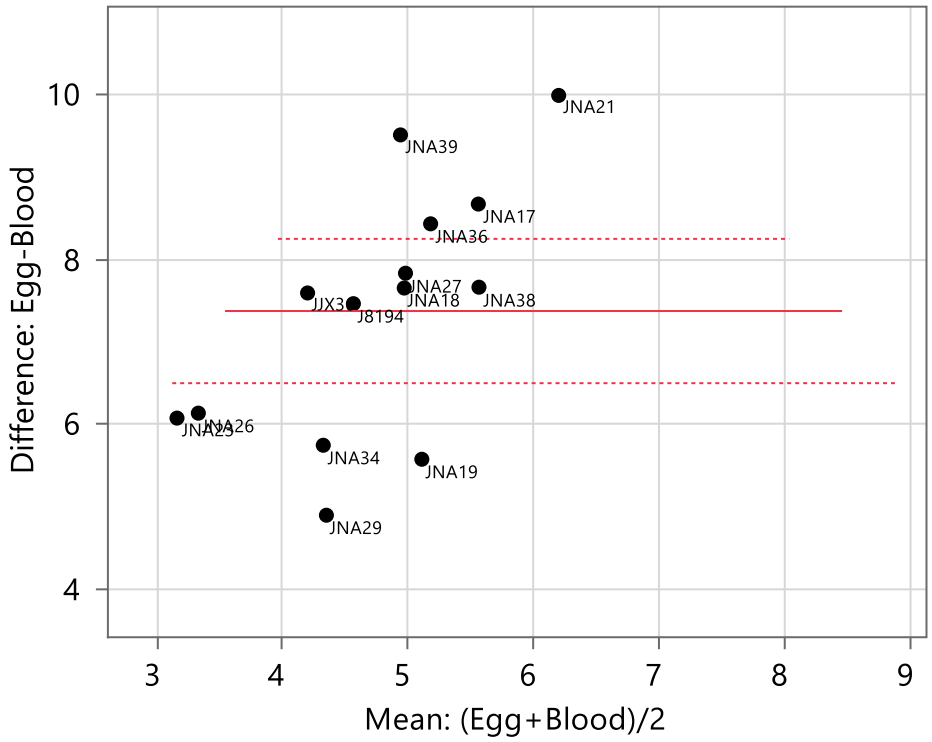


Figure 38 Difference in lipid content between eggs and blood shown by matched pairs *Inner Oslofjord.* Egg/females are labelled with their assigned name.

4.6.2 PBDE and brominated compounds

The PBDE congeners displaying the highest concentrations in herring gull from the Inner Oslofjord (both blood and eggs) were BDE-209, -99 and -47, although variability was high (**Figure 39**), and table A9. This corresponds with previous observations from the Urban fjord programme. As also observed/mentioned earlier, the concentrations of PBDEs (e.g. BDE-47 and -209) in herring gull eggs from the present study displayed concentrations that were higher than those observed in herring gull eggs from remote colonies in Norway (Sklinna and Røst; Huber et al. 2015) some years ago, indicating urban influence. It can also be mentioned that according to Gentes et al. (2015), intraspecific forage strategies have strong influence on the PBDE accumulation in gulls, and that foraging on waste

management facilities particularly results in higher BDE-209 exposure. The mean concentration (wet weight) of BDE-209 in the herring gull eggs was markedly higher than what was observed in eggs of sparrow hawk (a small bird of prey feeding on small to medium sized birds) from the Oslo area, while other congeners, such as BDE-47 appeared similar, or slightly lower (Heimstad et al. 2019; The Norwegian Environment Agency M-1402). As mentioned, BDE-47 is bioaccumulative and recalcitrant against degradation, and is a major constituent of the penta-BDE mixture (De Wit, 2002). Furthermore, BDE-47 is a degradation product from the debromination of higher brominated PBDEs (including BDE-209), and Roberts et al. (2011) describe species-specific differences in debromination of PBDEs.

Other brominated compounds are shown in **Figure 41**. Differences between the compounds observed in blood and eggs were found. In previous years, the DBDPE which is a substitute for BDE-209 in the market, was found in high concentrations in herring gulls. This year the LOQ for DBDPE was higher than previous years and could therefore not be determined >LOQ in 2020.

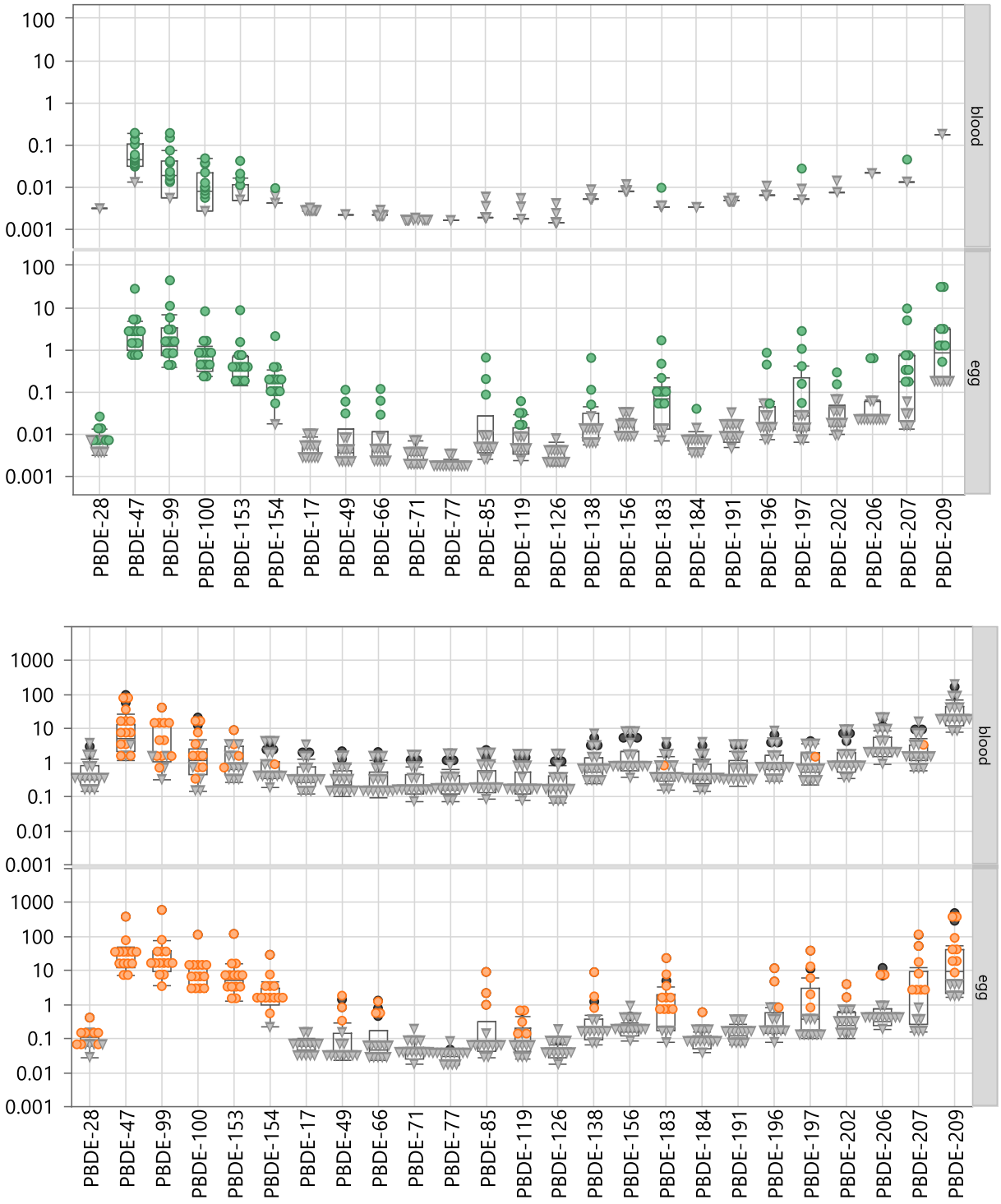


Figure 40. Boxplot of concentrations of PBDEs (ng/g ww (top); ng/g lipid (bottom)) in herring gull (blood and eggs) from the Inner Oslofjord. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

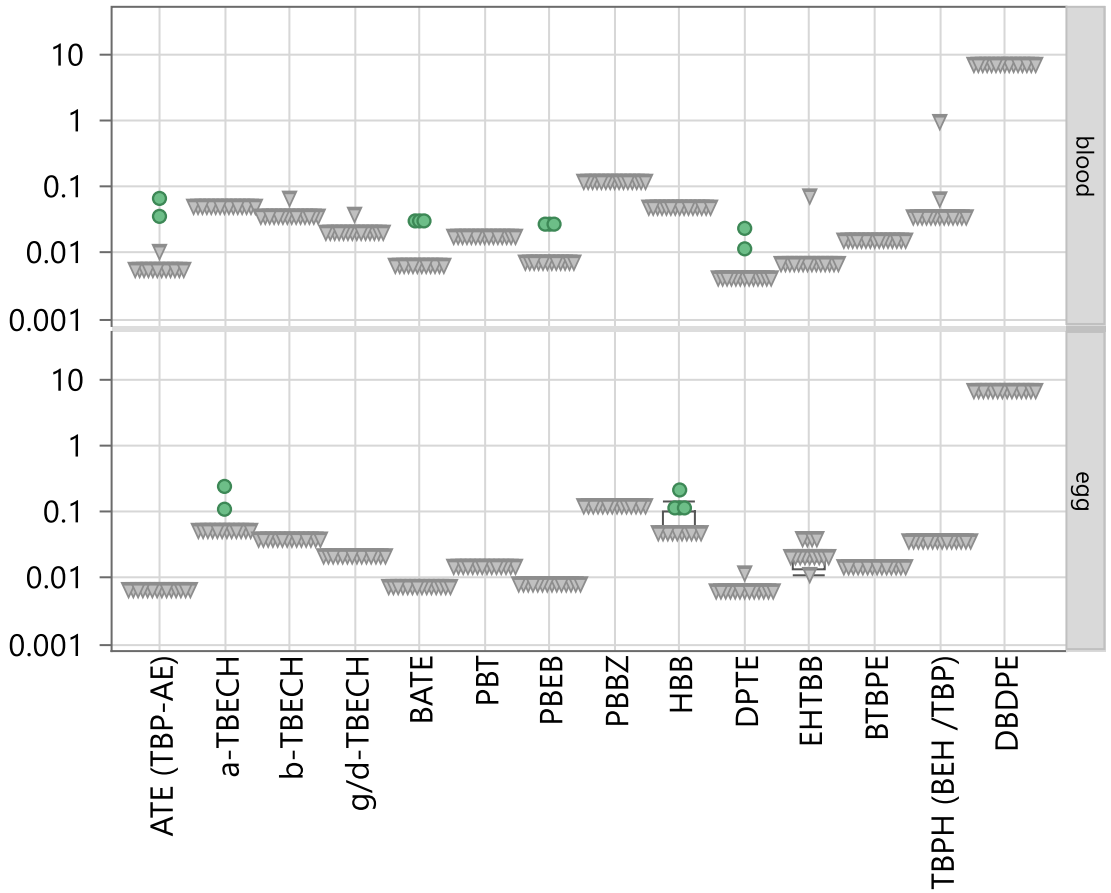


Figure 41 Concentrations of other brominated compounds in herring gull blood and egg (ng/g ww). Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.6.3 Siloxanes

Siloxanes were detected in eggs and blood of herring gull from the Inner Oslofjord (**Figure 42**) and the variability was high in both matrices, see also table A9. D5 displayed the highest concentrations in eggs. This corresponds with previous observations from the Urban fjord programme (Ruus et al., 2020; Ruus et al. 2019b; Ruus et al. 2019a; Ruus et al. 2017; Ruus et al. 2016; Ruus et al. 2015a; Ruus et al. 2014; The Norwegian Environment Agency M-1766, M-1441, M-1131, M-812, M-601, M-375 and M-205). M3T(Ph) was detected in 9 eggs and not detected in blood (**Figure 42**).

As observed/mentioned earlier (Ruus et al. 2015a; Ruus et al. 2016; Ruus et al. 2017; Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-375, M-601, M-812, M-1131, M-1441 and M-1766), mean D5 concentration in eggs from the Oslofjord area (present study) was notably higher than those observed in herring gull eggs from remote colonies in Norway (Sklinna and Røst; Huber et al. 2015) some years ago, indicating urban influence. As earlier observed the mean concentration of siloxanes in the herring gull eggs from the Oslofjord area appeared higher, and were detected in more samples, compared to of sparrow hawk (*Accipiter nisus*) from the Oslo area (Heimstad et al. 2019; The Norwegian Environment Agency M-1402). This may also reflect that while the sparrow hawk feeds mostly on birds, the herring gull might feed on human waste and leftovers.

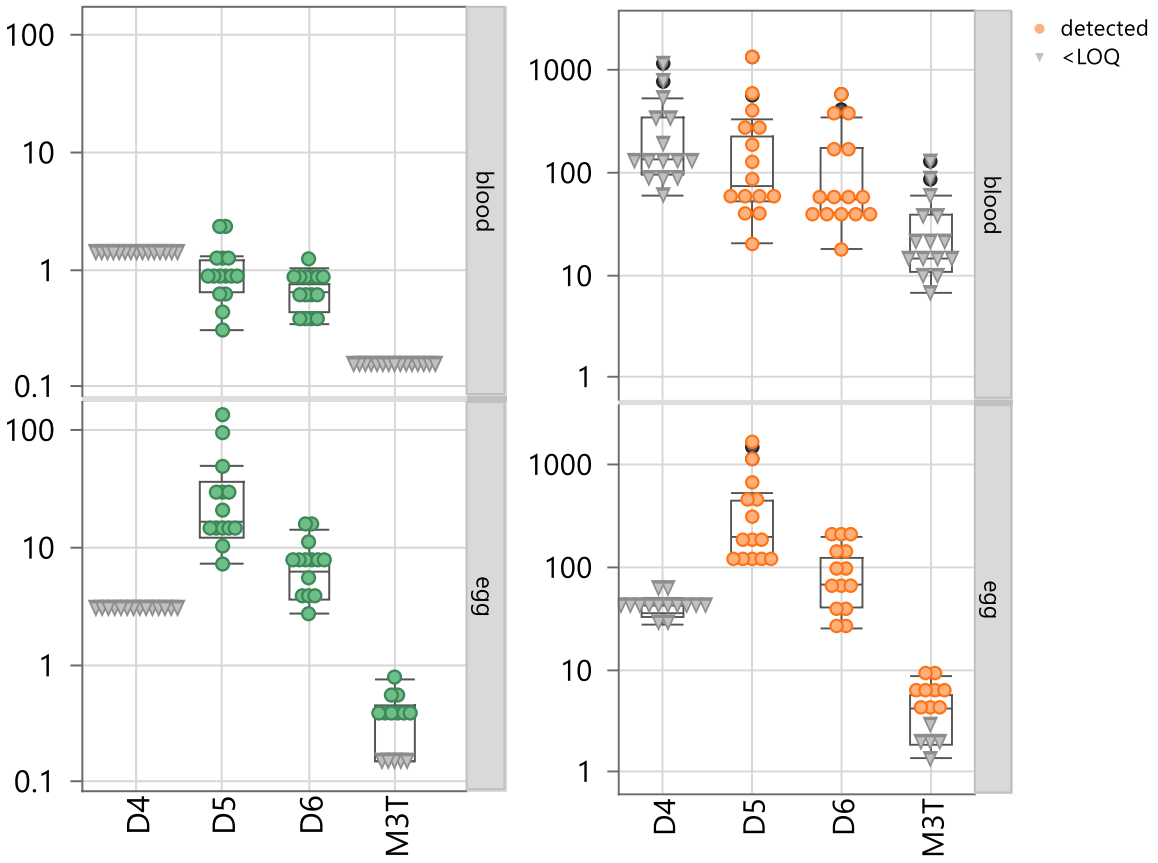


Figure 42. A. Concentrations of siloxanes (ng/g ww (green) and ng/g lipid wt. (orange)) in herring gull (blood and eggs) from the Inner Oslofjord. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.6.4 PCBs

As previously observed, concentrations of "legacy" contaminants, such as PCB-153 and Sum PCB_7 appeared lower in the eggs from Oslofjorden (**Figure 43**), than those observed in herring gull eggs from remote colonies in Norway (Sklinna and Røst; Huber et al. 2015). This suggests that these contaminants (associated with diffuse pollution) accumulate to somewhat higher concentrations in gulls foraging to a larger degree on marine prey organisms. However, the concentrations of PCBs in the sparrow hawk eggs from the Oslo area (Heimstad et al. 2019; The Norwegian Environment Agency M-1402) appeared higher than in the herring gull eggs from the Oslofjord area. This was also observed in previous surveys (Ruus et al. 2017; Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-812, M-1131, M-1441 and M-1766). No change in the concentration of D5 could be detected in all the years siloxanes have been quantified in herring gull eggs in the Urban fjord programme (Kruskal-Wallis test), and the variation has been high some years.

The consistent herring gull results between years in the "Urban fjord" programme, suggest the suitability of this species to study urban influence. In this regard, it is important to acknowledge that with the opportunistic feeding habits of herring gull, urbanization implies a shift towards less marine diet items and more diet items of terrestrial/anthropogenic origin. This is discussed in more detail by Thorstensen et al. (2021).

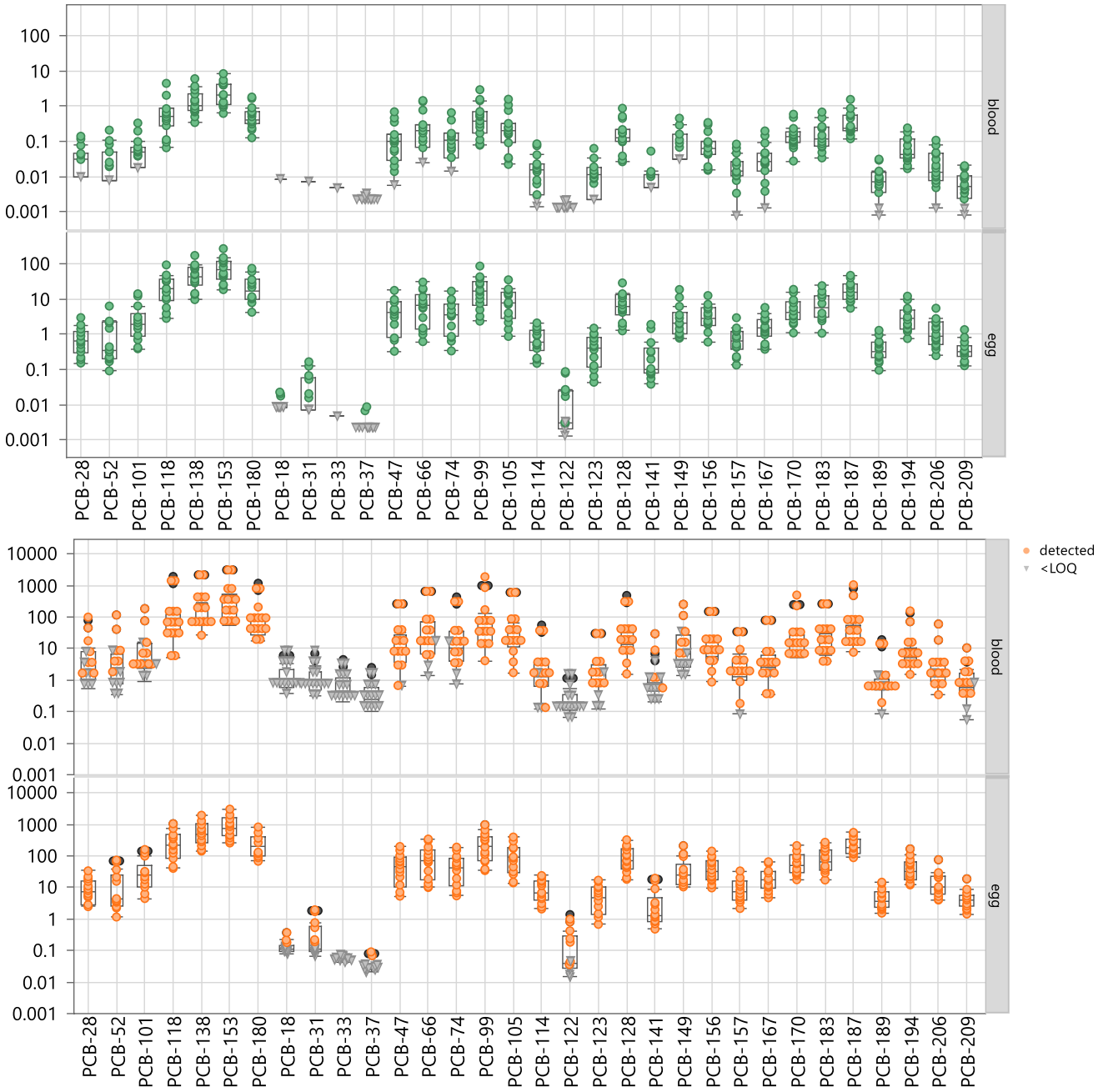


Figure 43 Concentrations (ng/g) of PCBs in herring gull blood and egg on a ww basis (top), and lipid weight (bottom). Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.6.5 Chlorinated paraffins

Chlorinated paraffins (SCCP and MCCP) were detected in eggs and blood of herring gull from the Inner Oslofjord (**Figure 44**) and the variability was high in both matrices. MCCP was the dominating compound in blood (ww and lipid normalized), whereas the mean concentrations were on the same level for these two CPs in eggs.

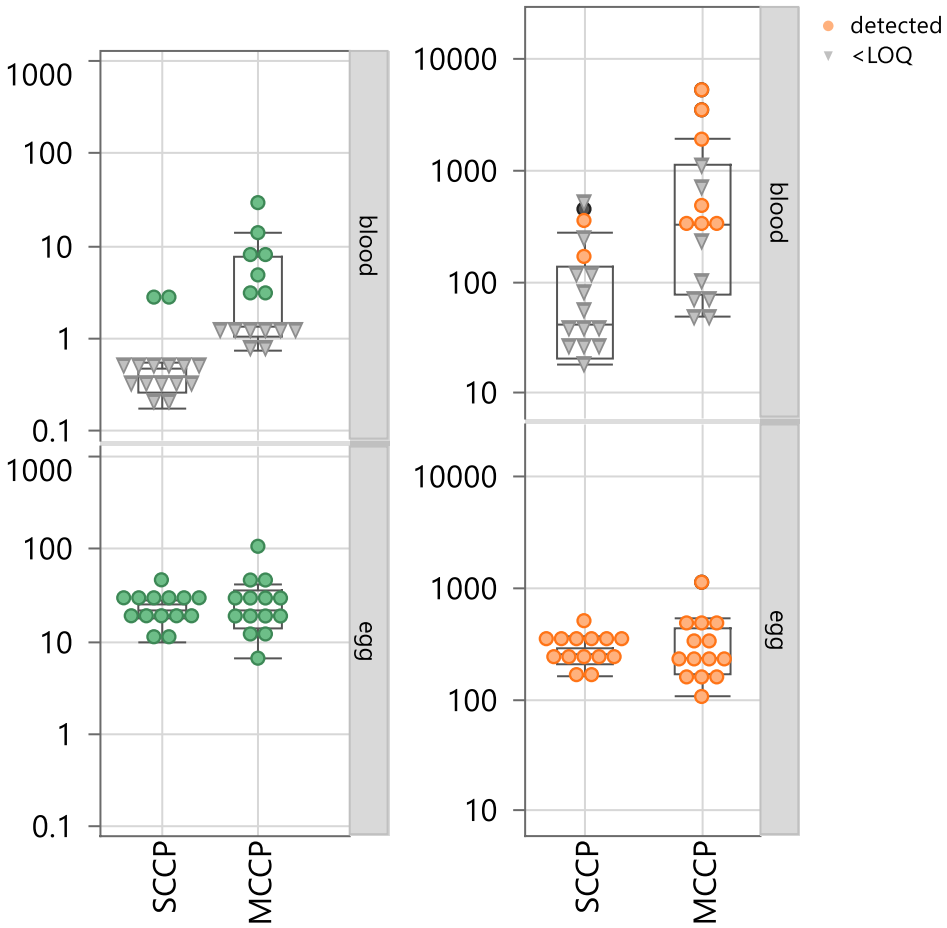


Figure 44 Concentrations (ng/g) of chlorinated paraffins in herring gull blood and egg on a ww basis (left) and lipid normalized (right). Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.6.6 PFAS

PFAS compounds were also detected in eggs and blood of herring gull from the Inner Oslofjord (**Figure 45**), and table A9. PFOS constituted the highest concentrations in both matrices. The variability was high. This corresponds with previous observations from previous finding in the Urban fjord programme. PFOS was also the dominating PFAS compound in sparrow hawk eggs from the Oslo area (Heimstad et al. 2019; The Norwegian Environment Agency M-1402). Furthermore, the PFOS concentrations were higher in sparrow hawk eggs, than in herring gull eggs. This corresponds with earlier observations (Ruus et al. 2017; Ruus et al 2019a; Ruus et al 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-812, M-1131, M-1441, M-1766).

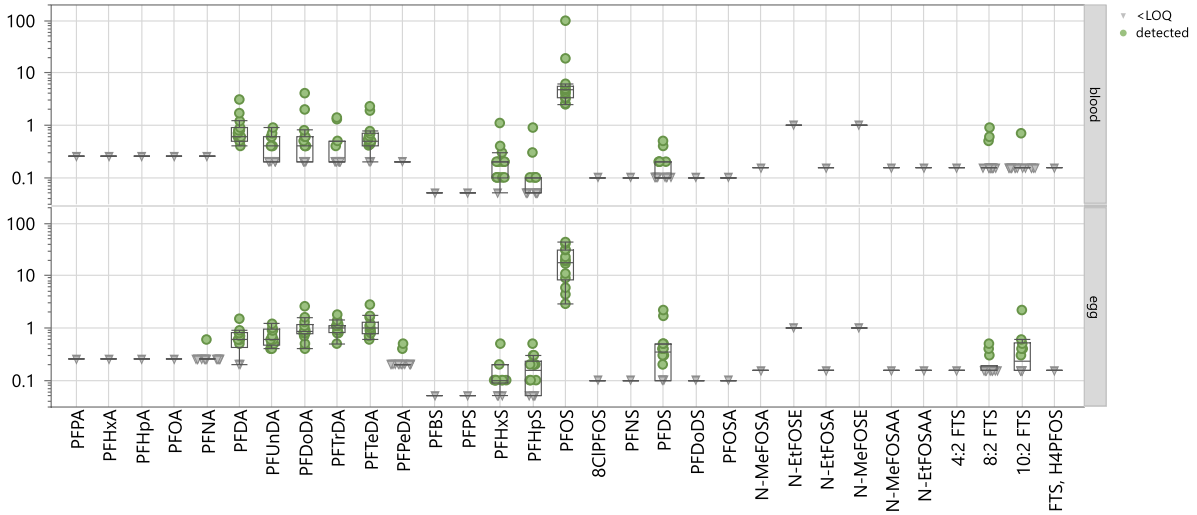


Figure 45. A. Concentrations (ng/g wet wt.) of PFAS in herring gull (blood and eggs) from the Inner Oslofjord. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.6.7 Other compounds

Concentration ranges for UV-compounds in herring gull (blood and eggs) are shown in **Figure 46**. Highest observed concentrations were octocrylene in blood samples, but LOQ were quite high. UV-328 was detected in a larger number of samples, but with great variability in both blood and egg samples.

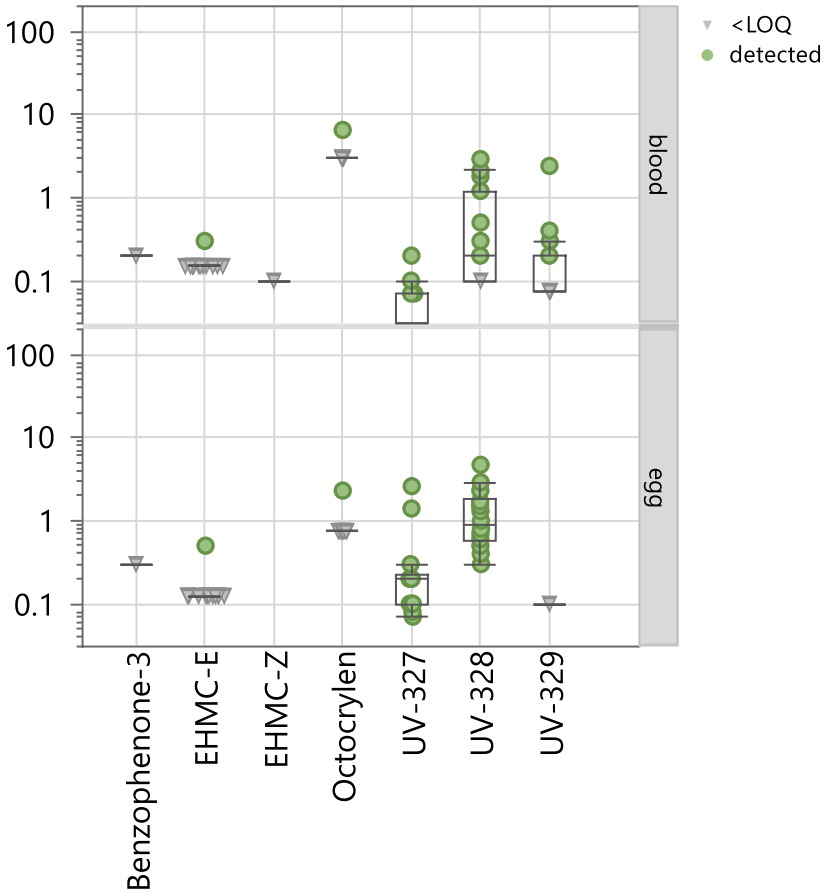


Figure 46 Concentrations (ng/g ww) of UV compounds in samples of herring gull blood and egg. See also table A9. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

Concentrations of metals in herring gull blood and eggs are provided in **Figure 47**. For Hg, concentrations are higher in blood samples (mean 65; range 8 – 170 ng/g ww) compared to eggs (mean 39; range 8 – 110 ng/g ww). Ag is almost exclusively found in eggs, and only one detection above LOQ in blood.

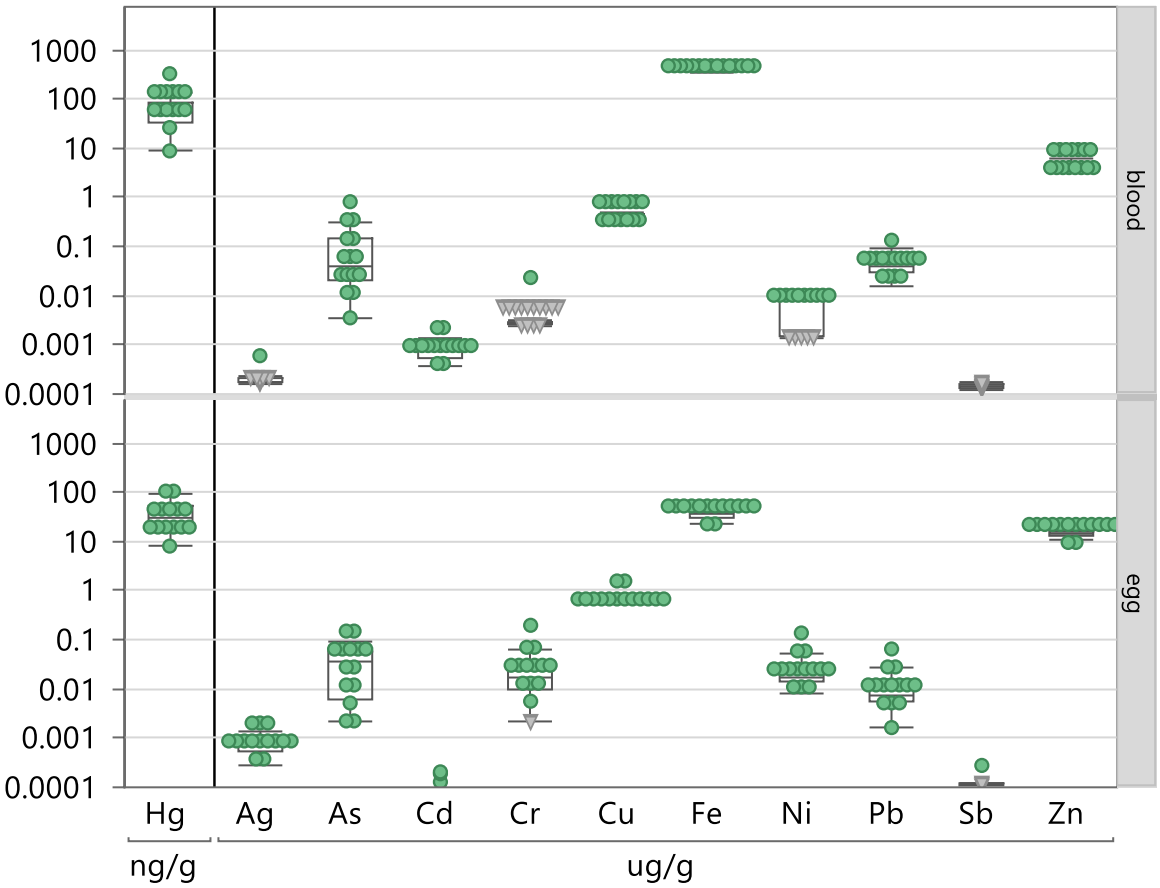


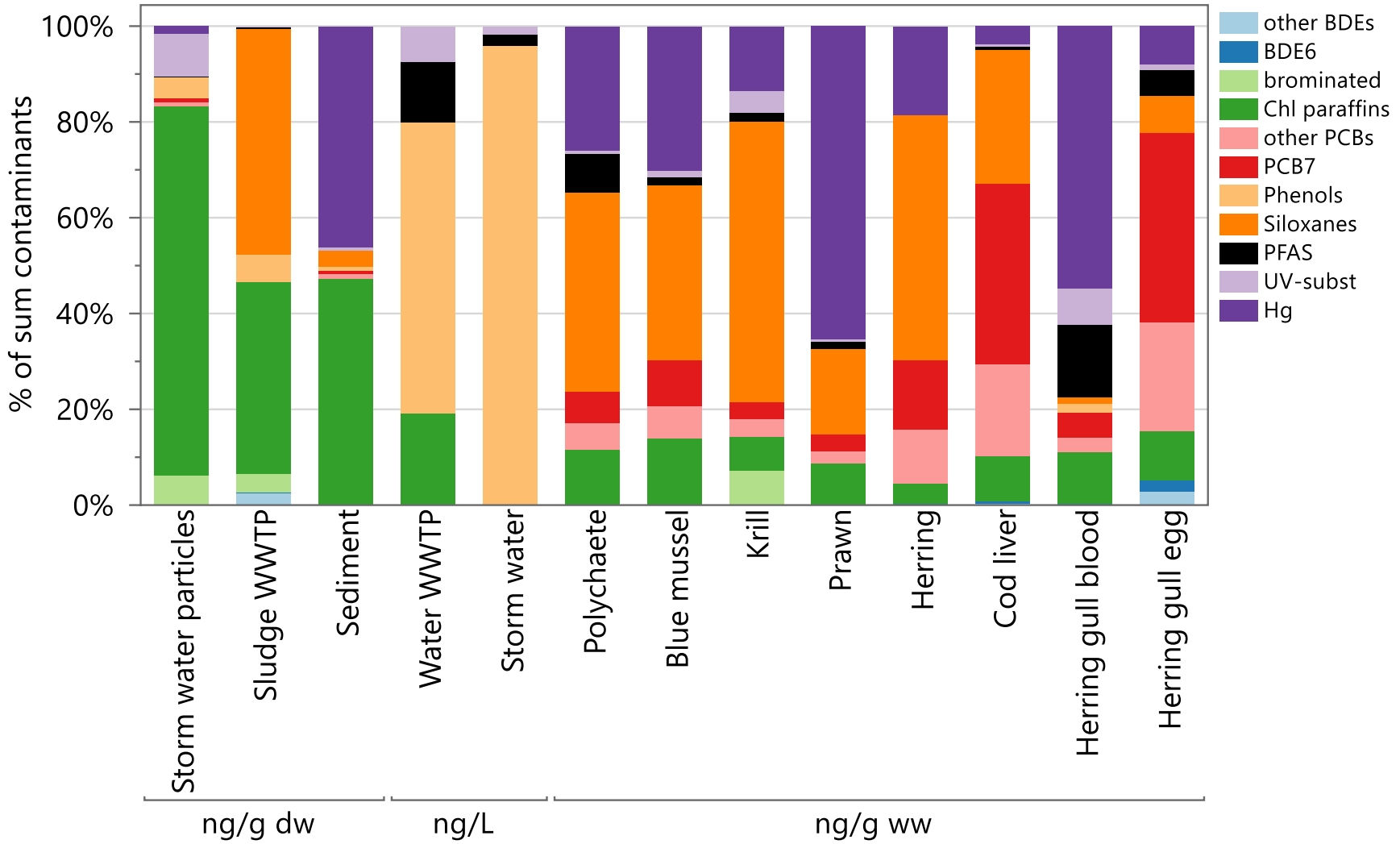
Figure 47 Concentrations of metals measured in herring gulls in µg/g ww. Data below LOQ is replaced with a value of LOQ/2 and are represented with a grey triangle in the figure.

4.7 Interspecies and matrix comparisons

In terms of sources and sinks of contaminants in the marine ecosystem of the Inner Oslofjord, it is of interest to give general impression of the dominating contaminants/groups of contaminants in the different species and matrices analysed. **Figure 48** shows relative contribution of selected contaminants/groups of contaminants to the sum of these contaminants/groups of contaminants in stormwater (dissolved and particulate fractions) entering the Oslofjord, sediments of the Inner Oslofjord, and polychaetes, blue mussel, krill, prawns, herring and cod (liver) from the Inner Oslofjord, as well as in effluent water (entering the Oslofjord) and sludge from Bekkelaget WWTP. The selected contaminants were BDE_6, other PBDEs, new brominated flame retardants, chlorinated paraffins (sum of SCCPs and MCCPs), sum PCB_7, other PCBs, sum siloxanes, sum phenolic compounds, Hg, sum PFAS compounds and sum UV compounds.

Chlorinated paraffins apparently constitute major proportions of the sum of contaminants in the particulate fraction of stormwater and sediments, as well as in wastewater sludge and mussels (**Figure 48**). PCBs and PBDEs do not constitute very high (< 4%) proportions of the sum of contaminants, except for PCBs in the lipid rich tissues cod liver and Herring gull eggs (**Figure 48**). Siloxanes (not analysed in stormwater) constituted major proportions of the sum of contaminants in sludge from the WWTP, as well as in organisms in the Inner Oslofjord marine food web. Siloxanes constituted >30% of the sum of contaminants in polychaetes, krill and herring, as well as in WWTP sludge (**Figure 48**). Phenolic compounds constituted major proportions of the sum of contaminants in stormwater (especially the dissolved fraction; **Figure 48**). Hg (not analysed in samples from the WWTP) constituted major proportions of the sum of contaminants in sediments and organisms from the Inner Oslofjord, especially in shrimp and herring gull blood (**Figure 48**). PFAS compounds constituted >5% of the sum of contaminants only in herring gull blood and effluent water from the WWTP (**Figure 48**). As such, the pattern was relative similar to those previously observed (Ruus et al. 2019a; Ruus et al. 2019b; Ruus et al., 2020; The Norwegian Environment Agency M-1131, M-1441 and M-1766), however, the proportion/concentration of phenolic compounds in WWTP effluent water appeared notably higher in 2019 than in 2020, and the proportion of PFASs were higher in 2020 (**Figure 48**).

A.


% of sum contaminants
100%
80%
60%
40%
20%
0%
other BDEs
BDE6
brominated
Chl paraffins
other PCBs
PCB7
Phenols
Siloxanes
PFAS
UV-subst
Hg
Storm water particles
Sludge WWTP
Sediment
Water WWTP
Storm water
Polychaete
Blue mussel
Krill
Prawn
Herring
Cod liver
Herring gull blood
Herring gull egg
ng/g dw
ng/L
ng/g ww

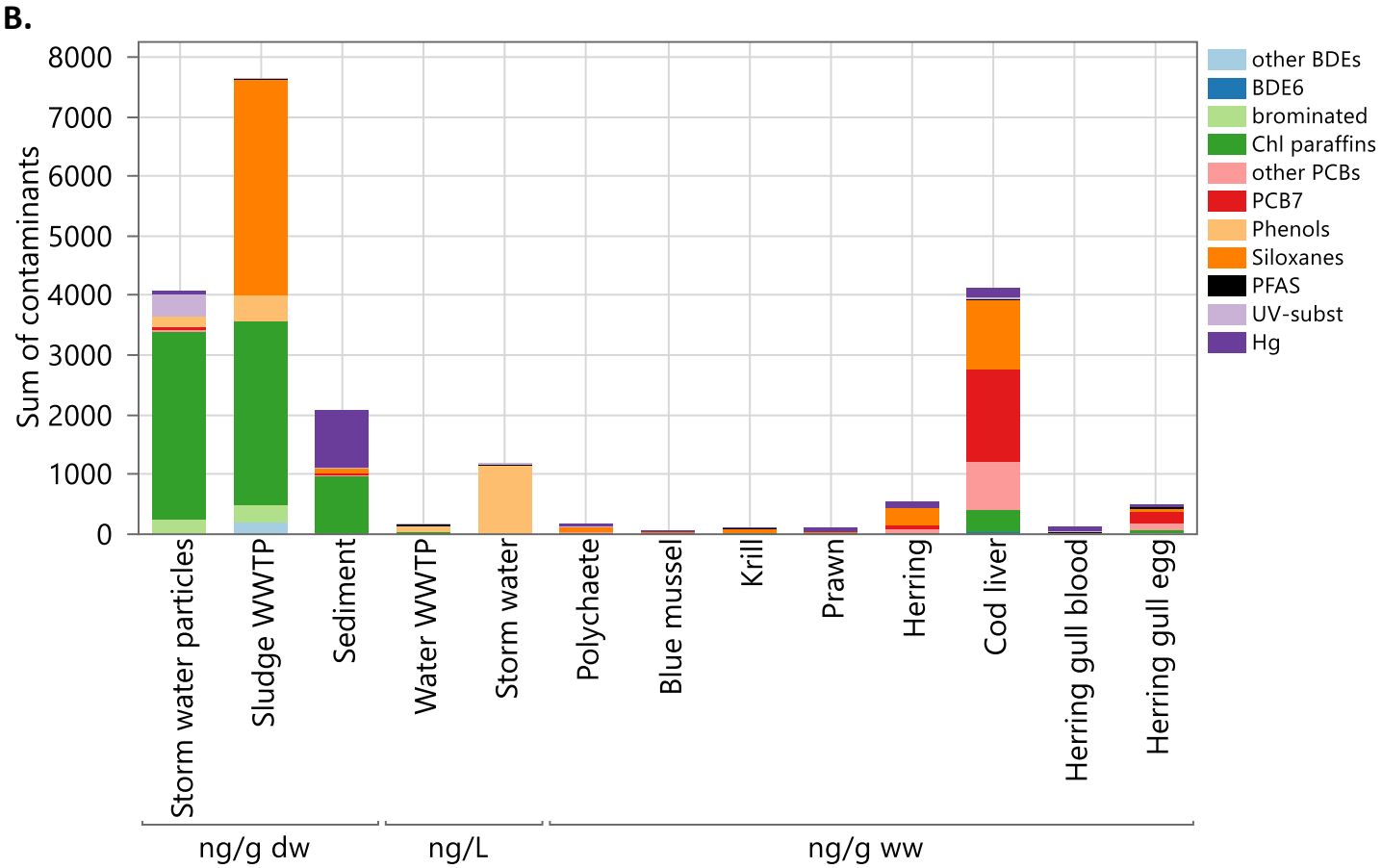


Figure 48. Relative contribution of selected contaminants/groups of contaminants to the sum of these contaminants/groups of contaminants (A.), as well as concentrations (B.), in stormwater (dissolved and particulate fractions) entering the Oslofjord, sediments of the Inner Oslofjord, and polychaetes, blue mussel, krill, prawns, herring and cod from the Inner Oslofjord, as well as in effluent water (entering the Oslofjord) and sludge from Bekkelaget WWTP. Note that PFRs were only analysed in samples from the WWTP, phenolic compounds were only analysed in cod, stormwater and WWTP samples, siloxanes were not analysed in stormwater, PCBs and Hg were not analysed in samples from the WWTP. In herring muscle tissue is analysed, while in cod Hg is analysed in muscle, phenolic compounds are analysed in bile, and other compounds are analysed in liver.

4.8 Support parameters

Miscellaneous support parameters were measured for the different matrices/samples/organisms: Particle fraction <63 µm (% dry wt.) and TOC (µg/mg dry wt.) in sediment, suspended solids (mg/L) in stormwater, $\delta^{13}C$, $\delta^{15}N$, C:N (W%), trophic position (deduced from $\delta^{15}N$,) and weight of egg (g) for herring gull eggs from the Inner Oslofjord, $\delta^{13}C$, $\delta^{15}N$, C:N (W%), trophic position (deduced from $\delta^{15}N$), wing length (mm), head length (mm) and body mass (g) for herring gulls (blood) from the Inner Oslofjord, $\delta^{13}C$, $\delta^{15}N$, C:N (W%), trophic position (deduced from $\delta^{15}N$), age (yr), body length (cm), body mass (g), liver weight (g), gonad weight (g) and sex of cod from the Inner Oslofjord, and $\delta^{13}C$, $\delta^{15}N$, C:N (W%) and trophic position (deduced from $\delta^{15}N$) of the organisms of the Inner Oslofjord food web. The measurements of these support parameters are presented in Tables A1-A6 in the Appendix.

5 Concluding remarks

In this programme, a large number of chemical parameters have been quantified, in addition to a few biological effect parameters and support parameters. Concentrations of various chemicals in different compartments of the Inner Oslofjord marine ecosystem are documented.

The sediments of the inner Oslofjord is a potential source of contaminants to organisms living in and on the sediments. As such, the contaminants may enter the food chain. Several of the target compounds were found in the sediment sample (only 1), such as PCBs, BDE-209 and other brominated flame retardants (e.g. TBPH (BEH/TBP)), S/MCCPs, siloxanes, metals, PFOS and UV chemicals. Inputs to the fjord via stormwater and WWTP effluent water for several of the compounds is also shown, including also phenolic compounds. Some compounds exceeded environmental quality standards. These were in sediments: D5, Cu, PCB_7, Zn, As, Ni, Hg and PFOS, in stormwater: Bisphenol A, Cu, PCB_7, Zn, As and PFOS, and in WWTP effluent water: only PFOS.

The aquatic food web sampled in 2020 was identical to that in 2015-2019. The results of the stable isotope analysis suggest that the marine species (fish and invertebrates) represent members of the marine food web of the Inner Oslofjord. The differences in $\delta^{15}N$ seem to reflect expected trophic relationships; blue mussel (filters particulate organic matter from the water) < zooplankton (herbivore) < polychaetes (different modes of living, largely detritivorous) < prawns (some scavenging behaviour) < herring (pelagic fish feeding on zooplankton) < cod (mesopelagic fish, predator on fish and benthic organisms). The food web spans over approximately 2 (~1.72) trophic levels with blue mussel defined at trophic level 2.

The biomagnification potential of contaminants was evaluated by calculation of Trophic Magnification Factors (TMFs), but only results for Hg is shown here because of pooled samples of cod liver that could not be related to individual analyses of stable isotopes in muscle. Previously, legacy contaminants with well-known biomagnifying behaviour have displayed a positive significant relationship between (log_{10}-)-concentrations and trophic position (deduced from the $\delta^{15}N$ isotopic ratio) in the studied Inner Oslofjord marine food web. This suggests that the selected food web is suitable for studying biomagnification in the Oslo fjord at least when enough material of the top marine predator cod is present.

UV chemicals were detected in several samples from the Inner Oslofjord marine food web. OC, UV-327 and UV-328 were most frequently detected. The UV-chemicals were also found in samples from stormwater particles, effluent water from Bekkelaget WWTP. In biota, UV chemicals were found in herring gull eggs and blood. Dominating compounds were UV-327 and -328 in eggs, and UV-328, -329 and octocrylene in herring gull blood. These findings reflect the use of UV-chemicals in sunscreens and other cosmetics, as well as in other products.

The PBDE congeners displaying the highest concentrations in herring gull from the Inner Oslofjord (both blood and eggs) were BDE-209, -47 and -99. The concentrations of PBDEs (e.g. BDE-47 and -209) and D5 in herring gull eggs from the present study (Inner Oslofjord) displayed concentrations that were higher than those previously observed in herring gull eggs sampled from remote colonies in Norway, indicating urban influence. On the other hand, concentrations of “legacy” contaminants, such as PCB-153 and sum PCB_7 appeared lower in the eggs from Oslofjorden, probably reflecting a less marine diet.

While the concentrations of PCBs and PFOS in sparrow hawk eggs from the Oslo area appeared higher than in the herring gull eggs from the Inner Oslofjord area, BDE-209 and siloxanes appeared higher in the gull eggs than in the sparrow hawk eggs. This is possibly reflecting that while the sparrow hawk feeds mostly on birds, the herring gull might feed on human waste and leftovers.

In summary, it is shown that sediments and organisms in the inner Oslofjord contain various contaminants in different concentrations, both legacy contaminants and contaminants of more emerging concern. Some pathways for these contaminants into the fjord are also shown, such as stormwater, and effluent water from wastewater treatment plants. For instance, chlorinated paraffins apparently constitute major proportions in all species/matrices examined. PCBs constituted a large proportion of the sum of contaminants in the lipid rich herring and cod livers. Furthermore, siloxanes were important constituents of the sum of contaminants in the species of the Inner Oslofjord marine food web. Mercury also constituted a large proportion of the sum of contaminants in the species of the Inner Oslofjord marine food web, as well as in sediment.

As the programme is in its 8th year in 2020, and is about to enter a third term in 2021, the following reflections are made:

- The aim of assessing bioaccumulation of contaminants at different trophic levels has been approached using trophic magnification factors, which have served the purpose. In this regard it has been important to include species that are constituents of the Inner Oslofjord marine food web. Herring gull has been shown not to represent the marine food web of the inner Oslofjord very well but has been a good indicator species as an urban inhabitant. Common eider is tighter linked to the marine food web, but reproduction physiology demands careful interpretation of results.

- During this programme, different biological effect parameters have been studied. They have provided some information about the health condition of the Inner Oslofjord organisms. Causal relationships with contaminant exposure have, however, been difficult to prove. The approach of using cumulative risk (comparing measured concentrations to toxicity data) has provided information about the main risk drivers in the system. These do not change much from year to year.

- Cod is a relevant species in the coastal marine food chain and provides a good basis of comparison in terms of temporal trends and data from other monitoring programmes. It is known, however, that the cod population in the Oslofjord and Skagerrak is under pressure. This is also something that we have experienced as poor catches when collecting samples, including the field season of 2020.

- As mentioned, the programme has provided useful information about a vast amount of substances, including some that are not produced in Europe (e.g. dechlorane plus in 2019). It has also shown that chlorinated paraffins constitute large proportions of the total contaminants in several matrices. In 2017, the Stockholm Convention amended its Annex A to list short chain chlorinated paraffins (SCCPs) as a Persistent Organic Pollutant (POP). Furthermore, the results from the Oslofjord, e.g. in 2019, have continuously indicated positive relationships between concentrations of silver and trophic position in the Inner Oslofjord food web, all thought there is little evidence of biomagnification of Ag in marine systems from the literature.

- Through the years of the programme, new knowledge has been gained regarding the Inner Oslofjord food web, and of environmental contaminants that it is exposed to. This knowledge has been used to modify and optimize the programme. As such, continued monitoring in the Inner Oslofjord will benefit from this knowledge base.

- The programme has benefited from optional modules and participation of MSc students. This has given unique possibilities to explore additional topics/objectives and further scrutinize results and phenomena.

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7 Appendix

Concentrations in individual samples and composition of (calculated) pooled samples of cod are available as electronic Appendix.

Table A1.
Support parameters measured for sediment from the inner Oslofjord.

Area	<63 µm (% dry wt.)	TOC (µg/mg dry wt.)
Inner Oslofjord, Ildjernet (station Cm21)	65	3.51

Table A2.
Support parameters measured for stormwater.

Sample	Suspended solids (mg/L)
Aln 125x Bryn	28.7
Aln 136X Alnabru	198

Table A3.
Support parameters measured for herring gull eggs from the Inner Oslofjord area.

Sample no.	Specimen/ nest	$\delta^{34}S$	$\delta^{13}C$	$\delta^{15}N$	C:N (W%)	Trophic position	Weight, egg (g)	Eggshell thickness (mm)
1	JNA17	n.a.	-26.25	8.65	7.73	2.57	n.a.	n.a.
2	JNA26	n.a.	-24.16	11.02	6.24	3.20	n.a.	n.a.
3	JNA27	n.a.	-26.89	9.18	7.47	2.71	n.a.	n.a.
4	JNA29	n.a.	-27.21	7.62	6.16	2.30	n.a.	n.a.
5	JNA36	n.a.	-27.37	7.71	7.42	2.32	n.a.	n.a.
6	J8194	n.a.	-27.08	7.78	7.21	2.34	n.a.	n.a.
7	JJX36	n.a.	-27.42	7.65	6.56	2.31	n.a.	n.a.
8	JNA38	n.a.	-26.91	8.97	7.65	2.66	n.a.	n.a.
9	JNA39	n.a.	-25.74	10.44	8.24	3.04	n.a.	n.a.
10	JNA37	n.a.					n.a.	n.a.
11	JNA34	n.a.	-26.57	9.07	6.39	2.68	n.a.	n.a.
12	JNA23	n.a.	-26.72	8.66	5.83	2.57	n.a.	n.a.
13	JNA18	n.a.	-24.36	12.45	7.39	3.57	n.a.	n.a.
14	JNA19	n.a.	-26.94	8.45	6.66	2.52	n.a.	n.a.
15	JNA21	n.a.	-27.55	8.91	8.29	2.64	n.a.	n.a.

Table A4.
Support parameters measured for herring gull blood from the Inner Oslofjord.

Sample no.	Specimen/ nest	$\delta^{34}S$	$\delta^{13}C$	$\delta^{15}N$	C:N (W%)	Trophic position	Wing (mm)	Head (mm)	Weight (g)
1	JNA17	n.a.	-23.66	8.51	3.75	2.53	428	118.1	905
2	JNA26	n.a.	-24.17	9.08	4.46	2.69	420	115.2	900
3	JNA27	n.a.	-25.17	7.77	4.57	2.34	419	116.2	810
4	JNA29	n.a.	-25.21	7.56	3.81	2.28	419	118.8	910
5	JNA36	n.a.	-24.78	7.74	3.61	2.33	427	116.4	900
6	J8194	n.a.	-24.58	7.23	3.31	2.20	420	120.7	970
7	JJX36	n.a.	-25.37	6.87	3.38	2.10	406	121	830
8	JNA38	n.a.	-23.93	8.04	3.31	2.41	418	113.6	870
9	JNA39	n.a.	-23.79	8.54	3.43	2.54	419	118.8	900
10	JNA37	n.a.	-23.97	7.80	3.39	2.35	430	120.4	970
11	JNA34	n.a.	-23.59	9.55	3.33	2.81	421	118.5	720
12	JNA23	n.a.	-25.22	8.47	3.34	2.52	420	116.1	920
13	JNA18	n.a.	-22.56	10.84	4.13	3.15	424	117.7	770
14	JNA19	n.a.	-24.36	7.63	3.40	2.30	417	117.7	1040
15	JNA21	n.a.	-24.52	7.85	3.35	2.36	435	117.2	940

Table A5.
Support parameters measured for Cod from the Inner Oslofjord.

Sample no.	$\delta^{13}C$	$\delta^{15}N$	C:N (W%)	Trophic position	Age (yr)	Length (cm)	Weight (g)	Liver weight (g)	Gonad weight (g)	Sex
1	-18.08	16.12	3.20	4.17	3	43	740	14	0.3	M
2	-18.36	15.20	3.21	3.93	na	38	530	8.2	2	F
3	-17.87	16.43	3.16	4.25	2	38.5	470	8.6	1	M
4	-18.17	15.84	3.19	4.09	2	41	710	18.8	1	M
5	-17.88	14.02	3.23	3.62	2	36.5	430	9	1	M
6	-18.30	15.73	3.15	4.07	3	57	1570	73.1	2.1	M
7	-18.88	17.04	3.24	4.41	2	38	560	14	1.2	M
8	-17.90	16.39	3.17	4.24	2	45	860	19.7	1.6	F
19	-17.80	16.56	3.08	4.28	na	46.5	1220	52		F
26	-18.15	16.31	3.16	4.22	na	44	990	41		F
11	-18.66	13.15	3.07	3.39	1	35	400	3.1	1	M
12	-18.82	17.01	3.44	4.40	2	43	740	7.8	1	M
13	-18.80	15.94	3.19	4.12	2	47	940	32	1.1	M
14	-18.62	15.86	3.36	4.10	5	60	2290	160	9	M
15	-17.69	16.15	3.08	4.18	3	44	730	17.8	4.9	F

A total of 40 cod were collected, with 15 analyses. Muscle samples were individuals (according to this table). Note that for several individual specimens, the livers were not sufficiently large for all chemical analyses, thus each liver was pooled with livers from other spare specimens (according to size) as follows: Fish no. 1 was pooled with no. 15; Fish no. 8 was pooled no. 17; Fish no. 4 was pooled with no. 20; No. 7 with 31; No.24 with 28; No 12 with no. 25 and 18; No. 21 with 22, 23 and 27; No. 2 with 3, 29, 30; No 5 with 16, 9, 10, 11 and 32; Finally no. 34 – 40 were all pooled into one liver sample.

Table A6.
Support parameters measured for compartments of the Inner Oslofjord marine food web; polychaetes, blue mussel, krill, prawns, herring, cod (mathematically derived pooled samples).

Species	Sample sub no.	$\delta^{13}C$	$\delta^{15}N$	C:N (W%)	Trophic position
Polychaeta	1	-18.47	11.48	3.64	2.95
Polychaeta	2	-19.41	11.93	3.72	3.07
Polychaeta	3	-19.00	12.40	4.03	3.19
Blue mussel	1	-17.90	7.57	5.15	1.92
Blue mussel	2	-18.60	8.06	4.61	2.05
Blue mussel	3	-18.51	8.00	4.61	2.03
Krill	1	-20.10	11.52	3.74	2.96
Krill	2	-20.17	11.71	3.76	3.01
Krill	3	-20.29	12.04	3.81	3.09
Prawns	1	-17.89	14.18	3.20	3.66
Prawns	2	-17.83	13.47	3.18	3.47
Prawns	3	-17.96	13.76	3.19	3.55
Herring	1	-21.62	13.48	5.50	3.47
Herring	2	-20.21	12.73	3.99	3.28
Herring	3	-21.41	13.73	4.67	3.54

Table A7.
Lipid content (%) and concentrations of the different analytes in cod liver (pooled samples) (Hg in muscle) from the Inner Oslofjord. Concentrations are ng/g wet wt., except for concentrations of Ni, Cu, Ag, Cd, Pb, Cr, Fe, Zn, As and Sb, which are expressed as µg/g wet wt. Arithmetic mean and range are presented (n=15). In calculations of mean, non-detected components were assigned a value of zero (0). Phenolic compounds (n=3 for liver) were also analyzed in bile (n=14) (see Table 11).

	Analyte	Mean	Range	Detection
	Lipid	10.4	2.52 - 21.33	15
	PeCB	0.609	0.2 - 1.2	15
	HCB	5.03	1.5 - 13.8	15
PCBS	**PCB-18**	0.724	0.19 - 1.53	15
	PCB-28	6.55	1.52 - 17.5	15
	PCB-31	1.57	0.21 - 5.04	15
	PCB-33	0.285	<0.05 - 0.87	14
	PCB-37	0.052	<0.04 - 0.11	13
	Sum-TriCB	15.2	4.1 - 38.3	15
	PCB-47	32.3	11.5 - 61.6	15
	PCB-52	36.3	9.35 - 105	15
	PCB-66	53.6	19 - 114	15
	PCB-74	32.0	13 - 66.9	15
	Sum-TetCB	231	71.1 - 566	15
	PCB-99	180	77.6 - 434	15
	PCB-101	124	46.7 - 302	15
	PCB-105	71.9	36.2 - 139	15
	PCB-114	4.16	1.97 - 8.49	15
	PCB-118	186	87 - 346	15
	PCB-122	0.456	<0.07 - 1.61	10
	PCB-123	4.30	1.92 - 7.2	15
	Sum-PenCB	790	380 - 1620	15
	PCB-128	72.0	27.4 - 178	15
	PCB-138	440	182 - 1110	15
	PCB-141	12.4	4.82 - 30.3	15
	PCB-149	65.6	18 - 155	15

	PCB-153	645	268 - 1640	15
	PCB-156	21.0	9.32 - 42.6	15
	PCB-157	6.44	2.84 - 11	15
	PCB-167	19.7	8.19 - 34.4	15
	Sum-HexCB	869	383 - 2090	15
	PCB-170	39.6	18.9 - 67.6	15
	PCB-180	116	48.8 - 217	15
	PCB-183	52.4	15.9 - 113	15
	PCB-187	73.3	25.4 - 167	15
	PCB-189	3.13	1.27 - 5.79	15
	Sum-HepCB	372	140 - 729	15
	PCB-194	26.6	7.88 - 56	15
	PCB-206	14.3	4.24 - 24.8	15
	PCB-209	2.77	0.84 - 5.25	15
	Sum 7 PCB	1554	710 - 3581	15
	Sum all PCB	2322	1210 - 4863	15
	TBA	n.a.	<0.06 - 0.42	3
PBDEs	**PBDE-17**	0.044	<0.03 - 0.54	4
	PBDE-28	0.250	0.08 - 0.72	15
	PBDE-47	17.5	5.81 - 87.1	15
	PBDE-49	2.25	0.29 - 9.94	15
	PBDE-66	n.a.	<0.02 - <0.02	0
	PBDE-71	0.268	<0.02 - 4.26	1
	PBDE-77	n.a.	<0.02 - 0.04	3
	PBDE-85	0.013	<0.02 - 0.18	4
	PBDE-99	0.375	0.08 - 0.89	15
	PBDE-100	5.61	1.71 - 26.8	15
	PBDE-119	0.074	0.02 - 0.18	15
	PBDE-126	0.038	<0.01 - 0.12	12
	PBDE-138	n.a.	<0.05 - 0.13	1
	PBDE-153	0.031	<0.05 - 0.15	9

	PBDE-154	1.20	0.62 - 3.12	15
	PBDE-156	n.a.	<0.08 - <0.08	0
	PBDE-183	n.a.	<0.04 - 0.06	1
	PBDE-184	n.a.	<0.03 - 0.07	4
	PBDE-191	n.a.	<0.05 - <0.05	0
	PBDE-196	n.a.	<0.07 - <0.07	0
	PBDE-197	n.a.	<0.05 - 0.05	1
	PBDE-202	n.a.	<0.08 - 0.15	4
	PBDE-206	n.a.	<0.22 - <0.22	0
	PBDE-207	n.a.	<0.14 - <0.14	0
	PBDE-209	n.a.	<1.83 - 3.52	2
nBFRs	**ATE (TBP-AE)**	n.a.	<0.1 - <0.07	0
	a-TBECH	n.a.	<0.52 - 1.52	1
	b-TBECH	n.a.	<0.38 - <0.38	0
	g/d-TBECH	n.a.	<0.21 - <0.21	0
	BATE	n.a.	<0.07 - <0.07	0
	PBT	n.a.	<0.15 - <0.15	0
	PBEB	n.a.	<0.08 - <0.08	0
	PBBZ	n.a.	<1.23 - <1.23	0
	HBB	n.a.	<0.48 - 0.75	3
	DPTE	n.a.	<0.06 - <0.06	0
	EHTBB	n.a.	<0.31 - <0.09	0
	BTBPE	n.a.	<0.15 - <0.15	0
	TBPH (BEH /TBP)	n.a.	<0.59 - <0.35	0
	DBDPE	n.a.	<68.7 - <68.7	0
Chl.pa	**SCCP**	n.a.	<171 - 125	1
	MCCP	30.9	<62.1 - 365	3
Phenols (liver)	**4,4-bis-A**	n.a.	<12 - <9.7	0
	2,4-bis-A	n.a.	<4.1 - <2.8	0
	Bis-FL	n.a.	<6.6 - <4.4	0
	Bis-B	n.a.	<7.2 - <3.9	0

	Bis-E	n.a.	<6.4 - <4.2	0
	4,4-bis-S	n.a.	<22 - <19	0
	2,4-bis-S	n.a.	<0.8 - <0.6	0
	4,4-bis-F	n.a.	<7 - <6.1	0
	2,4-bis-F	n.a.	<11 - <8.8	0
	2,2-bis-F	n.a.	<4.8 - <0.8	0
	bis-M	n.a.	<1.5 - <1	0
	bis-Z	n.a.	<5.9 - <4.5	0
	bis-AF	n.a.	<9.2 - <4.5	0
	bis-AP	n.a.	<3.4 - <2.4	0
	TBBPA	n.a.	<15 - <10	0
	4-tert-octylphenol	n.a.	<9.3 - <6.6	0
	4-octylphenol	n.a.	<8.7 - <6.1	0
Siloxanes	**D4**	45.8	15.4 - 116	15
	D5	1012	246 - 3181	15
	D6	87.2	26.9 - 253	15
	M3T	11.7	5.65 - 26	15
Elements (incl. metals)	**Cr**	0.082	0.017 - 0.24	15
	Fe	29.6	6.83 - 56.3	15
	Ni	0.152	0.033 - 0.35	15
	Cu	3.72	2.01 - 5.69	15
	Zn	18.2	6.1 - 26.4	15
	As	14.0	3.69 - 28.8	15
	Ag	3.52	1.02 - 9.43	15
	Cd	0.117	0.021 - 0.46	15
	Sb	0.006	0.001 - 0.01	15
	Pb	0.064	0.004 - 0.35	15
	Hg	153	63.3 - 291	15
PFAS	**PFPA**	n.a.	<0.5 - <0.5	0
	PFHxA	n.a.	<0.5 - <0.5	0
	PFHpA	n.a.	<0.5 - <0.5	0

	PFOA	n.a.	<0.5 - <0.5	0
	PFNA	n.a.	<0.5 - 0.7	2
	PFDA	1.05	<0.4 - 2.3	14
	PFUdA	1.45	0.5 - 2.8	15
	PFDoA	1.09	<0.4 - 2.1	14
	PFTrDA	0.7	<0.4 - 1.6	13
	PFTeDA	0.43	<0.4 - 1.3	11
	PFPeDA	n.a.	<0.4 - <0.4	0
	PFBS	n.a.	<0.1 - <0.1	0
	PFPS	n.a.	<0.1 - <0.1	0
	PFHxS	n.a.	<0.1 - 0.1	2
	PFHpS	n.a.	<0.1 - <0.1	0
	PFOS	4.0	1.8 - 8.1	15
	PFNS	n.a.	<0.2 - <0.2	0
	PFDS	0.55	<0.2 - 1.1	14
	PFDoS	n.a.	<0.2 - <0.2	0
	H4PFOS	n.a.	<0.3 - <0.3	0
	8Cl-PFOS	n.a.	<0.2 - <0.2	0
	PFOSA	9.2	2.7 - 13	15
	N-MeFOSA	n.a.	<0.3 - <0.3	0
	N-EtFOSA	n.a.	<0.3 - <0.3	0
	N-MeFOSAA	n.a.	<0.3 - <0.3	0
	N-EtFOSAA	n.a.	<0.3 - <0.3	0
	N-MeFOSE	n.a.	<2 - <2	0
	N-EtFOSE	n.a.	<2 - <2	0
	4:2 FTS	0.02	<0.3 - 3.3	2
	8:2 FTS	n.a.	<0.3 - <0.3	0
	10:2 FTS	n.a.	<0.3 - <0.3	0
UV comp.	**Benzophenone-3**	0.38	<0.8 - 2	9
	EHMC-E	0.08	<1 - 1.8	7
	EHMC-Z	0.06	<0.2 - 0.4	9

	Octocrylen	1.53	<6 - 7.3	9
	Sum EHMC	0.101	<1.24 - 2.2	7
	UV-327	2.88	1.3 - 8.4	15
	UV-328	10.3	3 - 46	15
	UV-329	n.a.	<2 - <0.8	0

Table A8.
Concentrations of phenolic compounds in cod bile from the Inner Oslofjord. Concentrations are ng/g wet wt. Arithmetic mean and range are presented (n=14). In calculations of mean, non-detected components were assigned a value of zero (0).

Phenolic compound in bile	Mean	Range	Detected in no. of samples
4,4-bis-A	78.0	<58 - 363	13
2,4-bis-A	n.a.	<8.1 - 3.4	1
Bis-FL	n.a.	<18 - <3.3	0
Bis-B	n.a.	<15 - <2.7	0
Bis-E	n.a.	<13 - <1.9	0
4,4-bis-S	n.a.	<112 - <20	0
2,4-bis-S	n.a.	<3 - <0.5	0
4,4-bis-F	n.a.	<29 - 6.2	2
2,4-bis-F	n.a.	<53 - <9.6	0
2,2-bis-F	n.a.	<2.9 - 1.2	3
bis-M	n.a.	<4.5 - <0.8	0
bis-Z	n.a.	<20 - <3.7	0
bis-AF	n.a.	<27 - <5	0
bis-AP	n.a.	<10 - <1.6	0
TBBPA	n.a.	<25 - 24	1
4-tert-octylphenol	n.a.	<22 - 71	2
4-octylphenol	n.a.	<28 - <5.1	0
4-nonylphenol	n.a.	<74 - <7	0

Table A9.
Lipid content (%) and concentrations of the different analytes in Herring gull eggs and blood. Concentrations are ng/g wet wt., except for concentrations of Ni, Cu, Ag, Cd, Pb, Cr, Fe, Zn, As and Sb, which are expressed as µg/g wet wt. Arithmetic mean and range are presented (n=14 and n=15 for eggs and blood, respectively). In calculations of mean, non-detected components were assigned a value of zero (0). "Det" is number of detections >LOD/LOQ

		EGG			BLOOD		
		Mean	Range	Detection	Mean	Range	Detection
	Lipid	8.44	6.2 - 11.2	14	1.01	0.12 - 2.32	15
	PeCB	0.179	0.071 - 0.457	14	n.a.	<0.035 - <0.035	0
	HCB	3.15	1.26 - 7.67	14	0.175	0.052 - 0.505	15
PCBs	PCB-18	0.021	<0.017 - 0.023	3	n.a.	<0.017 - <0.017	0
	PCB-28	0.870	0.153 - 2.96	14	0.025	<0.02 - 0.14	8
	PCB-31	0.075	<0.015 - 0.166	6	n.a.	<0.015 - <0.015	0
	PCB-33	n.a.	<0.01 - <0.01	0	n.a.	<0.01 - <0.01	0
	PCB-37	0.008	<0.005 - 0.009	2	n.a.	<0.007 - <0.005	0
	Sum-TriCB	1.39	0.206 - 4.6	14	0.126	0.077 - 0.154	3
	PCB-47	4.93	0.329 - 17.5	14	0.158	<0.012 - 0.692	14
	PCB-52	1.51	0.092 - 6.49	14	0.026	<0.016 - 0.209	7
	PCB-66	8.74	0.618 - 30.1	14	0.348	<0.051 - 1.44	12
	PCB-74	4.73	0.337 - 16.7	14	0.172	<0.028 - 0.667	12
	Sum-TetCB	21.7	1.61 - 77.1	14	1.03	0.247 - 2.99	11
	PCB-99	23.4	2.35 - 85.6	14	0.664	0.078 - 2.92	15
	PCB-101	3.60	0.389 - 14	14	0.055	<0.036 - 0.332	10
	PCB-105	10.5	0.869 - 34.9	14	0.359	0.022 - 1.57	15
	PCB-114	0.813	0.15 - 2.09	14	0.021	<0.004 - 0.085	12
	PCB-118	26.1	2.82 - 92.3	14	0.922	0.066 - 4.42	15
	PCB-122	0.034	<0.007 - 0.087	7	n.a.	<0.004 - <0.003	0
	PCB-123	0.512	0.044 - 1.49	14	0.016	<0.005 - 0.064	11
	Sum-PenCB	79.1	7.51 - 290	14	2.94	0.628 - 10.7	12
	PCB-128	8.52	1.25 - 28.5	14	0.218	0.027 - 0.87	15
	PCB-138	54.5	9.59 - 171	14	1.70	0.343 - 5.99	15
	PCB-141	0.383	0.038 - 1.90	14	0.0002	<0.01 - 0.053	5
	PCB-149	3.94	0.776 - 18.5	14	0.056	<0.063 - 0.454	7

	PCB-153	84.8	18.4 - 267	14	2.74	0.622 - 8.33	15
	PCB-156	3.95	0.602 - 12.5	14	0.099	0.015 - 0.343	15
	PCB-157	0.881	0.134 - 2.94	14	0.023	<0.002 - 0.084	14
	PCB-167	1.90	0.375 - 5.74	14	0.048	<0.003 - 0.198	14
	Sum-HexCB	107	22.9 - 346	14	3.45	1.21 - 10.1	14
	PCB-170	6.22	1.09 - 18.7	14	0.178	0.028 - 0.589	15
	PCB-180	24.6	4.21 - 73.9	14	0.618	0.127 - 1.81	15
	PCB-183	8.00	1.07 - 23.8	14	0.188	0.034 - 0.68	15
	PCB-187	19.5	5.47 - 46.6	14	0.406	0.119 - 1.55	15
	PCB-189	0.441	0.0956 - 1.29	14	0.009	<0.01 - 0.031	12
	Sum-HepCB	71.9	14.9 - 205	14	1.57	0.307 - 5.3	15
	PCB-194	3.97	0.756 - 12	14	0.073	0.017 - 0.241	15
	PCB-206	1.46	0.248 - 5.46	14	0.027	<0.003 - 0.108	14
	PCB-209	0.415	0.128 - 1.35	14	0.007	<0.003 - 0.021	12
	Sum 7 PCB	196	35.8 - 628	14	6.09	1.13 - 21	15
	Sum all PCB	287	48.5 - 935	14	8.03	0.32 - 29.5	15
	TBA	0.1	<0.024 - 0.1	1	n.a.	<0.025 - 0.013	1
PBDEs	**PBDE-17**	n.a.	<0.017 - <0.006	0	n.a.	<0.007 - <0.006	0
	PBDE-28	0.011	<0.015 - 0.027	8	n.a.	<0.006 - <0.006	0
	PBDE-47	3.93	0.723 - 27.8	14	0.064	<0.027 - 0.196	13
	PBDE-49	0.059	<0.014 - 0.091	3	n.a.	<0.005 - <0.005	0
	PBDE-66	0.061	<0.011 - 0.09	3	n.a.	<0.006 - <0.004	0
	PBDE-71	n.a.	<0.015 - <0.003	0	n.a.	<0.004 - <0.003	0
	PBDE-77	n.a.	<0.008 - <0.003	0	n.a.	<0.003 - <0.003	0
	PBDE-85	0.318	<0.016 - 0.659	3	n.a.	<0.012 - <0.004	0
	PBDE-99	4.88	0.391 - 43.9	14	0.039	<0.011 - 0.194	11
	PBDE-100	1.18	0.235 - 8.19	14	0.012	<0.006 - 0.049	10
	PBDE-119	0.024	<0.015 - 0.047	5	n.a.	<0.011 - <0.004	0
	PBDE-126	n.a.	<0.013 - <0.004	0	n.a.	<0.008 - <0.003	0
	PBDE-138	0.269	<0.054 - 0.649	3	n.a.	<0.018 - <0.011	0
	PBDE-153	1.06	0.143 - 8.68	14	n.a.	<0.017 - 0.043	4

	PBDE-154	0.327	<0.035 - 2.11	13	n.a.	<0.013 - 0.01	1
	PBDE-156	n.a.	<0.073 - <0.017	0	n.a.	<0.024 - <0.017	0
	PBDE-183	0.290	<0.029 - 1.68	10	n.a.	<0.008 - 0.01	1
	PBDE-184	0.041	<0.024 - 0.041	1	n.a.	<0.007 - <0.007	0
	PBDE-191	n.a.	<0.042 - <0.01	0	n.a.	<0.011 - <0.01	0
	PBDE-196	0.453	<0.077 - 0.847	3	n.a.	<0.022 - <0.013	0
	PBDE-197	0.896	<0.064 - 2.79	5	n.a.	<0.019 - 0.028	1
	PBDE-202	0.222	<0.097 - 0.288	2	n.a.	<0.029 - <0.016	0
	PBDE-206	0.638	<0.126 - 0.762	2	n.a.	<0.043 - <0.043	0
	PBDE-207	1.93	<0.109 - 8.06	8	n.a.	<0.027 - 0.046	1
	PBDE-209	9.01	<0.368 - 34	8	n.a.	<0.366 - <0.366	0
nBFRs	**ATE (TBP-AE)**	n.a.	<0.013 - <0.013	0	n.a.	<0.016 - 0.044	2
	a-TBECH	0.179	<0.104 - 0.246	2	n.a.	<0.12 - <0.099	0
	b-TBECH	n.a.	<0.077 - <0.077	0	n.a.	<0.085 - <0.071	0
	g/d-TBECH	n.a.	<0.043 - <0.043	0	n.a.	<0.054 - <0.04	0
	BATE	n.a.	<0.015 - <0.015	0	n.a.	<0.013 - 0.038	3
	PBT	n.a.	<0.03 - <0.03	0	n.a.	<0.035 - <0.035	0
	PBEB	n.a.	<0.016 - <0.016	0	n.a.	<0.014 - 0.032	3
	PBBZ	n.a.	<0.246 - <0.246	0	n.a.	<0.24 - <0.24	0
	HBB	0.124	<0.096 - 0.146	4	n.a.	<0.097 - <0.097	0
	DPTE	n.a.	<0.015 - <0.013	0	n.a.	<0.008 - 0.024	2
	EHTBB	n.a.	<0.083 - <0.022	0	n.a.	<0.144 - <0.014	0
	BTBPE	n.a.	<0.029 - <0.029	0	n.a.	<0.031 - <0.031	0
	TBPH (BEH /TBP)	n.a.	<0.08 - <0.071	0	n.a.	<1.93 - <0.069	0
	DBDPE	n.a.	<13.7 - <13.7	0	n.a.	<14.2 - <14.2	0
Chlr. Paraf.	**SCCP**	21.6	9.92 - 37.4	14	n.a.	<1.09 - 2.98	2
	MCCP	28.9	6.64 - 107	14	3.57	<2.68 - 29.5	7
Phenols	**4,4-bis-A**	n.a.	<12 - <11	0	n.a.	<4.2 - <2.2	0
	2,4-bis-A	n.a.	<1.4 - <1.3	0	n.a.	<0.5 - <0.3	0
	Bis-FL	n.a.	<3.6 - <3.3	0	n.a.	<1.3 - <0.7	0
	Bis-B	n.a.	<2.9 - <2.7	0	n.a.	<1 - <0.6	0

	Bis-E	n.a.	<2.1 - <1.9	0	n.a.	<0.7 - <0.4	0
	4,4-bis-S	n.a.	<22 - <20	0	n.a.	<8 - <4.3	0
	2,4-bis-S	n.a.	<0.7 - <0.5	0	n.a.	<0.2 - <0.1	0
	4,4-bis-F	n.a.	<5.7 - <5.2	0	n.a.	<2.1 - <1.1	0
	2,4-bis-F	n.a.	<11 - -9.6	0	n.a.	<3.8 - <2	0
	2,2-bis-F	0.700	<0.6 - 0.7	1	n.a.	<0.2 - <0.1	0
	bis-M	n.a.	<0.9 - <0.8	0	n.a.	<0.4 - <0.2	0
	bis-Z	n.a.	<4 - <3.7	0	n.a.	<1.4 - <0.8	0
	bis-AF	n.a.	<5.5 - <5	0	n.a.	<2 - <1.1	0
	bis-AP	n.a.	<2 - <1.9	0	n.a.	<0.7 - <0.4	0
	TBBPA	n.a.	<4.9 - <4.5	0	n.a.	<3.6 - <1	0
	4-tert-octylphenol	n.a.	<3.1 - <1.5	0	n.a.	<3.2 - 2.2	3
	4-octylphenol	n.a.	<5.6 - <5.1	0	n.a.	<2.1 - <1.2	0
	4-nonylphenol	n.a.	-7.7 - -7	0	n.a.	<5.4 - <2.9	0
	AO Mb1	n.a.	<21 - <19	0	n.a.	<7.5 - <4.1	0
Siloxanes	**D4**	n.a.	<6.11 - <6.11	0	n.a.	<2.81 - <2.81	0
	D5	31.0	7.25 - 101	14	1.00	0.303 - 2.44	15
	D6	6.83	2.72 - 14.2	14	0.645	0.337 - 1.03	15
	M3T	0.461	<0.3 - 0.746	9	n.a.	<0.31 - <0.31	0
Elements (incl. Metals)	**Cr**	0.036	<0.004 - 0.197	13	n.a.	<0.006 - 0.023	1
	Fe	35.6	22.5 - 49.9	14	472	353 - 551	15
	Ni	0.027	0.008 - 0.093	14	0.006	<0.003 - 0.012	10
	Cu	0.748	0.546 - 1.36	14	0.402	0.28 - 0.504	15
	Zn	14.3	8.27 - 18.8	14	4.65	3.39 - 5.99	15
	As	0.036	0.002 - 0.096	14	0.119	0.004 - 0.554	15
	Ag	0.001	0.0003 - 0.002	14	0.000	<0.0004 - 0.001	1
	Cd	0.000	<0.0001 - 0.0002	3	0.001	0.0004 - 0.001	15
	Sb	0.000	<0.0002 - 0.0003	1	n.a.	<0.0003 - <0.0002	0
	Pb	0.013	0.002 - 0.045	14	0.046	0.016 - 0.092	15
	Hg	39.4	8.01 - 111	14	64.8	8.77 - 169	15
	PFPA	n.a.	<0.5 - <0.5	0	n.a.	<0.5 - <0.5	0

PFAS	PFHxA	n.a.	<0.5 - <0.5	0	n.a.	<0.5 - <0.5	0
	PFHpA	n.a.	<0.5 - <0.5	0	n.a.	<0.5 - <0.5	0
	PFOA	n.a.	<0.5 - <0.5	0	n.a.	<0.5 - <0.5	0
	PFNA	0.6	<0.5 - 0.6	1	n.a.	<0.5 - <0.5	0
	PFDA	0.755	<0.4 - 1.5	11	0.88	0.4 - 3.1	15
	PFUdA	0.686	0.4 - 1.2	14	0.14	<0.4 - 0.9	8
	PFDoA	1.02	0.4 - 2.6	14	0.493	<0.4 - 4.1	9
	PFTrDA	1	0.5 - 1.8	14	0.007	<0.4 - 1.4	5
	PFTeDA	1.15	0.6 - 2.8	14	0.557	<0.4 - 2.3	12
	PFPeDA	0.45	<0.4 - 0.5	2	n.a.	<0.4 - <0.4	0
	PFBS	n.a.	<0.1 - <0.1	0	n.a.	<0.1 - <0.1	0
	PFPS	n.a.	<0.1 - <0.1	0	n.a.	<0.1 - <0.1	0
	PFHxS	0.164	<0.1 - 0.5	11	0.227	<0.1 - 1.1	14
	PFHpS	0.22	<0.1 - 0.5	10	0.047	<0.1 - 0.9	6
	PFOS	19.4	2.9 - 44	14	11.6	2.5 - 100	15
	PFNS	n.a.	<0.2 - <0.2	0	n.a.	<0.2 - <0.2	0
	PFDS	0.69	<0.2 - 2.2	10	n.a.	<0.2 - 0.5	6
	PFDoS	n.a.	<0.2 - <0.2	0	n.a.	<0.2 - <0.2	0
	H4PFOS	n.a.	<0.3 - <0.3	0	n.a.	<0.3 - <0.3	0
	8Cl-PFOS	n.a.	<0.2 - <0.2	0	n.a.	<0.2 - <0.2	0
	PFOSA	n.a.	<0.2 - <0.2	0	n.a.	<0.2 - <0.2	0
	N-MeFOSA	n.a.	<0.3 - <0.3	0	n.a.	<0.3 - <0.3	0
	N-EtFOSA	n.a.	<0.3 - <0.3	0	n.a.	<0.3 - <0.3	0
	N-MeFOSAA	n.a.	<0.3 - <0.3	0	n.a.	<0.3 - <0.3	0
	N-EtFOSAA	n.a.	<0.3 - <0.3	0	n.a.	<0.3 - <0.3	0
	N-MeFOSE	n.a.	<2 - <2	0	n.a.	<2 - <2	0
	N-EtFOSE	n.a.	<2 - <2	0	n.a.	<2 - <2	0
	4:2 FTS	n.a.	<0.3 - <0.3	0	n.a.	<0.3 - <0.3	0
	8:2 FTS	0.4	<0.3 - 0.5	3	n.a.	<0.3 - 0.9	3
	10:2 FTS	0.714	<0.3 - 2.2	7	n.a.	<0.3 - 0.7	1
	Benzophenone-3	n.a.	<0.6 - <0.6	0	n.a.	<0.4 - <0.4	0

UV compounds	**EHMC-E**	0.5	<0.25 - 0.5	1	n.a.	<0.3 - 0.3	1
	EHMC-Z	n.a.	<0.05 - <0.05	0	n.a.	<0.2 - <0.2	0
	Octocrylen	2.3	<1.5 - 2.3	1	n.a.	<6 - 6.5	1
	Sum EHMC (Etylheksylmetoksycinnamat)	0.5	<2.1 - 0.5	1	n.a.	<0.52 - <0.5	0
	UV-327	0.425	0.07 - 2.6	14	n.a.	<0.06 - 0.2	5
	UV-328	1.39	0.3 - 4.7	14	0.52	<0.2 - 2.9	8
	UV-329	n.a.	<0.2 - <0.2	0	0.11	<0.15 - 2.4	4

Table B1.
Compounds and elements that are/have been included in the Urban fjord programme (not all in 2020). Chemspider ID and/or CAS are given.

Compound	Name	Chemspider ID	CAS
SCCP	Short chain chlorinated paraffins		85535-84-8
MCCP	Medium chain chlorinated paraffins		85535-85-9
Dibromoaldrin			20389-65-5
PeCB	Pentachlorobenzene	21106570	608-93-5
HCB	Hexachlorobenzene	8067	118-74-1
PCB-18	2,2',5-Trichlorobiphenyl	34664	37680-65-2
PCB-28	2,4,4'-Trichlorobiphenyl	21924	7012-37-5
PCB-31	2,4',5-Trichlorobiphenyl	26011	16606-02-3
PCB-33	2,3',4'-Trichlorobiphenyl	34870	
PCB-37	3,4,4'-Trichlorobiphenyl	34873	
PCB-47	2,2',4,4'-Tetrachlorobiphenyl	16182	2437-79-8
PCB-52	2,2',5,5'-Tetrachlorobiphenyl	34189	35693-99-3
PCB-66	2,3',4,4'-Tetrachlorobiphenyl	33279	32598-10-0
PCB-74	2,4,4',5-Tetrachlorobiphenyl	33304	
PCB-99	2,2',4,4',5-Pentachlorobiphenyl	34848	38380-01-7
PCB-101	2,2',4,5,5'-Pentachlorobiphenyl	34668	37680-73-2
PCB-105	2,3,3',4,4'-Pentachlorobiphenyl	33282	32598-14-4
PCB-114	2,3,4,4',5-Pentachlorobiphenyl	47913	74472-37-0
PCB-118	2,3',4,4',5-Pentachlorobiphenyl	32952	31508-00-6
PCB-122	2,3,3',4',5'-Pentachlorobiphenyl	82828	76842-07-4
PCB-123	2,3',4,4',5'-Pentachlorobiphenyl	43353	65510-44-3
PCB-128	2,2',3,3',4,4'-Hexachlorobiphenyl	34853	38380-07-3
PCB-138	2,2',3,4,4',5'-Hexachlorobiphenyl	33984	35065-28-2
PCB-141	2,2',3,4,5,5'-Hexachlorobiphenyl	36771	52712-04-6
PCB-149	2,2',3,4',5',6-Hexachlorobiphenyl	34851	38380-04-0

PCB-153	2,2',4,4',5,5'-Hexachlorobiphenyl	33983	35065-27-1
PCB-156	2,3,3',4,4',5-Hexachlorobiphenyl	34854	38380-08-4
PCB-157	2,3,3',4,4',5'-Hexachlorobiphenyl	46136	69782-90-7
PCB-167	2,3',4,4',5,5'-Hexachlorobiphenyl	36984	52663-72-6
PCB-170	2,2',3,3',4,4',5-Heptachlorobiphenyl	33986	35065-30-6
PCB-180	2,2',3,4,4',5,5'-Heptachlorobiphenyl	33985	35065-29-3
PCB-183	2,2',3,4,4',5',6-Heptachlorobiphenyl	36981	52663-69-1
PCB-187	2,2',3,4',5,5',6-Heptachlorobiphenyl	36980	52663-68-0
PCB-189	2,3,3',4,4',5,5'-Heptachlorobiphenyl	35108	39635-31-9
PCB-194	2,2',3,3',4,4',5,5'-Octachlorobiphenyl	34192	35694-08-7
PCB-206	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	35206	40186-72-9
PCB-209	Decachlorobiphenyl	15484	2051-24-3
TBA	Tribromoanisole	21170966	
BDE-17	2,2',4-Tribromodiphenyl ether	10239061	
BDE-28	2,4,4'-Tribromodiphenyl ether	10239063	41318-75-6
BDE-47	2,2',4,4'-Tetrabromodiphenyl ether	85876	5436-43-1
BDE-49	2,2',4,5'-Tetrabromodiphenyl ether	21170704	123982-82-3
BDE-66	2,3',4,4'-Tetrabromodiphenyl ether	10239069	
BDE-71	2,3',4',6-Tetrabromodiphenyl ether	10239070	189084-62-6
BDE-77	3,3',4,4'-Tetrabromodiphenyl ether	10239072	
BDE-85	2,2',3,4,4'-Pentabromodiphenyl ether	154435	182346-21-0
BDE-99	2,2',4,4',5-Pentabromodiphenyl ether	33255	60348-60-9
BDE-100	2,2',4,4',6-Pentabromodiphenyl ether	135795	189084-64- 8
BDE-119	2,3',4,4',6-Pentabromodiphenyl ether	10239073	189084-66-0
BDE-126	3,3',4,4',5-Pentabromodiphenyl ether	21170703	366791-32-4
BDE-138	2,2',3,4,4',5'-Hexabromodiphenyl ether	10397336	182677-30-1
BDE-153	2,2',4,4',5,5'-Hexabromodiphenyl ether	136695	68631-49-2
BDE-154	2,2',4,4',5,6'-Hexabromodiphenyl ether	21170702	207122-15-4
BDE-156	2,3,3',4,4',5-Hexabromodiphenyl ether	28550781	
BDE-183	2,2',3,4,4',5',6-Heptabromodiphenyl ether	21170701	207122-16-5

BDE-184	2,2',3,4,4',6,6'-Heptabromodiphenyl ether	9105831	
BDE-191	2,3,3',4,4',5',6-Heptabromodiphenyl ether	30805224	
BDE-196	2,2',3,3',4,4',5',6-Octabromodiphenyl ether	28592527	32536-52-0
BDE-197	2,2',3,3',4,4',6,6'-Octabromodiphenyl ether	10141197	117964-21-3
BDE-202	2,2',3,3',5,5',6,6'-Octabromodiphenyl ether	2539191	67797-09-5
BDE-206	2,2',3,3',4,4',5,5',6-Nonabromodiphenyl ether	41371	63387-28-0
BDE-207	2,2',3,3',4,4',5,6,6'-Nonabromodiphenyl ether	9193547	437701-79-6
BDE-209	Decabromodiphenyl ether	13764	1163-19-5
ATE (TBP-AE)	allyl-2,4,6-tribromophenyl ether	69223	3278-89-5
a-TBECH	Tetrabromoethylcyclohexane		3322-93-8
b-TBECH	Tetrabromoethylcyclohexane		3322-93-8
g/d-TBECH	Tetrabromoethylcyclohexane		3322-93-8
BATE	2-bromoallyl 2,3,6-tribromophenylether		99717-56-3
PBT	Pentabromotoluene		87-83-2
PBEB	Pentabromoethylbenzene		85-22-3
HBB	Hexabromobenzene	6639	87-82-1
DPTE	2,3-dibromopropyl-2,4,6-tribromophenyl ether		35109-60-5
EHTBB	2-ethyl-hexyl tetrabromobenzoate	28419925	183658-27-7
BTBPE	1,1'-[1,2-Ethanediylbis(oxy)]bis(2,4,6-tribromobenzene)	34697	37853-59-1
TBPH (BEH /TBP)	bis(2-ethylhexyl) tetrabromophthalate	104816	26040-51-7
DBDPE	Decabromodiphenyl ethane	82781	84852-53-9
a-HCH	a-Hexachlorocyclohexane	10468511	319-84-6
b-HCH	b-Hexachlorocyclohexane	10468512	319-85-7
g-HCH	g-Hexachlorocyclohexane	10481896	58-89-9
d-HCH	d-Hexachlorocyclohexane	10430682	319-86-8
o,p'-DDE	1-Chloro-2-[2,2-dichloro-1-(4-chlorophenyl)vinyl]benzene	215802	3424-82-6
p,p'-DDE	1,1'-(2,2-Dichloro-1,1-ethenediyl)bis(4-chlorobenzene)	2927	72-55-9
o,p'-DDD	1-Chloro-2-[2,2-dichloro-1-(4-chlorophenyl)ethyl]benzene	4066	53-19-0
p,p'-DDD	1,1'-(2,2-Dichloro-1,1-ethanediyl)bis(4-chlorobenzene)	6057	72-54-8
o,p'-DDT	1-Chloro-2-[2,2,2-trichloro-1-(4-chlorophenyl)ethyl]benzene	12543	789-02-6

p,p'-DDT	1,1'-(2,2,2-Trichloro-1,1-ethanediyl)bis(4-chlorobenzene)	2928	50-29-3
TEP	Triethyl phosphate	6287	78-40-0
TCEP	Tris(2-chloroethyl) phosphate	7994	115-96-8
TPrP	Tripropyl phosphate	10106	513-08-6
TCPP	Tris(2-chloroisopropyl) phosphate	24387	13674-84-5
TiBP	Triisobutyl phosphate	29088	126-71-6
BdPhP	Butyl diphenyl phosphate	16714	2752-95-6
DBPhP	Dibutyl phenyl phosphate	16382	2528-36-1
TPP	Triphenyl phosphate	7988	115-86-6
TnBP	Tri-n-butyl phosphate	29090	126-73-8
TDCPP	Tris(1,3-dichloro-2-propyl)phosphate	24388	13674-87-8
TBEP	Tris(2-butoxyethyl) phosphate	6292	78-51-3
TCP	Tricresyl phosphate	21106216	1330-78-5
EHDP	2-Ethylhexyl diphenyl phosphate	14040	1241-94-7
TEHP	Tris(2-ethylhexyl) phosphate	6289	78-42-2
D4	2,2,4,4,6,6,8,8-Octamethyl-1,3,5,7,2,4,6,8-tetroxatetrasilocane	10696	556-67-2
D5	2,2,4,4,6,6,8,8,10,10-Decamethyl-1,3,5,7,9,2,4,6,8,10-pentoxapentasilecane	10451	541-02-6
D6	Dodecamethylcyclohexasiloxane	10449	540-97-6
M3T(Ph)	tris(trimethylsiloxy)phenylsilane	56211	2116-84-9
Cr	Chromium	22412	7440-47-3
Fe	Iron	22368	7439-89-6
Ni	Nickel	910	7440-02-0
Cu	Copper	22414	7440-50-8
Zn	Zinc	22430	7440-66-6
As	Arsenic	4514330	7440-38-2
Ag	Silver	22394	7440-22-4
Cd	Cadmium	22410	7440-43-9
Sb	Antimony	4510681	7440-36-0
Pb	Lead	4509317	7439-92-1
Hg	Mercury	22373	7439-9-76

Bisphenol FL	4,4'-(9H-Fluorene-9,9-diyl)diphenol	69174	3236-71-3
Bisphenol M	4,4'-(1,3-Phenylenedi-2,2-propanediyl)diphenol	2540817	13595-25-0
Bisphenol Z	4,4'-(1,1-Cyclohexanediyl)diphenol	202599	843-55-0
Bisphenol AF	4,4'-(1,1,1,3,3,3-Hexafluoro-2,2-propanediyl)diphenol	66498	1478-61-1
Bisphenol AP	4,4'-(1-Phenyl-1,1-ethanediyl)diphenol	541979	1571-75-1
Bisphenol S	4,4'-Sulfonyldiphenol	6374	80-09-1
4,4-bisphenol F	4,4'-Methylenediphenol	11614	620-92-8
2,2-bisphenol F	2,2'-Methylenediphenol	68100	2467-02-9
Bisphenol E	4,4'-(1,1-Ethanediyl)diphenol	528599	2081-08-5
Bisphenol A	4,4'-(2,2-Propanediyl)diphenol	6371	80-05-7
Bisphenol B	4,4'-(2,2-Butanediyl)diphenol	59553	77-40-7
4-tert-octylphenol	4-(2,4,4-Trimethyl-2-pentanyl)phenol	8483	140-66-9
4-nonylphenol	4-Nonylphenol	1688	104-40-5
Dodekylphenol			27193-86-8
TBBPA	Tetrabromobisphenol A	6366	79-94-7
AO-MB1	4,4'-methylenebis[2,6-bis (1,1-dimethylethyl)-phenol	8069	118-82-1
PFPA	Perfluoropentanoic acid	68426	2706-90-3
PFHxA	Perfluorohexanoic acid	60864	307-24-4
PFHpA	Perfluoroheptanoic acid	61135	375-85-9
PFOA	Perfluorooctanoic Acid	9180	335-67-1
PFNA	Perfluorononanoic acid	61138	375-95-1
PFDA	Perfluorodecanoic acid	9181	335-76-2
PFUdA	Perfluoroundecanoic acid	69649	2058-94-8
PFDoA	Perfluorododecanoic acid	60867	307-55-1
PFTrDA	Perfluorotridecanoic acid	2285907	72629-94-8
PFTeDA	Perfluorotetradecanoic acid	61139	376-06-7
PFBS	Perfluorobutanesulfonic acid	61132	29420-49-3
PFPS	Perfluoropentane-1-sulfonic acid	68427	2706-91-4
PFHxS	Perfluorohexanesulfonic acid	61053	82382-12-5
PFHpS	Perfluoroheptanesulfonic acid	61137	375-92-8

PFOS	Perfluorooctanesulfonic acid	67068	4021-47-0
8Cl-PFOS	8-chloroperfluoro-1-octanesulfonate		
PFNS	Perfluorononanesulfonic acid	78474	17202-41-4
PFDS	Perfluorodecane sulfonic acid	60955	67906-42-7
PFDoS	perfluoro-1-dodecansulfonate		79730-39-5
PFOSA	Perfluorooctanesulfonamide	62984	754-91-6
meFOSA	N-methylperfluoro-1-octanesulfonamide	2298910	31506-32-8
etFOSA	N-Ethylperfluoroctansulfonamid	70194	4151-50-2
meFOSE	2-(N-methylperfluoro-1-octanesulfonamido)-ethanol	81716	24448-09-7
etFOSE	2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol	13908688	1691-99-2
4:2 FTS	1H,2H-perfluorohexane sulfonate (4:2)	16166147	757124-72-4
6:2 FTS	1H,2H-perfluorooctane sulfonate (6:2)	106865	27619-97-2
8:2 FTS	1H,2H-perfluorodecane sulfonate (8:2)	2284056	481071-78-7
meFOSAA	2-(N-methylperfluoro-1-octanesulfonamido)acetic acid	11316301	2355-31-9
etFOSAA	2-(N-ethylperfluoro-1-octanesulfonamido)acetic acid	17128	2991-50-6
F53	potassium 1,1,2,2-tetrafluoro-2-(perfluorohexyloxy)ethane sulfonate		754925-54-7
F53B	potassium 2-(6-chloro-1,1,2,2,3,3,4,4,5,5,6,6-dodecafluorohexyloxy)-1,1,2,2-tetrafluoroethane sulfonate		73606-19-6
BP3	(2-Hydroxy-4-methoxyphenyl)(phenyl)methanone	4471	131-57-7
EHMC	2-Ethylhexyl (2E)-3-(4-methoxyphenyl)acrylate	4511170	5466-77-3
OC	Octocrylene	21165	6197-30-4
UV-327	2,4-di-tert-butyl-6-(5-chlorobenzotriazol-2- yl)phenol	69879	3864-99-1
UV-328	2-(2H-benzotriazol-2-yl)-4,6-ditertpentylphenol	30728	25973-55-1
UV-329 (Octrizole)	2-(2H-benzotriazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)phenol	56265	3147-75-9
ATAC-C20			15809-05-9
ATAC-C22			17301-53-0
TCC	Triclocarban	7266	101-20-2
Triclosan	Triclosan	5363	3380-34-5

7.1 TMF grouped by year

Table 20 TMFs for individual years for all compounds in this appendix. The equation for calculating the TMFs are shown in each graph below.

TMF	2017	2018	2019	2020	mean
BDE-100	3.3	5.1	2.6	4.3	3.2
CB180	4.5	6.4	4.7	5.9	4.5
PFOS	5.3	7.0	6.3	4.2	4.6
Hg	3.8	4.6	4.1	3.1	3.8
Ag	10	11	20	25	12

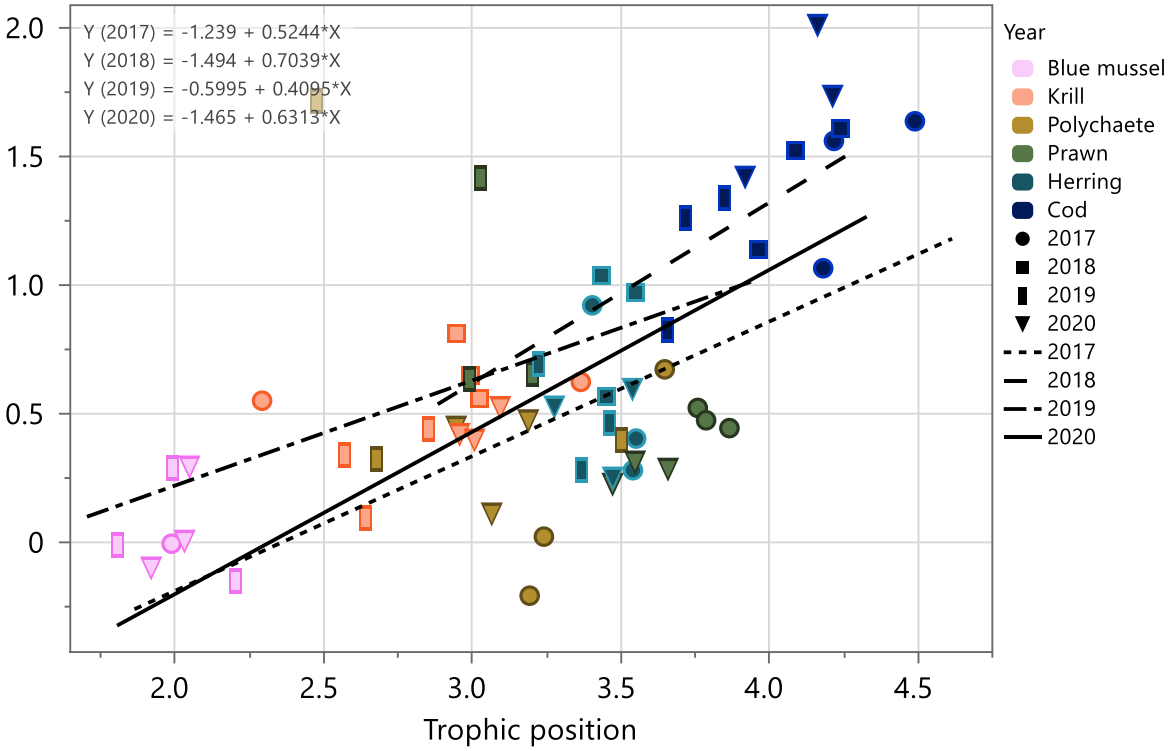

Figure 49 Concentrations of log_{10} BDE-100 lipid normalized against trophic postition. Each year's TMF are indicated in **Table 20**.

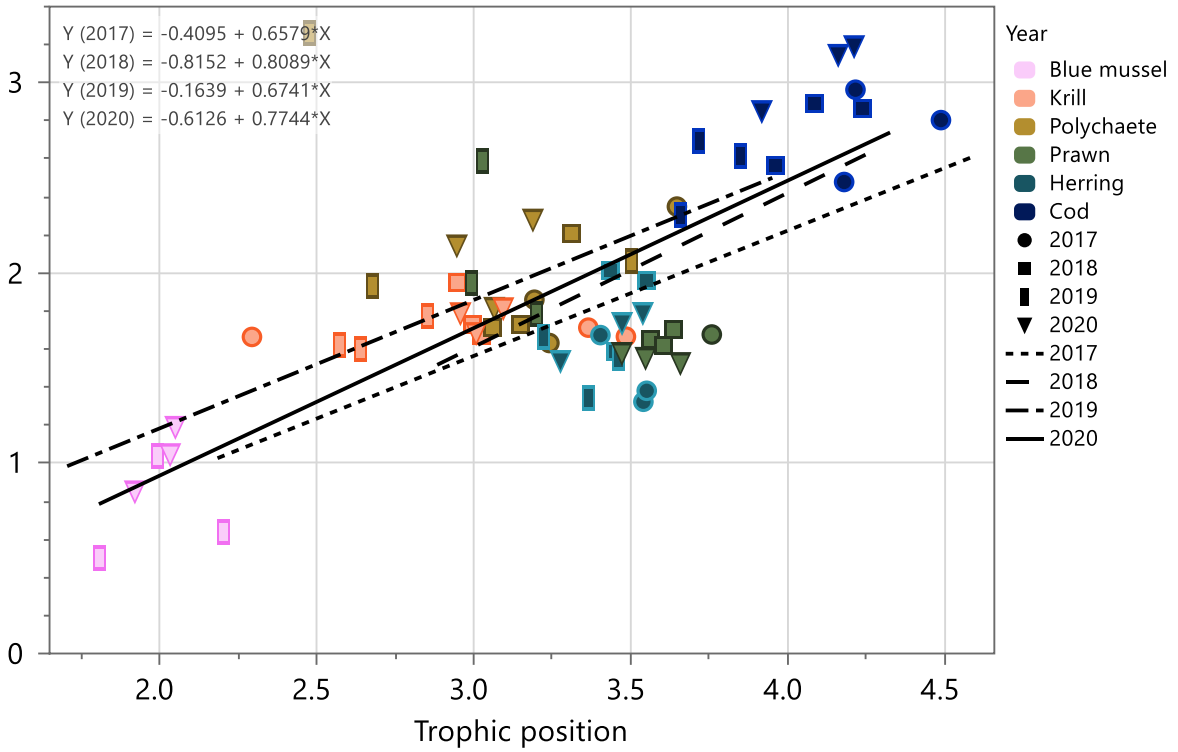

Figure 50 Concentrations of $\log_{10}$ CB-180 lipid normalized against trophic position. Each year's TMF indicated in **Table 20**.

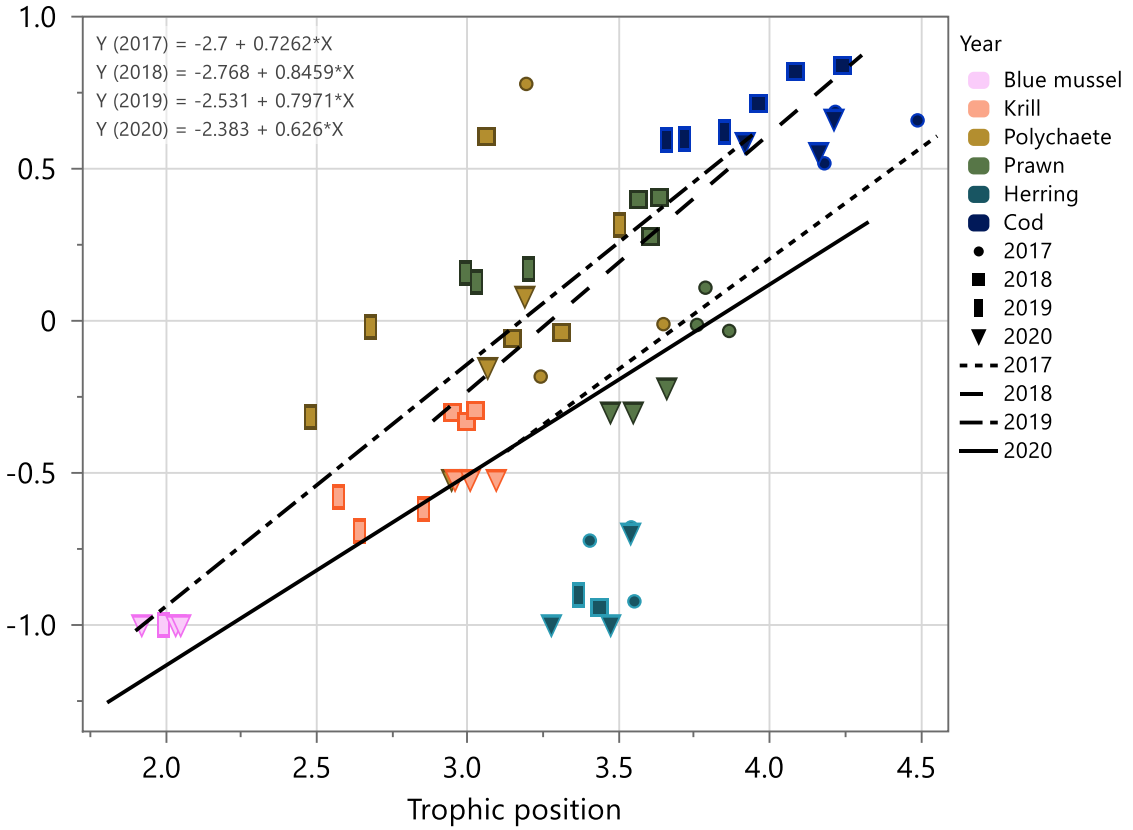

Figure 51 Concentrations of $\log_{10}$ PFOS (ww) against trophic position. Each year's TMF indicated in **Table 20**.

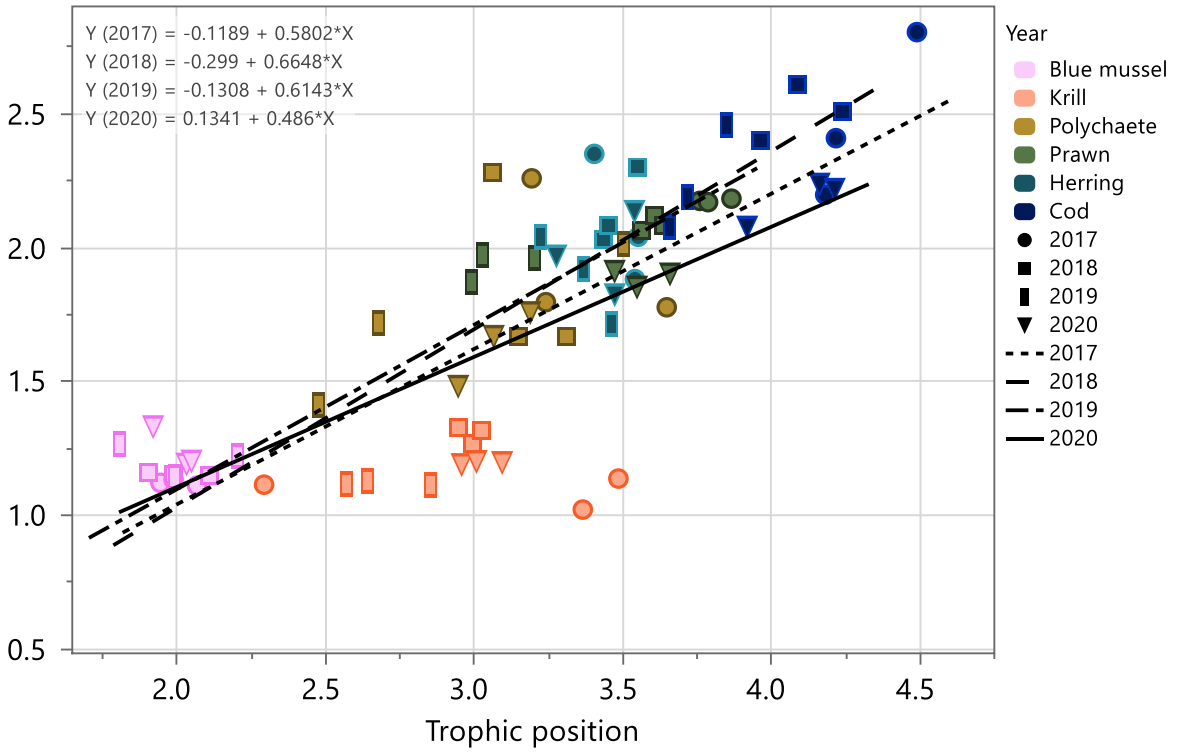

Figure 52 Concentraions of log_{10} Hg (ww) against trophic position. Each year's TMF indicated in **Table 20**.

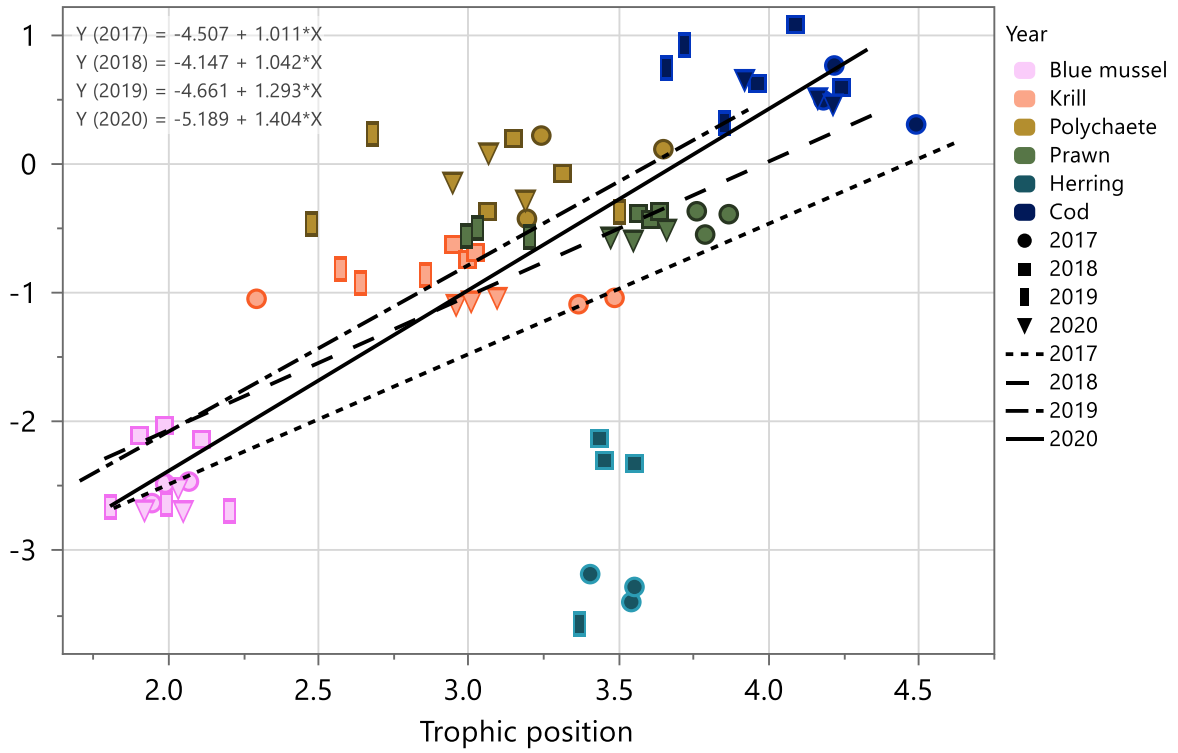

Figure 53 Concentrations of log_{10} Ag (ww) against trophic position. Each year's TMF indicated in **Table 20**.

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