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Contaminants in coastal waters of Norway 2019

Miljøgifter i norske kystområder 2019

Photo: Kjetil Sagerup, Akvaplan-niva

CORRIGENDUM

Changes to the print and electronic version of NIVA-report 7565-2020 «Contaminants in coastal waters of Norway 2019», published 16.12.2020.

Adjusted Tables 4, 11, 12, 14, 23 and 25, and adjusted Figure 14B.

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Summary
This monitoring programme examines levels, trends and effects of contaminants in biota along the coast of Norway. The 2019-investigation included analyses of more than 176 different contaminants or biological effect parameters in six species (blue mussel, dogwhelk, common periwinkle, cod, flounder and common eider). The contaminants measured includes metals (Hg, Cd, Pb, Cu, Zn, Ag, As, Ni, Cr and Co), tributyltin (TBT), organochlorines (e.g. PCBs (PCB-7), DDT, HCB, OCS and QCB), PAHs, polybrominated diphenyl ethers (PBDEs), and perfluorinated alkylated substances (PFAS), as well as contaminants that have recently received much attention such as hexabromocyclododecane (HBCD), chlorinated paraffins (SCCP, MCCP) and siloxanes (D4, D5 and D6). Biological effects parameters includes the imposex parameter VDSI, OH-pyrene metabolites, ALA-D and EROD. In the report, 30 contaminants or biological effects parameters were chosen for statistical analyses of 670 time series (last 10 years). Of these, there were statistically significant trends in 100 cases: 72 were downwards and 28 upwards. The upward trends were associated with metals (67.9 %), primarily Cr (14.3 %). The downwards trends for TBT-concentrations and effect parameter VDSI confirmed that the legislation banning the use of TBT has been effective. Of the 2019-medians (last year) for all 670 time series, there were 346 cases that could be classified against EQS, of which 232 (67.1 %) were below the EQS and 114 (32.9 %) were above the EQS. Of the 2019-medians for the 670 time series, 582 cases could be classified using Norwegian provisional high reference contaminant concentrations (PROREF). Of these, 407 were below PROREF and 175 exceeded PROREF: 82 by a factor of less than two, 51 by a factor between two and five, 31 by a factor between five and 10, four by a factor between 10 and 20, and seven by a factor greater than 20. Some cases warrant special concern, such as high concentrations of several organic contaminants in cod liver from the Inner Oslofjord. Results of analyses of stable isotopes of carbon and nitrogen are presented to investigate the role of food origin and trophic levels for observed concentrations of contaminants. Results from supplementary studies that investigated geographical trends in contaminants and trophic levels are also presented.

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This report is quality assured in accordance with NIVA's quality system and approved by:

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Contaminants in coastal waters of Norway 2019
Miljøgifter i norske kystområder 2019

Preface

This report presents the results of the monitoring programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) that includes investigations of contaminants in coastal waters of Norway in 2019. MILKYS also represents the Norwegian contribution to Coordinated Environmental Monitoring Programme (CEMP, a part of and referred to in earlier reports as the Joint Assessment and Monitoring Programme JAMP). CEMP is administered by the Oslo and Paris Commissions (OSPAR) in their effort to assess and remedy anthropogenic impact on the marine environment of the North East Atlantic. The current focus of the Norwegian contribution is on concentration levels, trends and effects of hazardous substances. The results from Norway and other OSPAR countries provide a basis for evaluating the state of the marine environment. OSPAR receives guidance from the International Council for the Exploration of the Sea (ICES).

The 2019 investigations were carried out by the Norwegian Institute for Water Research (NIVA) by contract from the Norwegian Environment Agency (*Miljødirektoratet*). Coordinator at the Norwegian Environment Agency is Bård Nordbø (deputy coordinator Gunn Lise Haugestøl) and the project manager at NIVA is Norman W. Green (deputy project manager Merete Schøyen).

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Thanks go also to the numerous fishermen and their boat crews for which we have had the pleasure of working with.

Oslo, 16 December 2020.

Norman W. Green
Project Manager
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Contents

Summary

The monitoring programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) examines the levels, trends and effects of contaminants along the coast of Norway from the Oslofjord and Hvaler region in the southeast to the Varangerfjord in the northeast. The programme provides a basis for assessing the state of the environment for the coastal waters.

The main finding is that most contaminant concentrations in marine organisms collected at stations in the Norwegian coastal water showed downward trends. In the Inner Oslofjord more contaminants have higher concentrations than in other areas along the coast and this area warrants special concern. Furthermore, in this area the investigation found a significant upward long-term (> 10 years) trend for mercury (Hg) in cod fillet (*Gadus morhua*).

Monitoring contaminants and associated parameters along the Norwegian coast contributes to the Oslo and Paris Commissions (OSPAR's) Coordinated Environmental Monitoring Programme (CEMP). The 2019-investigation monitored blue mussel (*Mytilus edulis*) at 23 stations, Atlantic cod (*Gadus morhua*) at 16 stations, European flounder (*Platichthys flesus*) at one station, dogwhelk (*Nucella lapillus*) at eight stations, common periwinkle (*Littorina littorea*) at one station and eider (*Somateria mollissima*) at one station. The stations are located both in areas with known or presumed point sources of contaminants, in areas of diffuse load of contamination like city harbour areas, and in more remote areas with presumed low exposure to pollution. In 2019 the following contaminants were among the ones monitored: metals (Hg, cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), nickel (Ni), chromium (Cr) and cobalt (Co)), tributyltin (TBT), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT, using dichlorodiphenyldichloroethylene (DDE) - principle metabolite of DDT as an indicator), hexachlorobenzene (HCB), pentachlorobenzene (QCB), octachlorostyrene (OCS), polycyclic aromatic hydrocarbons (PAHs), polybromated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS), hexabromocyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP) and siloxanes (the cyclic volatile methyl siloxanes, cVMS: D4, D5, D6), as well as biological effects parameters (imposex parameter VDSI, intersex parameter ISI, OH-pyrene, ALA-D and EROD).

The monitoring program in 2019 supplied data for a total of 3009 data sets (contaminant-station-species) on 176 different contaminants. All results are publicly available via Vannmiljo.no, but 30 contaminants and biological effect parameters were chosen for presentation in this report. This selection gave 670 time series; combinations of contaminants, stations, species and tissues. Of these 670, there were statistically significant temporal short-term trends (2010-2019) in 100 cases: 72 were downward- and 28 upward trends. The downward trends were largely associated with concentrations of metals (22.2 %), primarily Cd (6.9 %) and Cr (5.6 %), and tributyltin (TBT) and effects of TBT (VDSI - *vas deferens sequence index*), but also PFOS (5.6 %) and PFOSA (9.7 %). The dominance of downward trends indicated that contamination was decreasing. The upward trends were also associated with metals (67.9 %), primarily Cr (14.3 %).

In this report, the results were assessed primarily in relation to Environmental Quality Standards (EQS) for priority substances and river basin specific pollutants. Of the 670 time series, the median for 2019 in 346 cases could be classified against EQS for priority substances and river basin specific pollutants, of which 232 (67.1 %) were below the EQS and 114 (32.9 %) were above the EQS.

There were 582 time series where the median for 2019 could be compared to a NIVA-developed tool denoted Norwegian provisional high reference contaminant concentration (PROREF). PROREF is a comprehensive set of species-tissue-basis-specific contaminant concentrations that are statistically low when considering all MILKYS-results for the period 1991-2016. This tool sets reference concentrations for contaminants, mostly in areas presumed remote from point sources of contamination, and thus provides a valuable method of assessment of levels of contaminants in addition to EQS. Of the 582 time series, 407 (69.9 %) were below PROREF, and 175 (31.1 %) exceeded PROREF: 82 (14.1 %) by a factor of less than two, 51 (8.8 %) by a factor between two and five, 31 (5.3 %) by a factor between five and 10, four (0.7 %) by a factor between 10 and 20, and seven (1.2 %) by a factor greater than 20. The cases that exceeded PROREF should not be disregarded. For example, the blue mussel in the Mid and Outer Sørfjord exceeded PROREF for pesticides (DDE) by a factor greater than 20.

A supplementary study investigated geographical trends in contaminant in blue mussel and cod from less impacted stations. This was to test whether or not concentrations increased or decreased from the south to the north along the Norwegian coast. For statistically significant trends, the decrease in concentrations varied between nine and 55 % per 1 000 km, where the greatest decrease was for PFOSA in cod liver, whereas the increase varied from one to 101 %, where the greatest increase was for Cd in cod liver. Changes of 20 % or more in either or both species were restricted to Ag, Co, PCB-7, DDE, BDE100, PFOS, PFOSA, TBT and TPT as a decrease, and Ag, Cd, and HCB as an increase.

Levels and trends in blue mussel

The concentration of Pb in blue mussel was highest at Gressholmen in the Inner Oslofjord, and the PROREF was exceeded by a factor of 10 to 20. There were both significant upward long- and short-term trends for Pb at Gressholmen and Gåsøya. There were significant upward long- and short-term trends for Cr at Risøy at Risør.

PCB-7 in blue mussel at all stations exceeded both the EQS and PROREF. The highest PCB-7 concentration was found in blue mussel at Nordnes in Bergen harbour.

For DDE, blue mussel from Kvalnes in the Mid Sørfjord and Utne in the Outer Sørfjord exceeded PROREF by a factor greater than 20. Mussels at Krossanes in the Outer Sørfjord exceeded PROREF for DDE by a factor between 10 and 20. As for cod liver, contamination of this substance is related to earlier use of DDT as pesticide in the area of the Sørfjord.

Applying EQS for PAH in blue mussel, all stations had concentrations below this limit for the PAHs anthracene, fluoranthene, benzo(a)pyrene, napthalene and benzo(a)anthracene. The highest concentrations of PAHs in blue mussel were found in the Oslo harbour area. Blue mussel at all stations had concentrations below PROREF for PAHs. Concentrations of KPAHs were highest at the station Akershuskaia in the Inner Oslo harbour area. Blue mussel at all stations exceeded PROREF for KPAHs. Mussels at Akershuskaia exceeded PROREF for fluoranthene and benzo(a)anthracene.

Concentrations of PBDEs (sum of six compounds – BDE6S[1]) in blue mussel were highest in Bodø harbour area. All blue mussel stations were below PROREF for PBDEs, but all exceeded the EQS for BDE6S and BDE47.

[1] Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa)

All concentrations of HBCD were below the EQS, and the highest median concentrations of α-HBCD was found in Bodø harbour. Decreasing levels were found, with significant downward trends for HBCD in blue mussel from five stations.

All concentrations of SCCP and MCCP were below the EQS, except for MCCP in blue mussel from Bodø harbour. There were highest concentrations of SCCP in mussels from Ørland, and highest concentrations of MCCP in mussels from Bodø. Activities at the local airports might be a source to MCCPs and SCCPs. There was a significant long-term downward trend for SCCP in mussels from Færder and Tjøme, Outer Oslofjord. There were significant long-term and short-term upward trends for SCCP in blue mussel from Singlekalven in the Hvaler area.

There were only low concentrations of HCB, OCS and QCB, and all median concentrations in blue mussel were lower that the limit of quantification. A significant long-term downward trend was found for concentrations of HCB in mussels from Gressholmen in the Inner Oslofjord, Solbergstrand in the Mid Oslofjord, Færder and Tjøme in the Outer Oslofjord and at Odderøya in the Kristiansandfjord.

Levels and trends in fish

For Hg, the concentrations in cod fillet at all stations exceeded the EQS in 2019, also at the reference station at Svalbard. Cod fillet from the Inner Oslofjord exceeded the PROREF for Hg by a factor of two to five. Significant upward long-term (1984-2019) trends for Hg in cod fillet from the Inner Oslofjord were found both when using the OSPAR method which targets specific length-groups and when adjusting to expected concentrations for 50 cm cod using the method taking into considerations fish-length. Cod fillet from Tjøme in the Outer Oslofjord exceeded the PROREF for Hg by a factor of two to five. There were significant upward long-term and short-term trends for Hg in cod fillet from Kristiansand harbor, at Skågskjera in Farsund and at Bømlo. Trends were significant also after adjusting for cod length for the Kristiansand harbour and Farsund.The highest Hg concentration was found in cod fillet from the Inner Oslofjord (0.190 mg Hg/kg wet weight, w.w.).

All concentrations of PCB-7 in cod liver exceeded the EQS in 2019. Cod liver from the Inner Oslofjord and Bergen harbour exceeded the PROREF for PCB-7 by a factor between two and five. The second highest concentrations of PCB-7 in cod liver from the Inner Oslofjord is probably related to urban activities in the past in combination with little water exchange with the outer fjord.

All concentrations of DDE in cod liver were below the EQS in 2019. In the Inner Sørfjord, the exceedance of the PROREF was by a factor between two and five times. Contamination of this substance is related to earlier use of DDT as pesticide in orchards along the fjords (ca. 1945-1970).

All concentrations of PBDEs in cod liver exceeded the EQS in 2019. The highest median concentrations of sum PBDEs (28, 47, 99, 100, 153 and 154) were found in Bergen harbour and the Inner Oslofjord. The lowest level was observed at Svalbard. BDE47 was the dominant congener in all samples and was significantly higher in the Inner Oslofjord and Bergen harbour than the six other stations in remote areas. As for PCB-7, the high concentrations of PBDEs are probably related to urban activities and water exchange conditions.

PFAS in cod liver has been investigated from several fjords since 2005. PFOS and PFOSA, both abundant PFAS-compounds, were highest in cod liver from the Inner Oslofjord. In 2017 and 2019, PFOSA concentrations in cod liver from Tjøme did not exceed PROREF, whereas it was exceeded by a factor of five to 10 in 2018. Other studies have related PFAS concentrations in biota from the

Oslofjord to earlier use of firefighting foam at Rygge airport, as blue mussel in the Mossesundet. The reason behind the differences in concentrations between the stations in the Oslofjord are not fully understood, but it appears likely that a combination of urban sources and restricted water exchange provide high concentrations in the Inner Oslofjord. The lowest PFAS concentrations were found in Tromsø harbour. A supplementary study assessed possible correlation of PFOS, PFOSA and PFUdA in cod with distance from the nearest airport (alleged possible source), but no correlation was found.

All concentrations of hexabromocyclododecanes (HBCD) in cod liver were below the EQS in 2019, and α–HBCD was the most abundant diastereomer. The concentration of α–HBCD in cod liver was significantly higher in the Inner Oslofjord compared to the 12 other cod stations investigated, but HBCD levels were found to decline at several stations including at Stathelle, Kirkøy, Bømlo and the Inner Oslofjord. The high HBCD concentrations in the Inner Oslofjord found at several sites is probably related to urban activities, and for the Inner Oslofjord reduced water exchange with the outer fjord may have an added impact. There were both significant downward long- and short-term trends for HBCD in cod liver from Stathelle area in the Langesundfjord, from Kirkøy, Hvaler, Bømlo, Kristiansand harbour, Trondheim harbour and Tromsø harbour. A significant downward short-term trend was also found for HBCD in cod liver from the Inner Oslofjord.

Short and medium chain chlorinated paraffins (SCCP, MCCP, respectively) were highest in cod liver from the Kirkøy in the Hvaler area (but did not exceed PROREF). A significant upward long-term trend was found for MCCP in cod liver from Bømlo in the Outer Selbjørnfjord. Significant downward short-term and long-term trends were found for SCCP in cod liver from Bergen harbour area. There was also a significant downward long-term trend for SCCP in cod liver from the Inner Sørfjord. Cod from Svalbard had the same level of SCCP as cod from some urban areas along the coast of Norway.

Cod from Autnesfjord in Lofoten had concentrations of HCB that exceeded EQS. Long-term downward trends were found for HCB in cod liver from Skågskjera in Farsund, the Inner Oslofjord, Tjøme and the Inner Sørfjord.

All concentrations of the siloxane D5 in cod liver were below EQS. D5 was the most dominant, and the levels were highest in the Inner Oslofjord and lowest in the Isfjord at Svalbard. The same patterns were found for D4 and D6.

Levels in flounder

In flounder liver at Sande in the Mid Oslofjord, significant downward long-term trends were found for Pb, Cu, PCB-7, DDE and HCB. A significant upward short-term trend was found for cadmium in flounder liver from the same station.

Levels in eider

Contaminants were analysed in the blood and eggs (homogenate of yolk and albumin) of the eider from Svalbard for the third time in this programme. Concentrations of Hg, Pb, As, CB153, BDE47, PFOS and PFOSA in eggs were in the same level as from comparable studies from the Svalbard region.

The Hg concentrations in eider blood and eggs at Svalbard in 2019 was almost within the same range as in the comparable monitoring study, Environmental Contaminants in an Urban Fjord, in the Inner Oslofjord in 2017. The concentrations of PCB-7 was 14-122 times higher in eider blood and eggs, respectively, from the Inner Oslofjord in 2017 than at Svalbard in 2019. The concentrations of BDE 47 were eight times higher in eider eggs in the Inner Oslofjord in 2017 than

at Svalbard in 2019. The PFOS concentrations in eider blood and eggs were 10 times higher in the comparably study in the Inner Oslofjord than at Svalbard in 2019.

Biological effects

The ICES/OSPARs assessment criterion[1] (background assessment criteria, BAC) for OH-pyrene in cod bile was exceeded at all stations investigated (Inner Oslofjord, Inner Sørfjord, Farsund area, and Bømlo-Sotra area), in 2019, however only barely at the two latter. This indicates that the fish have been exposed to PAH compounds. The median concentration of OH-pyrene metabolites in bile from cod in the Inner Sørfjord was significantly higher in 2019, than in 2018, and this was the station with the highest concentrations of OH-pyrene.

The ALA-D activity in the the Inner Sørfjord and Inner Oslofjord in 2019 were lower than at Bømlo. Reduced activities of ALA-D reflect higher exposure to Pb. Higher concentrations of Pb in cod liver have generally been observed in the Inner Oslofjord and Inner Sørfjord compared to the Outer Selbjørnfjord at Bømlo.

In 2019, the median EROD activity appeared slightly higher in the Inner Oslofjord (st. 30B) and slightly lower in the Inner Sørfjord (st. 53B), compared to Bømlo (st. 23B), but these differences were not statistically different. High activity of hepatic cytochrome P4501A activity (EROD-activity) normally occurs as a response to planar organic molecules, such as certain PCBs, PAHs and dioxins. The EROD activities were below the ICES/OSPARs BAC. Concentrations over BAC would indicate possible impact by planar PCBs, PCNs, PAHs or dioxins. Statistically significant downward trends in EROD activity were observed on both a long-term basis (whole data series) and a short-term basis (last 5 years) at all three stations.

There were significant downward long-term trends for both TBT concentrations and the imposex parameter VDSI at seven of eight dogwhelk stations. No effects on dogwhelk (imposex parameter VDSI=0) was observed. For the first time since 1991, there were no effects of TBT on dogwhelk (imposex parameter VDSI=0) at any of the eight stations in 2017. The 2019 data also confirmed these results. The synchronous decreases in both TBT concentrations and imposex parameters in dogwhelk coincides with the TBT bans for longer vessels than 25 meters in 2003 and the global total ban in 2008. The results shows how regulations, like TBT-bans, can be effective in reducing levels and effects of environmental contaminants.

Stable isotopes

The stabile isotope $\delta^{15}N$ is analysed as a measure of trophic position. The isotopic signatures were different among stations (geographical variation). However, results showed very similar isotopic signatures for the stations in 2019 and 2018 and earlier, and indicated that the geographical variation is not changed over time. The isotopic signatures in mussels from the programme thus provide valuable information about the isotopic baselines along the Norwegian coast.

Baseline adjusted trophic position of cod differed between stations along the Norwegian coast. This suggests that parts of the spatial differences in contaminant concentrations may be attributed to different trophic positions of the cod at the different stations, and not merely differences in environmental concentrations between stations.

[1] Assessment criteria have specifically been compiled for the assessment of CEMP monitoring data on hazardous substances. They do not represent target values or legal standards.

Sammendrag

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Resultatene i overvåkingsprogrammet viser at det hovedsakelig var nedadgående trender for konsentrasjoner av de undersøkte miljøgiftene. Indre Oslofjord peker seg ut som et område der flere miljøgifter har relativt høye konsentrasjoner. Dette gir grunnlag for bekymring og behov for nærmere undersøkelser. I indre Oslofjord ble det observert en signifikant oppadgående langtidstrend (> 10 år) for kvikksølv (Hg) i torskefilét.

Undersøkelsen inngår som en del av Oslo og Paris konvensjonens (OSPARs) koordinerte miljøovervåkingsprogram Coordinated Environmental Monitoring Programme (CEMP). I 2019 omfattet overvåkingen miljøgifter i blåskjell (*Mytilus edulis*) fra 23 stasjoner, torsk (*Gadus morhua*) fra 16 stasjoner, skrubbe (*Platichthys flesus*) fra én stasjon, purpursnegl (*Nucella lapillus*) fra åtte stasjoner, strandsnegl (*Littorina littorea*) fra én stasjon og ærfugl (*Somateria mollissima*) fra én stasjon. Stasjonene er plassert i områder med kjente eller antatt kjente punktkilder for tilførsler av miljøgifter, i områder med diffus tilførsel av miljøgifter slik som byens havneområder og i fjerntliggende områder med antatt lav eksponering for miljøgifter. Overvåkingen i 2019 omfattet analyser av bl.a. metaller (kvikksølv (Hg), kadmium (Cd), bly (Pb), kobber (Cu), sink (Zn), sølv (Ag), arsen (As), nikkel (Ni), krom (Cr) og kobolt (Co)), tributyltinn (TBT), polyklorerte bifenyler (PCBer), pestisider (DDE og heksaklorbenzen (HCB)), pentaklorbenzen (QCB), oktaklorbenzen (OCB), polysykliske aromatiske hydrokarboner (PAHer), polybromerte difenyletere (PBDEer), perfluorerte alkylforbindelser (PFAS), heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP) og siloksaner (sykliske flyktige metylsiloksaner, cVMS: D4, D5, D6), samt biologiske effekt-parametere (imposex parameter VDSI, intersex parameter ISI, OH-pyren, ALA-D og EROD).

2019-resultatene omfatter totalt 3009 datasett (miljøgifter-stasjoner-arter) for 176 forskjellige miljøgifter. Alle resultater er tilgjengelig på Vannmiljø.no. Et utvalg av 30 miljøgifter og biologiske parametere presenteres i denne rapporten. Dette utvalget består av 670 tidsserier hvorav 100 viste statistisk signifikante korttids trender for perioden 2010 til 2019: 72 var nedadgående og 28 var oppadgående. De nedadgående trendene omfattet metaller (22,2 %), primært Cd (6,7 %) og Cr (5,6 %) og tributyltinn (TBT) og effekt av TBT (VDSI – sædlederindeks), men også PFOS (5,6 %) og PFOSA (9,7 %). Dominansen av nedadgående trender indikerer avtagende nivåer av miljøgifter. De oppadgående trendene var i hovedsak også for metaller (67,9 %), og da primært krom (14,3 %).

I denne rapporten, er resultatene vurdert primært i relasjon til miljøkvalitetsstandarder (EQS) for prioriterte stoffer. Av de 670 tidsseriene kunne median for 2019 i 346 av dem klassifiseres i forhold til EQS for prioriterte og vannregionspesifikke stoffer. I 2019 var 232 (67,1 %) lavere enn miljøkvalitetsstandardene og 114 (32,9 %) høyere enn miljøkvalitetsstandardene.

Det var 582 tidsserier hvor median for 2019 kunne vurderes i forhold til et nytt begrep kalt norsk provisorisk høy referansekonsentrasjon for miljøgifter (PROREF). Dette verktøyet angir referansekonsentrasjoner for miljøgifter, hovedsakelig i områder fjernt fra punktkilder, og er dermed en verdifull metode for å vurdere nivåer av miljøgifter i tillegg til EQS. Av disse var 407 (69,9 %) lavere enn PROREF og 175 (31,1 %) overskred PROREF. For 82 tidsserier (14,1 %) var

overskridelsen av PROREF på en faktor lavere enn to. For 51 tidsserier (8,8 %) var overskridelsen av PROREF på en faktor på mellom to og fem. For 31 tidsserier (5,3 %) var overskridelsen av PROREF på en faktor mellom fem og 10. For fire tidsserier (0,7 %) var overskridelsen av PROREF på en faktor mellom 10 og 20, og for syv tidsserier (1,2 %) var overskridelsen av PROREF på en faktor høyere enn 20. Tilfellene som overstiger PROREF bør ikke ignoreres. Et eksempel på dette er blåskjell i midtre og ytre Sørfjorden som hadde konsentrasjoner av DDE som oversteg PROREF med en faktor på over 20.

En supplerende undersøkelse analyserte korrelasjon mellom miljøgiftkonsentrasjoner i blåskjell og torsk fra mindre forurensede steder med avstand langs kysten fra svenske- til russisk grensen. Dette var for å teste om konsentrasjoner har økt eller avtatt fra syd til nord langs kysten. For de statistisk signifikante trender, nedadgående konsentrasjoner varierte fra ni til 55 % pr. 1000 km, hvor PFOSA i torskelever hadde størst nedgang, og oppadgående konsentrasjoner varierte fra en til 101 %, hvor Cd i torskelever hadde størst oppgang. Miljøgifter som varierte mer enn 20 % i en eller begge artene omfattet Ag, Co, PCB-7, DDE, BDE100, PFOS, PFOSA, TBT og TPT som nedadgående og Ag, Cd og HCB som oppadgående.

Konsentrasjoner og trender av miljøgifter i blåskjell
Blåskjell fra Gressholmen i indre Oslofjord hadde høyest konsentrasjon av bly i denne undersøkelsen, og overskridelsen var mellom 10 og 20 ganger høyere enn PROREF. Det var signifikant oppadgående langtids- og kortidstrend for bly på Gressholmen og Gåsøya. Det var signifikant oppadgående langtids- og korttidstrend for krom i blåskjell fra Risøy ved Risør.

Konsentrasjoner av PCB-7 i blåskjell overskred både EQS og PROREF ved alle stasjonene. Den høyeste PCB-7 konsentrasjonen var i blåskjell fra Nordnes i Bergen havn.

Blåskjell fra Kvalnes i midtre del av Sørfjorden og Utne i ytre del av Sørfjorden hadde konsentrasjoner av DDE som var mer enn 20 ganger høyrere enn PROREF. Skjell fra Krossanes i ytre del av Sørfjorden hadde overskridelse av PROREF for DDE med en faktor på mellom 10 og 20. Forurensning av denne miljøgiften i både blåskjell og torsk skyldes tidligere bruk av DDT som sprøytemiddel.

Ingen blåskjellstasjoner hadde konsentrasjoner som overskred EQS for antracen, fluoranten, benzo(a)pyren, naftalen eller benzo(a)antracen. Det var høyest konsentrasjoner av PAH-forbindelser i blåskjell fra havneområdet i indre Oslofjord. Ingen av blåskjellstasjonene overskred PROREF for PAH-16. Nivået av KPAH var høyest i blåskjell fra Akershuskaia i indre Oslo havneområde. Det var overskridelser av PROREF for KPAH ved alle stasjonene. Blåskjell ved Akershuskaia overskred PROREF for fluoranten og benzo(a)antracen.

Det var høyest nivå av PBDEer (sum av seks PBDE-forbindelser) i blåskjell fra Bodø havn. Det var ingen overskridelser av PROREF for PBDEer ved noen av blåskjellstasjonene, men alle overskred EQS.

I 2019 var alle konsentrasjonene av HBCD i blåskjell lavere enn miljøkvalitetsstandarden (EQS). Det var høyest konsentrasjon av α-HBCD i blåskjell fra Bodø havn. Det ble funnet nedadgående nivåer for HBCD i blåskjell, bl.a. var det signifikant nedadgående langtidstrend for HBCD i blåskjell fra Tjøme i ytre Oslofjord, Nordnes i Bergen, Ørland i ytre Trondheimsfjord, Bodø havn og Svolvær.

Alle konsentrasjonene av SCCP og MCCP var under EQS, bortsett for MCCP i blåskjell fra Bodø havneområde. Det var høyest konsentrasjoner av kortkjedete klorparafiner (SCCP) i blåskjell fra Ørland, og høyest konsentrasjon av mellomkjedete klorparafiner (MCCP) i blåskjell fra Bodø havn.

De lokale flyplassene kan være mulige kilder til SCCP og MCCP på disse stedene. Det ble påvist signifikant oppadgående langtidtrend og korttidstend for SCCP i blåskjell fra Singlekalven i Hvaler.

Det var kun lave konsenrasjoner av HCB, OCS og QCB, og alle mediankonsentrasjonene i blåskjell var lavere enn kvantifiseringsgrensen. Det var nedadgående langtidstrend for HCB i blåskjell fra Gressholmen i indre Oslofjord, Solbergstrand i Midtre Oslofjord, Tjøme i ytre Oslofjord og ved Odderøya i Kristiansandsfjorden.

Konsentrasjoner og trender av miljøgifter i fisk
I 2019 var det overskridelse av EQS for kvikksølv i torskefilét fra samtlige stasjoner, også ved referansestasjonen på Svalbard. Torsk fra indre Oslofjord hadde konsentrasjon av kvikksølv i filét som var to til fem ganger høyere enn PROREF, og det var signifikante oppadgående langtidstrender (1984-2019) både med OSPARs metode for spesifikke lengdegrupper og ved beregning med metode som tar hensyn til fiskelengde ved justering til forventede konsentrasjoner for 50 cm torsk. Torsk fra Tjøme i ytre Oslofjord hadde konsentrasjon av kvikksølv i filét som var to til fem ganger høyere enn PROREF. Det var signifikante oppadgående lang- og kortidstrender for kvikksølv i torskefilét fra Kristiansand havn, Skågskjera ved Farsund og Bømlo. Trender var signifikante også etter justering for fiskelengde i Kristiansand havn og Farsund. Den høyeste kvikksølvkonsentrasjonen ble funnet i torskefilét fra indre Oslofjord (0,190 mg Hg/kg våtvekt, v.v.).

Konsentrasjonene av PCB-7 i torskelever var høyere enn EQS. Det var forhøyede nivåer av PCB-7 i torskelever fra indre Oslofjord og Bergen havn, med overskridelse av PROREF med en faktor på mellom to og fem. Den nest høyeste konsentrasjonen av PCB-7 som ble observert i torskelever fra indre Oslofjord skyldes trolig forurensning fra lang tid tilbake samt lav vannutskifting med ytre fjord.

Konsentrasjonene av DDE i torskelever var lavere enn EQS. I indre Sørfjord var det en overskridelse av PROREF med en faktor på mellom to og fem. Forurensning av dette stoffet skyldes tidligere bruk av DDT som plantevernmiddel i forbindelse med fruktdyrking langs fjordene (ca. 1945-1970).

Konsentrasjonene av PBDEer i torskelever var høyere en EQS for BDE6S and BDE47. I 2019 var de høyeste nivåene av sum PBDEer (28, 47, 99, 100, 153 and 154) i torskelever fra henholdsvis Bergen havn og indre Oslofjord, og lavest nivå ble observert i torsk fra Svalbard. BDE47 var den dominerende PBDE-forbindelsen i alle prøvene, og det var signifikant høyere nivåer av denne forbindelsen i torskelever fra indre Oslofjord og Bergen havn enn i torsk fra seks stasjoner fra områder lengre unna urbane områder. Som for PCB-7, er urban påvirkning og vannutskiftingsforhold trolig årsaker til de høye nivåene.

PFAS har blitt undersøkt i torskelever i mange fjorder siden 2005. PFOS og PFOSA, som begge er vanlige PFAS-forbindelser, var høyest i torskelever fra indre Oslofjord. I 2017 og 2019 var det ingen overskridelse av PROREF for PFOSA i torskelever fra Tjøme, sammenliknet med en overskridelse på mellom fem og 10 ganger i 2018. Flere andre studier har relatert PFAS konsentrasjoner i biota til bruken av brannskum på Rygge flystasjon, som for eksempel blåskjell i Mossesundet. Nivåforskjellene mellom de ulike områdene i Oslofjorden kan foreløpig ikke forklares fullt ut, men det er sannsynlig at en kombinasjon av urbane kilder og begrenset vannutskifting gir høyere konsentrasjonene i indre Oslofjord. De laveste PFAS konsentrasjonene ble registrert i Tromsø havn. En supplerende undersøkelse viste ingen korrelasjon for PFOS, PFOSA og PFUdA i torskelever med avstand til nærmeste flyplass.

I 2019 var alle konsentrasjonene av heksabromsyklododekaner (HBCD) i torskelever lavere enn EQS. Av HBCDene var α-HBCD den mest dominerende diastereomeren. Konsentrasjonen av α–HBCD i

torskelever var signifikant høyere i indre Oslofjord enn for de 12 andre undersøkte stasjonene. Det var nedadgående nivåer av HBCD på flere stasjoner, bl.a. for Stathelle, Kirkøy, Bømlo og indre Oslofjord. De høye konsentrasjonene av HBCD i indre Oslofjord har trolig sammenheng med urbane aktiviteter, og for indre Oslofjord kan den langsomme utskifting av vannmassene ha en tilleggsvirkning. Det var signifikant nedadgående langtidstrend og korttidstrend for HBCD i torskelever fra Kirkøy på Hvaler, Stathelleområdet i Langesundsfjorden, Kristiansand havn, Bømlo, Trondheim havn og Tromsø havn. Det var også signifikant nedadgående korttidstrend for HBCD i lever av torsk fra indre Oslofjord.

Det var høyest konsentrasjon av kortkjedete klorparafiner (SCCP) og mellomkjedete klorparafiner (MCCP) i lever av torsk som var fanget ved Kirkøy på Hvaler. Det var signifikant oppadgående langtidstrend for MCCP i torskelever fra Bømlo i ytre Selbjørnsfjord. Det var signifikant nedadgående langtidstrend og kortidstrend for SCCP i torskelever fra Bergen havn. Det var også signifikant nedadgående langtidstrend for SCCP i torskelever fra indre Sørfjorden. Torsk fra Svalbard hadde omtrent samme nivå av SCCP som torsk fra noen urbane områder langs kysten.

Torsk fra Autnesfjord i Lofoten hadde konsentrasjon av HCB i lever som overskred EQS for dette stoffet. Det ble påvist nedadgående langtidstrender for median konsentrasjon av HCB i torskelever fra indre Oslofjord, Tjøme, Skågskjera i Farsund og indre Sørfjorden.

Det ble analysert for siloksaner i torskelever, og for D5 var alle konsentrasjonene under EQS. D5 var den mest dominerende forbindelsen. Det var høyest nivå av D5-siloksan i torskelever fra indre Oslofjord, og lavest konsentrasjon i torsk fra Isfjorden på Svalbard. Det samme mønsteret ble funnet for siloksanene D4 og D6.

Konsentrasjoner av miljøgifter i skrubbe
Det ble funnet signifikante nedadgående langtidstrender for bly, kobber, PCB-7, DDE og HCB i skrubbelever fra Sande i midtre Oslofjord. Det var signifikant oppadgående korttidstrend for konsentrasjon av kadmium i lever av skrubbe fra Sande.

Konsentrasjoner av miljøgifter i ærfugl
Det ble gjort analyser av blodprøver og egg fra ærfugl fra Svalbard for tredje gang i dette programmet. Konsentrasjonene av kvikksølv, bly, arsen, PCB153, BDE47, PFOS og PFOSA i egg var på samme konsentrasjonsnivåer som i andre lignende studier fra Svalbard området.

Konsentrasjonene av kvikksølv i blod og egg hos ærfugl på Svalbard i 2019 var omtrent på samme nivå som i et sammenliknbart overvåkingsstudie, Miljøgifter i en urban fjord, fra indre Oslofjord i 2017. Konsentrasjonene av PCB-7 var 14-22 ganger høyere i henholdsvis blod og egg fra indre Oslofjord i 2017 enn på Svalbard i 2019. Konsentrasjonene av BDE 47 var åtte ganger høyere i ærfuglegg fra indre Oslofjord i 2017 enn på Svalbard i 2019. PFOS-konsentrasjonene i ærfuglblod og egg var 10 ganger høyere i indre Oslofjord enn på Svalbard i 2019.

Biologiske effekter
ICES/OSPARs vurderingskriterium for bakgrunnsnivå[1] («background assessment criteria», BAC) for OH-pyren i torskegalle ble overskredet på alle undersøkte stasjoner (indre Oslofjord, indre Sørfjorden, Farsund-området og Bømlo-Sotra området) i 2019, men kun så vidt på de to siste stasjonene. Dette viser at fisken har vært eksponert for PAH. Mediankonsentrasjonen av OH-pyren

[1] Vurderingskriteriene er spesielt utarbeidet for vurdering av CEMP-overvåkingsdata for farlige forbindelser. De representerer ikke målverdier eller juridiske standarder.

metabolitter i galle i torsk fra indre Sørfjorden var signifikant høyere i 2019 enn i 2018, og dette var stasjonen med høyest konsentrasjon av OH-pyren.

I 2019 var ALA-D aktivitet i torsk fra indre Oslofjord og indre Sørfjorden lavere enn i torsk fra Bømlo. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly. Det har generelt vært høyere konsentrasjoner av bly i torskelever fra indre Oslofjord og indre Sørfjorden enn i torsk fra Bømlo i ytre Selbjørnfjord.

I 2019 fremsto median EROD-aktivitet i lever fra indre Oslofjord noe høyere, og i indre Sørfjorden noe lavere, enn på referansestasjonen (ytre Selbjørnfjord på Bømlo). Høy aktivitet av hepatisk cytochrome P4501A (EROD-aktivitet) skjer normalt som en respons på plane organiske molekyler som PCBer, PAH-forbindelser og dioksiner. EROD-aktiviteten var lavere enn ICES/OSPARs bakgrunnsvurderingsnivå (BAC). Konsentrasjoner over dette nivået vil indikere mulig påvirkning fra plane PCBer, PCNer, PAHer eller dioksiner. Statistisk signifikante nedadgående langtids- og korttids-trender i EROD-aktivitet ble observert på alle tre stasjoner

Det ble registrert signifikante nedadgående langtidstrender for både TBT konsentrasjoner og imposex parameter (VDSI) på syv av de åtte purpursnegl stasjonene. Ingen effekt av TBT i purpursnegl (imposex parameter VDSI=0) ble funnet. I 2017 var det for første gang siden 1991 ingen effekter av TBT på purpursnegl (imposex parameter VDSI=0) på noen av de åtte stasjonene. Undersøkelsen i 2019 bekreftet disse resultatene. Den synkrone nedgangen i både TBT-konsentrasjoner og imposex-parametere i purpursnegl samsvarer med TBT-forbudene i 2003 for skip lenger enn 25 meter og det globale totalforbudet i 2008. Resultatene er et godt eksempel på at lovgivningen som forbyr miljøgifter, slik som TBT, har vært effektiv.

Stabile isotoper

Stabile isotoper av nitrogen (uttrykt som $\delta^{15}N$) er analysert for å tolke en organismes posisjon i næringskjeden. Isotop-signaturene var forskjellige blant stasjonene (geografiske forskjeller). Likevel viste resultatene like isotop-signaturer i 2019 som i 2018 og tidligere. Dette tyder på at den romlige trenden er stabil over tid og at isotopsignaturer i blåskjell gir verdifull informasjon om bakgrunnsnivået for isotopsignaturer langs norskekysten.

Baselinje-justert trofisk posisjon for torsk var forskjellig på ulike stasjoner langs norskekysten. Dette kan innebære at noen av forskjellene i konsentrasjoner av stoffer med biomagnifiseringspotensiale, mellom stasjoner, skyldes torskenes plassering i næringskjeden, og ikke kun ulikheter i eksponering på de forskjellige lokalitetene.

1. Introduction

1.1 Background

The monitoring programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) is administered by the Norwegian Environment Agency (*Miljødirektoratet*), that monitors on the levels, trends and effects of hazardous substances in fjords and coastal waters in Norway. The objective of this monitoring programme is to obtain updated information on levels and trends of selected hazardous substances known or suspected to have a potential for causing detrimental biological effects in Norway. The programme also represents the Norwegian contribution to the Coordinated Environmental Monitoring Programme (CEMP). CEMP is a joint European monitoring programme under the auspices of Oslo and Paris Commissions (OSPAR). The Norwegian contribution to CEMP addresses several aspects of OSPAR's assessment of hazardous substances. All the results in this report are considered part of the Norwegian contribution to the CEMP programme as well as to the European Environment Agency (EEA) as part of the assessment under the EU Water Framework Directive (WFD).

Concentrations of hazardous substances in sediment, pore water, mussels and fish are time-integrating indicators for the quality of coastal water. Many hazardous substances accumulate and show higher concentrations in tissues (bioaccumulation) and organisms than in the surrounding environment (i.e. in water and in some cases sediment). Hence, it follows that substances which would otherwise be difficult to detect when analysing water or sediment in some instances may only be detected in tissues and organisms. Furthermore, biota concentrations, as opposed to water or sediment, are of direct ecological importance and also provides information for that is relevant to human health (dietary exposure assessments and recommendations on food intake) and to commercial interests involved in harvesting marine resources.

MILKYS applies the OSPAR CEMP methods (OSPAR 2018). These OSPAR methods suggest *inter alia* monitoring of blue mussel, snails and Atlantic cod on an annual basis.

An overview of MILKYS stations in Norway is shown in maps in ***Appendix D***. The program has previously included monitoring in sediment (Green *et al.* 2010) and to a larger degree biota, the main emphasis being monitoring of environmental pollutants and their effects in blue mussel, cod, dogwhelk, periwinkle, flounder and sediment in:

- Inner- and Outer-Oslofjord, including Hvaler and the Outer Hvaler National Park marine national park, Singlefjord and Grenlandfjord, since 1981.
- Sørfjord/Hardangerfjord since 1987.
- Orkdalsfjord area and other areas in outer Trondheimfjord, 1984-1996 and 2004-2005.
- Arendal and Lista since 1990.
- Lofoten since 1992.
- Coastal areas of Norway's northern county Troms and Finnmark since 1994.
- Bergen since 2015.
- Svalbard since 2018.

The previous investigations have shown that the Inner Oslofjord has elevated levels of polychlorinated biphenyls (PCB-7) in cod liver, mercury (Hg), lead (Pb) and zinc (Zn) in sediments and elevated concentrations of Hg in cod fillet. Cod liver in the Inner Oslofjord also revealed the

highest median concentration of α–HBCD in 2014. Investigations of the Sørfjord/Hardangerfjord have shown elevated levels of PCB-7, dichlorodiphenyltrichloroethane (DDT, using dichlorodiphenyldichloroethylene (DDE) - principle metabolite of DDT as an indicator), cadmium (Cd), Hg and Pb. Investigations in Orkdalsfjord focused on three blue mussel stations. The results from these investigations have been reported earlier by Green *et al*. (2007; 2008).

Environmental status has in previous reports been classified according to environmental quality criteria based on the classification system of the Norwegian Environment Agency (Molvær *et al*. 1997), or presumed background levels applied in a previous report (Green *et al*. 2016) (***Appendix C*)**. In this report, the results were assessed primarily in relation to Environmental Quality Standards (EQS) for priority substances and river basin specific pollutants (Norwegian_Environment_Agency 2016a), according to the EU Water Framework Directive. Furthermore, in lieu of the aforementioned classification system (i.e. (Molvær *et al*. 1997)), *Norwegian provisional high reference contaminant concentrations* (termed herein as PROREF) have been calculated based on MILKYS data (see **Chapter 2.7**).

In addition to monitoring the Oslofjord and the Sørfjord/Hardangerfjord, MILKYS also includes the annual monitoring of contaminants at selected stations in Lista and Bømlo on the Norwegian South- and West coast, respectively. During the periods 1993-1996 and 2006-2007, MILKYS also included sampling of blue mussel from reference areas along the coast from Lofoten to the Russian border. Fish is also sampled from four key areas north of Lofoten in the Finnsnes-Skjervøy area, Hammerfest-Honningsvåg area, and Varanger Peninsula area. Fish from the Lofoten and Varanger Peninsula areas are sampled annually. The intention is to assess the level of contaminants in leas polluted reference areas, and to assess possible temporal trends. ***Figure 1***, ***Figure 2*** and ***Figure 3*** indicates which stations were monitored for the 2019-investigation and discussed in this report, and ***Appendix D*** provides maps which show the stations have been monitored previously.

Biomarkers (or biological effects methods, BEM) were introduced in MILKYS in 1997. Biomarkers have several definitions, where one is “a biological response to a chemical or chemicals that gives a measure of exposure and sometimes, also, of toxic effect” (Peakall 1994). The levels of “biological responses” that can be considered range from the molecular to community structure and even to the function and structure of ecosystems. As such, this is a broad definition. Biomarkers may be indicative of exposure, response or effect, and susceptibility (Timbrell 2009) and can be used to monitor exposures and a wide variety of responses ranging from abnormal development to early disease indicators. They provide an early warning signal indicating whether biological systems or an organism is affected by toxic compounds and can assist in establishing an understanding of the effects and underlying molecular mechanisms involved in toxicity. Such knowledge cannot be derived from measurements of tissue levels of contaminants only. One reason is the vast number of chemicals (known and unknown) that are not analysed. Another reason is the possibility of combined effects (“cocktail effects”) of multiple chemical exposures. In addition to enabling conclusions on the health of marine organisms, some biomarkers assist in the interpretation of contaminant bioaccumulation. The biological effects component of MILKYS includes imposex and intersex in snails as well as biomarkers in fish. The methods were selected because they can reflect the impact of specific contaminants or specific groups of contaminants on organisms. The methods were also selected because they are relatively robust compared to other biological effects methods.

The state of contamination is assessed by examining levels, trends and effects. Different monitoring strategies are used to address these three aspects of monitoring, especially with regards to the selection of indicator media (blue mussel, snail, cod, liver etc.) and selection of contaminants to be monitored (OSPAR 2018). Biota were sampled annually. The programme

underwent an extensive revision in 2012 and again in 2017 in regard to stations and choice of contaminants to be analysed. Monitoring of flatfish was discontinued in 2012, and only one station at Sande was investigated in 2019. Three more cod-stations were added in 2012, and a fourth added in 2015 and another station (Svalbard) was added in 2017 bringing the total to 17. The blue mussel stations were reduced from 38 to 26 in 2012. Investigations of blood and eggs of the eider duck from Svalbard were also added in 2017.

The contaminants selected for each station has changed considerably after 2011. Pesticides and dioxin analyses have since been discontinued except for DDTs and HCB at some stations, including the Sørfjord/Hardangerfjord. However, many new contaminants were added, including analyses of short- and medium chain chlorinated paraffins (SCCP and MCCP), phenols (e.g. bisphenol A, tetrabrombisphenol A), organophosphorus flame retardants (PFRs) and stabile isotopes. PFRs were discontinued in 2017, and phenols were discontinued in 2019. The Norwegian Pollution and Reference Indices (Green 2011; 2012) are not included in the revised programme, and for the years 2012-2015 passive sampling of contaminants in water was included. The report on the 2017-investigations also included, for the first time, investigations of siloxanes and microplastics. Monitoring of microplastics was discontinued after 2017, however, monitoring of siloxanes continued on an annual basis and included the cod station in Varangerfjord from 2018.

Based on an evaluation of the Norwegian environmental monitoring (Miljødirektoratet 2012), many time series previously included in this monitoring programme have been discontinued since the evaluation in 2012. However, some of the time series were maintained also after 2012. In 2017 additional stations were discontinued, this included one blue mussel station and two flatfish stations, and from 2018 six more blue mussel stations were discontinued. The results for the flatfish station in Mid Oslofjord that is still being monitored, are included in this report. Investigation of biological effect in cod from the Inner Sørfjord and from Bømlo on the West Coast were continued. The results for blue mussel and cod from these investigations are also included in this report.

All monitoring results from this monitoring programme are made publicly available via yearly reports and Vannmiljø[1] and are included in the submission to ICES (including results for the eider duck).
Where possible, MILKYS is integrated with other national monitoring programmes to achieve a better practical and scientific approach for assessing the levels, trends and effects of contaminants. In particularly, this concerns sampling for the Norwegian Environmental Specimen Bank (Miljøprøvebanken), a programme funded by the Norwegian Ministry of Climate and Environment to sustain time trend monitoring and local (county) investigations. Other programmes that can be relevant are: Comprehensive Study on Riverine Inputs and Direct Discharges (RID, *Elvetilførsler og direkte tilførsler til norske kystområder*), Ecosystem Monitoring in Coastal Waters (*Økosystemovervåking i kystvann* (ØKOKYST)), Environmental Contaminants in an Urban Fjord (*Miljøgifter i en urban fjord*) as well as MAREANO[2] and Arctic Monitoring and Assessment Programme (AMAP)[3]. The first three programmes are operated by NIVA on behalf of Norwegian Environment Agency.

[1] See https://vannmiljo.miljodirektoratet.no/

[2] See http://www.mareano.no/en/about_mareano. MAREANO maps depth and topography, sediment composition, biodiversity, habitats and biotopes as well as pollution in the seabed in Norwegian offshore areas.

[3] See https://www.amap.no/

1.2 Purpose

A principal function of the Norwegian Environment Agency is to collate and communicate environmental information, including information about the state and development of the Norwegian environment.

An aim of this environmental monitoring programme is to provide an overview of the status and trends of environmental pollutants in Norwegian marine costal environment as well as to assess the importance of various sources of pollution.

The OSPAR Hazardous Substances Strategy is to prevent pollution by hazardous substances, by eliminating their emissions, discharges and losses, to achieve levels that do not give rise to adverse effects on human health or the marine environment. Under OSPAR, data from MILKYS and other monitoring programmes support this strategy by:

1. Monitoring the levels of a selection of hazardous substances in biota and water;
2. Evaluating the bioaccumulation of priority hazardous substances in biota of coastal waters;
3. Assessing the effectiveness of previous remedial action;
4. Considering the need for additional remedial action;
5. Assessing the risk to biota in coastal waters;
6. Fulfilling obligations to EU Water Framework Directive;
7. Fulfilling obligations to OSPAR regional sea convention.

MILKYS is part of the Norwegian contribution to CEMP which aims to deliver comparable data from across the OSPAR Maritime Area, which can be used in assessments to address the specific questions raised in the OSPAR's Joint Assessment and Monitoring Programme, and is designed to address issues relevant to OSPAR (2014) including also OSPAR priority substances (OSPAR 2007).

MILKYS also contribute data to support the implementation of the Water Framework Directive (WFD) (2000/60/EC 2000) and its daughter directive the Environmental Quality Standards Directive (EQSD) (2013/39/EU 2013) to achieve good chemical and ecological status by assessing the results using EU EQSD in Norway. In this regard, Norway has supplemented the EQS with their own EQS for Water Basin Specific Contaminants. The results from MILKYS can also be useful in addressing aspects of the EU Marine Strategy Framework Directive (MSFD) (2008/56/EC 2008). One of the goals of WFD and MSFD is to achieve concentrations of hazardous substances in the marine environment near background values for naturally occurring substances and close to zero for manmade synthetic substances. OSPAR has also adopted this goal (OSPAR 1998).

2. Material and methods

2.1 Sampling

2.1.1 Stations

Samples for the investigation of contaminants were collected along the Norwegian coast, from the Swedish border in the south and to the Russian border in the north, as well as Svalbard (***Figure 1***, ***Figure 2***, ***Figure 3***, ***Appendix D***). The sampling involved blue mussel at 28 stations (whereof eight were completely funded by the Ministry of Climate and Environment, see **Chapter 1.1**), dogwhelk at eight stations (nine were planned), common periwinkle at one station, cod at 17 stations and the common eider at one station.

Samples were collected during 2019 and analysed according to OSPAR guidelines (OSPAR 2003, 2018)[1] where these could be applied. The data was screened and submitted to ICES by agreed procedures ICES (1996) as well as to the national database *Vannmiljø*. Blue mussel (*Mytilus edulis*), dogwhelk (*Nucella lapillus*), common periwinkle (*Littorina littorea*) and Atlantic cod (*Gadus morhua*) are the target species selected for MILKYS to indicate the degree of contamination in the sea. Blue mussel is attached to shallow-water surfaces, thus reflecting exposure at a fixed point (local pollution). Mussels and snails are usually abundant, robust and widely monitored in a comparable way. The species are, however, restricted to the shallow waters of the shoreline. Cod is widely distributed and commercially important fish species. It is a predator and, as such, will for hydrophobic compounds mainly reflect contamination levels in their prey. Recently, however, it has become increasingly difficult to catch sufficient numbers of adequate size of both blue mussel and cod. The 2019-programme also included investigation of contaminants in the European flounder (*Platichthys flesus*) and the common eider (*Somateria mollissima*). Deviations from what was planned for the 2019 sampling and analyses and what was realized, together with what was realized in the 2018 investigation is shown in ***Appendix E***.

As mentioned above (see ***Chapter 1.1***) the results from some supplementary monitoring to maintain long-term trends are included in this report. These concern some contaminants in blue mussel and cod (cf. ***Table 3***).

Some details on methods applied in previous years of monitoring are provided in Green *et al.* (2008).

[1] See also http://www.ospar.org/work-areas/hasec

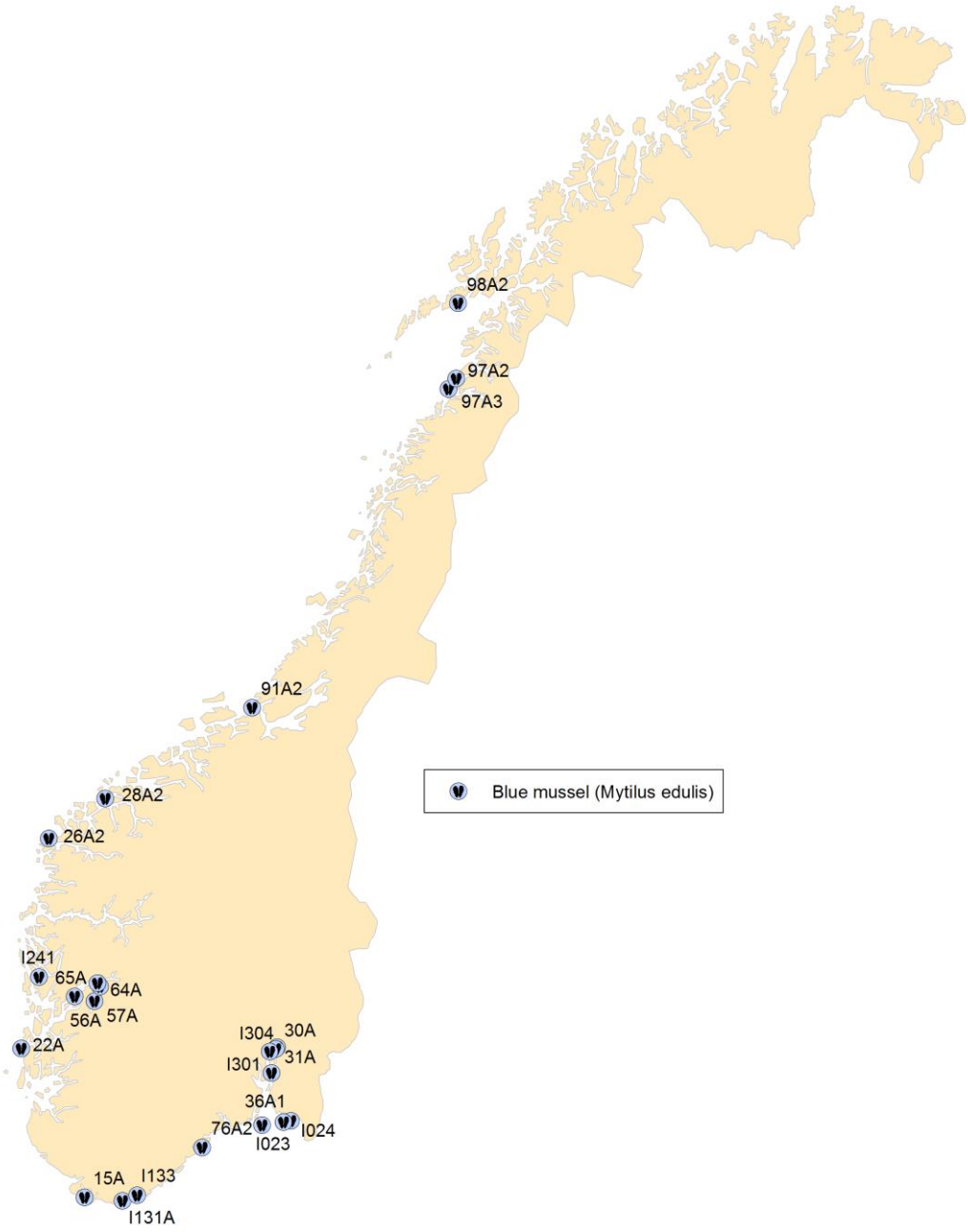


***Figure 1**. Stations where blue mussel were sampled in 2019. See also station information in detailed maps in **Appendix D**.*

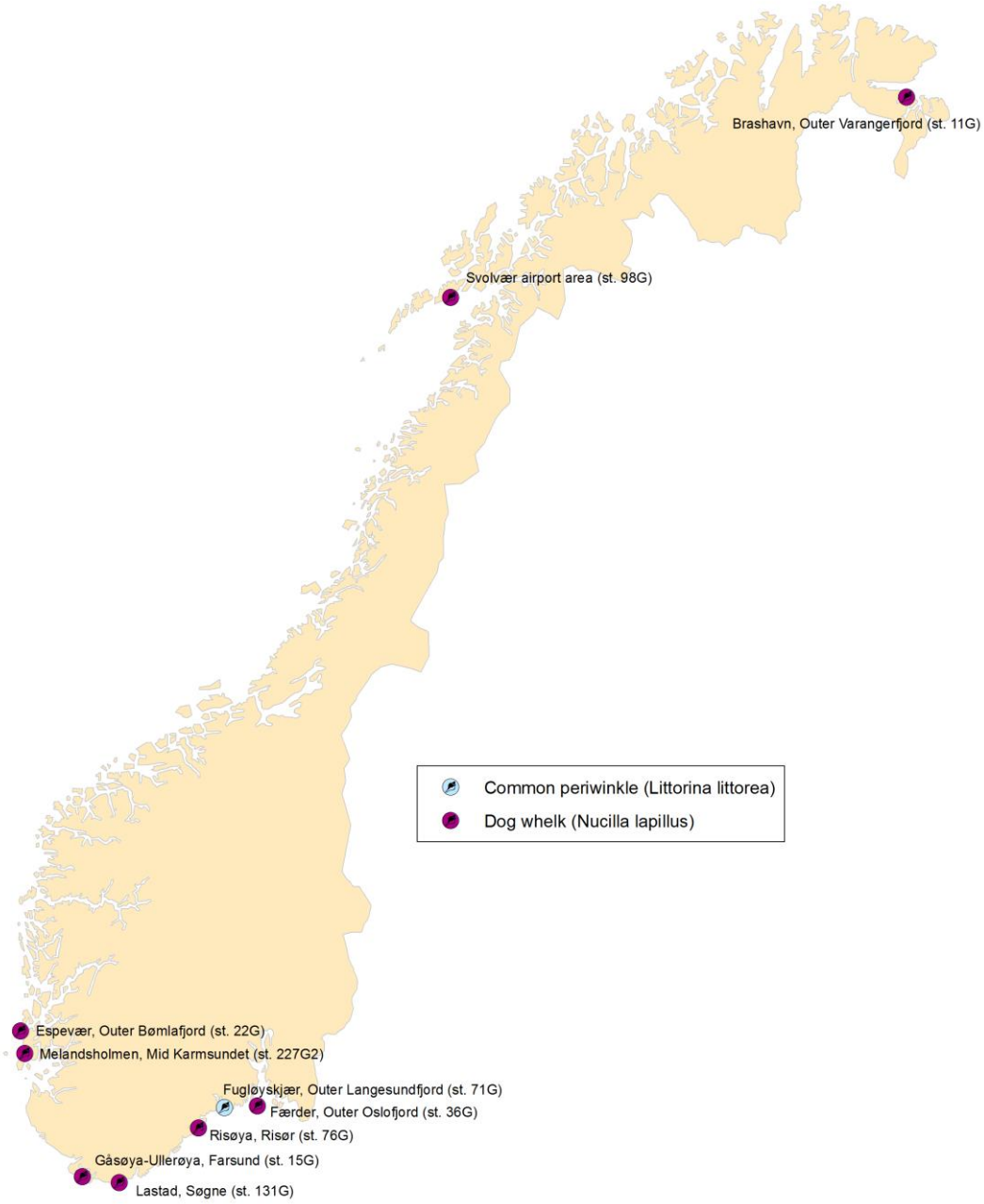


***Figure 2**. Stations where dogwhelk and common periwinkle were sampled in 2019. See also station information in detailed maps in **Appendix D**.*

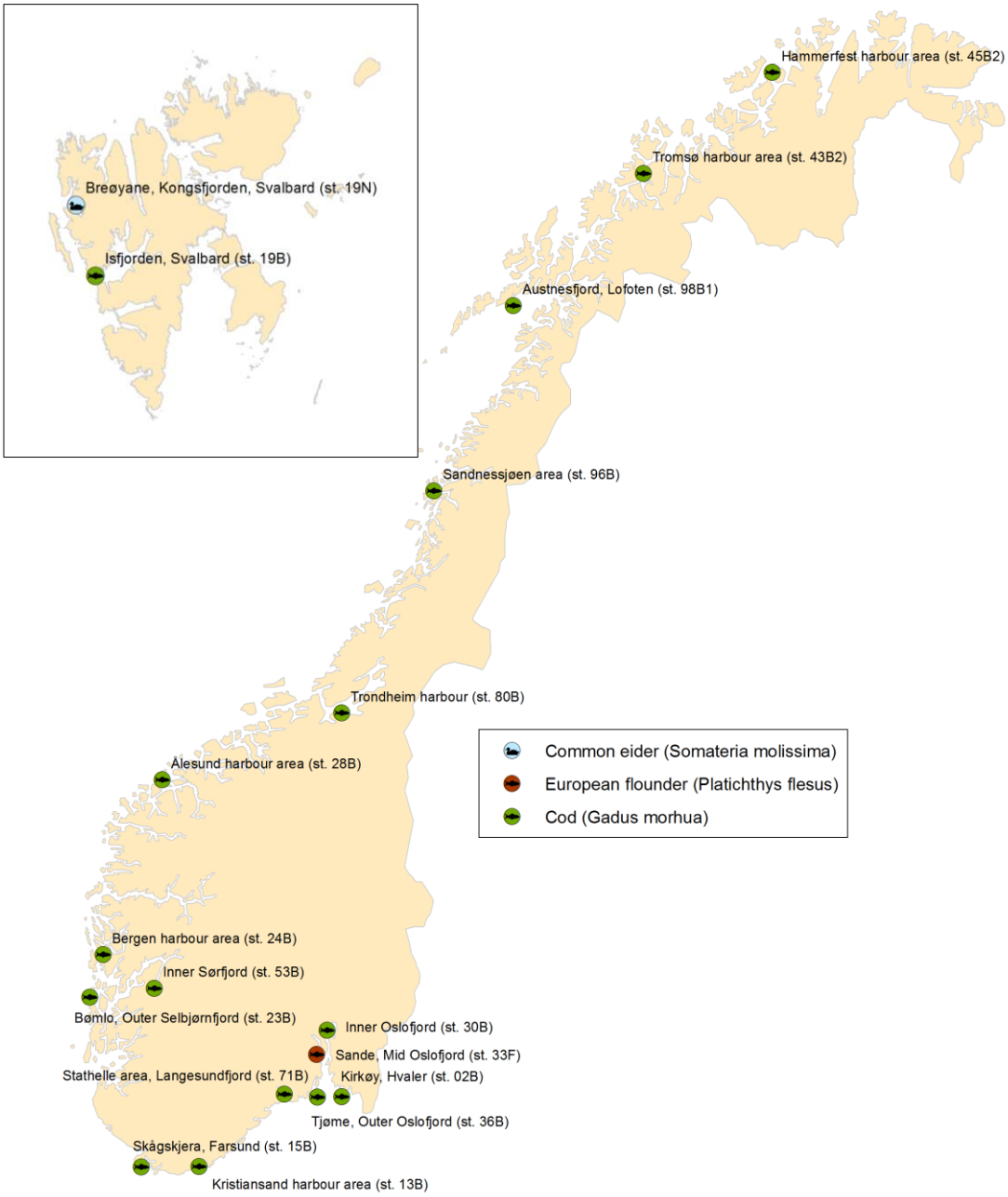


***Figure 3**. Stations where cod, flounder and the common eider were sampled in 2019. Note insert map of Svalbard and see also station information in detailed maps in **Appendix D**.*

2.1.2 Blue mussel

Blue mussel has been proven as a promising indicator organism for contaminants (Beyer *et al*. 2017). In general, blue mussel is widely used to monitoring in controlled field studies (Schøyen *et al*. 2017).

A sufficient number of individuals for three pooled samples of blue mussel were found at nearly all of the 27 stations, including the eight stations previously funded directly by the Ministry of Climate and Environment[1]. The exceptions being two stations in the Grenlandfjord area (Bjørkøya st. 71A and Sylterøya st. I714) where, even after intensive search, only insufficient quantities were found, and two stations in the Varangerfjord area (Skallneset st. 10A2 and Brashavn st. 11X) where during shipping the samples were misplaced. Furthermore, only two pooled samples were of sufficient size at one station in the Inner Oslofjord (Gåsøya st. I304).

Blue mussel of sufficient size and quantity were not found at Færder in the Outer Oslofjord (st. 36A) and the alternative site at Tjøme was used (st. 36A1)[2]. The alternative site has been used for this reason for the years 2013-2015 and 2018. The two sites are separated by 7.7 km. However, tests, though inconclusive being based only on one sample, have provided some indication that the results can be viewed collectively with respect to time trends[3]. Where time-trend series are presented in this report both stations are referred to collectively as station 36A.

The stations are located as shown in ***Figure 1*** (see also maps in ***Appendix D***). The stations were chosen to represent highly polluted or reference stations distributed along the Norwegian coast. It has been shown that the collected individuals are not all necessarily *Mytilus edulis* (Brooks and Farmen 2013), but may be other *Mytilus* species (*M. trossulus* and *M. galloprovincialis*). Possible differences in contaminant uptake between *Mytilus* species were assumed to be small and they were not taken into account in the interpretations of the results for this investigation.

The blue mussel samples were collected from 15th August to 16th December 2019. This is within the OSPAR guidelines and considered to be outside the mussel spawning season.

Generally, blue mussel was not abundant on the exposed coastline from Lista (southern Norway) to the north of Norway. The mussel was more abundant in more protected areas and were collected from dock areas, buoys or anchor lines. All blue mussels were collected by NIVA, except for the blue mussels collected in Lofoten and Varangerfjord, which were collected by local contacts.

The method for collecting and preparing blue mussels was based on the National Standard for mussel collection (NS 2017). Three pooled samples of 20 individuals (size range of 3-5 cm) were collected at each station and kept frozen until later treatment. Shell length was measured by slide callipers. The blue mussel was scraped clean on the outside by using knives or scalpels before taking out the tissue for the analysis. Mussel samples were frozen (-20°C) for later analyses.

[1] Budget constraints for 2018 permitted analyses of only seven of the eight blue mussel stations sampled in 2017 and that are exclusively financed by the Ministry of Climate and Environment.

[2] Færder, Outer Oslofjord (st. 36A) has the geo-position 59.02740N and 10.52500E and Tjøme, Outer Oslofjord (st. 36A1) has the geo-position 59.07357N and 10.42522E.

[3] In 2015 one sample from Færder, Outer Oslofjord (st. 36A) was obtained and analyzed in addition to the three samples from Tjøme, Outer Oslofjord (st. 36A1). The results, where concentrations were above the LOQ, indicated no statistically difference for Hg, TBT, DDEpp, MCCP and SCCP, but st. 36A1 had significantly higher concentrations of PCB-7, and lower concentrations of sum of six PBDEs (BDE6S) and BDE47. The differences in all cases was less than two.

For certain stations prior to the 2012-investigations the intestinal canal was cleared for contents (depuration) in mussels following OSPAR guidelines (OSPAR 2018), cf. (Green *et al*. 2012). There is some evidence that for a specific population/place the depuration has no significant influence on the body burden of the contaminants measured (Green 1989; 1996; 2001)). The practice of depuration was discontinued in 2012.

2.1.3 Dogwhelk and common periwinkle

Concentrations and effects of organotin on dogwhelk were investigated at eight stations and one station for common periwinkle (***Figure 2***, see also maps in ***Appendix D***). TBT-induced development of male sex-characters in female dogwhelk, known as imposex, was quantified by the *Vas Deferens Sequence Index* (VDSI) analysed according to OSPAR-CEMP guidelines. The VDSI ranges from zero (no effect) to six (maximum imposex effect) (Gibbs *et al*. 1987). Detailed information about the chemical analyses of the animals is given in Følsvik *et al*. (1999).

Effects (imposex, ICES (1999)) and concentrations of organotin in dogwhelk were investigated using 50 individuals from each station. Individuals were kept alive in a refrigerator (at +4°C) until possible effects (imposex) were quantified. All snails were sampled by NIVA except for the dogwhelk collected in Lofoten and in the Varangerfjord. The snail samples were collected from 2nd September to 30th October 2019.

TBT-induced development of male sex-characters in female common periwinkle, known as intersex, was quantified by the *intersex stage index* (ISI) analysed according guidelines described by Bauer *et al*. (1995)). The ISI ranges from zero (no effect) to four (maximum intersex effect).

2.1.4 Atlantic cod

At least 15 individuals of Atlantic cod were sampled at most of the 17 stations, the exceptions being Varangerfjord (st. 10B) where during shipping the samples were misplaced, as well as Tjøme, Outer Oslofjord (st. 36B), Kristiansand harbour area (st. 13B) and Trondheim harbour (st. 80B) (***Figure 3***).

The cod were sampled from 20th August 2019 to 8th December 2019. All the cod were sampled by local fishermen except for the cod in the Inner Oslofjord (st. 30B) that was collected by NIVA by trawling from the research vessel *F/F Trygve Braarud* owned and operated by the University of Oslo. Instructions were given to the fishermen to catch coastal cod. Coastal cod is more attached to one place than open ocean cod which migrate considerably farther than coastal cod. Some spot checks were taken looking at the cross-section pattern of the otoliths (Stransky *et al*. 2007) which confirmed, at least for these samples, that only coastal cod were caught. The otoliths are stored for further verification if necessary. If possible, cod were sampled in five length classes (***Table 2***), three individuals in each class. Tissue samples from each fish were prepared in the field and stored frozen (-20°C) until analysis or the fish was frozen directly and prepared later at NIVA.

***Table 1**. Target length (mm) groups for sampling of cod.*

Size-class	Cod (mm)
1	370-420
2	420-475
3	475-540
4	540-615
5	615-700

Livers were in general not large enough to accommodate all the analyses planned (see ***Appendix E***). Skågskjera near Farsund (st. 15B), Bømlo in the Outer Selbjørnfjord (st. 23B), Ålesund harbour area (st. 96B), Austnesfjord in Lofoten (st. 98B1), Tromsø harbour (st. 43B2), Hammerfest harbour area (st. 45B2) and the reference station Isfjorden, Svalbard (st. 19B) were the seven stations where all 15 individuals had sufficient liver size to complete all of the intended analyses. The general lack of material was partially compensated for by making pooled samples of livers. These are noted in the tables below (e.g. ***Table 14***). The concerns using pooled samples or small sample size in cod are discussed in an earlier report (Green *et al*. 2015).

The age of the fish was determined by noting the number opaque and hyaline zones in otoliths (Vitale, Worsøe_Clausen, and Ni_Chonchuir 2019). These results, along with results from some other parameters (e.g. liver weight, shell lengths, dry weight percentages) are publically available but not necessarily used for this report.

2.1.5 European flounder

The monitoring of flatfish (including European flounder) was last reported for the 2011 investigation (Green *et al*. 2012), taken out of this programme for the period 2012-2018, but the funding for chemical analyses for one flounder station (Sande, Mid Oslofjord st. 33F) was continued by the *Ministry of Climate and Environment*. Discussion of the results for this station are included in this report. Fifteen individuals of European flounder were sampled at Sande, Mid Oslofjord (st. 33F) (***Figure 3***).

The flounder were sampled 28th August 2019 by a local fisherman. If possible, flounder were sampled in five length classes (***Table 2***), three individuals in each class. Tissue samples from each fish were prepared in the field and stored frozen (-20°C) until analysis or the fish was frozen directly and prepared later at NIVA.

***Table 2**. Target length (mm) groups for sampling of flounder.*

Size-class	Flounder (mm)
1	300-320
2	320-340
3	340-365
4	365-390
5	390-420

2.1.6 Common eider

Contaminants in the Common eider were investigated at one station in Svalbard (Breøyane st. 19N), which the present study considered as a reference station. Blood samples were collected from 15 individuals (two subsamples from each) and eggs from 15 other individuals on 8th July 2019 (***Figure 3***). All samples are from adult nesting females.

2.2 Chemical analyses of biological samples

2.2.1 Choice of chemical analyses and target species/tissues

An overview of chemical analyses performed on 2019-samples is shown in ***Table 3***.

Table 3*. Analyses and target organisms of 2019. The value indicates the total number of stations investigated*. (See also* ***Appendix B*** *for complete list of chemical codes.)*

Parameter	Blue mussel	Dogwhelk	Common periwinkle	Cod liver	Cod fillet	Flounder liver	Flounder fillet	Eider blood	Eider eggs*
Metals Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)	22			16		1		1	1
Mercury (total Hg)	23				16		1	1	1
Organotin (MBT, DBT, TBT, TPT)	7	8	1						
PCB-7 (PCB28, -52, -101, -118, -138, -153, and -180**)**	22			15				1	1
ΣDDT (p-p`-DDT**, p-p`-DDE, p-p`-DDD**)**	12			6		1			
PAH-16* and KPAH** ACNE, ACNLE, ANT, BAA, BAP, BBJF, BKF, BGHIP, BKF, DBA3A, FLE, FLU, ICDP, NAP, PA, PYR	6								
Polybrominated diphenyl ethers (PBDEs) BDE28, 47, 99, 100, 126, 153, 154, 183, 196 and 209	10			11				1	1
Perfluorinated alkylated substances (PFAS) PFNA, PFOA, PFHpA, PFHxA, PFHxS, PFOS, PFBS, PFOSA	6			10				1	1
Hexabromocyclododecane (HBCD: α-, ß-, γ-HBCD**)**	9			10				1	1
Chlorinated paraffins (SCCP (C10-C13) and MCCP (C14-C17)**)**	10			13				1	1
Siloxanes (D4, D5 and D6)				4				1	1
HCB, OCS, QCB**	11			6		1		1	1

*) Homogenate of yolk and albumin.
**) Referred to as DDE in the report
***) Chrysene (CHR) has been discontinued.

An overview of the applied analytic methods is presented in ***Table 4***. Because of technical challenges, metal analyses were moved to another Eurofins laboratory (WEJ) and a different methods was applied[1]. The new method had LOQs that were the same or better with the exception for Ag which had a LOQ of 0.004 mg/kg w.w. before and 0.05 mg/kg w.w. with the new methods. This was accepted by Norwegian Environment Agency on 20th November 2019. Chemical analyses were performed separately for each cod liver, if possible, otherwise a pooled sampled was taken (see «count» for the relevant tables, e.g. ***Table 16)***. Mercury was analysed on a fillet sample from each cod. Furthermore, Biological Effects Methods (BEM) were performed on individual cod.

[1] Standard method prior to 2019 investigation was Standard method NS EN ISO 17294-2, and now is Standard method NS EN ISO 15763 (2010) except for nickel, silver and zinc which now has Standard method NS EN ISO 17294-2-E29.

***Table 4**. Overview of method of analyses (see **Appendix B** for description of chemical codes). Limit of quantification (LOQ, usually taken at three times the standard deviation) is indicated. See **Chapter 2.2.2** for description of the labs used for the different analysis.*

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
Metals						
cadmium (Cd)	7440-43-9	**WEJ**	0.001 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
cadmium (Cd)	7440-43-9	**NILU**	0.0003 mg/kg	20 %	Standard method	ISO 17025, accredited
copper (Cu)	7440-50-8	**WEJ**	0.02 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
copper (Cu)	7440-50-8	**NILU**	0.06 mg/kg	20 %	Standard method	ISO 17025, accredited
lead (Pb)	7439-92-1	**WEJ**	0.005 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
lead (Pb)	7439-92-1	**NILU**	0.01 mg/kg	20 %	Standard method	ISO 17025, accredited
zinc (Zn)	7440-66-6	**WEJ**	0.5 mg/kg	20 %	Standard method NS EN ISO 17294-2-E29	ISO 17025, accredited
zinc (Zn)	7440-66-6	**NILU**	0.5 mg/kg	20 %	Standard method	ISO 17025, accredited
silver (Ag)	7440-22-4	**WEJ**	0.05 mg/kg	20 %	Standard method NS EN ISO 17294-2-E29	ISO 17025, accredited
silver (Ag)	7440-22-4	**NILU**	0.02 mg/kg	20 %	Standard method	Not accredited but follows the routines and systems of ISO 17025
arsenic (As)	7440-38-2	**WEJ**	0.001 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
arsenic (As)	7440-38-2	**NILU**	0.03 mg/kg	20 %	Standard method	ISO 17025, accredited
chromium (Cr).	7440-47-3	**WEJ**	0.01 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
chromium (Cr).	7440-47-3	**NILU**	0.03 mg/kg	20 %	Standard method	ISO 17025, accredited
nickel (Ni)	7440-02-0	**WEJ**	0.01 mg/kg	20 %	Standard method NS EN ISO 17294-2-E29	ISO 17025, accredited
nickel (Ni)	7440-02-0	**NILU**	0.003 mg/kg	20 %	Standard method	ISO 17025, accredited
cobalt (Co)	7440-48-4	**WEJ**	0.001 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
cobalt (Co)	7440-48-4	**NILU**	0.002 mg/kg	20 %	Standard method	ISO 17025, accredited
tin (Sn)	7440-31-5	**WEJ**	0.01 mg/kg	20 %	Standard method NS EN ISO 15763 (2010)	ISO 17025, accredited
tin (Sn)	7440-31-5	**NILU**	0.002 mg/kg	30 %	Standard method	Not accredited but follows the routines and systems of ISO 17025
Total-Hg	7439-9-76	**WEJ**	0.001 mg/kg	25 %	Standard method	ISO 17025, accredited
Total-Hg	7439-9-76	**NILU**	0.0003-0.003 mg/kg	25 %	Standard method	ISO 17025, accredited
PCB-7						
PCB28	7012-37-5	**GFA**	0.3 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
PCB28	7012-37-5	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB52	35693-99-3	**GFA**	0.3 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025, accredited
PCB52	35693-99-3	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB101	37680-73-2	**GFA**	0.3 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
PCB101	37680-73-2	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
PCB118	31508-00-6	**GFA**	0.01 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025, accredited
PCB118	31508-00-6	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB138	35065-28-2	**GFA**	0.3 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025, accredited
PCB138	35065-28-2	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB153	35065-27-1	**GFA**	0.3 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
PCB153	35065-27-1	**NILU**	0.3-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB180	35065-29-3	**GFA**	0.3 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
PCB180	35065-29-3	**NILU**	0.3-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
p-p`DDT	50-29-3	**GFA**	0.2 µg/kg low fat. 4 µg/kg high fat	60 %	Internal method	ISO 17025, accredited
p-p`DDE	82413-20-5	**GFA**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
p-p`DDD	72-54-8	**GFA**	0.1 µg/kg low fat. 2 µg/kg high fat	50 %	Internal method	ISO 17025, accredited
PAHs						
PAH 16			0.3-5.3 µg/kg	30 %	Internal method	ISO 17025, accredited
acenaphthene	83-32-9	**GFA**	1.5 µg/kg	30 %	Internal method	ISO 17025, accredited
acenaphthylene	208-96-8	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
anthracene	120-12-7	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
benzo[a]anthracene	56-55-3	**GFA**	0.5 µg/kg	30 %	Internal method	ISO 17025, accredited
benzo[a]pyrene	50-32-8	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
benzo[b+j]fluoranthene	GM	**GFA**	0.5 µg/kg	30 %	Internal method	ISO 17025, accredited
benzo[ghi]perylene	191-24-2	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
benzo[k]fluoranthene	207-08-9	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
chrysene	218-01-9	**GFA**	0.5 µg/kg	30 %	Internal method	ISO 17025, accredited
dibenz[a c/a h]anthracene	GM	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
fluorene	86-73-7	**GFA**	1.5 µg/kg	30 %	Internal method	ISO 17025, accredited
fluoranthene	206-44-0	**GFA**	1.0 µg/kg	30 %	Internal method	ISO 17025, accredited
indeno[1 2 3-cd]pyrene	193-39-5	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
naphthalene	91-20-3	**GFA**	0.3 µg/kg	30 %	Internal method	ISO 17025, accredited
phenanthrene	85-01-8	**GFA**	4.0 µg/kg	30 %	Internal method	ISO 17025, accredited
pyrene	129-00-0	**GFA**	0.6 µg/kg	30 %	Internal method	ISO 17025, accredited
PAH metabolite – OH-pyrene		**NIVA**				
PBDEs						
BDE47	5436-43-1	**GFA**	0.005 µg/kg mussels. 0.1 µg/kg high fat	30 %	Internal method	ISO 17025, accredited
BDE47	5436-43-1	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE99	60348-60-9	**GFA**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
BDE99	60348-60-9	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE100	189084-64- 8	**GFA**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
BDE100	189084-64- 8	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE126	366791-32-4	**GFA**	0.01 µg/kg mussels	50 %	Internal method	ISO 17025, accredited

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
BDE126	366791-32-4	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE153	68631-49-2	**GFA**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
BDE153	68631-49-2	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE154	207122-15-4	**GFA**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
BDE154	207122-15-4	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE183	207122-16-5	**GFA**	0.03 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
BDE183	207122-16-5	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE196	32536-52-0	**GFA**	0.05 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025, accredited
BDE196	32536-52-0	**NILU**	0.1 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
BDE209	1163-19-5	**GFA**	0.5 µg/kg mussels. 0.5 µg/kg high fat	50 %	Internal method	ISO 17025, accredited
BDE209	1163-19-5	**NILU**	1.0 µg/kg	30-45 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
α, ß, γ-HBCD	134237-50-6 (α isomer), 134237-51-7 (ß isomer), 134237-52-8 (γ isomer)	**GFA**	0.006 ng/g	40 %	Internal method, validated	ISO 17025, accredited
α, ß, γ-HBCD	134237-50-6 (α isomer), 134237-51-7 (ß isomer), 134237-52-8 (γ isomer)	**NILU**	0.03-0.2 µg/kg	40-50 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
Tetrabrombisphenol A (TBBPA)	79-94-7	**GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025, accredited
		NILU	3-15 µg/kg	30-40 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
Bisphenol A (BPA)	80-05-7	**GFA**	1-5 ng/g	40 %	Internal method, validated	ISO 17025, accredited
		NILU	3-15 µg/kg	30-40 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
PFAS						

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
PFNA	375-95-1	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOA	335-67-1	**NIVA**	0.4 µg/kg	40 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHpA	375-85-9	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHxA	307-24-4	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOS	1763-23-1	**NIVA**	0.1 µg/kg	25 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFBS	29420-49-3	**NIVA**	0.1 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOSA	4151-50-2	**NIVA**	0.1 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
SCCP/MCCP						
SCCP (C10-C-13)	85535-84-8	**GFA**	0.6-3.5 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
SCCP (C10-C-13)	85535-84-8	**NILU**	0.5-10 µg/kg	>50 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
MCCP (C14-C17)	85535-85-9	**GFA**	5-10 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025, accredited
MCCP (C14-C17)	85535-85-9	**NILU**	0.5-15 µg/kg	>50 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
Tin compounds						
Monobutyltin (MBT)	2406-65-7 (78763-54-9)	**GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025, accredited
Dibutyltin (DBT)	1002-53-5	**GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025, accredited
Tributyltin (TBT)	688-73-3	**GFA**	0.5 ng/g	30 %	Internal method, validated	ISO 17025, accredited
Triphenyltin (TPhT)	668-34-8	**GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025, accredited
Siloxanes						
Octamethylcyclo-tetrasiloxane (D4)	556-67-2	**NILU**	0,5-2.7 µg/kg	20 %	Internal method	Not accredited but follows the routines and systems of ISO 17025
Decamethylcyclo-pentasiloxane (D5)	541-02-6	**NILU**	0,5-1.5 µg/kg	20 %	Internal method	

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
Dodecamethylcyclo-hexasiloxane (D6)	540-97-6	**NILU**	1.5-2.0 µg/kg	20 %	Internal method	
Other chlorinated compounds						
HCB	118-74-1	**GFA**	1.30 µg/kg		Internal method	ISO 17025, accredited
HCB	118-74-1	**NILU**	0.05 µg/kg		Internal method	ISO 17025, accredited
OCS	29082-74-4	**GFA**	0.13 µg/kg		Internal method	ISO 17025, accredited
QCP	608-93-5	**GFA**	1.3 µg/kg		Internal method	ISO 17025, accredited
SIA						
15N/14N		**IFE**	0,1‰	0,12‰	EA-IRMS	Not accredited
13C/12C		**IFE**	0,1‰	0,12‰	EA-IRMS	Not accredited
BEM						
VDSI		**NIVA**		10-20 %	ICES 1999	Not accredited
EROD		**NIVA**		10-20 %	ICES 1991	Not accredited
ALA-D		**NIVA**		20 %	ICES 2004	Not accredited
OH-pyrene		**NIVA**	0,2 ng/g	30 %		Not accredited

2.2.2 Laboratories and brief method descriptions

The 2019-samples were largely analysed by Eurofins Moss (EFM), and by one of the Eurofins laboratories in Germany (GFA) and one Eurofins laboratory in Bulgaria (Sofia) (see ***Table 4***). Norwegian Institute for Atmosphere Research (NILU) performed all siloxane-analyses as well as all analyses (except PFAS) in the blood and eggs (homogenate of yolk and albumin) of the common eider (*Somateria mollissima*). NIVA was responsible for all PFAS analyses. A brief description of the analytical methods can be found in Green *et al.* (2008).

Metals were analysed at EFM according to NS EN ISO 17294-2. Metals were extracted using nitric acid and quantified using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), except for Cr, which was determined using GAAS or ICP-Atomic Emission Spectroscopy (ICP-AES). Mercury (total) has been analysed using Cold-Vapour AAS (CVAAS). When metals are analyzed at NILU the samples are added with acid and digested with high pressure and temperature before determination with ICP-MS.

Polychlorinated biphenyls (PCB-7) and other chlororganic hazardous substances like HCB, QCB and OCS were analysed at Eurofins-Moss using GC-MS. Fat content was extracted using a mixture of cyclohexane and acetone or iso-propanol on the target tissue.

Samples for analyses of PCB-7 and HCB at NILU were extracted with a suitable organic solvent. The lipid and other interferences are removed with the use of sulfuric acid and silica SPE (solid phase extraction) before the compounds are detected with help of GC-HRMS or GC-QTOf-MS.

Among the individual PCBs quantified, seven (PCB-7) are commonly used for interpretation of the results[1] (***Table 5***).

Table 5*. The seven suggested PCB-congeners (the sum is denoted as PCB-7), which according to OSPAR (2019) are to be quantified in biota.*

IUPAC/CB no.	Structure
28	2 4-4'
52	2 5-2'5'
101	2 4 5-2'5'
118	2 4 5-3'4'
138	2 3 4-2'4'5'
153	2 4 5-2'4'5'
180	2 3 4 5-2'4'5'

Polycyclic aromatic hydrocarbons (PAH) were analysed at GFA using a gas chromatograph (GC) coupled to a mass-selective detector (MSD). The individual PAHs are distinguished by the retention time and/or significant ions. From 2016 to 2017 there was an increase in LOQs for naphthalene, which might impact results for this group of compounds but also where they are included in other summations of PAHs (see ***Table 4***).

PAH metabolites were determined at NIVA by HPLC with fluorescence detection. The method separates individual components from each other after the phase 2 metabolites have been deconjugated by an enzyme (i.e. both phase 1 and phase 2 metabolites, glucuronide / sulphate are analyzed).

[1] Several marine conventions (e.g. OSPAR and HELCOM[1]) use ΣPCB-7 to provide a common basis for PCB assessment.

All seven potential carcinogenic PAHs (IARC 1987) are included in the list of single components determined to constitute the total concentration of PAH. For this report the total PAH is the sum of tri- to hexacyclic PAH compounds which are named in EPA protocol 8310. Naphthalene (a dicyclic PAH) is not included, hence the total PAH includes 15 compounds. This is so that the classification system of the Norwegian Environment Agency can be applied (see ***Appendix C***).

Analysis of organotin (TBT, MBT, DBT and TPT) in *N. lapillus* and *M. edulis* were done by NIVA until 2010. The method included solvent extraction, derivatization, and detection by gas chromatography - mass spectrometry (GC-MS) as described by Følsvik *et al.* (1999) and Green *et al.* (2008). Since 2010, these analyses were carried out by Eurofins GFA Lab Service GmbH with a method that is similar with the one described for NIVA. One exception was the samples from 2016 which were analyzed at GALAB Laboratories GmbH. Here the extraction was similar, but the detection was done by gas chromatography – atomic emission detector (GC-AED). All the three labs are accredited according to ISO 17025, but the analysis at NIVA was not accredited. Quantification of individual organotin components was performed by using the internal standard method and the limit of quantification (LOQ) was set individual on each sample. The range of the LOQ was from 0.2 to 5 µg/kg w.w. Quality assurance of organotin analyses included routine analyses of Standard Reference Materials and in-house reference materials. All three laboratories have participated in QUASIMEME international intercalibration exercises of organotin analyses with acceptable results Green *et al.* (2017).

Analyses of polybrominated diphenylether (PBDE) in cod liver and blue mussel were done at EFM in 2018/2019. Results are given based on the total extractable fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

Samples for analyses of PBDE and chlorinated paraffins (SCCP/MCCP) at NILU were extracted with a suitable organic solvent. The lipid and other interferences were removed with the use of sulfuric acid and silica SPE (solid phase extraction) before the compounds were detected with help of GC-HRMS or GC-QTOf-MS.

Analysis of perfluorinated alkylated substances (PFAS) in blue mussel and cod liver in 2019 (including supplementary analyses of stored codliver samples for the perioded 1990-2009) were done at NIVA. The general procedures include extractions with solvents using ultrasonic bath before intensive clean up and LC/MS/MS-analysis (liquid chromatography mass spectrometry) (ESI negative mode). Since 2013, LC-qTOF (liquid chromatography quadropole time of flight) has been used for detection and quantification. The limit of quantification has improved for analyses with regards to the 2016-samples and later, primarily due to a slight modification in the method and better access to internal standards. Previously most of the analyses were performed at NIVA, using different procedures and instrumentation. In order to minimize methodical inconsistencies in time series, the transfer of analyses from NIVA to EFM has also included several intercalibrations between the two labs.

Chlorinated paraffins (SCCP (C10-C13), MCCP (C14-C17)) and nonyl- and octylphenols were determined by GC-MS at Eurofins GFA. Hexabromocyclododecane (α, ß, γ-HBCD) was determined by LC-MS-MS by Eurofins GFA.

Analyses of chlorinated paraffins (SCCP/MCCP) at NILU were extracted with a suitable organic solvent. The lipid and other interferences were removed with the use of sulfuric acid and silica SPE (solid phase extraction) before the compounds were detected with help of GC-HRMS or GC-qTOF-

MS. Samples for HBCD were extracted and cleaned together with the PBDEs, but the quantification was done with LC-TOF-MS.

Siloxanes, i.e. octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed by NILU. Already established methods based on liquid/liquid extraction (Warner *et al.* 2010; 2012) were used to extract and quantify siloxanes. Biota tissues were extracted using solid-liquid extraction with a biphasic solvent system of acetonitrile and hexane. Collected extracts from biota tissues were analysed using concurrent solvent recondensation large volume injection gas chromatography mass spectrometry.

For fish, the target tissues for quantification of hazardous substances were liver and fillet (***Table 3***), whereas for the biological effects methods (BEM) liver, blood, and bile were used (cf. ***Table 6***). In addition, the age, sex, and visual pathological state for each of the individuals was determined. Other measurements include fish weight and length, weight of liver, liver dry weight and fat content (% total extractable fat), the fillet dry weight and its % fat content. These measurements are stored in the database and have been published periodically, the latest edition in 2008 (Shi, Green, and Rogne 2008).

The shell length of each mussel was measured. On a bulk basis the total shell weight, total soft tissue weight, dry weight and % fat content were measured. These measurements were stored in the database and published periodically.

The dogwhelk and common periwinkle were analysed for organotin compounds (see ***Table 4***).

2.3 Biological effects analysis

Four biological effects methods (BEM) are assessed using methods described by ICES (see ***Table 4***) and includes the measurement of OH-pyrene. These methods have been applied for this investigation, as has been done in previous annual MILKYS investigations. Each method is in theory generally indicative of one or a group of contaminants. For EROD however, some interaction effects are known. Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs and is thus a marker of PAH exposure. An overview of the methods, tissues sampled, and contaminant specificity is shown in ***Table 6***. One of the major benefits of BEM used at the individual level (biomarkers) is the feasibility of integrating biological and chemical methods, as both analyses are done on the same individual.

Table 6*. The relevant contaminant-specific biological effects methods applied.*

Code	Name	Tissue sampled	Specificity
OH-pyrene	Pyrene metabolite	fish bile	PAH
ALA-D	δ-aminolevulinic acid dehydrase inhibition	fish red blood cells	Pb
EROD-activity	Cytochrome P4501A-activity	fish liver	planar PCBs/PCNs, PAHs, dioxins
TBT	Imposex/Intersex	whole body	organotin

Sampling for BEM-analyses is performed by trained personnel, most often under field conditions. Analyses for ALA-D and EROD-activity requires that the target fish is kept alive until just prior to tissue or blood sampling. The tissue samples are removed immediately after the fish are

inactivated by a blow to the head. Samples are then collected and stored in liquid nitrogen. Analyses of a metabolite of pyrene (OH-pyrene) were done on bile samples stored at -20°C.

Analysis of imposex (in dogwhelk) and intersex (in common periwinkle) are measures of effects of TBT, and are usually performed on fresh samples, but can be performed after the samples have been frozen.

2.3.1 Rationale and overview

A thorough analysis and review of BEM-results has been performed twice since their inclusion in 1997 (Ruus, Hylland, and Green 2003; Hylland *et al*. 2009). Clear relationships were shown between tissue contaminants, physiological status, and responses in BEM parameters in cod (Hylland *et al*. 2009). Although metals contributed substantially to the models for ALA-D (and also for metallothionein (MT) included in the programme 1997-2001) and organochlorines in the model for CYP1A activity, other factors were also shown to be important. Liver lipid and liver somatic index (LSI) contributed for all three BEM-parameters, presumably reflecting the general health of the fish. Size or age of the fish also exerted significant contributions to the regression models. It was concluded that the biological effect methods clearly reflected relevant processes in the fish even if they may not be used alone to indicate pollution status for specific stations at given times. Furthermore, the study showed that it is important to integrate a range of biological and chemical methods in any assessment of contaminant impacts. Through continuous monitoring within CEMP, a unique BEM time series/dataset are generated, that will also be of high value as a basis of comparison for future environmental surveys.

Since the biological effect methods were included in the programme, there have been some modifications of the methods in accordance to the ICES guidelines (cf. ***Table 4***). In 2002, reductions were made in parameters and species analysed. There have also been improvements in the methods, such as discontinuation of single wavelength fluorescence and use of HPLC in the analysis of bile metabolites since 2000.

The MILKYS programme for 2019 included four biological effects methods (BEM) (cf. ***Table 6***). Measures of OH-pyrene and EROD-activity increase with increased exposure to their respective inducing contaminants. The activity of ALA-D on the other hand is inhibited by contamination (i.e., lead), thus lower activity means a response to higher exposure.

The impact of TBT can impact the reproductive capabilities of dogwhelk and common periwinkle. This impact is assessed when dogwhelk and the common periwinkle are analysed for imposex and intersex[1], respectively see ***Table 4***).

2.4 Information on quality assurance

2.4.1 International intercalibrations

The laboratories (NIVA and subcontractor Eurofins) have participated in the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME), International Food Analysis Proficiency Testing Services (FAPAS), international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, QUASIMEME round 2018-1 apply to the 2019-samples. The results are acceptable. These QUASIMEME exercises

[1] This is the ICES tissue designation Vas Deferens Sequence Index is determined

included nearly all the contaminants as well as imposex analysed in this programme. The quality assurance programme is corresponding to the analyses of the 2018 samples (Green *et al*. 2019).

NIVA participated in the QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" in July-September 2017. Shell height, penis-length-male, penis-length-female, average-shell-height and female-male-ratio were measured. NIVA got the score satisfactory for all parameters except number of females for one sample, which got the score questionable. The score for VDSI was satisfactory for both samples tested.

2.4.2 Analyses of certified reference materials

In addition to the QUASIMEME exercises, certified reference materials (CRM) and in-house reference materials are analysed routinely with the MILKYS samples. The results for CRM are shown in ***Appendix A***. It should be noted that for biota, the type of tissue used in the CRMs does not always match the target tissue for analysis. Uncertain values identified by the analytical laboratory or the reporting institute are flagged in the database. The results are also "screened" during the import to the database at NIVA and ICES.

The laboratories used for the chemical testing are accredited according to ISO 17025:2005, except for the PFAS.

2.5 Stable isotopes

Stable isotopes of nitrogen and carbon were analysed by the Institute for Energy Technology (IFE). Analyses of nitrogen and carbon isotopes were 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). Stable isotope ratios were expressed in δ notation as the deviation from standard (Ruus 2015). Abundances were expressed in δ notation as parts per thousand (‰) according to the following:

$$\delta X = [(R_{sample}/R_{standard}) - 1] \times 1000$$

where X is ^{13}C or ^{15}N and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{14}N$. $R_{standard}$ for ^{13}C and ^{15}N are the Vienna Pee Dee Belemnite (VPDB) standard and atmospheric air N_2 (AIR), respectively.

2.6 Treatment of values below the quantification limit

Values below the limit of quantification (LOQ) are set to an average of ten random numbers between the LOQ and half of the value of this limit for calculation for use in time trends. This is approximately in accordance to OSPAR protocol (OSPAR 2013). For "sum" variables (e.g. PCB-7) the value is set to zero. This is in accordance to EU directive (2009/90/EC 2013). Hence, a sum of a group of compounds (like BDE6S[1]) could be zero whereas a compound included in the sum, which might also be used as a proxy for the sum, would be assigned half the LOQ. This could then result in a situation where the sum was below the EQS but the proxy compound was above the EQS. The annual median is classified as less-than if over half of the values are below the limit of quantification and is assigned the median value prefixed with a "<" sign in ***Appendix F***. When such values are presented in tables of the main text, then the cells are shaded, and the LOQ value is

[1] Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa)

shown. It should be noted that the LOQ for the same parameter can vary within and among sets of samples if all the conditions are not met, and comparisons of quantification limits should be made with caution.

Dominance of values below the LOQ could invalidate the statistical assumption behind the trend analysis (Rob Fryer, pers. comm. CEFAS, UK). In calculating trends for this report, a time series must have at most only one “less-than median” provided it is not the first in the series. The effect that less-than values has on the trend analysis has not been quantified; however, the results should be treated with caution. Furthermore, if a dataset contains values below LOQ the median takes these as an average of ten random numbers between half the LOQ and the LOQ.

2.7 Classification of environmental quality

2.7.1 EQS and PROREF

There are several systems that can be used to classify the concentrations of contaminants observed. No system is complete in that it covers all the contaminants and target species-tissues investigated in this programme. Up to and including 2015 investigations, MILKYS relied largely on a national classification system prepared by the Norwegian Environment Agency (*Miljødirektoratet*) as described by Molvær *et al.* (1997). This system was based on high background concentrations derived from an array of national and international monitoring programme and investigative literature.

With the ratification of EU Water Framework Directive (WFD) (2000/60/EC 2000) by Norway in 2007 and the subsequent application of the daughter directive on Environmental Quality Standards (EQS) (2013/39/EU 2013) the assessment of the environment using EQS became imperative. The daughter directive outlines 45 priority substances or groups of substances. Several of these substances are monitored by MILKYS. The EQS apply to concentrations in water, and for fifteen substances it also applies to concentrations in biota (***Table 11***, ***Table 12***). There is a provision in this daughter directive which allows a country to develop their own EQS for water, sediment and biota provided these offer the same level of protection as the EQS set for water. Norway used this approach and developed their own EQS for biota, water, and sediments for “river basin specific pollutants” not otherwise accounted for by the EU directives (Direktoratsgruppen_vanndirektivet 2018).

Assessing the risk to human consumption from elevated concentrations of contaminants in seafood has not been the task of this programme and hence, the EU foodstuff limits have not been applied. However, it should be noted that the Norwegian Environment Agency communicates the results to the Norwegian health authorities. However, it should be noted that the background dossiers for the EQS (2013/39/EU 2013) as well as the national environmental quality standards (Norwegian_Environment_Agency 2016a) applied foodstuff limits if these are lower than the limits found by assessing risk of secondary poisoning of marine organisms.

Both EU and national standards are referred to collectively in this report as EQS. Both standards are risk-based, i.e., exceedances of EQS are interpreted as potentially harmful to the environment and remedial action should be considered.

The application of these standards has been discussed previously (Green *et al.* 2016), and three main challenges were noted. The first is that the standards for biota are generally not species or tissue specific but refer to whole organisms. The second is that the standards are often in large conflict with the system based on background concentrations (see Chapter 3.8.3 in Green *et al.*

2016). And lastly, the standards do not address all the contaminants in all the tissues that are monitored, for example, there are no EQS for metals in biota except for Hg. To address this issue for this report, and in dialogue with the Norwegian Environment Agency, *Norwegian provisional high reference contaminant concentrations* (PROREF) were derived and used in parallel with the risk-based standards (see method description below).

This report of the 2019-investigations addresses the principle cases primarily where median concentrations exceeded EQS and secondarily where median concentrations exceeded PROREF (***Table 11***, ***Table 12***). Exceedances of PROREF (x, see derivation explained in **Chapter 2.7.2)** were grouped in six factor-intervals: <x, 1-2x (between PROREF and two times PROREF), 2-5x, 5-10x, 10-20x and >20x.

The EQS and PROREF as well as time trend analyses use concentrations on a wet weight (w.w.) basis. The choice of basis (i.e. concentrations on a wet weight, dry weight or fat weight basis) follows the OSPAR approach aimed at meeting several considerations: scientific validity, uniformity for groups of contaminants for specific tissues and a minimum loss of data. As to the latter, the choice of basis will affect the number of data that can be included in the assessment, depending on available information on dry weights, wet weights and lipid weights.

2.7.2 Derivation of PROREF

The MILKYS programme (and its forerunners) have monitored an extensive list of contaminants along the coast in both impacted and less impacted areas since 1981. The results from this programme have generated over 400 000 analyses on concentrations of over 100 contaminants in biota alone. Most of the data concern blue mussel and cod which are the two key monitoring species for MILKYS. This unique dataset provides a good basis for determining of Norwegian provisional high reference contaminant concentrations (PROREF) of contaminants mostly in areas presumed remote from point sources of contamination, and thus provides a valuable method of assessment of levels of contaminants along the coast of Norway both in impacted and less impacted areas in addition to EQS.

The derivation of PROREF is derived entirely from MILKYS data. It has two basic steps: the selection of stations to be used and the calculation of PROREF. The following outlines the approach:

1. Selection of reference stations:
    a. Only data from 1991 to 2015 were considered (25 years) on the general assumption that prior to this time important discharge reductions were not in place.
    b. Annual median concentrations were determined for each combination of contaminant, station, species, tissue and basis (e.g. wet weight).
    c. The highest 10 % of these medians were discarded for each station; as this was considered a reasonable limit to remove medians which had substantially higher concentrations than other years.
    d. In order to get a robust set of stations, we considered only stations which had at least five years of data, counting only years with at least two analysed samples for blue mussel stations and 10 analysed samples for cod stations. I.e., we allowed for some deviance from standard sample size, which according to present procedures is three for blue mussel and 15 for cod.
    e. The stations were ordered by concentration from the lowest to the highest based on the median of the annual medians.
    f. Values below the limit of quantification (LOQ) were set to a random value between half the LOQ and the LOQ.

g. The station with the lowest concentration was compared to the station with the next lowest using a t-test where the log-transformed annual medians were used to determine the variance at the station.
h. If the two stations were not statistically different, these data were compared to the third lowest station, and this process continued until a significant difference was noted.
i. All stations that were not statistically different formed the group of reference stations for a unique combination for contaminant, species, tissue and basis.

2. Application of raw data
   j. All the raw data from the reference stations for the unique combination of contaminant, species, tissue and basis for the period 1991-2015 were used.
   k. PROREF was defined as the upper 95 percentile.

The upper 90 % and 95 % confidence limits as well as the upper 90 percentile were also calculated. The upper 95 percentile was consistently higher that the other three limits.

It should be noted that the selection of reference stations can vary depending on the combination of contaminant, species, tissue, and basis. PROREF were also calculated for cod length normalized to 50 cm.

An overview of the PROREF applied in this report is shown in ***Appendix C***, and a summary comparing PROREF with the existing EQS and the national classification system used in previous reports is shown in ***Table 7***. PROREF values were adjusted slightly for the previous report to ensure that the values used are exclusively from the MILKYS programme. In only four cases did the revised PROREF lead to a difference of over 20 % and only restricted to blue mussel: 32 and 38 % lower for As and anthracene, respectively, and 46 and 47 % higher for PCB-7 and BDE6S, respectively (***Table 7***, ***Appendix C***).

In this report assessment of the change in PROREF from 2018 to 2019 is based on the revised PROREF values. Hence, as a precautionary measure, comparison to PROREF values used previously (Green *et al.* 2018) should be avoided.

For this report, 177 PROREF values are defined based on 1 to 29 stations and 1 to 4071 values. For example, following the procedure outlined above, we were left with only one station to determine PROREF for, *inter alia*, TBT and sum carcinogen PAHs (KPAH) in blue mussel and, *inter alia,* Hg, PCB-7, BDE6S, HBCDA, PYR10 and ALAD in cod. PROREF could not be calculated for three PCBs (PCB81, PCB126 and PCB169) and PFAS in blue mussel and perfluoroundecanoic acid (PFUdA) in cod liver because the data did not meet criteria “d” above.

As described above, once the stations to be used as reference are determined, the raw data was used from these stations to determine the PROREF. Hence it is not only the number stations but also the variance within each station that can have an influence on PROREF. Concentrations of individual compounds can, but not always, vary more than a sum that includes the individual compound, which can lead to a PROREF of a single compound to be considerably higher than the PROREF of a sum where it is included. A case in point is for the carcinogen PAH BGHIP in blue mussel which has a PROREF of 2.07 µg/kg w.w. This value is the upper 95 percentile of all 254 BGHIP-concentrations on a wet weight basis from seven stations (98A2, 0123, I304, I306, I307, I913, and 71A) since 1991 (***Appendix C***). Whereas the PROREF for the sum of carcinogen PAHs (KPAH) in blue mussel is 0.62 µg/kg w.w., which is based on only 17 KPAH-concentrations from one station (98A2) and which is considerably lower than the PROREF for BGHIP.

Thirty-two PROREF values could be compared to 23 EQS. PROREF was lower than EQS in 20 cases (including some PAHs and PBDEs).

This is the fourth annual MILKYS report where PROREF values have been applied. PROREF values should be periodically reviewed in the light of further monitoring, the results from reference localities and introduction of new analytical methods, and/or units.

***Table 7**. Overview of Norwegian provisional high reference contaminant concentration (PROREF) used in this report for the stations from which PROREF was derived (in w.w.). Also shown are the Environmental Quality Standards (EQS) for "biota" [1] (2013/39/EU 2013) and national environmental quality standards [2] (Norwegian_Environment_Agency 2016a) (these two are collectively referred to as EQS). The number of stations and the total number of values that were used to determine PROREF are indicated. The yellow indicates where PROREF has increased or decreased over 20 %, and green and pink cells indicate where PROREF is below or above the EQS, respectively. (See complete list of PROREF used in this report in **Appendix C**.)*

Parameter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet weight. basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
As	Mytilus edulis	**Soft body**	31A,I301,I023,30A,I712	**5**	116	mg/kg	2.503	3.3150	1.3247		
Hg	Mytilus edulis	**Soft body**	36A,46A,10A2	**3**	137	mg/kg	0.012	0.0100	0.8197	0.020	1.6393
PCBS7[3]	Mytilus edulis	**Soft body**	10A2,41A,11X,98A2,64A,97A2	**6**	194	µg/kg	1.157	0.4891	0.4228	0.600[4]	0.5187
DDE	Mytilus edulis	**Soft body**	43A,41A,10A2,11X	**4**	147	µg/kg	0.224	0.2240	1.0000	610.000[5]	2 723.2143
HCB	Mytilus edulis	**Soft body**	48A,43A,15A,22A,46A,41A,98A2,11X,30A,10A2,36A	**11**	473	µg/kg	0.100	0.1000	1.0000	10.000	100.0000
HBCDA	Mytilus edulis	**Soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.110	0.1099	1.0000	167.000	1 520.2549
BDE6S[7]	Mytilus edulis	**Soft body**	98A2,26A2,91A2,71A,I023,97A2,30A	**7**	109	µg/kg	0.408	0.1900	0.4657	0.009	0.0208
BDE47	Mytilus edulis	**Soft body**	98A2,26A2,71A,I023,91A2,30A	**6**	94	µg/kg	0.171	0.1410	0.8270	0.009[8]	0.0499
SCCP	Mytilus edulis	**Soft body**	I023,71A,91A2,97A2,26A2,30A	**6**	90	µg/kg	20.260	20.2600	1.0000	6 000.000	296.1500
MCCP	Mytilus edulis	**Soft body**	I023,26A2,71A,91A2,97A2,30A	**6**	89	µg/kg	87.600	87.6000	1.0000	170.000	1.9406
ANT[6]	Mytilus edulis	**Soft body**	98A2,I131A,I307,I915,I913,71A	**6**	208	µg/kg	0.800	1.1000	1.3750	2 400.000	3 000.0000
BAA[6]	Mytilus edulis	**Soft body**	I023,98A2	**2**	32	µg/kg	1.490	1.4900	1.0000	300.000	201.3423
BAP[6]	Mytilus edulis	**Soft body**	98A2,I307,I131A,I306,I304,30A,I913	**7**	354	µg/kg	1.200	1.3000	1.0833	5.000	4.1667
FLU[6]	Mytilus edulis	**Soft body**	98A2,I023	**2**	32	µg/kg	5.350	5.3500	1.0000	30.000	5.6075
NAP[6]	Mytilus edulis	**Soft body**	I023,98A2,71A	**3**	47	µg/kg	17.300	17.3000	1.0000	2 400.000	138.7283
TBT	Mytilus edulis	**Soft body**	11X	**1**	20	µg/kg	7.107	7.1065	1.0000	150.000	21.1074
TBT	Nucella lapillus	**Soft body**	11G,131G,15G,98G	**4**	66	µg/kg	23.540	23.5350	0.9998	150.000	6.3721
PCB7	Gadus morhua	**Liver**	98B1,10B,92B,43B	**4**	1229	µg/kg	614.000	614.0000	1.0000	0.600	0.0010
DDE	Gadus morhua	**Liver**	23B,10B,98B1	**3**	1498	µg/kg	160.750	160.7500	1.0000	610.000[5]	3.7947
HCB	Gadus morhua	**Liver**	36B,53B	**2**	1079	µg/kg	14.000	14.0000	1.0000	10.000	0.7143
4-N-NP	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	131.000	131.0000	1.0000	3 000.000	22.9008
4-N-OP	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	23.500	23.5000	1.0000	0.004	0.0002
4-T-NP	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	240.900	240.9000	1.0000	3 000.000	12.4533
HBCDA	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	7.000	7.0000	1.0000	167.000	23.8571
BDE6S[7]	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	19.882	19.8800	0.9999	0.009	0.0004
BDE47	Gadus morhua	**Liver**	98B1,36B,23B	**3**	557	µg/kg	16.000	16.0000	1.0000	0.009[8]	0.0005
SCCP	Gadus morhua	**Liver**	23B,43B2,80B	**3**	245	µg/kg	154.000	154.0000	1.0000	6 000.000	38.9610
MCCP	Gadus morhua	**Liver**	23B,43B2	**2**	174	µg/kg	392.800	392.8000	1.0000	170.000	0.4328
PFOA	Gadus morhua	**Liver**	43B2,13B,80B,53B,36B,98B1,23B,30B	**8**	1289	µg/kg	10.000	10.0000	1.0000	91.000	9.1000
PFOS	Gadus morhua	**Liver**	43B2,80B	**2**	251	µg/kg	10.250	10.2500	1.0000	9.100	0.8878
Hg	Gadus morhua	**Fillet**	10B	**1**	504	mg/kg	0.056	0.0600	1.0714	0.020	0.3571

1) Environmental Quality Standard (EQS) as derived from 2013/39/EU and compounds and national environmental quality standards as derived from Arp *et al.* (2014) and modified by the Norwegian Environment Agency and finalized (Norwegian_Environment_Agency 2016a). EQS concern fish unless otherwise stated. An alternative biota taxon or another matrix may be monitored instead as long as the EQS applied provides an equivalent level of protection.
2) The contaminants for which the national environmental quality standards apply are termed in the EU system as "river basin specific pollutants"
3) Sum of PCB congeners 28, 52, 101, 118, 138, 153 and 180.
4) In Norwegian Environment Agency report (2016a) the EQS is 1 µg/kg wet weight, but this was adjusted down to 0.6 (Direktoratsgruppen vanndirektivet, 2018) and is in line with Arp *et al.* (2014) (Miljødirektorat, pers. comm. 16th June 2017).
5) For the present study the same limit was applied to DDE (p,p DDE).
6) Applies to Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish). Benzo(a)pyrene is considered a marker for other PAHs (2013/39/EU).
7) Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa).
8) Not official EQS for BDE47, but this PBDE is often the most dominant BDE.

Proposed background assessment criteria (BAC) for EROD, OH-pyrene and VDSI (OSPAR 2013) were used to assess the results (***Table 8***).

Table 8*. Assessment criteria for biological effects measurements using Background Assessment Criteria (BAC) and Ecotoxicological Assessment Criteria (EAC) (OSPAR 2013). Note that Assessment criteria have specifically been compiled for the assessment of CEMP monitoring data on hazardous substances. They do not represent target values or legal standards (OSPAR 2009).*

Biological effect	Applicable to:	BAC	EAC	Units, method
EROD	cod liver	145	-	pmol/min/ mg microsomal protein
OH-pyrene	cod liver	0.8*	-	ng/ml; HPLC-F
VDSI	dogwhelk	0.3	2	

*) Values in this report are normalized and the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380nm. Normalization in this investigation reduced the BAC from 21 to 0.8 ng/ml or by a factor of about 27.

2.8 Statistical time trend analysis – the model approach

A simple model approach has been developed within OSPAR and ICES to study time trends for contaminants in biota based on median concentration (ASMO 1994). The method has been applied to Norwegian data and results are shown in ***Appendix F***. The results can be presented as shown in ***Figure 4***. It should be noted that this robust method has been developed so that it could provide a rough guide to possible trends in the OSPAR region. Further investigation is necessary to better understand the factors affecting a particular trend. This may lead to different conclusions. As an exercise in this respect the times series for Hg in cod fillet from the Inner Oslofjord was examined more closely (Green *et al*. 2015).

The model approach uses a Loess[1] smoother based on a running six-year interval where a non-parametric curve is fitted to median log-concentration as defined by Nicholson *et al*. (1991; 1994; 1997) with revisions noted by Fryer and Nicholson (1999). The concentrations are on the preferred basis of wet weight as mentioned above. Supplementary analyses were performed on a dry weight basis for blue mussel data and lipid weight basis for chlororganic contaminants in blue mussel and fish liver (see ***Appendix F***). Since some contaminants (e.g. Hg) have tendency to bioaccumulate, supplementary analyses were performed on concentrations in cod normalized to 50 cm length (as a proxy for age). For statistical tests based on the fitted smoother to be valid, the contaminants indices should be independent to a constant level of variance and the residuals for the fitted model should be log-normally distributed (Nicholson, Fryer, and Larsen 1998). A constant of +1 was added to VDSI data prior to log transformation to enable analysis of observations that were equal to zero.

An estimate was made of the power of the temporal trend series expressed as the percent change that the test is able to detect. The power is based on the percentage relative standard deviation (RLSD) estimated using the robust method described by (ASMO 1994) and Nicholson *et al*. (1998). The estimate was made for series with at least five years of data.

The assessment method used up to and including the 2011 investigation have differed slightly from the method now employed by OSPAR. Before a linear trend for the whole time series period was tested whereas now OSPAR currently uses linear or non-linear tests, based on the number of years of data with at least one non-censored measurement (N_+). If N_+ is 5-6, a linear trend is tested, if N_+ is ≥7, one tests whether there is a significant difference in the smoothed annual concentration at

[1] Derived from the term "locally weighted scatter plot smooth", e.g. used in linear regression.

the beginning of the time series compared the smoothed annual concentration at the end of the time series. This report presents an assessment in line with the current OSPAR approach. The smoothed values were determined for the whole time series. The whole time series is termed in this report as a long-term trend. The smooth values were also used as a basis for assessing the trend for the last 10 years of the series, which is referred to in this report as short-term or recent trend. Be aware that a series may have gaps and recent trend may not necessarily include data for 2017. Time series is truncated from the left (omitting early years) until (1) at least 50 % of the years should have at least one non-censored measurement, and (2) the first year has at least one non-censored measurement. If the measurements in the most recent year(s) of the time series are all less-than, then the expected concentration in the most recent year(s) is assumed to be constant.

The term “significant” refers to the results of a statistical analysis at 0.05 significance level used for detecting differences between the beginning and the end of the time series and can be found in the tables in ***Appendix F***. In this appendix the statistical significance (p) is given as well as the annual detectable change (%) that can be detected with statistical probability of 90 % (power) in two-sided testing with a 10 % significance level (alpha). It can be noted that difference between significant and not-significant trends is not always readily evident in a figure.

No attempt has been made to compensate for differences in size groups or number of individuals of blue mussel or fish in the present study. However, investigations prior to 2007 showed significant differences between “small” and “large” fish. With respect to blue mussel, there is some evidence that concentrations do not vary significantly among the three size groups employed for the present study (i.e. 2-3, 3-4 and 4-5 cm) (WGSAEM 1993).

The statistical analysis of time trends was carried out on all the results, including those for biological effects parameters. These analyses as well as the figures similar to that shown in ***Figure 4*** were performed on R version 4.0.2 with the packages nlme (ver. 3.1-148) and mgcv (ver. 1.8-31).

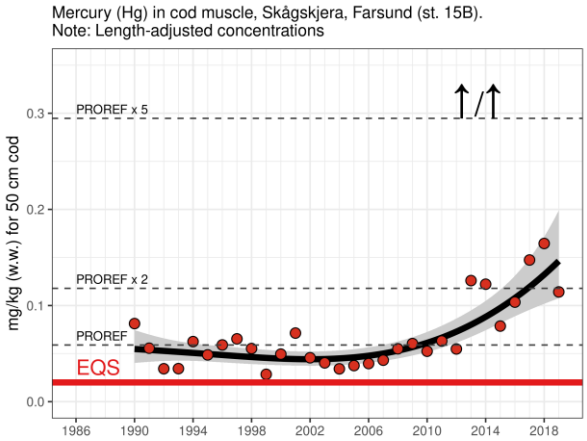


***Figure 4**. Example of time series (Hg in cod fillet from Skågskjera, Farsund, st. 15B, normalized for length) that show the median concentration (dots), running mean of median values (Loess smoother – thick black line) and 95 % confidence intervals surrounding the running mean (grey zone). A horizontal thick red line indicates the Environmental Quality Standard (EQS) if it can be applied and if it can be shown on the scale of concentration provided. A red dot indicates that the median value is above the EQS, a blue dot indicates that the value is below the EQS (not shown in the example figure), and a grey dot (not shown in the example figure) indicates that EQS can not be applied. The horizontal dashed grey lines indicate the lower boundaries relative to PROREF[1]; where, in addition to values below PROREF, exceedances are indicated, by a factor of: 1-2, 2-5, 5-10, 10-20 and greater than 20 (the latter three categories are not shown in the example figure, cf. **Table 27**). Note that PROREF can vary depending on species, tissue and contaminant. A light blue triangle (see for example **Figure 69 B**) indicates that the median was below the LOQ. A summary of the trend analyses is indicated on time series with five or more years and the results, before the slash "/" (i.e. long-term trend which means the entire time series), are indicated by an upward (🡅) or downward (🡇) arrow where significant trends were found, or a zero (O) if no trend was detected. Where there was sufficient data a time series analysis was performed for the last ten-year for the period 2010-2019 (short-term or recent trend) and the result is shown after the slash. A small filled square (▪) (not shown in the example figure) indicates that chemical analysis has been performed, but data either were insufficient to do a trend analysis or was not presented. Results marked with a star (★) (not shown in the example figure) indicate that there is insufficient data above the quantification limit to perform a trend analysis. Note that scales for the x axis and y axis can vary from figure to figure.*

2.9 A closer look at geographical differences

2.9.1 Contaminants and trophic levels

A generalized additive mixed model (GAMM) was used to test if there is a statistically significant correlation between concentrations of contaminants or trophic lever parameters and distance along the Norwegian coast. From the model, both a linear trend and non-linear component can be tested.

[1] PROREF related boundaries are in grey tones and not coloured so as not to be mistaken for color codes applied by Molvær *et al.* (1997 – TA-1467/1997) in previous reports.

MILKYS stations can be divided into three groups according to ICES guidelines (***Table 28*** in ***Appendix G***); for brevity noted here as "background", "reference" or "impacted". Selection criteria for data to be included were as follows:

1. Blue mussel and cod data from presumably non impacted stations.
2. Rawdata for all years.
3. Minimum two stations north of 65°N latitude for non-linear analyses.
4. For values below LOQ, an average was taken of three random numbers between LOQ and one half LOQ.
5. Focus on contaminant or trophic level parameters that are currently being monitored.

Distance was the Norwegian coastline from the Swedish border in the south (0 km) to the Russian border in the North (2685 km) as shown in ***Figure 5***. All values were log10-transformed before applying GAMM. The analyses and associated tables and figures were generated with R version 4.0.2 with the packages nlme (ver. 3.1-148) and mgcv (ver. 1.8-31).

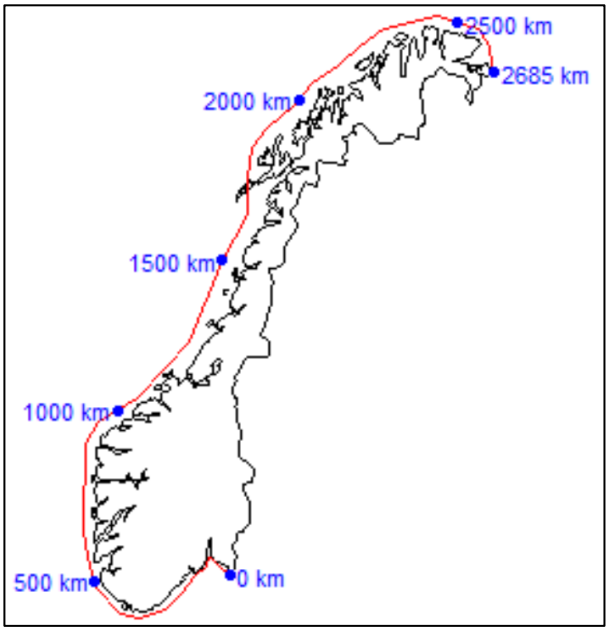


Figure 5. *Norwegian coastline distance from the Swedish border in the south to the Russian border in the north.*

2.9.2 Perfluorinated alkylated substances (PFAS)

PFAS for the years 2005-2019 analysed in cod liver were included in the material. PFAS was measured in more samples for cod and detection frequencies were higher than for blue mussel samples and were therefore used in this dataset. It should be noted that this in-depth approach is based on individual samples and differs from the general overview of PFAS in ***Chapter 3.2.24*** which is based on yearly medians and where the time trend analyses is based on the OSPAR methodology for the whole time series and the last 10 years (2010-2019) provided certain qualifications are met (see ***Chapter 2.8***). Also note that for stations 10B and 15B, PFASs were last monitored in this programme in 2007 and 2011, respectively, and are not discussed elsewhere in this report in regard to PFAS.

The number of stations included each year is given in ***Table 30*** (***Appendix G***). PFHxS, PFDcA and PFUdA were not analysed prior to 2012. PFOSA analyses were done since 2007. The sample size for each station/year are shown in ***Table 31*** (***Appendix G***). In general, the sample size up to 2011 was 25 fish/station, and afterwards 15 fish/station. However, the sample size was smaller for some stations. The detection frequencies for the different PFAS compounds are listed in ***Table 32*** (***Appendix G***). The detection frequency varied from 0.8 % (PFHxS) to 91 % (PFOS). For multivariate statistics, a high detection frequency is desirable, at least 80 % (Cohen and Cohen (1983) as cited by Figueredo *et al*. (2000)). We decided to include the three PFASs with the highest detection frequency (>40 %) in the analyses, and PFOS, PFOSA and PFUdA were used. It must therefore be kept in mind that for the hierarchical statistical method used, there are some weaknesses because the criterion of 80 % detection frequency is not met.

For the correlation with distance to the nearest airport, the correlations were done for the mean of each station in 2019 (see distances in ***Table 33*** (***Appendix G***) and location of stations and airports in ***Figure 6***). The PFAS concentrations were calculated assuming an equally fast degradation for all stations. This was done to make an easy regression with only one point/station. Any significant correlation found could afterwards be checked by using all the data in a mixed model. Since the concentrations measured in 2019 were lower than historically, the year with the highest mean concentrations for each station was selected. The distances along the coast (starting at the Swedish border (south)) are also given in ***Table 33***, was also used to test the hypothesis.

The statistical software JMP (version 15.1) was used for making some of the figures. The difference between slopes were tested by ANOVA and the post hoc test Tukey Kramer was used. For the hierarchical clustering, similar observations were clustered into a successively hierarchy of clusters (JMP). The data were standardized by the software, and the hierarchical method used was Ward. PFAS data were log10 transformed prior to clustering.

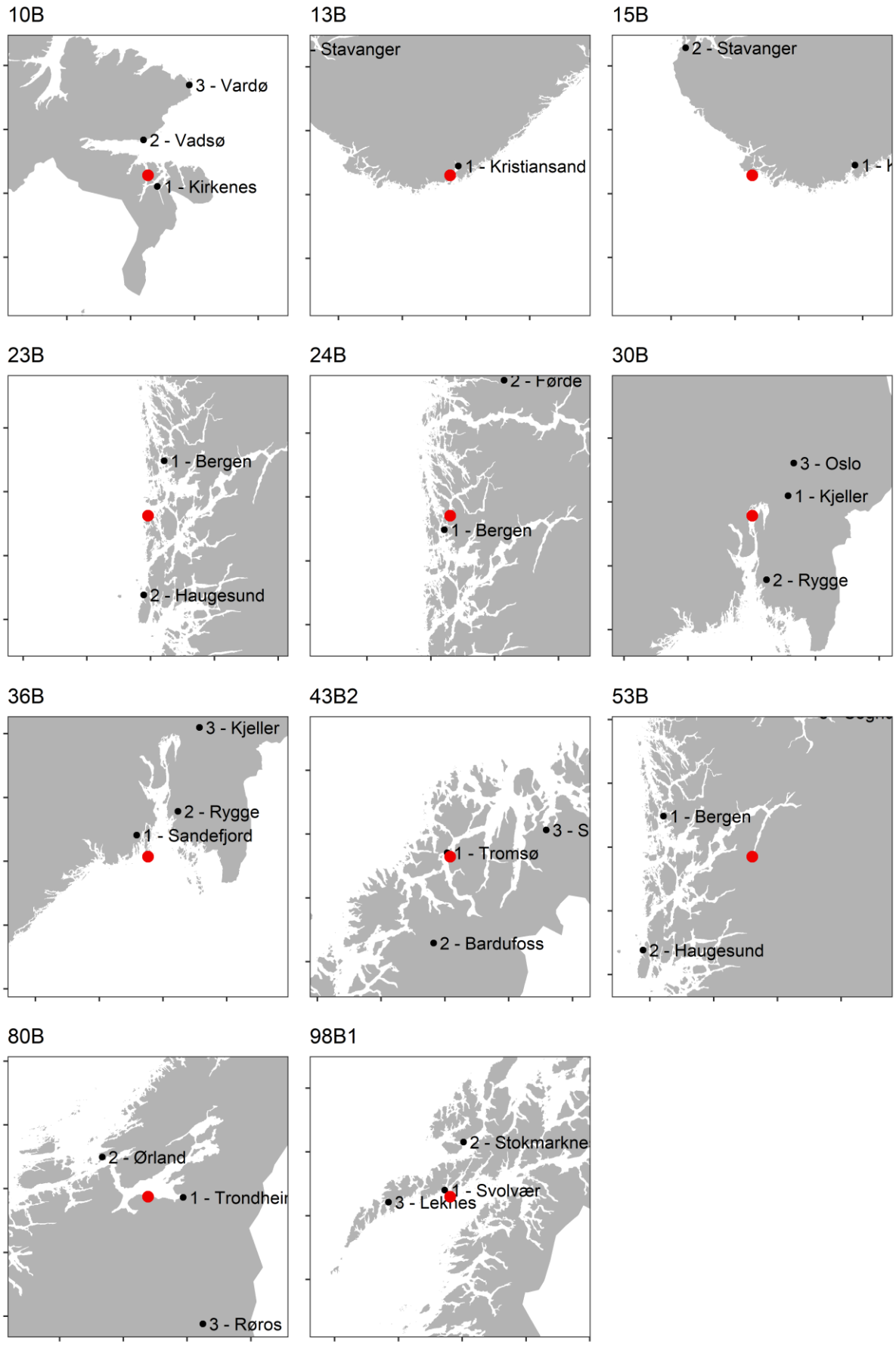


***Figure 6**. Location of sampling stations (red dots) and nearest airport(s) (black dots).*

2.10 Other statistical analyses

Specific analyses to test the differences between stations or years were done on the statistical package JMP Statistical Discovery™ from SAS using the non-parametric Tukey-Kramer HSD. A significance level of α = 0.05 was chosen.

Statistical analyses (linear regression) on stable isotope data were performed using Statistica software (Ver 13; Dell inc./Statsoft). A significance level of α = 0.05 was chosen.

2.11 Note on presentation of contaminant tables

Summaries of the results for some organic contaminants are presented in ***Table 14*** to ***Table 15***. These tables provide some extensive details and warrant explanation. Some of the analyses, especially of the "new" contaminants (e.g. HBCD, SCCP/MCCP, BPA and TBBPA), revealed a vast number of results that are below the limit of quantification (LOQ). This resulted in a number of median values below the LOQ. It was considered added-value to convey some information about the concentrations that were quantifiable even though the median was below the LOQ. To achieve this, *Detectable data information* (D.d.i.) was introduced. D.d.i. shows the count of concentrations above the LOQ and the minimum and maximum of these values.

An extract from ***Table 16*** is shown below in ***Table 9*** in regards to the PBDE compound BDE28. With respect to "Count" the first number indicates the number of individuals or pooled samples that were analysed. For example, for blue mussel from Gressholmen three samples were analysed and all three were pooled samples, and the maximum number of individual mussels that went into the pooled sample was 50. For cod liver from the Inner Oslofjord there were 14 samples whereof 11 were pooled with a maximum of four fish livers in each pool. This means that analyses were done on three individual cod (14-11=3). Note that the values for median ("Med.") and standard deviation ("S.d.") are rounded, and for example "0.000" represents a number greater than zero but less than 0.0005. The "D.d.i." for Eider duck egg from Breøyane is blank and indicates that none of the 15 values were above LOQ, whereas for blue mussel from Gressholmen, the D.d.i. indicates that only one of the three samples had concentrations of BDE28 above LOQ (0.0012 µg/kg w.w.). Note that when a dataset contains values below LOQ the median takes these as an average of ten random numbers between half the LOQ and the LOQ (see **Chapter 2.6**).

Table 9. *Example table – extract from* ***Table 16***. *Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in any one of the pooled samples. Shaded cells indicate that the median (Med.) was the limit of quantification (LOQ) and value shown in these cells is this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See text for more detail).*

Component	Count	BDE28		
Species and sampling locality	2019	Med.	S.d.	D.d.i
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.001	0.000	1 [0.0012]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.001	0.000	2 [0.0011-0.0015]
Cod, liver				
Inner Oslofjord (st. 30B)	14 (11-4)	0.322	0.108	14 [0.122-0.533]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-3)	0.092	0.039	5 [0.0632-0.152]
Eider, blood				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14	0.004	0.001	0 [n.a.]
Eider, egg				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.000	0 [n.a.]

3. Results and discussion

3.1 General information on measurements

3.1.1 Levels and temporal trends of contaminants

This report describes findings from monitoring activities conducted as part of MILKYS in 2019. A selected set of the contaminants (or groups of contaminants) monitored in biota as part of this monitoring programme is shown in ***Table 10***. A summary of levels and trends for the selected contaminants and effects in Atlantic cod, blue mussel, dogwhelk and common periwinkle along the coast of Norway in 2019 is shown in ***Table 11*** and ***Table 12***, respectively. Details on trend analyses that include results from either 2018 or 2019 are shown in ***Appendix F***. These results include a total of 3009 data sets (contaminant[1]-station-species-tissue) for 176 individual chemical substances. Of these substances, 30 have been selected for particular review in this report. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period[2], whereas a short-term trend refers to the analysis on data for the last 10 years, i.e. 2010-2019 and can also be referred to as recent trend.

Assessment of levels and time trend analyses were performed on a selection of 30 contaminants (only levels were reported for the common eider[3]) or their effect (VDSI), and totalled 670 data series[4] for the 2019 data (***Table 10***). Of the 670 cases, 346 cases could be classified against EQS, of which 232 (67.1 %) were below the EQS and 114 (32.9 %) were above the EQS (***Figure 7 A***, ***Figure 8 A***). Of the 670 cases, 582 could be compared to PROREF, and of these 407 (69.9 %) were below PROREF. Of the 582 cases, 175 of these (30.1 %) exceeded PROREF: 82 (14.1 %) by a factor of less than two, 51 (8.8 %) by a factor between two and five, 31 (5.3 %) by a factor between five and 10, four (0.7 %) by a factor between 10 and 20, and seven (1.2 %) by a factor greater than 20 (***Figure 7 B***, ***Figure 8 B***). Of the 670 data series recent and significant trends were registered in 100 cases: 72 (10.7 %) were downwards trends and 28 (4.2 %) were upwards (***Figure 7 C***). The downward trends were primarily associated with metals (22.2 %), tributyltin (TBT, 2.8 %) and VDSI (the effect of TBT) (1.4 %), but also PFOS (5.6 %) and PFOSA (9.7 %) (***Figure 8 C***). The upward trends were also mainly associated with metals (67.9 %), primarily Cr (14.3 %) and Hg, Co and Ni (each with 10.7 %).

The primary focus in for this report has been on identifying which of the 30 selected contaminants had median concentration in 2019 that exceeded the EQS. The report secondarily focused on those contaminants where the provisional high reference concentration (PROREF) was exceeded, and where significant upward trends were found. To a lesser extent, the report addressed those cases where no significant trends were found or significant downward trends were found, as well as those cases where median concentrations in 2019 were below PROREF in combination with significant upward trends. An overview of trends, classifications and median concentrations is presented in ***Appendix F***. The results are presented by classes and with results for observed trend analyses. The results were also assessed against EQS (2013/39/EU 2013) and Norwegian Environment Agency (2016b).

[1] In this regard «contaminants» include *inter alia* results from biological effects methods, stable isotopes and some biological co-variables.

[2] This can be as early as 1981 but can vary depending on the station, species-tissue and contaminant.

[3] The results are excluded because this was only the second year this bird species has been investigated within the MILKYS programme and there is insufficient data to do a temporal trend analysis. Also note that there are currently no EQS or PROREF values to assess levels.

[4] Consisting of one or more annual medians contrasting earlier reports which tallied only datasets of five or more annual medians.

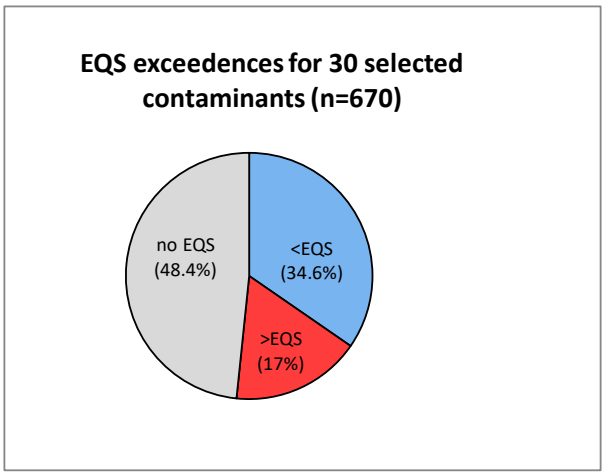
A summary of the results when assessed by EU EQS (2013/39/EU 2013) and supplemented with national environmental quality standards (Norwegian_Environment_Agency 2016a) is presented in ***Appendix C***.

Table 10*. Selection of 30 contaminants and number of time series assessed for each target species-tissue. The specific results are shown in* ***Table 12****.*

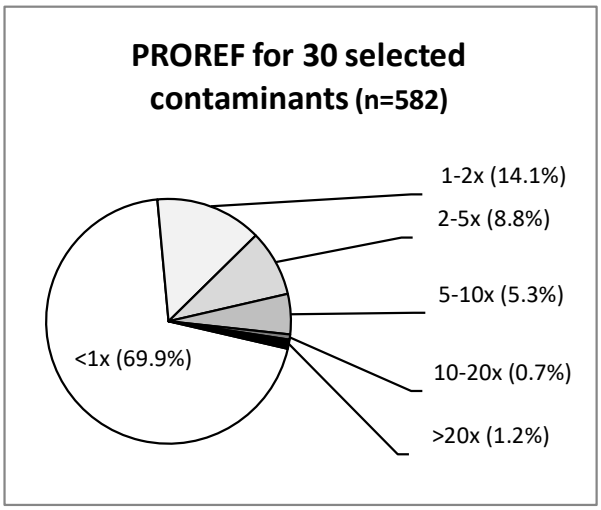
Contaminant /BEM	Description	Blue mussel	Periwinkle	Dogwhelk	Cod, liver	Cod fillet	Flounder, liver	Flounder, fillet	Eider, blood	Eider, egg*	TOTAL
Ag	Silver	22			16		1		1	1	41
Cd	Cadmium	22			16		1		1	1	41
Co	Cobalt	22			16		1		1	1	41
Cr	Chromium	22			16		1		1	1	41
Hg	Mercury	23				16		1	1	1	42
Ni	Nickel	22			16		1		1	1	41
Pb	Lead	22			16		1		1	1	41
PCB-7	Sum of PCB congeners 28+52+101+118+138+153+180	22			15		1		1	1	40
DDE	p,p'-DDE (a DDT metabolite)	12			6		1				19
HCB	Hexachlorobenzene	11			6		1		1	1	20
HBCDA	□□hexabromocyclododecane	10			13				1	1	25
BDE6S	Sum of PBDE congeners 28+47+99+100+153+154	10			11				1	1	23
BDE47	PBDE congeners 47	10			11				1	1	23
BDE100	PBDE congeners 100	10			11				1	1	23
BDE209	PBDE congeners 209	10			11				1	1	23
SCCP	Short-chain chlorinated Paraffins (C10-C13)	10			13				1	1	25
MCCP	Medium-chain chlorinated Paraffins (C14-C17)	10			13				1	1	25
PAHs (P_S)	Sum nondicyclic PAHs	6									6
ANT	Anthracene	6									6
BAA	Benzo[a]anthracene	6									6
B[a]P	Benzo[a]pyrene	6									6
FLU	Fluoranthene	6									6
NAP	Naphthalene	6									6
PFOA	Perfluorooctanoic acid	6			10				1	1	18
PFOS	Perfluorooctanesulfonic acid	6			10				1	1	18
PFOSA	Perfluorooctanesulfonamide	6			10				1	1	18
TBT	Tributyltin (formulation basis)	7	1	8							16
TPT	Triphenyltin	7	1	8							16
VDSI	Vas Deferens Sequence Index		1	7							8
D5	Decamethylcyclopentasiloxane				4				1	1	6
TOTAL		**338**	**3**	**23**	**240**	**16**	**9**	**1**	**20**	**20**	**670**

*) Egg homogenate of yolk and albumin

A



B



C

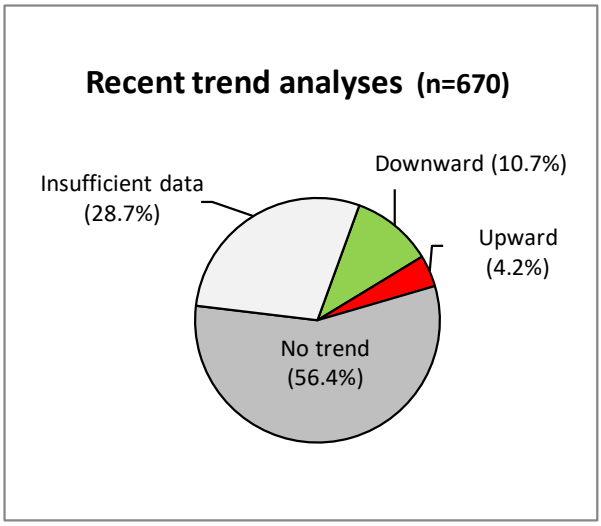


Figure 7. *Percent of samples (station-species-tissue) exceeding EQS (**A**), in different categories relating to Norwegian provisional high reference contaminant concentration (PROREF) (**B**) and relating to the results from short-term trend analyses (**C**) for 30 selected contaminants (including results from the common eider, cf.* ***Table 10****).*

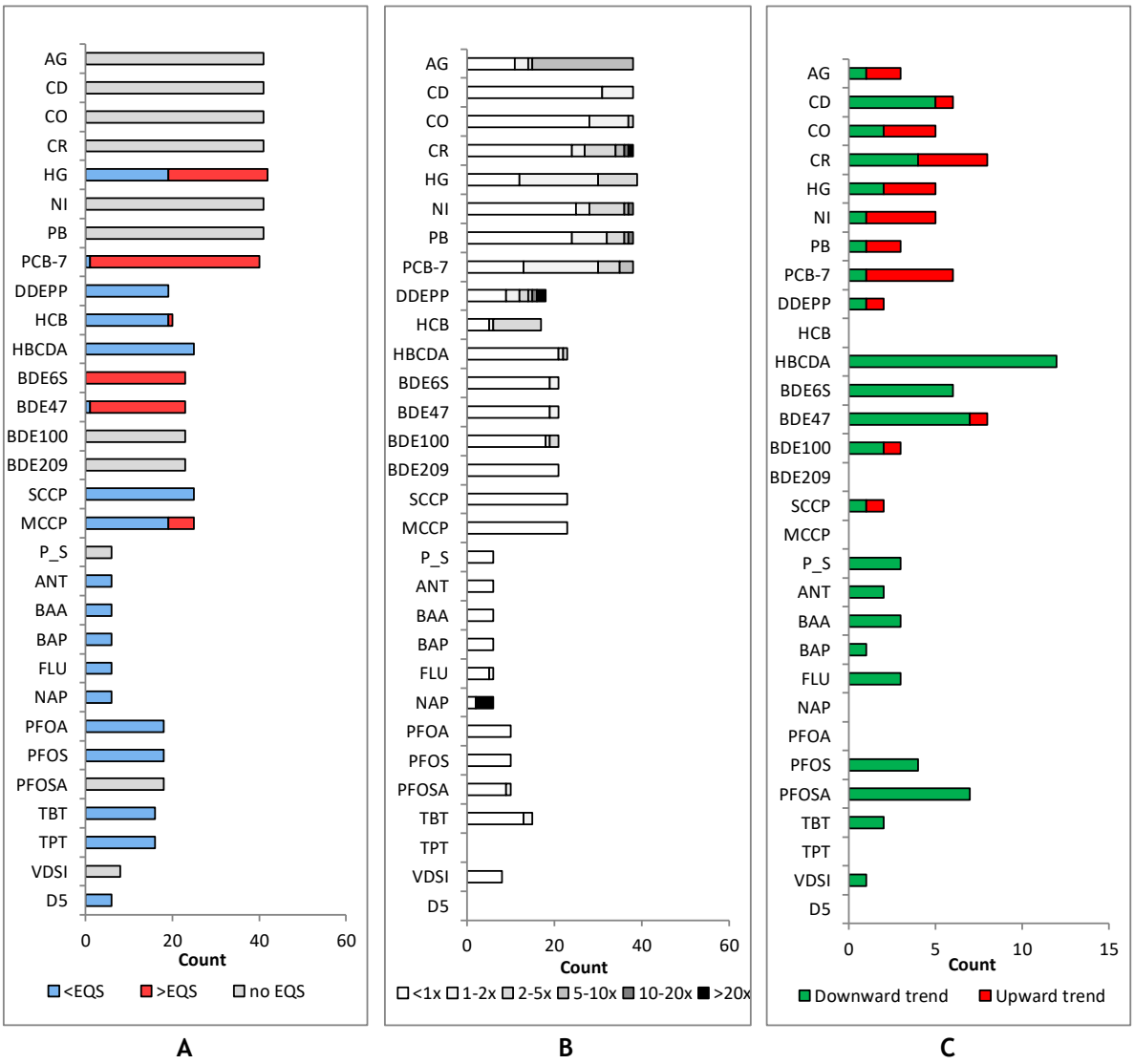


Figure 8. *Count of samples (station-species-tissue) exceeding EQS (**A**), in different categories relating to Norwegian provisional high reference contaminant concentration (PROREF) (**B**) and relating to the results from short-term trends (**C**) for each of the 30 selected contaminants (including results from the common eider, cf.* ***Table 10****, (see* ***Appendix B*** *for description of chemical codes).*

Table 11. *Assessment of levels of median concentrations of contaminants with respect to EQS (priority substances* and river basin specific pollutants**) and PROREF in samples collected in 2019 in six species: blue mussel, cod, flounder, eider duck, common periwinkle and dogwhelk. Tissues***: soft body (for blue mussel, dogwhelk and common periwinkle), liver (cod except for Hg***, fillet (cod, Hg)), blood (eider duck) and eggs (eider duck). The grey-shade coding refers to exceedances of Norwegian provisional high reference contaminant concentration (PROREF): below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 20 (see* ***Appendix C****). Blue-filled circles indicate that the EQS was not exceeded and red-filled circles indicate that the EQS was exceeded. The EQS are set by the Framework Directive (WFD), cf. Environmental Quality Standard Directive-(2013/39/EU 2013) for hazardous substances in "biota". Abbreviations for contaminants can be seen in* ***Appendix B****.*

Station name	Species	Tissue***	HG***	PCB-7**	DDE*	HBCDA*	BDE6S*	BDE47*	SCCP*	MCCP**	ANT*	BAA**	BAP*	FLU*	NAP*	PFOA**	PFOS*	TBT*	TPTIN**	D5**	HCB*	QCB*
Gressholmen, Inner Oslofjord (st. 30A)	Blue mussel	Soft body	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
Akershuskaia, Inner Oslofjord (st. I301)	Blue mussel	Soft body	●	●	●						●	●	●	●	●			●	●		●	●
Gåsøya, Inner Oslofjord (st. I304)	Blue mussel	Soft body	●	●	●						●	●	●	●	●			●	●		●	●
Solbergstrand, Mid Oslofjord (st. 31A)	Blue mussel	Soft body	●	●	●													●	●		●	●
Tjøme, Outer Oslofjord (st. 36A1)	Blue mussel	Soft body	●	●	●	●	●	●	●	●						●	●	●	●		●	●
Singlekalven, Hvaler (st. I023)	Blue mussel	Soft body	●	●		●	●	●	●	●	●	●	●	●	●							
Kirkøy, Hvaler (st. I024)	Blue mussel	Soft body	●	●																		
Risøy (st. 76A2)	Blue mussel	Soft body	●	●	●																●	●
Lastad, Søgne (st. I131A)	Blue mussel	Soft body	●								●	●	●	●	●							
Odderøya, Kristiansand harbour (st. I133)	Blue mussel	Soft body	●	●	●													●	●		●	●
Gåsøya-Ullerøya, Farsund (st. 15A)	Blue mussel	Soft body	●	●																		
Kvalnes, Mid Sørfjord (st. 56A)	Blue mussel	Soft body	●	●	●																●	●
Krossanes, Outer Sørfjord (st. 57A)	Blue mussel	Soft body	●	●	●																●	●
Utne, Outer Sørfjord (st. 64A)	Blue mussel	Soft body	●	●	●																	
Vikingneset, Mid Hardangerfjord (st. 65A)	Blue mussel	Soft body	●	●	●																●	●
Espevær, Outer Bømlafjord (st. 22A)	Blue mussel	Soft body	●	●	●											●	●	●	●		●	●
Nordnes, Bergen harbour (st. I241)	Blue mussel	Soft body	●	●		●	●	●	●	●						●	●					
Vågsvåg, Outer Nordfjord (st. 26A2)	Blue mussel	Soft body	●	●		●	●	●	●	●												
Ålesund harbour (st. 28A2)	Blue mussel	Soft body	●	●		●	●	●	●	●						●	●					
Ørland area, Outer Trondheimsfjord (st. 91A2)	Blue mussel	Soft body	●	●		●	●	●	●	●												
Mjelle, Bodø area (st. 97A2)	Blue mussel	Soft body	●	●		●	●	●	●	●												
Bodø harbour (st. 97A3)	Blue mussel	Soft body	●	●		●	●	●	●	●												
Svolvær airport area (st. 98A2)	Blue mussel	Soft body	●	●		●	●	●	●	●	●	●	●	●	●	●	●					
Inner Oslofjord (st. 30B)	Cod	Liver	●	●	●	●	●	●	●	●						●	●			●	●	●
Tjøme, Outer Oslofjord (st. 36B)	Cod	Liver	●	●	●	●	●	●	●	●						●	●				●	●
Kirkøy, Hvaler (st. 02B)	Cod	Liver	●	●		●			●	●												
Stathelle area, Langesundfjord (st. 71B)	Cod	Liver	●			●			●	●												
Kristiansand harbour area (st. 13B)	Cod	Liver	●	●		●	●	●	●	●						●	●					
Skågskjera, Farsund (st. 15B)	Cod	Liver	●	●	●																●	●
Inner Sørfjord (st. 53B)	Cod	Liver	●	●	●	●	●	●	●	●						●	●				●	●
Bømlo, Outer Selbjørnfjord (st. 23B)	Cod	Liver	●	●	●	●	●	●	●	●						●	●				●	●
Bergen harbour area (st. 24B)	Cod	Liver	●	●		●	●	●	●	●						●	●			●		
Ålesund harbour area (st. 28B)	Cod	Liver	●	●		●	●	●	●	●												

Station name	Species	Tissue***	HG* ***	PCB-7**	DDE*	HBCDA*	BDE6S*	BDE47*	SCCP*	MCCP**	ANT*	BAA**	BAP*	FLU*	NAP*	PFOA**	PFOS*	TBT*	TPTIN**	D5**	HCB*	QCB*
Trondheim harbour (st. 80B)	Cod	Liver	●	●		○	●	●	○	●						○	○					
Sandnessjøen area (st. 96B)	Cod	Liver	●	●																		
Austnesfjord, Lofoten (st. 98B1)	Cod	Liver	●	●	○	○	●	●	○	○						○	○				●	○
Tromsø harbour area (st. 43B2)	Cod	Liver	●	●		○	●	●	○	○						○	○			○		
Hammerfest harbour area (st. 45B2)	Cod	Liver	●	●																		
Svalbard (st. 19B)	Cod	Liver	●	●		○	●	●	○	○						○	○			○		
Sande, Mid Oslofjord (st. 33F)	Flounder	Liver	●	●	○																○	○
Breøyane (st. 19N)	Eider duck	Blood	●	○		○	●	●	○	○						○	○			○	○	
Breøyane (st. 19N)	Eider duck	Egg	●	●		○	●	●	○	○						○	○			○	○	
Fugløyskjær, Outer Langesundfjord (st. 71G)	Dog whelk / common periwinkle	Soft body																○	○			
Færder, Outer Oslofjord (st. 36G)	Dog whelk	Soft body																○	○			
Risøya, Risør (st. 76G)	Dog whelk	Soft body																○	○			
Lastad, Søgne (st. 131G)	Dog whelk	Soft body																○	○			
Gåsøya-Ullerøya, Farsund (st. 15G)	Dog whelk	Soft body																○	○			
Flatskjær (st. 227G)	Dog whelk	Soft body																○	○			
Espevær, Outer Bømlafjord (st. 22G)	Dog whelk	Soft body																○	○			
Svolvær airport area (st. 98G)	Dog whelk	Soft body																○	○			
Brashavn, Outer Varangerfjord (st. 11G)	Dog whelk	Soft body																○	○			

***) In cod Hg measured in fillet

***Table 12**. Assessment of levels and trends of median concentrations of 30 selected contaminants/Biological Effect Methods (BEM) with respect to the Norwegian provisional high reference contaminant concentration (PROREF) in samples collected in 2019 in six species: blue mussel, cod, flounder, eider duck, common periwinkle and dogwhelk. Tissues: soft body (for blue mussel, dogwhelk and common periwinkle), liver (cod except for Hg) and fillet (cod for Hg). The colour coding indicate to what degree the measured levels exceed PROREF, with levels below PROREF indicated in white and levels exceeding PROREF by a factor of 1-2, 2-5, 5-10, 10-20 or greater than 20 highlighted in shades from light grey to black (see also **Appendix C**). For biota, trend analyses were done on time series with data from five or more years. An upward (🡅) or downward (🡇) arrow indicates statistically significant trends, whereas a zero (**O**) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed but the results were insufficient to do a trend analysis. Results marked with a star (★) indicate that there is insufficient data above the quantification limit (LOQ) to perform a trend analysis. The result from the trend analysis for the entire time series (long-term) is shown before the slash "/", and the result for the last 10 years (short-term) is shown after the slash. The results for the length-adjusted trend analyses (concerns only cod) are not shown. (See **Appendix B** for description of chemical codes.) The asterisk after the station name indicates those stations considered less impacted by contamination. Abbreviations for contaminants can be seen in **Appendix B**. For common periwinkle, ISI and not VDSI was measured.*

Station name	Species	Tissue	AG	CD	CO	CR	HG	NI	PB	CB_S7	DDEPP	HCB	HBCDA	BDE6S	BDE47	BDE100	BDE209	SCCP	MCCP	P_S	ANT	BAA	BAP	FLU	NAP	PFOA	PFOS	PFOSA	TBT	TPhT	VDSI/ISI	D5
Gressholmen, Inner Oslofjord (st. 30A)	Blue mussel	Soft body	O/O	O/O	🡅/🡅	🡅/🡅	O/O	🡅/🡅	🡅/🡅	🡇/O	🡇/O	🡇/★	O/O	🡇/O	🡇/🡇	🡇/O	★/★	O/O	O/O	🡇/🡇	🡇/🡇	🡇/🡇	★/★	🡇/🡇	O/★	▪/▪	▪/▪	▪/▪	🡇/O	▪/▪		
Akershuskaia, Inner Oslofjord (st. I301)	Blue mussel	Soft body	O/O	O/O	O/O	🡅/O	O/O	O/O	🡇/O	🡇/O	🡇/O	O/★		▪/▪	▪/▪	▪/▪	▪/▪			🡇/🡇	O/🡇	🡇/🡇	🡇/🡇	🡇/🡇	O/★				🡇/🡇	▪/▪		
Gåsøya, Inner Oslofjord (st. I304)	Blue mussel	Soft body	O/O	🡅/O	O/O	🡅/O	🡅/O	O/O	🡅/🡅	🡇/O	🡇/O	O/★		▪/▪	▪/▪	▪/▪	▪/▪			O/🡇	★/★	O/🡇	★/★	🡇/🡇	★/★				🡇/🡇	▪/▪		
Solbergstrand, Mid Oslofjord (st. 31A)	Blue mussel	Soft body	O/O	🡇/O	O/O	O/O	🡇/O	O/O	O/O	🡇/O	O/O	🡇/★		▪/▪	▪/▪	▪/▪	▪/▪												O/O	▪/▪		
Tjøme, Outer Oslofjord (st. 36A1)*	Blue mussel	Soft body	O/O	🡇/O	O/O	O/O	🡇/O	O/O	O/O	🡇/O	O/O	🡇/★	🡇/🡇	O/O	🡇/O	O/O	★/★	🡇/O	O/O							▪/▪	▪/▪	▪/▪	🡇/O	▪/▪		
Singlekalven, Hvaler (st. I023)	Blue mussel	Soft body	O/O	O/🡇	O/O	🡅/O	O/🡇	O/O	O/O	🡇/O			O/O	O/O	O/O	O/O	★/★	🡅/🡅	O/O	O/O	★/★	★/★	★/★	O/O	★/★							
Kirkøy, Hvaler (st. I024)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	🡇/O	O/O	O/O	🡇/O																						
Risøy (st. 76A2)	Blue mussel	Soft body	★/★	O/O	O/O	🡅/🡅	O/O	🡅/🡅	O/O	O/O	O/O	★/★																				
Lastad, Søgne (st. I131A)	Blue mussel	Soft body	▪/▪	O/O	🡇/O	O/O	O/O	O/O	O/O											O/O	O/O	🡇/O	★/★	O/O	★/★							
Odderøya, Kristiansand harbour (st. I133)	Blue mussel	Soft body	O/O	O/O	🡇/🡇	O/O	O/O	O/O	O/O	🡇/O	🡇/O	🡇/O								▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪				🡇/O	▪/▪		
Gåsøya-Ullerøya, Farsund (st. 15A)	Blue mussel	Soft body	O/O	O/🡇	🡇/O	O/O	O/O	O/O	O/O	O/O																						
Kvalnes, Mid Sørfjord (st. 56A)	Blue mussel	Soft body					🡇/O			🡇/🡅	🡅/O	O/★																				
Krossanes, Outer Sørfjord (st. 57A)	Blue mussel	Soft body	O/O	🡇/🡇	O/O	O/🡅	🡇/O	🡅/🡅	🡇/O	O/🡅	O/O	O/★																				
Utne, Outer Sørfjord (st. 64A)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O																					
Vikingneset, Mid Hardangerfjord (st. 65A)	Blue mussel	Soft body	O/O	🡇/🡇	O/O	O/O	O/O	O/O	🡇/O	O/🡅	O/O	O/★																				
Espevær, Outer Bømlafjord (st. 22A)	Blue mussel	Soft body	O/O	🡇/O	O/O	O/O	O/O	O/O	🡇/O	🡇/O	O/🡅	★/★														▪/▪	▪/▪	▪/▪	🡇/O	▪/▪		
Nordnes, Bergen harbour (st. I241)	Blue mussel	Soft body	★/★	🡇/O	O/O	O/O	O/O	O/O	🡇/O	🡇/O			🡇/🡇	🡇/🡇	🡇/🡇	O/O	★/★	O/O	O/O							▪/▪	▪/▪	▪/▪				
Vågsvåg, Outer Nordfjord (st. 26A2)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	O/O	O/O	🡅/🡅			O/O	O/O	🡅/🡅	🡅/🡅	★/★	O/O	O/O													
Ålesund harbour (st. 28A2)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				
Ørland area, Outer Trondheimsfjord (st. 91A2)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O			🡇/🡇	O/O	O/O	O/O	★/★	O/O	O/O													
Mjelle, Bodø area (st. 97A2)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O			🡇/🡇	O/O	🡇/🡇	O/O	★/★	O/O	O/O													
Bodø harbour (st. 97A3)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪													
Svolvær airport area (st. 98A2)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	🡇/O	O/O	🡇/O	O/O			🡇/🡇	🡇/O	🡇/O	🡇/O	★/★	O/O	O/O	O/O	★/★	★/★	★/★	O/O	★/★	▪/▪	▪/▪	▪/▪				

*) Timeseries includes station at Færder, Outer Oslofjord (st. 36A)

Table 12 (cont.)

Station name	Species	Tissue	AG	CD	CO	CR	HG	NI	PB	CB_S7	DDEPP	HCB	HBCDA	BDE6S	BDE47	BDE100	BDE209	SCCP	MCCP	P_S	ANT	BAA	BAP	FLU	NAP	PFOA	PFOS	PFOSA	TBT	TPhT	VDSI/ISI	DS
Inner Oslofjord (st. 30B)	Cod	Liver	O/O	↑/O	O/O	↓/↓	↑/O	O/O	↓/O	O/O	↓/O	↓/O	O/↓	↓/↓	↓/↓	↓/↓	★/★	O/O	O/O							▪/▪	↓/↓	O/↓				▪/▪
Tjøme, Outer Oslofjord (st. 36B)	Cod	Liver	O/O	↓/O	O/O	↓/↓	O/O	↓/↓	↓/O	↓/O	↓/O	↓/O	O/O	O/O	↓/O	O/O	★/★	O/O	O/O							▪/▪	↓/O	O/O				
Kirkøy, Hvaler (st. 02B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	★/★	↓/↓			↓/↓					O/O	O/O													
Stathelle area, Langesundfjord (st. 71B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/O				↓/↓					O/O	O/O													
Kristiansand harbour area (st. 13B)	Cod	Liver	O/O	O/O	O/O	↓/↓	↑/↑	↓/O	O/O	O/O			↓/↓	↓/O	↓/O	O/O	★/★	O/O	O/O							▪/▪	↓/↓	↓/↓				
Skågskjera, Farsund (st. 15B)	Cod	Liver	↑/↑	O/O	↑/↑	O/↑	↑/↑	O/↑	↓/★	↓/O	↓/↓	↓/O																				
Inner Sørfjord (st. 53B)	Cod	Liver	O/O	↓/↓	O/O	O/O	O/O	O/O	↓/O	O/O	O/O	↓/O	O/O	O/↓	O/↓	O/O	★/★	↓/O	O/O							★/★	↓/O	↓/↓				
Bømlo, Outer Selbjørnfjord (st. 23B)	Cod	Liver	O/O	O/O	O/O	O/O	↑/↑	O/O	↓/O	↓/O	↓/O	O/O	↓/↓	↓/↓	↓/O	↓/O	★/★	O/O	↑/O							▪/▪	O/O	↓/↓				
Bergen harbour area (st. 24B)	Cod	Liver	↓/↓	O/O	O/O	O/O	O/O	O/O	O/O	O/O			O/O	O/O	O/O	O/O	★/★	↓/↓	O/O							★/★	O/O	O/O				▪/▪
Ålesund harbour area (st. 28B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O			O/O	O/O	O/O	O/O	★/★	O/O	O/O													
Trondheim harbour (st. 80B)	Cod	Liver	O/O	O/O	O/O	↓/↓	O/O	O/O	↓/O	↓/O			↓/↓	↓/↓	↓/↓	O/O	★/★	O/O	O/O							★/★	↓/O	↓/↓				
Sandnessjøen area (st. 96B)	Cod	Liver	↑/↑	O/O	↑/↑	O/O	O/O	O/O	★/★	O/O																						
Austnesfjord, Lofoten (st. 98B1)	Cod	Liver	O/O	O/O	O/↓	O/O	O/O	O/O	↓/★	O/↑	O/O	O/O	O/O	O/O	O/O	O/O	★/★	O/O	O/O							▪/▪	↓/↓	↓/↓				
Tromsø harbour area (st. 43B2)	Cod	Liver	O/O	O/O	O/O	O/O	↑/O	O/O	O/O	O/O			↓/↓	↓/↓	↓/↓	↓/↓	★/★	O/O	O/O							▪/▪	↓/↓	↓/↓				▪/▪
Hammerfest harbour area (st. 45B2)	Cod	Liver	O/O	O/O	O/O	O/O	↓/↓	O/O	↓/↓	O/O																						
Svalbard (st. 19B)	Cod	Liver	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				▪/▪
Sande, Mid Oslofjord (st. 33F)	Flounder	Liver	O/O	O/↑	O/O	O/O	O/O	O/O	↓/O	↓/O	↓/O	↓/O																				
Breøyane (st. 19N)	Eider duck	Blood	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				▪/▪
Breøyane (st. 19N)	Eider duck	Egg	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				▪/▪
Fugløyskjær, Outer Langesundfjord (st. 71G)	Periwinkle	Soft body																											★/★	▪/▪	↓/O	
Færder, Outer Oslofjord (st. 36G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Risøya, Risør (st. 76G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Lastad, Søgne (st. 131G)	Dogwhelk	Soft body																											↓/★	▪/▪	↓/O	
Gåsøya-Ullerøya, Farsund (st. 15G)	Dogwhelk	Soft body																											↓/★	▪/▪	↓/O	
Melandsholmen, Mid Karmsundet (st. 227G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Espevær, Outer Bømlafjord (st. 22G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Svolvær airport area (st. 98G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/↓	
Brashavn, Outer Varangerfjord (st. 11G)	Dogwhelk	Soft body																											★/★	▪/▪	O/O	

3.1.2 Geographical coastal contaminant trends

The MILKYS programme has a network of monitoring stations along the Norway's coastline which is formed along the Skagerrak, North Sea, Norwegian Sea, and Barents Sea (see ***Appendix D***). Considering how extensive the Norwegian coastline is and that known coastal currents flow predominantly from south to north, there is a need to gain knowledge about underlying geographical trends in contaminant concentrations or trophic level parameters.

To investigate coastal trends, contaminant levels in blue mussels and cod from 37 blue mussel and 16 cod stations, from what are considered by expert judgement to be less contaminated sites, were investigated (***Table 28***, ***Appendix G***). The selected stations cover entire coastline of mainland Norway from South to North and extend over 11 degrees of latitude for both species; from the blue mussel station at Gåsøy-Ullerøya, Farsund (st. 15A) in the South to blue mussel station at Skallnes, Outer Varangerfjord (st. 10A2) in the North (***Figure 1*** and ***Map 20*** in ***Appendix D***), and from the cod station at Skågskjera, Farsund (st. 15B) in the south to cod station at Kjøfjord, Outer Varangerfjord area (st. 10B) in the north (***Figure 3*** and ***Map 20*** in ***Appendix D***). The stations extended along 2685 km of coastline (***Figure 5***).

The results for the 30 contaminants or groups of contaminants are presented (***Table 13***). The number of measured concentrations per substance-species-tissue varied from 32 for PFOA measured in blue muscle to 3367 for Hg measured in cod fillet (***Table 29***, ***Appendix G***). Concentrations were generally low; less than 2x PROREF in at least 70 % of the cases, with the exception PAH16, KPAH and DDE. This supports the assumption that the data used for this assessment of geographical trends came from less impacted stations. The results indicate that data for both species confirm statistically significant decreasing concentrations from south to north for Co and PCB-7. In only one case, for Ag (***Figure 9***), did the results show opposite significant trends, increasing for blue mussel and decreasing for cod. In addition, the results showed that concentrations were significantly decreasing for Hg (***Figure 10***), DDE (***Figure 11***), HBCDA (***Figure 13***), TBT (***Figure 10***) and TPT in blue mussel, and As, Cu, Zn, BDE6S (***Figure 13***), BDE100, PFOS (***Figure 13***) and PFOSA (***Figure 13***) in cod liver. The results also showed that concentrations were significantly increasing for Cd (***Figure 9***), HCB (***Figure 11***) and QCB (***Figure 11***) in cod liver. No trends were registered for PAH16, BAP, SCCP and MCCP (***Figure 12***).

The significant percent decrease in concentrations from the southern to the northern Norway was between nine and 55 % per 1000 km, where the greatest decrease of 55 % was observed for PFOSA in cod liver. The significant percent increase varied from one to 101 %, where the greatest increase was for Cd in cod liver. Changes of 20 % or more were restricted to Ag (in cod liver), Co, PCB-7, DDE, BDE100, PFOS, PFOSA, TBT and TPT as a decrease and Ag (in blue mussel), Cd, and HCB as an increase. Note that even though the results for both species don't always concur, except for Ag, they don't necessarily indicate that geographical trends for these two species are opposite. The reasons for these geographical trends in less-polluted stations along the coast has not been resolved.

Similar geographical trends to those observed in this study for blue mussel and cod were also found in investigations of offshore sediment by Everaert *et al.* (2017). This investigation found higher concentrations of Hg, PCB-7 and DDE in surficial sediment from south to north along the coast of Norway whereas decreasing concentrations were found for HCB. Possible underlying geographical trends should be taken into account when assessing levels and trends in contaminants in blue mussel and cod, especially for those contaminants where changes are greater than 20 % per 1000 km.

***Table 13**. Change in contaminant concentrations along the Norwegian coast for blue mussel and cod. Only cases are shown that are statistically significant (p<0.05). The test took into account any effect of year (see **Table 29** in **Appendix G** for all analyses). The variability of the non-linear component varies between one (a straight line) and seven (for these cases) indicating considerable variability. The estimated percent change in log10-transformed concentrations per 1000 km and the percent change per 10 years is shown where analyses are significant.*

		Coastal distance effect adjusted for year				Value count and relation to PROREF		
Parameter	Tissue	Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
AG	Liver	-30	< 0.001	5.51	< 0.001	1278	78	92
AG	Whole soft body	23	0.04	2.22	< 0.001	607	65	86
AS	Liver	-9	0.02	4.94	< 0.001	1270	90	97
AS	Whole soft body		0.99	3.37	< 0.001	660	66	95
CD	Liver	101	< 0.001	4	< 0.001	3148	88	97
CD	Whole soft body		0.06	5.04	< 0.001	1330	41	85
CO	Liver	-22	< 0.001	6.51	< 0.001	1270	77	93
CO	Whole soft body	-12	< 0.001	1	< 0.001	639	71	99
CR	Liver		0.24	1.36	0.29	1298	93	97
CR	Whole soft body		0.23	5.94	< 0.001	647	74	90
CU	Liver	-14	< 0.001	6.53	< 0.001	3148	88	99
CU	Whole soft body		0.83	5.45	0.001	1229	85	99
HG	Muscle		0.05	6.817056	< 0.001	3367	41	77
HG	Whole soft body	-17	0.001	2.57	< 0.001	1299	36	79
NI	Liver		0.93	3.19	< 0.001	1278	96	97
NI	Whole soft body		0.67	2.75	0.003	647	66	91
PB	Liver		0.05	1	0.11	3148	97	99
PB	Whole soft body		0.25	6.38	< 0.001	1330	49	80
ZN	Liver	-9	< 0.001	6.1	< 0.001	3150	83	100
ZN	Whole soft body		0.05	2.42	0.04	1244	50	99
CB_S7	Liver	-27	< 0.001	6.83	< 0.001	3232	90	97
CB_S7	Whole soft body	-27	< 0.001	5.63	< 0.001	1242	54	89
BAP	Whole soft body		0.65	1	0.35	160	65	78
KPAH	Whole soft body		0.55	1	0.93	158	0	3
PAH16	Whole soft body		0.21	1	0.24	159	45	57
BDE100	Liver	-21	0.01	3.9	< 0.001	948	80	94
BDE100	Whole soft body		0.18	1	0.61	190	95	99
BDE209	Liver		0.32	NA	NA	820	88	95
BDE209	Whole soft body		0.37	1	0.56	173	98	99
BDE47	Liver		0.08	3.94	< 0.001	952	88	96
BDE47	Whole soft body		0.39	2.12	0.08	190	98	99
BDE6S	Liver	-15	0.04	3.94	< 0.001	948	86	95
BDE6S	Whole soft body		0.88	1	0.52	190	97	99
HBCDA	Liver		0.05	NA	NA	513	94	99
HBCDA	Whole soft body		0.09	1.79	0.03	161	98	100
HCB	Liver	25	< 0.001	2.97	< 0.001	2834	87	99
HCB	Muscle	39	< 0.001	1	< 0.001	613	NA	NA
HCB	Whole soft body		0.06	1	0.03	998	81	88
OCS	Liver		0.07	3.51	< 0.001	2771	NA	NA
OCS	Muscle		0.66	1	0.72	612	NA	NA
OCS	Whole soft body		0.82	1	0.89	1004	NA	NA
QCB	Liver	12	< 0.001	1	< 0.001	2768	NA	NA
QCB	Muscle		0.63	1	0.49	613	NA	NA
QCB	Whole soft body		0.58	1	0.27	1019	NA	NA
PFOA	Liver		0.67	NA	NA	815	98	100
PFOA	Whole soft body		0.63	NA	NA	32	NA	NA
PFOS	Liver	-43	< 0.001	NA	NA	839	80	89
PFOS	Whole soft body		0.45	NA	NA	32	NA	NA
PFOSA	Liver	-55	< 0.001	NA	NA	769	83	96
PFOSA	Whole soft body		0.3	NA	NA	32	NA	NA
MCCP	Liver		0.8	NA	NA	527	92	97
MCCP	Whole soft body		0.95	1	0.88	164	95	99
SCCP	Liver		0.05	NA	NA	530	92	98

Parameter	Tissue	Coastal distance effect adjusted for year				Value count and relation to PROREF		
		Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
SCCP	Whole soft body		0.87	1	0.68	166	96	99
DDE	Liver		0.39	3.62	< 0.001	2834	95	99
DDE	Whole soft body	-34	0.02	6.74	< 0.001	1046	42	61
TBT	Whole soft body	-45	0.004	NA	NA	221	90	96
TPT	Whole soft body	-29	0.04	NA	NA	83	NA	NA

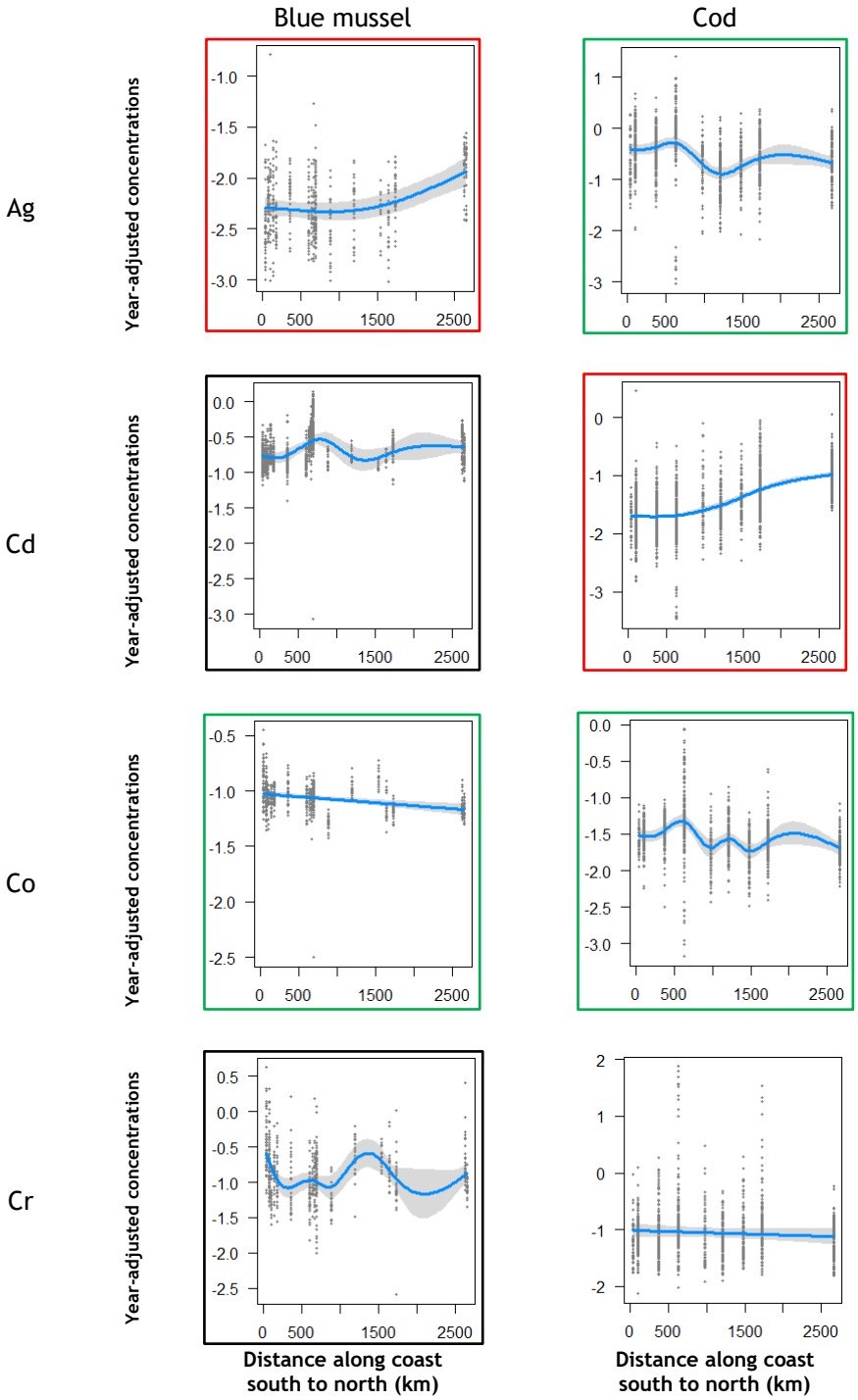


Figure 9. *Year-adjusted concentrations of silver (Ag), cadmium (Cd), cobalt (Co) and chromium (Cr) (log10 mg/kg w.w.) as a function of distance along the coast from south to north (km). Significant linear trends are indicated by a solid border (all cases with a significant non-linear component). No border indicates that no significant trend was found. South-north variation in concentrations are indicated: increasing (red), decreasing (green) and no trend but a significant non-linear component (black border). (See also* ***Table 13****).*

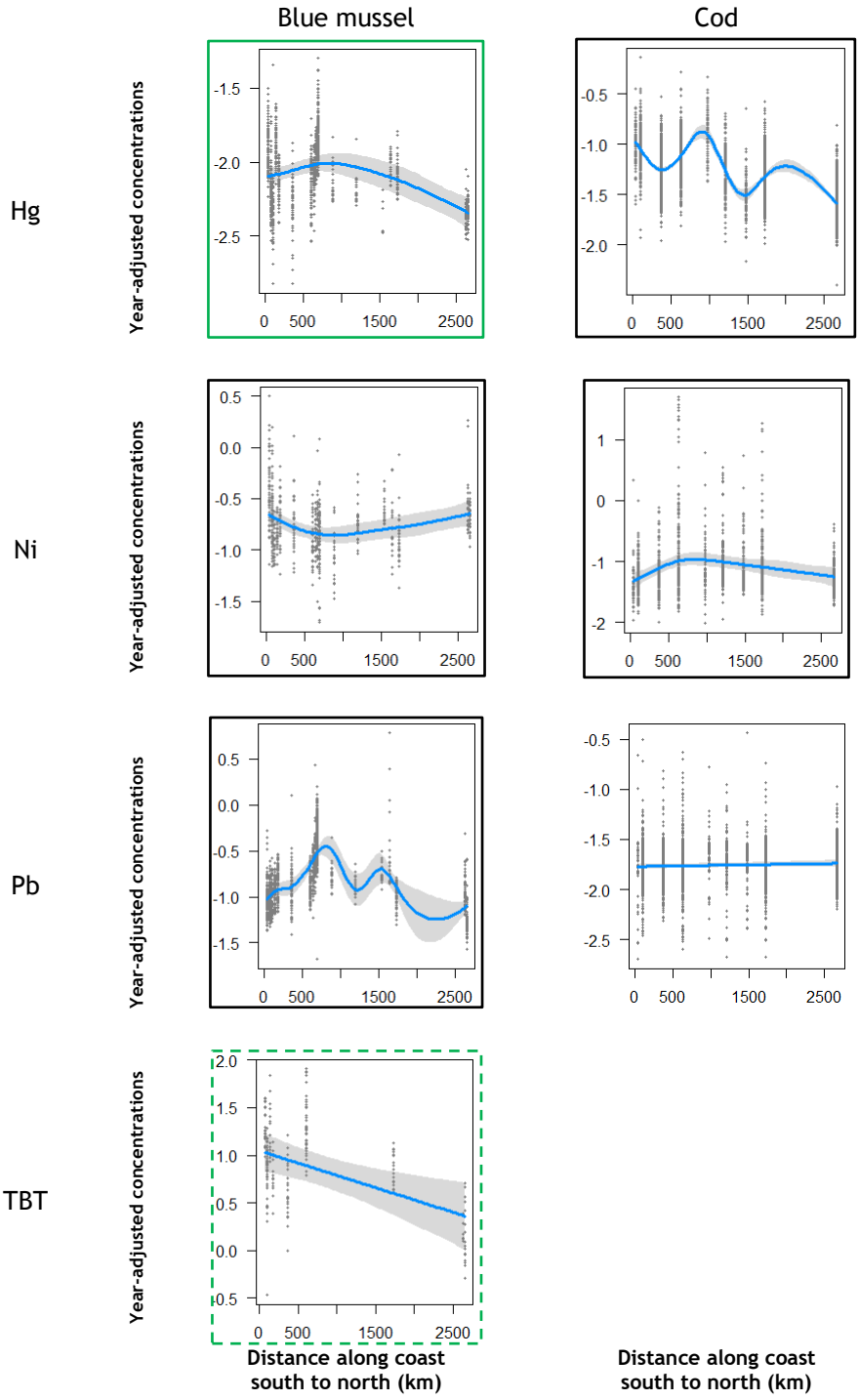


Figure 10. *Year-adjusted concentrations of mercury (Hg), nickel (Ni), lead (Pb) and TBT (log10 mg/kg w.w.) as a function of distance along the coast from south to north (km). Significant linear trends are indicated by a solid border (all cases with a significant non-linear component) or a dashed border (insufficient data to assess the non-linear component). No border indicates that no significant trend was found. South-north variation in concentrations are indicated: increasing (red), decreasing (green) and no trend but a significant non-linear component (black border). (See also* ***Table 13****).*

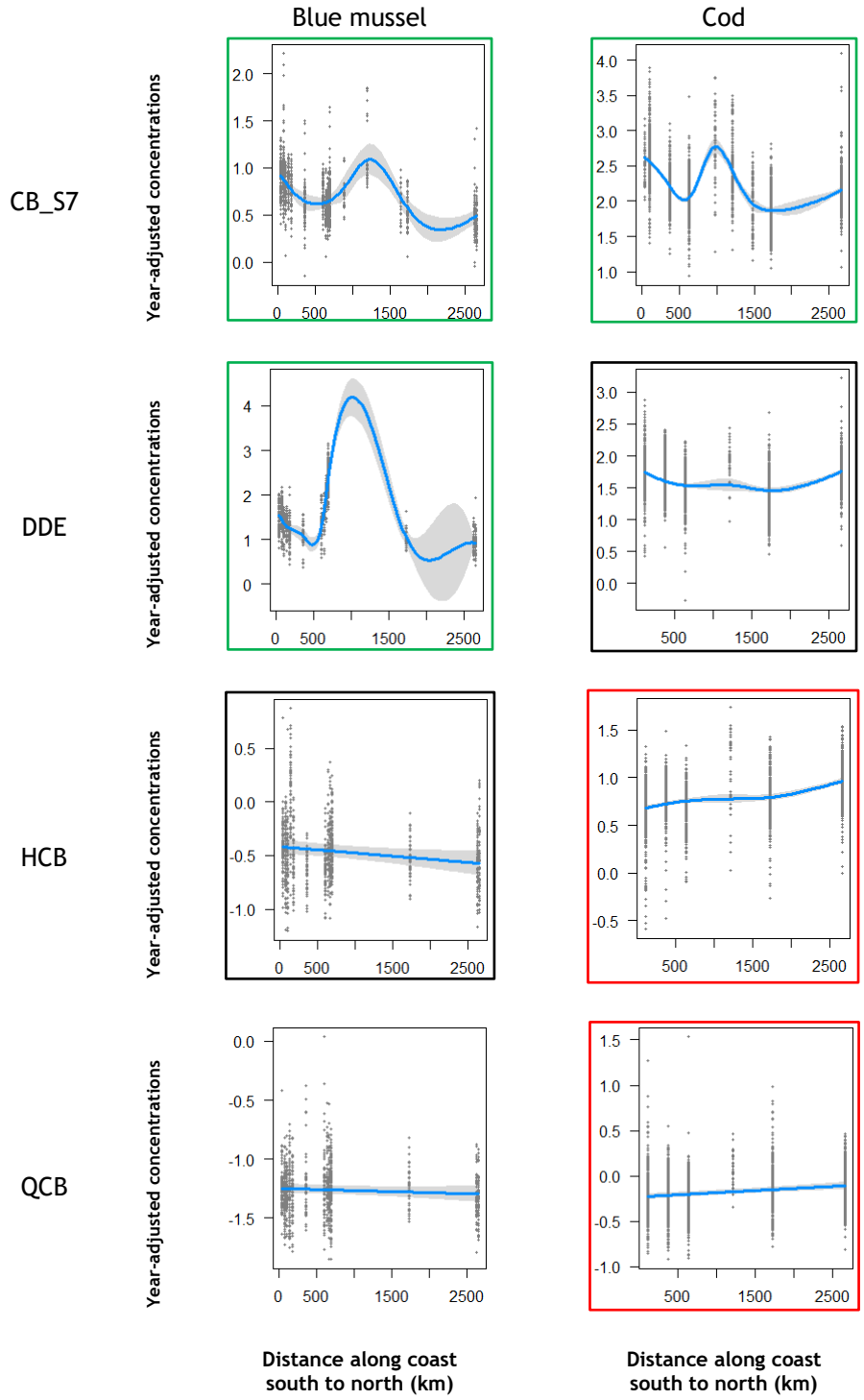


Figure 11. *Year-adjusted concentrations of PCB-7, DDE, HCB and pentachlorobenzene (QCB) (log10 mg/kg w.w.) as a function of distance along the coast from south to north (km). Significant linear trends are indicated by a solid border (all cases with a significant non-linear component) or a dashed border (insufficient data to assess the non-linear component). No border indicates that no significant trend was found. South-north variation in concentrations are indicated: increasing (red), decreasing (green) and no trend but a significant non-linear component (black border). (See also* ***Table 13****).*

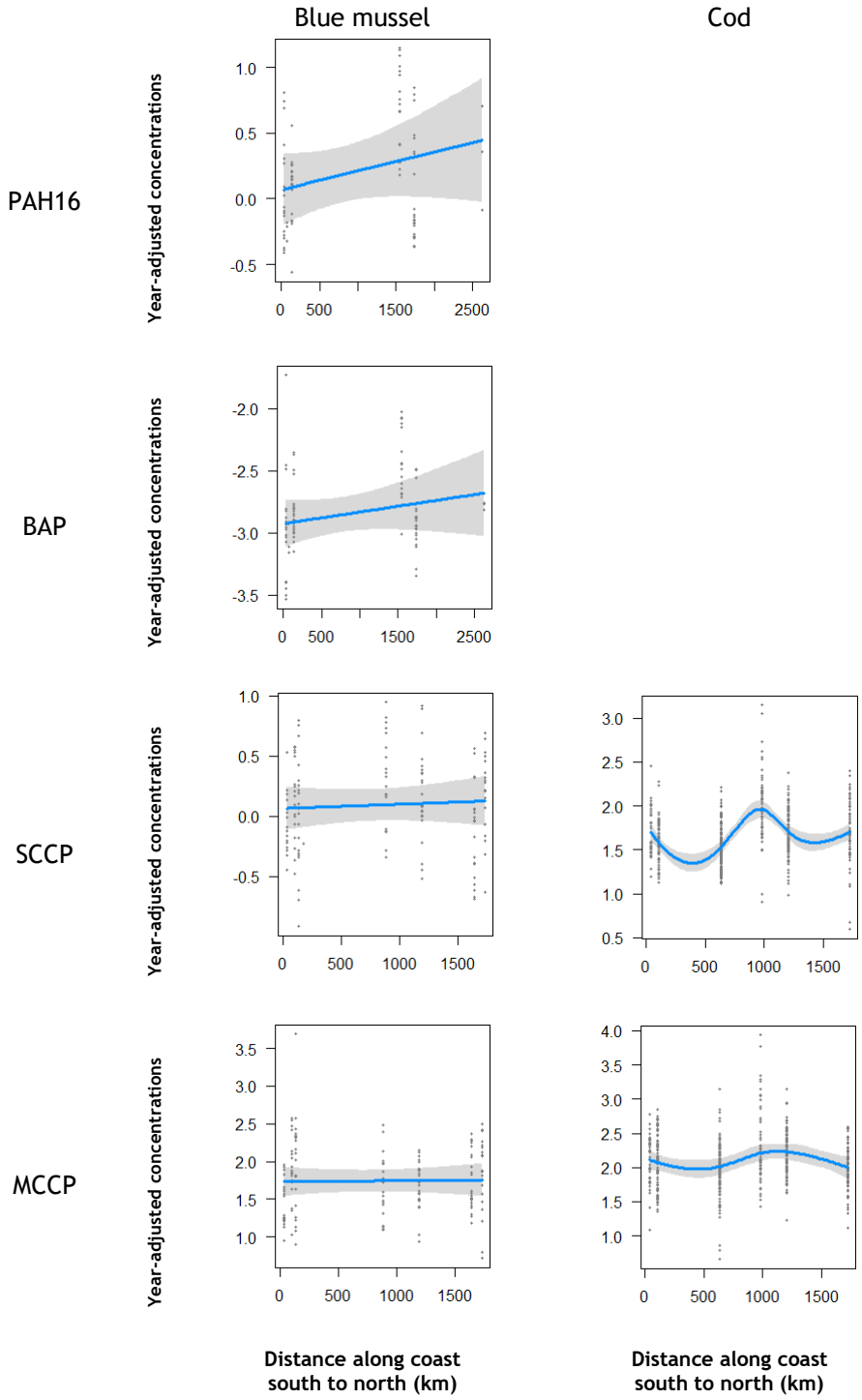


Figure 12. *Year-adjusted concentrations* of PAH16, benzo[a]pyrene (BAP), SCCP and MCCP *(log10 mg/kg w.w.) as a function of distance along the coast from south to north (km). Significant linear trends are indicated by a solid border (all cases with a significant non-linear component) or a dashed border (insufficient data to assess the non-linear component). No border indicates that no significant trend was found. South-north variation in concentrations are indicated: increasing (red), decreasing (green) and no trend but a significant non-linear component (black border). (See also* ***Table 13***).

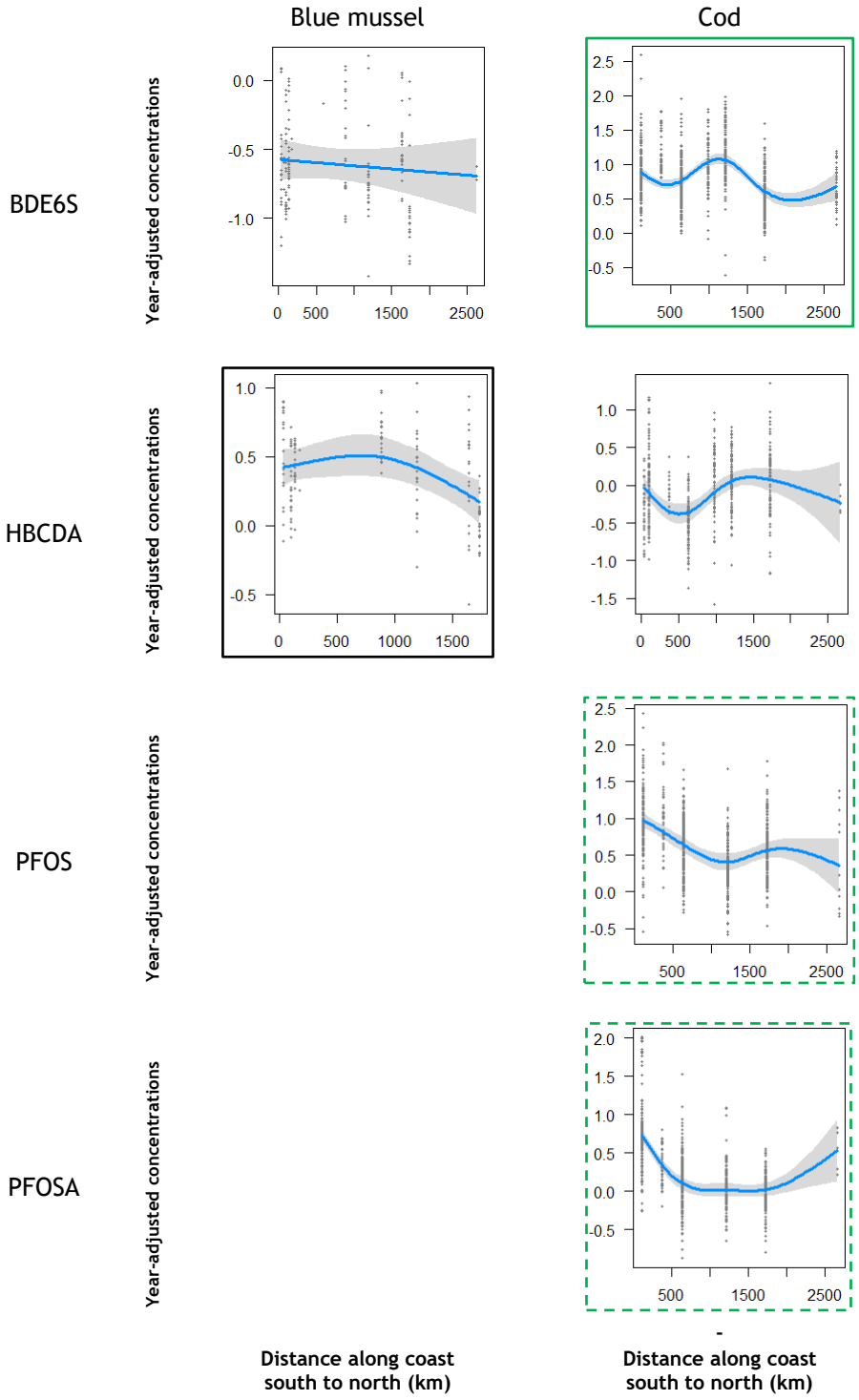


Figure 13. *Year-adjusted concentrations of sum of six PBDEs (BDE6S), HBCDA, PFOS and PFOSA (log10 mg/kg w.w.) as a function of distance along the coast from south to north (km). Significant linear trends are indicated by a solid border (all cases with a significant non-linear component) or a dashed border (insufficient data to assess the non-linear component). No border indicates that no significant trend was found. South-north variation in concentrations are indicated: increasing (red), decreasing (green) and no trend but a significant non-linear component (black border). (See also* ***Table 13****).*

3.2 Levels and trends in contaminants

3.2.1 Overview of metals

In 2019, metals were analysed in blue mussel from 23 stations, in cod from 16 stations, in flounder from one station and in eider from one station (two tissues were analysed) (***Table 14***). The results are discussed in more detail in **Chapters 3.2.2 - 3.2.11**, and only a brief summary is provided here.

EQS for metals was only applicable for Hg, and it was exceeded at 23 (56 %) of the 41 stations where samples were taken (***Figure 8*** **A**). Applying PROREF to assess the 288 metal concentrations, 58.1 % of the measured metal concentrations were found to be below PROREF and the rest were above it (***Figure 14 A***). Four measurements exceeded PROREF by a factor of more than 10 (two cases for Cr and one case for each of Pb and Ni). Analyses showed that 72.6 % of the data series for metals indicated no short-term trends, but for 12.2 % of these series for metals, a significant trend was found; 5.6 % downward and 6.6 % upward (***Figure 14 B***).

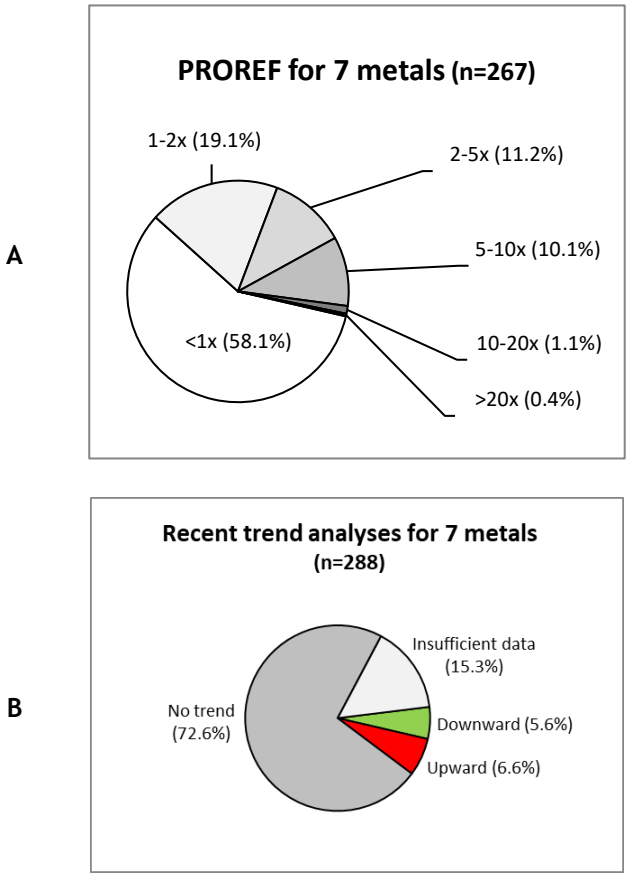


Figure 14. *Summary for 2019 showing the percent of samples (station-species-tissue) exceeding the Norwegian provisional high reference contaminant concentration (PROREF) (**A**) and relating to the results from short-term trend analyses for seven metals (**B**). Details can be seen in **Table 12**.*

***Table 14**. Median concentrations (mg/kg w.w.) and standard deviations for metals in blue mussel, cod liver, and eider blood and eggs in 2019. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See also **Chapter 2.11** for more details and **Appendix B** for description of chemical codes.)*

Component	Count	AG			AS			CD			CO			CR		
Species and sampling locality	2019	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																
Akershuskaia, Inner Oslofjord (st. I301)	3 (3-50)	0.050	0.000	0 [n.a.]	2.300	0.436	3 [2.2-3]	0.170	0.040	3 [0.17-0.24]	0.076	0.057	3 [0.051-0.16]	2.200	3.866	3 [1.3-8.4]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.050	0.000	0 [n.a.]	1.500	0.100	3 [1.4-1.6]	0.170	0.006	3 [0.17-0.18]	0.120	0.006	3 [0.11-0.12]	0.480	0.236	3 [0.11-0.55]
Gåsøya, Inner Oslofjord (st. I304)	2 (2-50)	0.050	0.000	0 [n.a.]	1.700	0.141	2 [1.6-1.8]	0.180	0.000	2 [0.18-0.18]	0.077	0.001	2 [0.076-0.077]	0.560	0.028	2 [0.54-0.58]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	0.050	0.000	0 [n.a.]	3.500	0.058	3 [3.5-3.6]	0.140	0.015	3 [0.13-0.16]	0.099	0.009	3 [0.093-0.11]	1.100	0.552	3 [0.26-1.3]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.050	0.260	1 [0.5]	4.900	0.451	3 [4.4-5.3]	0.210	0.015	3 [0.19-0.22]	0.070	0.008	3 [0.064-0.08]	0.150	0.053	3 [0.077-0.18]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.050	0.000	0 [n.a.]	1.100	0.265	3 [1-1.5]	0.130	0.029	3 [0.13-0.18]	0.110	0.008	3 [0.096-0.11]	4.000	0.872	3 [2.6-4.2]
Kirkøy, Hvaler (st. I024)	2 (2-50)	0.050	0.000	0 [n.a.]	1.100	0.000	2 [1.1-1.1]	0.195	0.007	2 [0.19-0.2]	0.255	0.049	2 [0.22-0.29]	9.550	4.879	2 [6.1-13]
Risøya, Risør (st. 76A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.300	0.100	3 [2.2-2.4]	0.140	0.015	3 [0.12-0.15]	0.090	0.014	3 [0.067-0.092]	1.300	0.573	3 [0.99-2.1]
Lastad, Søgne (st. I131A)	3 (3-50)	0.050	0.000	0 [n.a.]	1.700	0.200	3 [1.5-1.9]	0.150	0.010	3 [0.14-0.16]	0.054	0.009	3 [0.05-0.068]	0.190	0.070	3 [0.13-0.27]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	0.050	0.000	0 [n.a.]	1.400	0.000	3 [1.4-1.4]	0.200	0.015	3 [0.18-0.21]	0.130	0.020	3 [0.096-0.13]	1.200	0.785	3 [0.43-2]
Gåsøya-Ullerøya, Farsund (st. 15A)	3 (3-50)	0.050	0.000	0 [n.a.]	2.500	0.058	3 [2.4-2.5]	0.150	0.000	3 [0.15-0.15]	0.071	0.010	3 [0.067-0.086]	1.100	0.480	3 [0.75-1.7]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)															
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	0.050	0.000	0 [n.a.]	2.300	0.100	3 [2.2-2.4]	0.250	0.042	3 [0.23-0.31]	0.100	0.012	3 [0.098-0.12]	0.800	1.710	3 [0.68-3.7]
Utne, Outer Sørfjord (st. 64A)	3 (3-50)	0.050	0.000	0 [n.a.]	2.700	0.208	3 [2.6-3]	0.220	0.012	3 [0.22-0.24]	0.084	0.003	3 [0.083-0.089]	0.140	0.307	3 [0.098-0.65]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	0.050	0.000	0 [n.a.]	3.300	0.153	3 [3.1-3.4]	0.150	0.006	3 [0.14-0.15]	0.079	0.004	3 [0.072-0.08]	1.100	0.219	3 [0.78-1.2]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.050	0.000	0 [n.a.]	3.200	0.252	3 [2.9-3.4]	0.110	0.000	3 [0.11-0.11]	0.059	0.010	3 [0.056-0.075]	0.083	0.046	3 [0.077-0.16]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.050	0.000	0 [n.a.]	1.700	0.058	3 [1.7-1.8]	0.099	0.014	3 [0.082-0.11]	0.044	0.006	3 [0.035-0.045]	0.100	0.041	3 [0.081-0.16]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.050	0.000	0 [n.a.]	9.000	1.620	3 [6.3-9.2]	0.099	0.009	3 [0.092-0.11]	0.042	0.003	3 [0.038-0.044]	0.150	0.044	3 [0.08-0.16]
Ålesund harbour (st. 28A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.700	0.252	3 [2.4-2.9]	0.081	0.010	3 [0.071-0.09]	0.040	0.004	3 [0.04-0.047]	0.140	0.021	3 [0.13-0.17]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.700	0.153	3 [2.6-2.9]	0.120	0.006	3 [0.11-0.12]	0.079	0.006	3 [0.07-0.082]	0.290	0.588	3 [0.099-1.2]
Bodø harbour (st. 97A3)	3 (3-50)	0.050	0.000	0 [n.a.]	2.100	0.058	3 [2.1-2.2]	0.120	0.010	3 [0.11-0.13]	0.082	0.007	3 [0.07-0.083]	1.700	0.451	3 [1.2-2.1]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.050	0.000	0 [n.a.]	3.200	0.173	3 [3.2-3.5]	0.140	0.006	3 [0.14-0.15]	0.084	0.004	3 [0.082-0.09]	2.200	0.173	3 [1.9-2.2]
Svolvær airport area (st. 98A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.000	0.200	3 [1.8-2.2]	0.220	0.015	3 [0.21-0.24]	0.057	0.003	3 [0.056-0.061]	0.170	0.102	2 [0.17-0.2]
Cod, liver (all metals except Hg), filet (Hg)																
Inner Oslofjord (st. 30B)	13 (10-3)	5.900	3.148	13 [0.15-12]	19.000	29.793	13 [4-120]	0.081	0.051	13 [0.028-0.21]	0.059	0.023	13 [0.018-0.093]	0.015	0.004	11 [0.014-0.024]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-2)	1.800	1.035	5 [0.26-3.1]	7.100	3.810	5 [2.5-11]	0.035	0.013	5 [0.015-0.049]	0.050	0.007	5 [0.04-0.057]	0.037	0.023	4 [0.016-0.065]
Kirkøy, Hvaler (st. 02B)	11 (4-3)	0.260	0.651	10 [0.1-1.5]	4.300	1.869	11 [2.9-8.7]	0.014	0.013	11 [0.008-0.045]	0.027	0.010	11 [0.014-0.046]	0.042	0.039	11 [0.018-0.13]
Stathelle area, Langesundfjord (st. 71B)	13 (9-3)	0.450	0.473	13 [0.21-1.9]	3.700	1.792	13 [3-9.9]	0.030	0.018	13 [0.012-0.082]	0.035	0.008	13 [0.022-0.05]	0.042	0.024	13 [0.017-0.093]
Kristiansand harbour area (st. 13B)	9 (3-2)	1.100	1.364	9 [0.14-4.1]	5.200	5.594	9 [3-21]	0.039	0.025	9 [0.012-0.09]	0.050	0.027	9 [0.026-0.096]	0.020	0.009	7 [0.014-0.035]
Skågskjera, Farsund (st. 15B)	15 (0-1)	1.600	0.751	15 [0.65-3.6]	6.200	2.814	15 [2.3-13]	0.021	0.009	15 [0.01-0.043]	0.045	0.027	15 [0.019-0.11]	0.560	0.347	15 [0.31-1.7]
Inner Sørfjord (st. 53B)	15 (6-2)	0.830	3.454	15 [0.18-14]	5.100	7.378	15 [2.6-33]	0.028	0.130	15 [0.008-0.42]	0.038	0.055	15 [0.014-0.23]	0.024	0.019	15 [0.018-0.086]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (0-1)	2.200	1.309	15 [0.32-4.2]	7.100	5.080	15 [2.7-24]	0.038	0.019	15 [0.01-0.07]	0.039	0.038	15 [0.016-0.15]	0.024	0.017	15 [0.012-0.066]
Bergen harbour area (st. 24B)	14 (4-2)	0.150	0.719	11 [0.06-2.2]	2.100	1.388	14 [1.5-6.1]	0.020	0.034	14 [0.007-0.14]	0.038	0.030	14 [0.01-0.11]	0.024	0.017	14 [0.012-0.07]
Ålesund harbour area (st. 28B)	14 (0-1)	0.135	0.184	13 [0.07-0.73]	3.450	0.646	14 [2.4-4.6]	0.013	0.478	14 [0.005-1.8]	0.009	0.030	14 [0.003-0.12]	0.049	0.547	13 [0.012-2]
Trondheim harbour (st. 80B)	11 (0-1)	0.140	0.176	10 [0.06-0.56]	4.300	12.988	11 [2.6-39]	0.030	0.074	11 [0.012-0.23]	0.036	0.025	11 [0.008-0.087]	0.015	0.005	8 [0.012-0.023]
Sandnessjøen area (st. 96B)	15 (0-1)	0.310	0.531	13 [0.07-2.2]	4.700	2.931	15 [1.8-13]	0.031	0.019	15 [0.014-0.072]	0.017	0.017	15 [0.007-0.07]	0.330	0.328	15 [0.085-1.2]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	0.340	1.244	15 [0.08-5.1]	3.900	2.212	15 [1.7-10]	0.041	0.070	15 [0.011-0.27]	0.014	0.011	15 [0.006-0.049]	0.022	0.009	15 [0.014-0.043]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.450	0.453	15 [0.11-1.8]	3.900	2.454	15 [1.3-11]	0.063	0.100	15 [0.017-0.4]	0.013	0.014	15 [0.005-0.048]	0.012	0.007	10 [0.011-0.036]
Hammerfest harbour area (st. 45B2)	15 (0-1)	0.400	0.539	15 [0.09-1.9]	3.700	0.785	15 [2.2-4.4]	0.093	0.072	15 [0.021-0.26]	0.019	0.011	15 [0.009-0.052]	0.230	0.213	15 [0.016-0.8]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.230	0.222	13 [0.06-0.77]	2.800	1.513	15 [1.6-6.4]	0.170	0.212	15 [0.075-0.71]	0.017	0.007	15 [0.01-0.036]	0.010	0.008	6 [0.013-0.032]
Flounder, liver (all metals except Hg), filet (Hg)																
Sande, Mid Oslofjord (st. 33F)	3 (3-5)	0.090	0.075	3 [0.09-0.22]	2.300	0.529	3 [2.1-3.1]	0.160	0.060	3 [0.1-0.22]	0.110	0.012	3 [0.11-0.13]	0.081	0.089	3 [0.072-0.23]
Eider, blood																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	0.001	0.001	14 [2e-04-0.0048]	0.023	0.017	14 [0.0161-0.0786]	0.006	0.002	14 [0.0021-0.0089]	0.003	0.002	14 [8e-04-0.0057]	0.005	0.000	0 [n.a.]
Eider, egg																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.007	0.006	15 [0.0016-0.0218]	0.123	0.052	15 [0.0587-0.2941]	0.000	0.000	15 [1e-04-4e-04]	0.005	0.001	15 [0.0041-0.0085]	0.011	0.009	12 [0.0073-0.0408]

Table 14. *(cont.)*

Component	Count	CU		HG		NI		PB		ZN	
Species and sampling locality	2019	Med.	S.d. D.d.i	Med.	S.d. D.d.i	Med.	S.d. D.d.i	Med.	S.d. D.d.i	Med.	S.d. D.d.i
Blue mussel											
Akershuskaia, Inner Oslofjord (st. I301)	3 (3-50)	0.600	0.370 3 [0.22-0.96]	0.009	0.004 3 [0.006-0.014]	1.300	2.058 3 [0.82-4.6]	0.260	0.072 3 [0.25-0.38]	18	4.041 3 [13-21]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.710	0.309 3 [0.49-1.1]	0.018	0.003 3 [0.015-0.02]	0.400	0.152 3 [0.29-0.59]	2.000	0.289 3 [1.5-2]	20	1.000 3 [19-21]
Gåsøya, Inner Oslofjord (st. I304)	2 (2-50)	0.640	0.085 2 [0.58-0.7]	0.011	0.001 2 [0.01-0.011]	0.460	0.014 2 [0.45-0.47]	0.385	0.134 2 [0.29-0.48]	15	1.414 2 [14-16]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	1.900	0.529 3 [1.1-2.1]	0.014	0.001 3 [0.012-0.014]	0.450	0.165 3 [0.27-0.6]	0.170	0.012 3 [0.15-0.17]	17	2.887 3 [17-22]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	1.300	0.404 3 [1.3-2]	0.012	0.002 3 [0.01-0.013]	0.210	0.040 3 [0.18-0.26]	0.170	0.035 3 [0.13-0.2]	24	7.371 3 [21-35]
Singlekalven, Hvaler (st. I023)	3 (3-50)	1.500	0.674 3 [0.96-2.3]	0.014	0.004 3 [0.012-0.02]	2.500	0.513 3 [1.8-2.8]	0.230	0.046 3 [0.15-0.23]	20	1.732 3 [17-20]
Kirkøy, Hvaler (st. I024)	2 (2-50)	1.600	0.283 2 [1.4-1.8]	0.018	0.001 2 [0.017-0.018]	5.550	2.475 2 [3.8-7.3]	0.535	0.064 2 [0.49-0.58]	17	0.000 2 [17-17]
Risøya, Risør (st. 76A2)	3 (3-50)	1.100	0.153 3 [1-1.3]	0.010	0.002 3 [0.009-0.013]	0.950	0.376 3 [0.78-1.5]	0.170	0.072 3 [0.16-0.29]	15	1.000 3 [14-16]
Lastad, Søgne (st. I131A)	3 (3-50)	0.950	0.188 3 [0.64-0.98]	0.010	0.003 3 [0.008-0.014]	0.200	0.046 3 [0.14-0.23]	0.180	0.044 3 [0.17-0.25]	14	2.656 3 [9.4-14]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	0.950	0.841 3 [0.6-2.2]	0.017	0.004 3 [0.015-0.023]	1.300	0.566 3 [0.67-1.8]	1.800	0.361 3 [1.3-2]	18	1.528 3 [17-20]
Gåsøya-Ullerøya, Farsund (st. 15A)	3 (3-50)	1.200	0.058 3 [1.1-1.2]	0.009	0.001 3 [0.009-0.01]	0.700	0.301 3 [0.51-1.1]	0.170	0.015 3 [0.15-0.18]	18	1.155 3 [18-20]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)			0.051	0.020 3 [0.046-0.083]						
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	1.200	0.265 3 [1.1-1.6]	0.044	0.011 3 [0.025-0.045]	0.650	1.253 3 [0.61-2.8]	0.750	0.275 3 [0.45-1]	16	2.887 3 [11-16]
Utne, Outer Sørfjord (st. 64A)	3 (3-50)	0.630	0.225 3 [0.49-0.93]	0.020	0.001 3 [0.02-0.021]	0.260	0.176 3 [0.17-0.51]	0.350	0.023 3 [0.31-0.35]	17	1.155 3 [15-17]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	1.100	0.058 3 [1-1.1]	0.017	0.002 3 [0.016-0.019]	0.800	0.155 3 [0.58-0.88]	0.250	0.032 3 [0.24-0.3]	18	1.155 3 [18-20]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	1.100	0.110 3 [0.91-1.1]	0.016	0.011 3 [0.015-0.035]	0.180	0.031 3 [0.16-0.22]	0.130	0.021 3 [0.12-0.16]	17	2.517 3 [14-19]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	1.200	0.153 3 [1.1-1.4]	0.014	0.008 2 [0.014-0.016]	0.100	0.022 3 [0.088-0.13]	0.430	0.061 3 [0.42-0.53]	22	1.528 3 [20-23]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	1.300	0.058 3 [1.2-1.3]	0.011	0.001 3 [0.01-0.011]	0.170	0.042 3 [0.11-0.19]	0.140	0.020 3 [0.12-0.16]	21	3.055 3 [19-25]
Ålesund harbour (st. 28A2)	3 (3-50)	0.940	0.153 3 [0.93-1.2]	0.015	0.001 3 [0.014-0.015]	0.140	0.035 3 [0.14-0.2]	0.250	0.020 3 [0.23-0.27]	17	1.528 3 [16-19]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	2.400	0.000 3 [2.4-2.4]	0.010	0.001 3 [0.009-0.01]	0.270	0.159 3 [0.21-0.51]	0.130	0.031 3 [0.11-0.17]	14	1.528 3 [12-15]
Bodø harbour (st. 97A3)	3 (3-50)	1.400	0.361 3 [1.2-1.9]	0.016	0.001 3 [0.015-0.017]	0.990	0.225 3 [0.75-1.2]	0.520	0.074 3 [0.49-0.63]	19	2.000 3 [17-21]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.800	0.050 3 [0.75-0.85]	0.021	0.001 3 [0.02-0.022]	1.400	0.000 3 [1.4-1.4]	0.220	0.046 3 [0.22-0.3]	13	1.155 3 [13-15]
Svolvær airport area (st. 98A2)	3 (3-50)	0.720	0.299 3 [0.51-1.1]	0.014	0.002 3 [0.011-0.015]	0.160	0.066 3 [0.099-0.23]	0.170	0.010 3 [0.16-0.18]	17	1.528 3 [15-18]
Cod, liver (all metals except Hg), filet (Hg)											
Inner Oslofjord (st. 30B)	13 (10-3)	4.300	1.548 13 [2.5-7.6]	0.190	0.095 15 [0.089-0.4]	0.056	0.028 13 [0.021-0.11]	0.096	0.164 13 [0.015-0.57]	23	7.362 13 [11-36]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-2)	4.500	6.661 5 [0.81-17]	0.140	0.047 9 [0.077-0.25]	0.031	0.017 5 [0.025-0.065]	0.013	0.015 5 [0.006-0.043]	30	10.310 5 [20-47]
Kirkøy, Hvaler (st. 02B)	11 (4-3)	4.300	3.103 11 [2.9-12]	0.088	0.091 15 [0.029-0.39]	0.034	0.021 11 [0.014-0.092]	0.006	0.004 11 [0.002-0.017]	26	4.579 11 [17-32]
Stathelle area, Langesundfjord (st. 71B)	13 (9-3)	6.900	3.283 13 [4.1-15]	0.110	0.123 15 [0.078-0.44]	0.053	0.029 13 [0.036-0.14]	0.017	0.026 13 [0.008-0.11]	28	3.449 13 [24-36]
Kristiansand harbour area (st. 13B)	9 (3-2)	13.000	3.464 9 [6.9-17]	0.130	0.078 13 [0.049-0.27]	0.052	0.042 9 [0.017-0.14]	0.014	0.024 9 [0.003-0.08]	36	9.171 9 [25-49]
Skågskjera, Farsund (st. 15B)	15 (0-1)	8.700	3.830 15 [3.7-18]	0.130	0.039 15 [0.06-0.22]	0.380	0.199 15 [0.22-0.98]	0.008	0.008 15 [0.005-0.032]	25	5.514 15 [16-37]
Inner Sørfjord (st. 53B)	15 (6-2)	9.000	12.394 15 [4.2-50]	0.120	0.199 15 [0.059-0.79]	0.030	0.033 15 [0.015-0.12]	0.043	0.051 15 [0.016-0.22]	22	9.484 15 [11-44]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (0-1)	12.000	8.424 15 [4.5-34]	0.130	0.097 15 [0.078-0.39]	0.026	0.022 15 [0.013-0.1]	0.006	0.009 15 [0.004-0.036]	35	10.555 15 [19-50]
Bergen harbour area (st. 24B)	14 (4-2)	3.500	5.304 14 [1.5-21]	0.075	0.137 15 [0.016-0.49]	0.027	0.058 14 [0.019-0.23]	0.011	0.010 14 [0.006-0.047]	21	5.522 14 [16-34]
Ålesund harbour area (st. 28B)	14 (0-1)	2.100	1.641 14 [0.59-6.8]	0.130	0.221 15 [0.045-0.94]	0.041	0.320 11 [0.019-1.2]	0.008	0.005 14 [0.003-0.02]	10	4.993 14 [4-24]
Trondheim harbour (st. 80B)	11 (0-1)	4.500	1.742 11 [2.2-8]	0.093	0.087 11 [0.031-0.31]	0.028	0.017 9 [0.013-0.055]	0.004	0.002 11 [0.002-0.009]	23	10.898 11 [1.8-33]
Sandnessjøen area (st. 96B)	15 (0-1)	2.500	1.060 15 [1-4.4]	0.046	0.030 15 [0.026-0.14]	0.230	0.205 15 [0.082-0.8]	0.007	0.006 15 [0.004-0.026]	16	5.680 15 [12-31]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	2.700	4.330 15 [1.3-19]	0.069	0.034 15 [0.027-0.17]	0.028	0.015 14 [0.015-0.073]	0.005	0.011 15 [0.002-0.046]	17	6.945 14 [11-38]
Tromsø harbour area (st. 43B2)	15 (0-1)	3.500	3.517 15 [0.38-15]	0.054	0.035 15 [0.024-0.16]	0.026	0.019 14 [0.018-0.076]	0.006	0.004 15 [0.004-0.014]	18	8.573 15 [10-41]
Hammerfest harbour area (st. 45B2)	15 (0-1)	5.500	1.953 15 [2.4-9.1]	0.030	0.022 15 [0.022-0.11]	0.140	0.139 15 [0.022-0.51]	0.010	0.007 15 [0.004-0.029]	20	6.248 15 [6.2-28]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	1.500	1.779 15 [0.63-7.5]	0.026	0.031 15 [0.014-0.14]	0.034	0.024 15 [0.025-0.12]	0.005	0.013 15 [0.003-0.051]	17	3.127 15 [13-23]
Flounder, liver (all metals except Hg), filet (Hg)											
Sande, Mid Oslofjord (st. 33F)	3 (3-5)	21.000	4.509 3 [16-25]	0.076	0.027 3 [0.07-0.12]	0.057	0.022 3 [0.046-0.089]	0.028	0.009 3 [0.026-0.043]	50	4.933 3 [42-51]
Eider, blood											
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	0.520	0.100 14 [0.331-0.7462]	0.125	0.059 14 [0.0382-0.2442]	0.003	0.000 0 [n.a.]	0.049	0.165 14 [0.0318-0.6655]	5.269	0.612 14 [4.2908-6.3741]
Eider, egg											
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	1.442	0.194 15 [1.0559-1.7509]	0.094	0.030 15 [0.0546-0.1723]	0.005	0.004 12 [0.0033-0.0182]	0.008	0.016 14 [0.002-0.0568]	17.006	1.736 15 [15.1164-20.7933]

3.2.2 Mercury (Hg)

Mercury (Hg) is found naturally in the earth's crust and can be spread both from natural sources and through anthropogenic activity. Mercury can be organic, inorganic or elemental, and has toxic effects on *inter alia* the nerve system. The toxic substance can be transported by water and air over long distances and end up in the environment in completely different parts of the globe than where it was released. With a few exceptions, there is a general prohibition on the use of Hg in products in Norway. In the present study, Hg was analysed in blue mussel at 23 stations, in cod fillet at 16 stations, in flounder fillet at one station and in eider blood and eggs at one station (***Table 3***).

Environmental Quality Standards (EQS) for priority substances

EU has provided EQS of 0.02 mg/kg w.w. in biota (cf. ***Table 7***). Applying this EQS for blue mussel, concentrations of Hg were above or at the EQS at Kvalnes (st. 56A, 0.051 mg/kg w.w.), Krossanes (st. 57A, 0.044 mg/kg w.w.) and Utne (st. 64A, 0.020 mg/kg w.w.) in the Sørfjord, and at Mjelle (st. 97A2, 0.021 mg/kg w.w.) in the Bodø area (***Table 11***).

The EQS for biota is provided for fish and are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in the present study only measured Hg in fillet. Converting concentrations in fillet to concentrations in whole fish is uncertain. Using fillet probably represents an overestimate of the whole fish concentration because Hg accumulates more in the fillet than in other tissues (Kwasniak and Falkowska 2012). If it is assumed, for this exercise, that the same concentration is found in all fish tissue types, then the results of Hg (in cod fillet) would have exceeded the EQS at all stations in 2019, also at the reference station (st. 19B) at Svalbard (0.026 mg/kg w.w.) (***Table 11***).

Applying this EQS for flounder liver, the Hg concentration would have exceeded the EQS (***Table 11***).

Applying this EQS for eider blood and eggs, the Hg concentrations would have exceeded the EQS (***Table 11***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Hg by a factor of two to five at Kvalnes (st. 56A) and Krossanes (st. 57A) in the Sørfjord (***Table 12***). For blue mussel, the exceedances were a factor of up to two in the Oslofjord at Gressholmen (st. 30A) and Solbergstrand (st. 31A). This was also the result at Singlekalven (st. I023) and Kirkøy (st. I024) in the Outer Oslofjord, and at Odderøya (st. I133) in the Kristiansandfjord. This was also observed at Utne (st. 64A) in the Outer Sørfjord, Vikingneset (st. 65A) in the Mid Hardangerfjord, Espevær (st. 22A) in the Outer Bømlafjord and Nordnes (st. I241) close to Bergen harbour. This was also the result in Ålesund harbour (st. 28A2), Bodø harbour (st. 97A3), Mjelle (st. 97A2) in the Bodø area and Svolvær airport area (st. 98A2).

Cod fillet exceeded PROREF of Hg by a factor of two to five in the Inner Oslofjord (st. 30B), Tjøme (st. 36B) in the Outer Oslofjord, Kristiansand harbour area (st. 13B), Skågskjera in Farsund (st. 15B), in the inner Sørfjord (st. 53B), at Bømlo (st. 23B) and in Ålesund harbour (st. 28B). The exceedances were a factor up to two at Kirkøy (st. 02B) at Hvaler, Stathelle area in the Grenlandfjord (st. 71B), Bergen harbour (st. 24B), Trondheim harbour (st. 80B) and Austnesfjord in Lofoten (st. 98B1).

Increase in PROREF factor since 2018

Cod fillet from Tjøme (st. 36B) exceeded the PROREF for Hg by a factor up to two in 2018, compared to between two to five times in 2019.

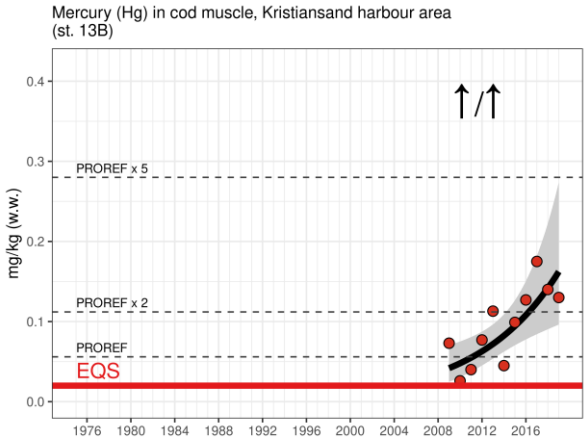
Upward trends

In cod fillet, both significant upward long- and short-term trends were found for Hg in Kristiansand harbour (st. 13B) (***Figure 15 A***), at Skågskjera (st. 15B) in Farsund (***Figure 16 A***) and at Bømlo (st. 23B) (***Figure 17 A***) in the Outer Selbjørnfjord. When fish-length was taken into account only, cod fillet at Kristiansand harbour (***Figure 15 B***) and at Skågskjera in Farsund (***Figure 16 B***) both showed significant upward long- and short-term trends.

A significant upward long-term trend was found in the Inner Oslofjord (st. 30B) (***Figure 18 A***) and in Tromsø harbour (st. 43B2) (***Figure 19 A***). When fish-length was taken into account only, a significant upward long-time trend was also found for Hg in cod fillet from the Inner Oslofjord (***Figure 18 B***).

In blue mussel, a significant upward long-term trend was found at Gåsøya (st. I304) in the Inner Oslofjord.

A



B

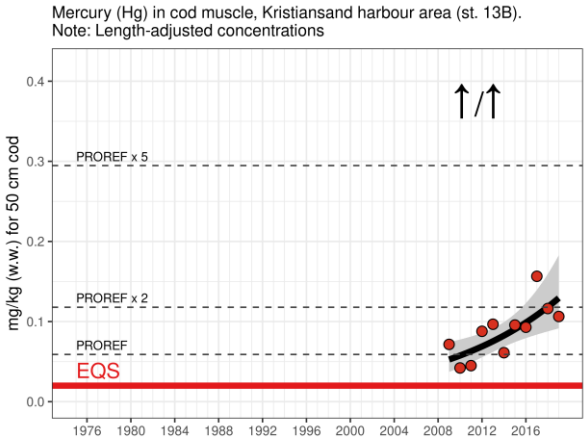
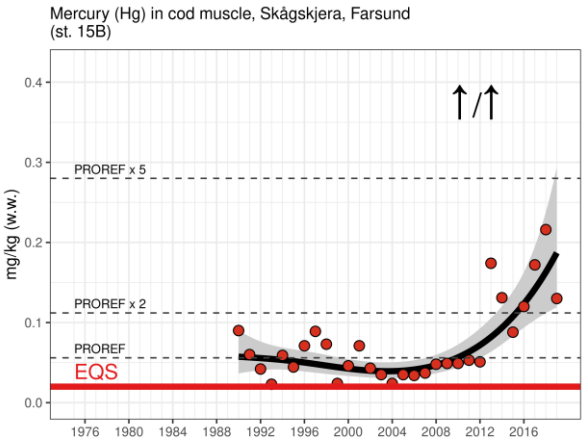


Figure 15. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Kristiansand harbour (st. 13B); no adjustment for length (**A**) and adjusted for length (**B**). (see* ***Figure 4*** *and* **Appendix C**.*)*

A



B

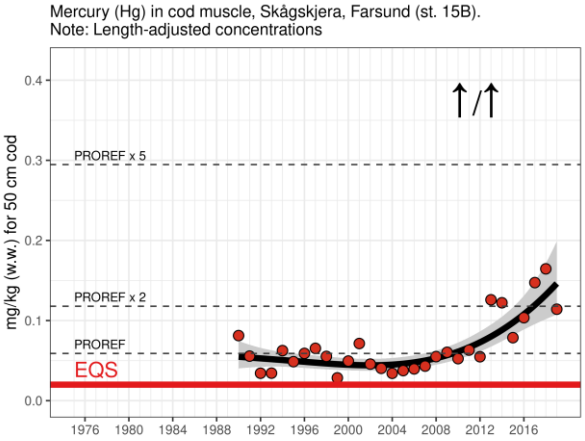
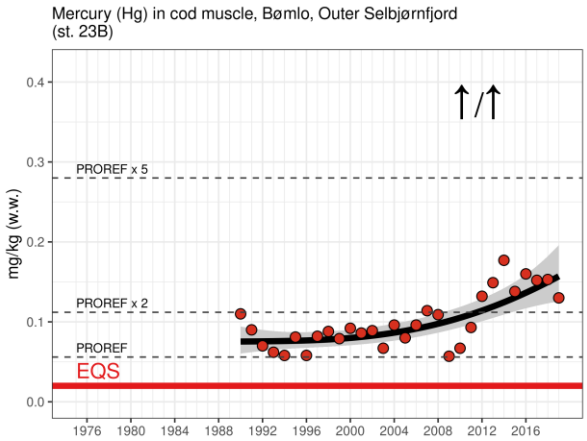


Figure 16. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Skågskjera (st. 15B) in Farsund; no adjustment for length (**A**) and adjusted for length (**B**). (see **Figure 4** and **Appendix C**.)*

A



B

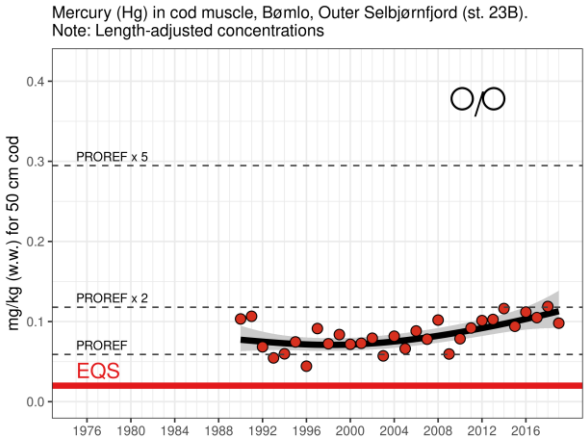
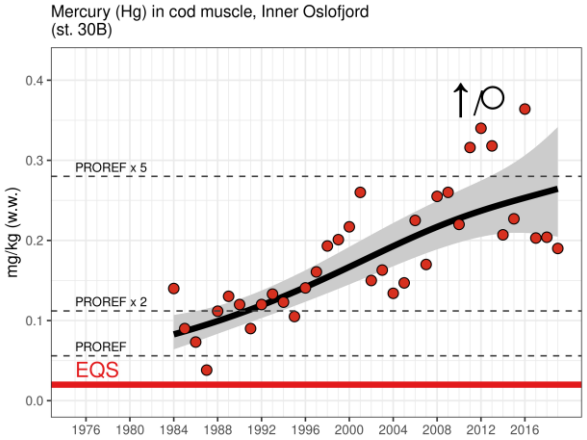


Figure 17. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Bømlo (st. 23B); in the Outer Selbjørnfjord; no adjustment for length (**A**) and adjusted for length (**B**). (see **Figure 4** and **Appendix C**.)*

A



B

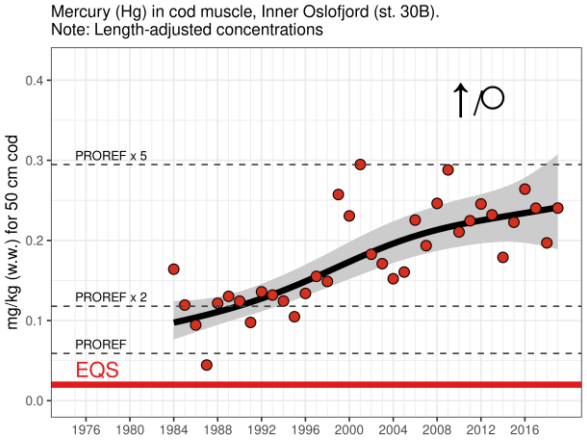


***Figure 18**. Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from in the Inner Oslofjord (st. 30B); no adjustment for length (**A**) and adjusted for length (**B**). (see **Figure 4** and **Appendix C**.)*

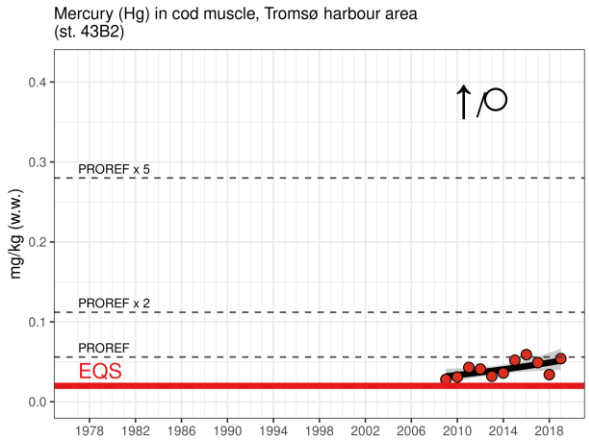


Figure 19. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Tromsø harbour (st. 43B2). (see* ***Figure 4*** *and* ***Appendix C****.)*

Decrease in PROREF factor since 2018

Blue mussel exceeded PROREF for Hg by a factor of two to five in 2018, and up to two times in 2019 at Odderøya (st. I133) in the Kristiansandfjord. The mussel at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord and Tjøme (st. 36A1) in the Outer Oslofjord exceeded the PROREF by a factor up to two times in 2018, while there was no exceedance in 2019. This was also the result at Risøy (st. 76A2) by Risør, Lastad (st. I131A) at Søgne, Gåsøya-Ullerøya (st. 15A) at Farsund and Vågsvåg (st. 26A2) in the Outer Nordfjord.

Cod fillet from the Ålesund harbour (st. 28B) exceeded the PROREF for Hg by a factor of five to 10 in 2018, compared to two to five times in 2019. Cod fillet from Kirkøy (st. 02B) at Hvaler, Stathelle area (st. 71B) in Langesund and Bergen harbour (st. 24B) exceeded the PROREF by a factor of two to five in 2018, and below two in 2019. Cod fillet from Sandnessjøen (st. 96B) exceeded the PROREF by a factor up to two in 2018, while it was no exceedance in 2019.

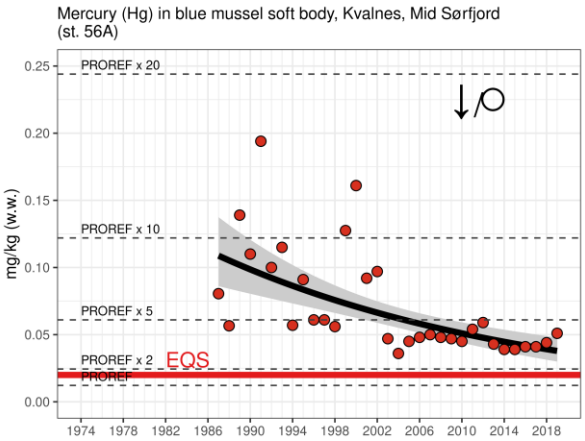
Downward trends

In blue mussel, a significant downward long-term trend was found at Solbergstrand (st. 31A) in the Mid Oslofjord, at Færder (st. 36A[1]) in the Outer Oslofjord and at Kirkøy (st. I024) at Hvaler. This was also observed in the Sørfjord at Kvalnes (st. 56A) (***Figure 20 A***) and Krossanes (st. 57A) (***Figure 20 B)***. The same result was seen at Svolvær (st. 98A2) in Lofoten. A significant downward short-term trend was found at Singlekalven (st. I023) at Hvaler.

In cod fillet, both significant downward long- and short-term trends for Hg were found in Hammerfest (st. 45B2).

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

A



B

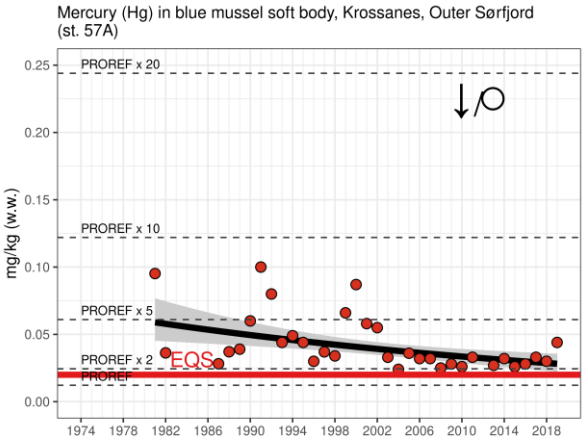


Figure 20. *Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from Kvalnes (st. 56A) in the Mid Sørfjord (***A***) and Krossanes in the Outer Sørfjord (st. 57A) (***B***). (see* ***Figure 4*** *and* ***Appendix C****.)*

Levels in flounder

In flounder at Sande (st. 33F) in the Mid Oslofjord, the Hg concentration in fillet was 0.076 mg/kg w.w.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Hg concentrations were 0.125 mg/kg w.w. in blood, and 0.094 mg/kg w.w. in eggs.

Comparison with other studies

In the present study, blue mussel at Kvalnes in the Mid Sørfjord had lower Hg concentration (median 0.051 mg/kg w.w.) than at Byrkjenes in the Inner Sørfjord in 2019 (mean 0.1 mg/kg w.w.) in a comparable study (Ruus 2020). Hg concentrations exceeded EQS at all three blue mussel stations in the Sørfjord in that survey. The collection of blue mussel in both studies took place during the autumn.

In the present study, the median concentration of Hg in cod fillet from the Inner Oslofjord was 0.190 mg/kg Hg w.w. In a comparable study from the Inner Oslofjord in 2019, the mean concentration was 0.175 mg/kg Hg w.w. (Ruus 2020 In prep), and the levels are within the same range. The collection of cod in both studies took place during the autumn.

In the Tromøysund close to Arendal in 2019, blue mussel at seven stations had Hg concentrations below EQS (Øxnevad 2020a). In the Karmsundet close to Haugesund in 2019, blue mussel at three stations had Hg concentrations below EQS (Øxnevad 2020c). One of these stations was the former MILKYS station at Høgevarde (st. 227A2). In the Årdalsfjord in 2019, blue mussel at all three stations had Hg concentrations below EQS (Øxnevad 2020b). In the Vefsnfjord in 2019, blue mussel at three out of six stations had Hg concentrations that exceeded the EQS (Øxnevad 2020e). In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Hg concentrations below EQS (Øxnevad 2020d).

Concentrations of Hg in cod from the Barents Sea collected in 1976, 1995 and 2000 did not seem to have increased in the period of 25 years (Ervik 2003).

Most of the Hg-pollution in Norwegian lakes is now due to atmospherically deposited Hg originating from other parts of the world (Jartun 2019). The concentration of Hg in trout from Mjøsa showed a decreasing trend in the period 1980-2005, and showed more or less unchanged concentrations during the period 2006-2014 (Løvik 2016). Surveys from 2008 suggests that the length adjusted average Hg-concentrations in ten perch populations from forest lakes, increased with 63 % since the early 1990s (Fjeld 2009).

Fifty years of measurements show that Hg concentrations in freshwater fish were lower than before in Norway, Sweden, Finland and the Kolahalvøya in Russia (Fennoskandia), although Hg coming through the atmosphere is still a problem (Braaten 2017).

In the present study, Hg concentration (median 0.094 mg/kg w.w.) in eider eggs at Svalbard was at the same level as in a comparable study (median 0.07 mg/kg w.w.) (Hill 2018).

In the present study, the median concentrations were 0.125 mg Hg/kg w.w. in blood and 0.094 mg Hg/kg w.w. in eider eggs from Svalbard. A comparable study of eider duck from the Inner Oslofjord in 2017, found mean values of 0.187 mg Hg/kg w.w. in blood and 0.154 mg Hg/kg w.w. in eggs (Ruus 2018). The Hg concentrations in eider blood and eggs at Svalbard in 2019 was almost within the same range as in the Inner Oslofjord in 2017.

General, large scale trends

In 2017, 0.5 tons of Hg was released in Norway, and there has been an 80 % reduction in emissions of Hg and Hg compounds since 1995[1].

For the period 1990-2006, OSPAR (2010) found 70-75 % reduction in riverine and direct discharges of Hg to the North Sea, and sediment from the North Sea showed a predominance of downward over upward significant trends. This reduction is not so evident for the Norwegian discharges.

Total riverine input of Hg in Norway has been 148 kg in 2017 (Kaste 2018). The riverine inputs of Hg to different seawater were 63 kg to Skagerrak, 35 kg to the North Sea, 31 kg to the Norwegian Sea and 20 kg to the Lofoten/Barents Sea, indicating higher input in the southern part of Norway. In addition to riverine inputs was the contribution by direct discharges from sewage (10 kg) and industrial (9 kg) effluents amounting to 19 kg or about 11 % of the total (167 kg). In the present study, several stations with observed increase in Hg are not directly associated with rivers in the monitoring program (Kaste 2018). The exception is river Alna close to the stations in the Inner

[1] https://miljostatus.miljodirektoratet.no/kvikksolv

Oslofjord and river Otra close in the Kristiansandfjord, but no direct links can be observed (personal notification by Cathrine Gundersen, NIVA).

For MILKYS long-term trends, there are some evidences of downward trends. Seven downward long-term trends were found in blue mussel. One significant downward short-term trend was found at Singlekalven in Hvaler. However, both upward long- and short-term trends were found in cod fillet from Kristiansand harbour. A significant upward long-term trend was found for cod fillet from Tromsø harbour, while a significant upward short-term trend was found at Skågskjera in Farsund. Both downward long-and short-term trends were found in cod fillet from Hammerfest harbour area.

When considering the total of 39 possible recent short-term (2010-2019) trends for both cod and blue mussel, significant trends are limited to upwards at three stations (***Table 12***, ***Figure 21***).

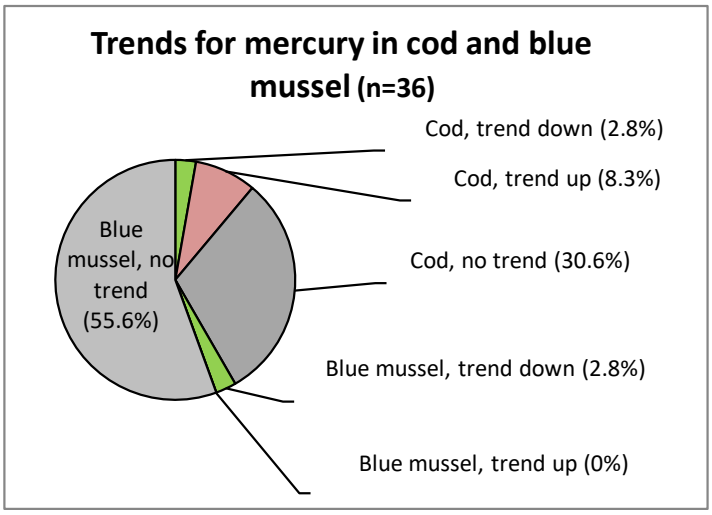


Figure 21. *Frequency of short-term (recent) trends (2010-2019) for Hg in blue mussel and cod fillet.*

In the present study, there were significant upward long-and short term trends for Hg at Farsund (Skågskjera) and at Bømlo. There were also upward long-term trends for cod fillet from the Inner Oslofjord, Tjøme, the harbours of Kristiansand, the Inner Sørfjord and Tromsø. Possible explanations of increasing trends could be related to factors such as; climate change, more favourable conditions for methyl Hg formation, increased bioavailability of Hg stored in the sediments, increased access of cod to contaminated feeding areas due to improved oxygen levels in deep water, changes in what the cod eat, etc.

Atmospheric deposition is a major source to the seas surrounding Norway and considerably larger than other sources such as riverine discharges, shipping and offshore installations (Green 2013). Bjerkeng *et al.* (2009) found that more than 60 % of the Hg input to the Bunnefjord was from atmospheric deposition. Present discharge of Hg to the Inner Oslofjord has been calculated to be around 7.3 kg/year (Berge 2013b). Berge *et al.* (2013b) estimated the discharges of Hg from various sources to the Inner Oslofjord; rivers (2.2 kg Hg/year), atmosphere (1.6 kg Hg/year), impermeable surfaces (2.1 kg Hg/year), wastewater treatment plants (WWTP) (0.9 kg Hg/year) and overflow (0.5 kg Hg/year). There was some indication that Norwegian atmospheric deposition in southern Norway is decreasing for the period 1995-2006, but this was not statistically confirmed (Wängberg 2010). Newer data show small downward trends for Hg at Birkenes (19 %) and Zeppelin (10 %), and a larger

downward trend is observed in precipitation than in air for Hg at Lista/Birkenes (Bohlin-Nizzetto 2018). The riverine input to the Inner Oslofjord from Alna river was 0.03 kg Hg in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 0.48 kg Hg in 2019 to the Inner Oslofjord (VEAS 2020).

Emissions of Hg to air from land-based industries showed essentially a decrease from 1999 (436 kg Hg/year) to 2009 (104 kg Hg/year), and the emission was 95 kg Hg/year in 2019 (***Figure 22***). The emissions to air varied between 104 kg Hg/year in 2009 to 95 kg Hg/year in 2019 for the period 2009-2019. The discharges to water from land-based industries were at a maximum in 2000 (36 kg Hg/year), and at a minimum in 2019 (6.7 kg Hg/year).

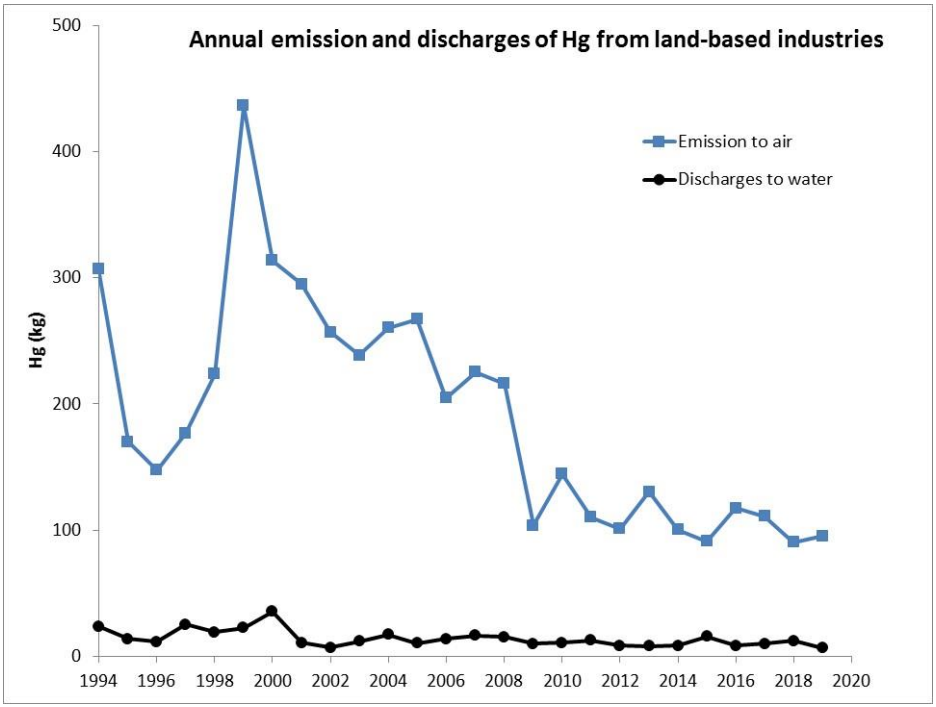


Figure 22. *Annual emissions of Hg to air and discharges to water from land-based industries for the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.3 Cadmium (Cd)

Cadmium (Cd) is a naturally occurring heavy metal. Sources are agricultural and industrial emissions, long-range air pollutants and Cd naturally found in small quantities in the earth's crust. In the present study, Cd was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

Blue mussel at five stations exceeded the PROREF for Cd by a factor of up to two (***Table 12***). These blue mussel stations were at Tjøme (st. 36A1) and Kirkøy (st. I024) at Hvaler in the Outer Oslofjord, at Odderøya (st. I133) in the Kristiansandfjord, at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord and at Svolvær (st. 98A2) in Lofoten.

Cod liver from Svalbard (st. 19B) exceeded the PROREF for Cd by a factor up to two.

Increase in PROREF factor since 2018

Blue mussel exceeded PROREF for Cd by a factor up to two in 2019, while there were no exceedances in 2018 at Kirkøy (st. I024) at Hvaler, and Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord.

Cod liver from Svalbard (st. 19B) had concentration below PROREF for Cd in 2018, while the exceedance was by a factor of up to two in 2019.

Upward trends

In cod liver from the Inner Oslofjord (st. 30B), a significant upward long-term trend for Cd was found (***Figure 23***).

There was a significant upward long-term trend for Cd in blue mussel at Gåsøya (st. I304) in the Inner Oslofjord (***Figure 24***).

Decrease in PROREF factor since 2018

Blue mussel at Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, and at Singlekalven (st. I023) at Hvaler, had Cd concentrations that exceeded PROREF by a factor up to two in 2018, while the concentrations were below PROREF in 2019.

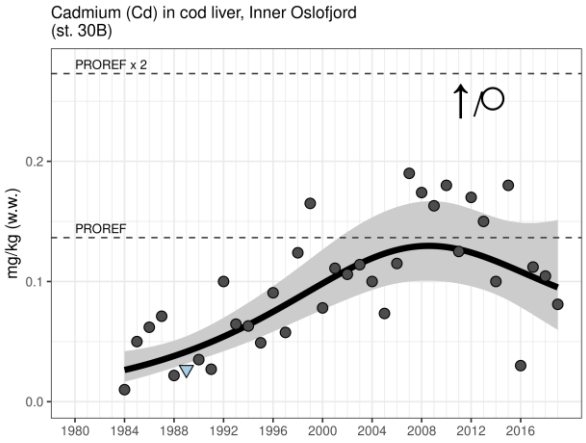


Figure 23. *Median concentrations (mg/kg w.w.) of cadmium (Cd) in cod liver from in the Inner Oslofjord (st. 30B). (see* ***Figure 4*** *and* ***Appendix C****.)*

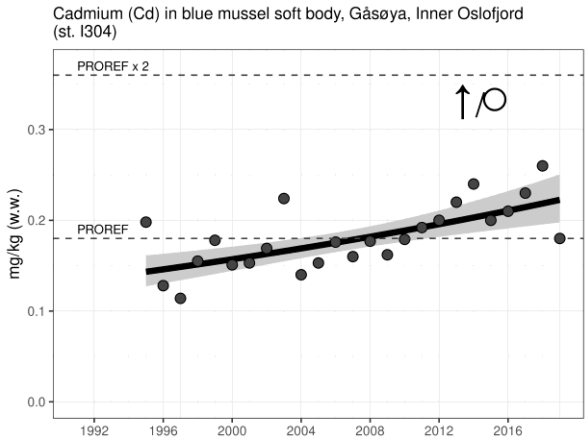


Figure 24. *Median concentrations (mg/kg w.w.) of cadmium (Cd) in blue mussel from the Inner Oslofjord from 1995 to 2019* at *Gåsøya (st. I304). (see* ***Figure 4*** *and* ***Appendix C****.)*

Downward trends
In blue mussel, there were both significant downward long- and short-term trends at Krossanes (st. 57A) in the Outer Sørfjord and at Vikingneset (st. 65A) in the Mid Hardangerfjord. There were significant downward long-term trends at Solbergstrand (st. 31A) in the Mid Oslofjord, at Færder (st. 36A[1]) in the Outer Oslofjord, at Espevær (st. 22A) in the Outer Bømlafjord and at Nordnes (st. I241) in Bergen harbour.

In cod liver, there were both significant downward long- and short-term trends for Cd in the Inner Sørfjord (st. 53B). There was a significant downward long-term trend at Tjøme (st. 36B) in the Outer Oslofjord.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the Cd concentration in liver was 0.160 mg/kg w.w., and a significant upward short-term trend was found.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cd concentrations were 0.006 mg/kg w.w. in blood and <0.0002 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord had concentration (median 0.081 mg/kg Cd w.w.) in the same range as a comparable study from the Inner Oslofjord in 2019 (mean 0.074 mg/kg Cd w.w.) (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

Recent surveys in compliance with the EU Water Framework Directive, showed that Cd-concentrations in blue mussel from the Karmsundet in 2019 were below PROREF at two stations (Schøyen, Håvardstud, *et al*. 2019). The highest Cd concentration was 0.14 mg/kg w.w. in that survey. In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Cd concentrations below PROREF (Øxnevad 2020d).

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

General, large scale trends

In 2017, one ton of Cd was released in Norway compared with 43 tons in 1985. Today, the metal- and mining industries account for the largest emissions[1].

Discharges of Cd to water from land-based industries showed a decrease from 2000 (1468 kg Cd/year) to 2019 (82 kg Cd/year) (***Figure 25***). The emission of Cd to air showed a gradually decrease from 1999 (560 kg Cd/year) to 2014 (53 kg Cd/year).

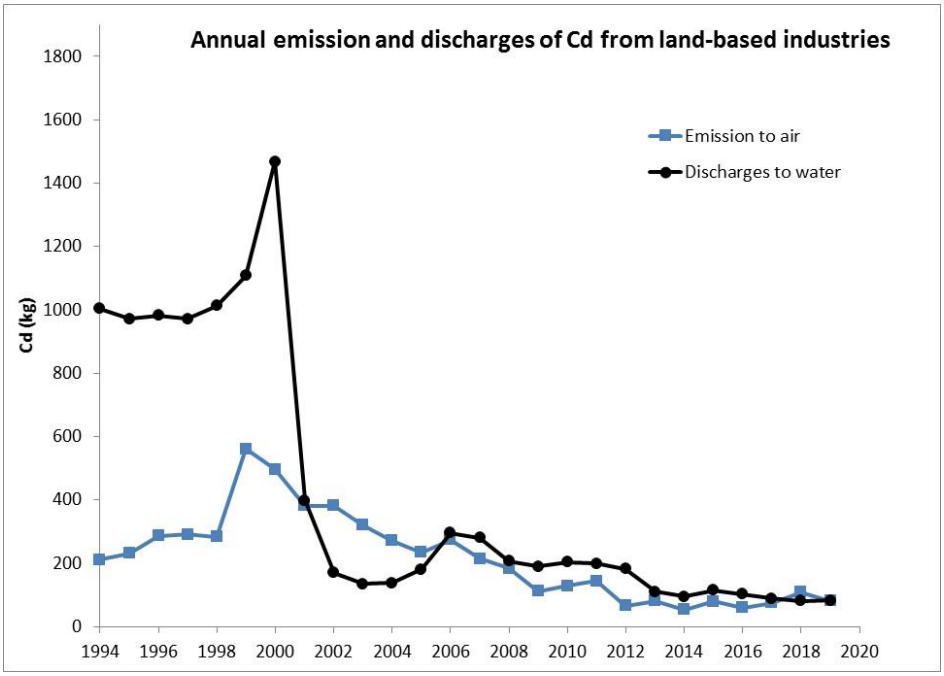


Figure 25. *Annual emissions of Cd to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no,* 3 June 2020*). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

The discharge of Cd to water from local industry in Odda in the Inner Sørfjord had decreased from 46.76 kg/year in 2015 to 13.58 kg/year in 2019 (www.norskeutslipp.no). There were both significant downward long- and short-term trends in blue mussel at Krossanes in the Outer Sørfjord.

Total riverine input of Cd in Norway has been estimated to be 2 tonnes in 2017 (Kaste 2018). The total riverine inputs of Cd in different seawaters were 1 tonne to Skagerrak. The riverine input to the Inner Oslofjord from Alna river was 0.00 tonnes Cd in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 6.0 kg Cd to the Inner Oslofjord in 2019 (VEAS 2020).

Berge *et al.* (2013b) estimated the discharges of Cd from various sources to the Inner Oslofjord; rivers (14 kg Cd/year), atmosphere (7 kg Cd/year), impermeable surfaces (19 kg Cd/year), wastewater treatment plants (WWTP) (7 kg Cd/year) and overflow (3 kg Cd/year).

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/kadmium-og-kadmiumforbindelser/

3.2.4 Lead (Pb)

Lead (Pb) is an element, and both emissions from man-made and natural sources can contribute to pollution. In the present study, Pb was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

Blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Pb by a factor of 10 to 20. The exceedance was by a factor of five to 10 at Odderøya (st. I133) in the Kristiansandfjord. The exceedance was by a factor of two to five at Kirkøy (st. I024) at Hvaler in the Outer Oslofjord, Krossanes (st. 57A) in the Outer Sørfjord, Nordnes (st. I241) in the Bergen harbour area and Bodø harbour (st. 97A3). Blue mussel exceeded PROREF by a factor of up to two at seven stations (***Table 12***). These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, and Singlekalven (st. I023) at Hvaler in the Outer Oslofjord. This was also the result at Utne (st. 64A) in the Outer Sørfjord and at Vikingneset (st. 65A) in the Mid Hardangerfjord. This was also the case at Ålesund (st. 28A2) and Mjelle (st. 97A2) in the Bodø area.

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Pb by a factor up to two (***Table 12***).

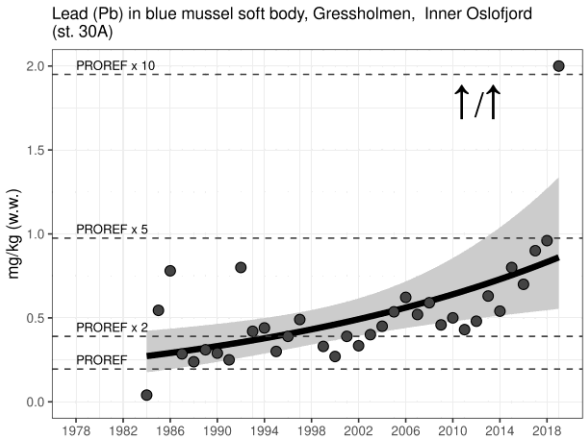
Increase in PROREF factor since 2018

Blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord exceeded PROREF of Pb by a factor of two to five in 2018, while the exceedance was between 10 and 20 times in 2019. The exceedance of Pb was between two and five in 2019, while the exceedance was by a factor below two at Bodø harbour (st. 97A3) and below PROREF at Kirkøy (st. I024) at Hvaler in 2018. At Singlekalven (st. I023) at Hvaler and Mjelle (st. 97A2) in the Bodø area, the concentrations of Pb were below PROREF in 2018, while the exceedances were by a factor up to two in 2019.

Upward trends

There were both significant upward long- and short-term trends in blue mussel from Gressholmen (st. 30A) (***Figure 26 A***) and at Gåsøya (st. I304) (***Figure 26 B***) in the Inner Oslofjord.

A



B

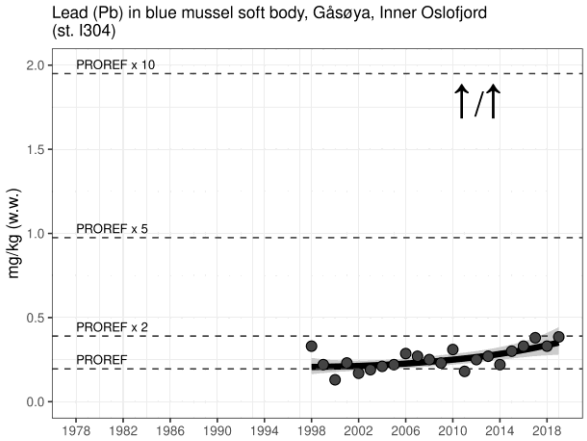


Figure 26. *Median concentrations (mg/kg w.w.) of lead (Pb) in blue mussel from Gressholmen (st. 30A) (**A**) and* Gåsøya *(st. I304) (**B**) in the Inner Oslofjord. (see **Figure 4** and **Appendix C**.)*

Decrease in PROREF factor since 2018

Blue mussel exceeded PROREF of Pb by a factor greater than 20 at Odderøya (st. I133) in 2018, while the exceedance was by a factor of five to 10 in 2019. Blue mussel at Lastad (st. I131A) in Søgne and Gåsøya-Ullerøya (st. 15A) in Farsund exceeded PROREF by a factor up to two in 2018, while the concentrations were below PROREF in 2019.

Downward trends

Of the trend analysis performed for blue mussel, six revealed significant downward long-term trends (***Table 12***). Significant downward long-term trends were found at Akershuskaia (st. I301) in the Oslofjord, Krossanes (st. 57A) in the Sørfjord and Vikingneset (st. 65A) in the Mid Hardangerfjord. This was also observed in blue mussel at Espevær (st. 22A) in the Outer Bømlafjord, Nordnes (st. I241) in Bergen harbour and Svolvær airport (st. 98A2).

In cod liver, both significant downward long- and short-term trends were found in Hammerfest (st. 45B2). Significant downward long-term trends were found in the Inner Oslofjord (st. 30B) and at Tjøme (st. 36B) in the Outer Oslofjord. This was also found at Skågskjera in Farsund (st. 15B), and in the Inner Sørfjord (st. 53B). This was also the case at Bømlo (st. 23B) in the Outer Selbjørnfjord, In Trondheim Harbour (st. 80B) and in the Austnesfjord (st. 98B1) in Lofoten.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the Pb concentration in liver was 0.028 mg/kg w.w., and a significant downward long-term trend was found.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Pb concentrations were 0.049 mg/kg w.w. in blood and 0.008 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord showed concentration (median 0.096 mg/kg Pb w.w.) within the same range as observed in a comparable study (mean 0.071 mg/kg Pb w.w.) in the Inner Oslofjord in 2019 (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

In the present study, the Pb concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was 1.8 mg/kg w.w. and exceeded the PROREF by a factor of five to 10. Another recent survey in compliance with the EU Water Framework Directive, showed that Pb concentrations in blue mussel from the Kristiansandfjord in 2019 exceeded PROREF at four of five stations (Schøyen 2019). The highest Pb concentration (1.3 mg/kg w.w.) was found at Kolsdalsbukta in that survey.

In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Pb concentrations that exceeded PROREF (Øxnevad 2020d).

In the present study, Pb concentration (median 0.008 mg/kg w.w.) in eider eggs at Svalbard was at the same level as in a comparable study (median 0.005 mg/kg w.w.) (Hill 2018).

General, large scale trends
In 2017, 87 tons of Pb was released in Norway and there has been a 90 % decline since 1995[1]. Lead-free gasoline has significantly reduced the emissions, and now the largest emissions come from ammunition and blowing sand.

There were low levels of Pb in cod liver, and the highest concentration was found in the Inner Oslofjord (st. 0.066 mg/kg w.w.). EU banned leaded-fuel in road vehicles 1 January 2000, but some countries had banned the fuel beforehand (e.g. Sweden, Germany, Portugal). The results indicate that the ban of Pb in gasoline has had a positive effect.

OSPAR (2010) found 50-80 % reduction in riverine and direct discharges of Pb to the North Sea for the period 1990-2006. While the total riverine input of Pb in Norway was 26 tonnes in 2017, the riverine inputs of Pb in different areas were 14 tonnes to Skagerrak, 8 tonnes to the North Sea, 3 tonnes to the Norwegian Sea and 1 tonnes to the Lofoten/Barents Sea (Kaste 2018), indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from industrial (1 tonnes) effluents amounting about 7 % of the total (28 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.02 tonnes Pb in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 68 kg Pb in 2019 (VEAS 2020).

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/bly-og-blyforbindelser/

Berge *et al.* (2013b) estimated the discharges of Pb from various sources to the Inner Oslofjord; rivers (429 kg Pb/year), atmosphere (168 kg Pb/year), impermeable surfaces (544 kg Pb/year), wastewater treatment plants (WWTP) (79 kg Pb/year) and overflow (60 kg Pb/year).

Discharges of Pb to water from land-based industries in Norway showed a decrease from 2010 (6841 kg Pb/year) to 2019 (1447 kg Pb/year) (***Figure 27***).

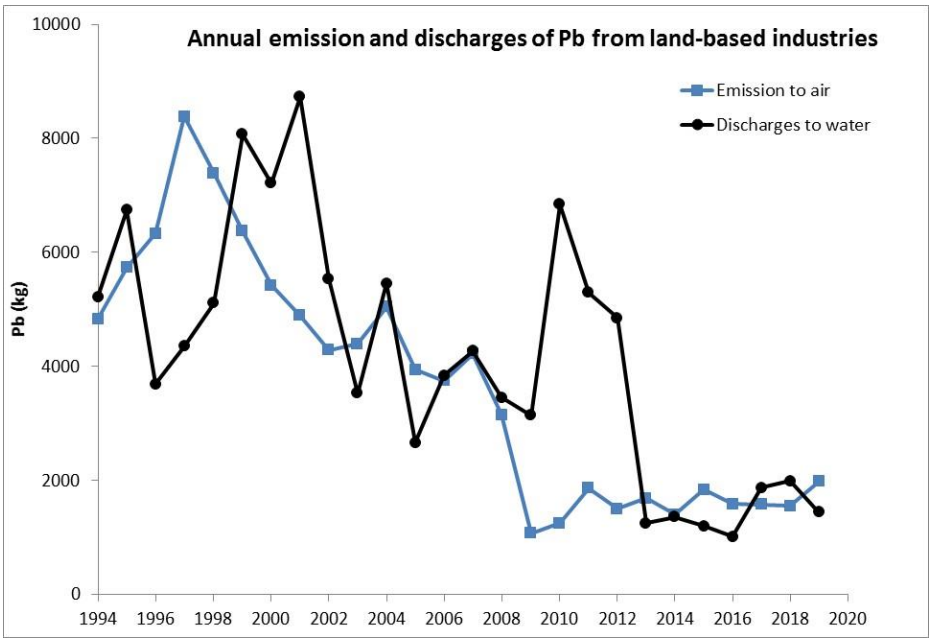


Figure 27. *Annual emissions of Pb to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.5 Copper (Cu)

Copper (Cu) is an element. In the past, wood was often impregnated with Cu. Today such use is prohibited, and the use has been significantly reduced. In the present study, Cu was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

In 2019, the Cu concentrations exceeded the PROREF in blue mussel at Solbergstrand (st. 31A) in the Mid Oslofjord, and at Kirkøy (st. I024) and Singlekalven (st. I023) at Hvaler in the Outer Oslofjord (***Table 12***). This was also observed in blue mussel from the Ørland area (st. 91A2) in the Outer Trondheimfjord.

All Cu concentrations in cod liver were below PROREF.

Upward trends
In cod liver, a significant upward short-term trend was found at Skågskjera in Farsund (st. 15B) (***Figure 28***).

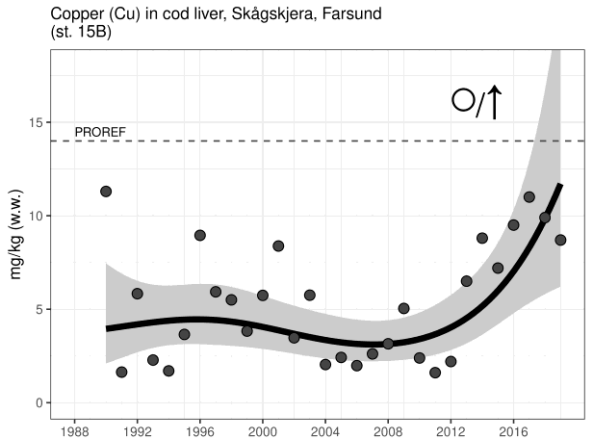


Figure 28. *Median concentrations (mg/kg w.w.) of copper (Cu) in cod liver from Skågskjera in Farsund (st. 15B).* (*see* ***Figure 4*** *and* ***Appendix C.****)*

Downward trends
There were both significant downward long- and short-term trends in mussel from Gåsøya (st. I304) in the Inner Oslofjord, Lastad (st. I131A) in Søgne, Utne (st. 64A) in the Outer Sørfjord and at Mjelle in the Bodø area (97A2). Significant downward long-term trends were observed at Krossanes (st. 57A) in the Outer Sørfjord and Vikingneset (st. 65A) in the Mid Hardangerfjord. Significant downward short-term trends were found at Odderøya (st. I133) in the Kristiansand harbour.

There were both significant downward long- and short-term trends in cod liver from Bergen harbour (st. 24B). Cod liver from the Inner Oslofjord (st. 30B) and Tjøme (st. 36B) in the Outer Oslofjord had significant downward long-term trends.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the Cu concentration in liver was 21.0 mg/kg w.w., and a significant downward long-term trend was found.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cu concentrations were 0.520 mg/kg w.w. in blood and 1.442 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord (median 4.3 mg/kg Cu w.w.) was lower than in a comparable study from the Inner Oslofjord in 2019 (mean 6.09 mg/kg Cu w.w.) (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

In the present study, the Cu concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was 0.95 mg/kg w.w. Another recent survey in compliance with the EU Water Framework Directive, showed that Cu concentrations in blue mussel from the Kristiansandfjord in

2019 exceeded PROREF at one of five stations (Schøyen 2019). The highest Cu concentration (3.3 mg/kg w.w.) was found at Glencore harbour in that survey.

In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Cu concentrations below PROREF (Øxnevad 2020d).

General, large scale

In the past, wood was often impregnated with Cu, Cr and As. Today is it prohibited to use, and the use has been significantly reduced. In 2013, 1239 tonnes of Cu were used in the aquaculture industry to prevent overgrowth of the nets, and 80-90 % leaks into the sea[1].

Discharges of Cu to water from land-based industries showed a gradually decrease from 1998 (19 385 kg Cu/year) to 2015 (5 560 kg Cu/year) (***Figure 29***).

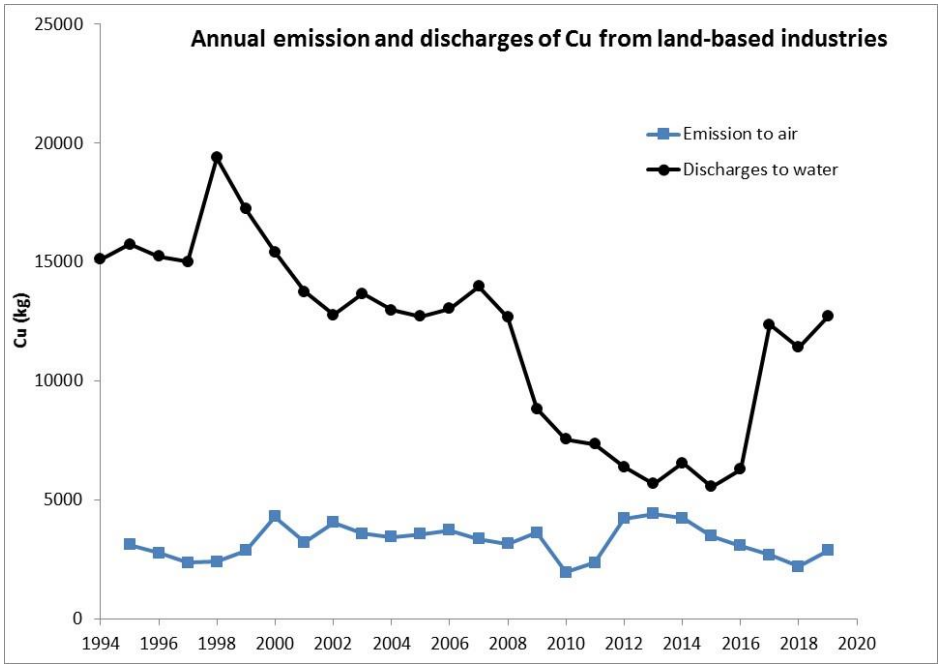


Figure 29. *Annual emissions of Cu to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data*, and this is the reason why this figure for 2019 looks very different than for 2018.

Total riverine input of Cu in Norway has been 165 tonnes in 2017 (Kaste 2018). The total riverine inputs of Cu were 59 tonnes to Skagerrak, 24 tonnes to the North Sea, 45 tonnes to the Norwegian Sea and 36 tonnes to the Lofoten/Barents Sea. The input of Cu along the coast of the Barent Sea has increased significantly from 1990 to 2018. In addition to riverine inputs, comes the contribution by direct discharges from sewage (5 tonnes) and industrial (5 tonnes) effluents and fish farming (1088 tonnes) amounting to 1099 tonnes (Kaste 2018), or about 87 % of the total (1264 tonnes). The

[1] https://www.environment.no/no/Tema/Hav-og-kyst/Fiskeoppdrett/Kobber-og-andre-kjemikalier-i-fiskeoppdrett/

riverine input to the Inner Oslofjord from Alna river was 0.10 tonnes Cu in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 605 kg Cu in 2019 (VEAS 2020).

Berge *et al.* (2013b) estimated the discharges of Cu from various sources to the Inner Oslofjord; rivers (2538 kg Cu/year), atmosphere (100 kg Cu/year), impermeable surfaces (1081 kg Cu/year), wastewater treatment plants (WWTP) (2528 kg Cu/year) and overflow (229 kg Cu/year).

3.2.6 Zinc (Zn)

Zink (Zn) is an element. In the present study, Zn was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

Blue mussel from 10 stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Zn, but by less than a factor of two (***Table 12***). These stations were Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler and Tjøme (st. 36A1) in the Outer Oslofjord. This was also the result at Odderøya (st. I133) in the Kristiansandfjord and Gåsøy-Ullerøya (st. 15A) in Farsund. This was also the case at Vikingneset (st. 65A) in the Mid Hardangerfjord, Nordnes (st. I241) in Bergen harbour area, Vågsvåg (st. 26A2) in the Outer Nordfjord and Bodø harbour (st. 97A3).

Cod liver exceeded PROREF for Zn by a factor up to two in the Kristiansand harbour (st. 13B).

Increase in PROREF factor since 2018

In 2018, no exceedances in PROREF for Zn were found in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler and Vikingneset (st. 65A) in the Mid Hardangerfjord, while the concentrations exceeded PROREF by a factor of up to two in 2019.

Upward trends

A significant upward short-term trend was found in blue mussel from Færder (st. 36A[1]) in the Outer Oslofjord.

A significant upward long-term trend was found in cod liver from the Kristiansand harbour (st. 13B) and from the Austnesfjord (st. 98B1) in Lofoten. A significant upward short-term trend was found at Skågskjera in Farsund (st. 15B).

Decrease in PROREF factor since 2018

In 2018, the exceedance of PROREF for Zn in blue mussel was less than two times at Gåsøya (st. I304) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord, Kirkøy (st. I024) at Hvaler and in Ålesund harbour (st. 28A2), while it was no exceedance in 2019.

In cod liver, the exceedance of PROREF for Zn was by a factor of below two in 2018, while it was no exceedance in 2019 at Stathelle area (st. 71B) in Langesund, Skågskjera (st. 15B) in Farsund and at Bømlo (st. 23B)

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

Downward trends
In blue mussel, a significant downward long-term trend was found at Gressholmen (st. 30A) in the Inner Oslofjord, Lastad (st. I131A) at Søgne, Krossanes (st. 57A) in the Outer Sørfjord, Vikingneset (st. 65A) in the Mid Hardangerfjord, Espevær (st. 22A) in the Outer Bømlafjord and at Mjelle (st. 97A2) in the Bodø area.

In cod liver, a significant downward long-term trend was found for Zn at Tjøme (st. 36B) in the Outer Oslofjord.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the Zn concentration in liver was 50.0 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Zn concentrations were 5.269 mg/kg w.w. in blood and 17.006 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord (median 23.0 mg/kg Zn w.w.) was lower than a comparable study from the Inner Oslofjord in 2019 (mean 27.3 mg/kg Zn w.w.) (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

In the present study, the Zn concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was 18.0 mg/kg w.w. Another recent survey in compliance with the EU Water Framework Directive, showed that Zn concentrations in blue mussel from the Kristiansandfjord in 2019 exceeded PROREF at four of five stations (Schøyen 2019). The highest Zn concentration (23 mg/kg w.w.) was found in Hanneviksbukta in that survey.

In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964) and Bjørnbærviken (st. I969) had Zn concentration below PROREF, while the level at Moholmen (st. I965) exceeded PROREF (Øxnevad 2020d).

General, large scale
Discharges of Zn to water from land-based industries showed a gradually decrease from 1999 (89 290 kg Zn/year) to 2019 (11 649 kg Zn/year) (***Figure 30***).

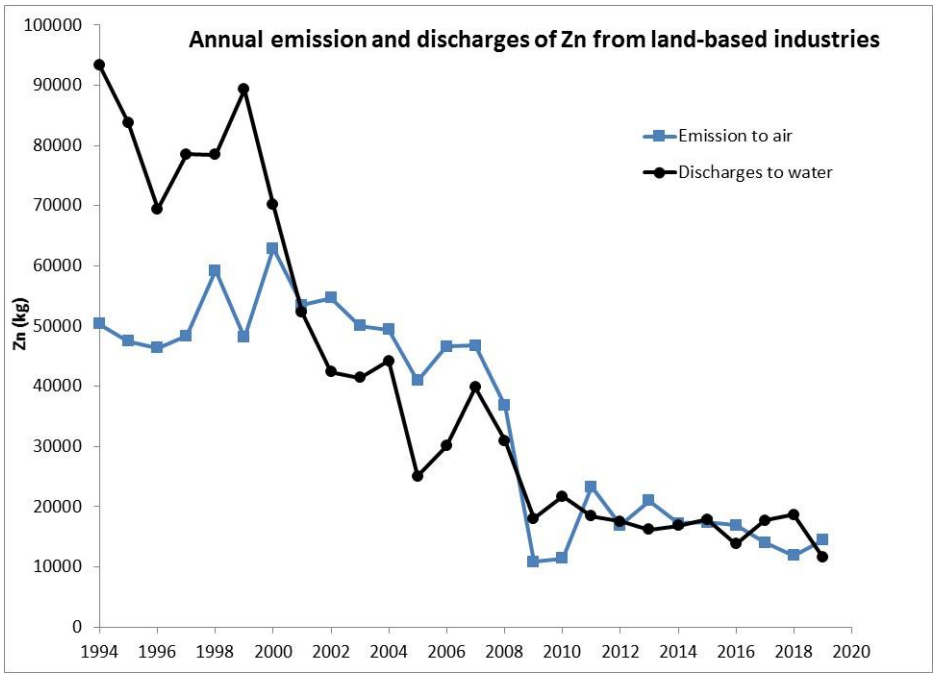


Figure 30. *Annual emissions of Zn to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data*, and this is the reason why this figure for 2019 looks very different than for 2018.

Total riverine input of Zn in Norway has been 407 tonnes in 2017 (Kaste 2018). Total riverine inputs of Zn were 186 tonnes to Skagerrak, 94 tonnes to the North Sea, 92 tonnes to the Norwegian Sea and 36 tonnes to the Lofoten/Barents Sea (Kaste 2018), indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from sewage (20 tonnes) and industrial (16 tonnes) effluents amounting to 36 tonnes or about 8 % of the total (443 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.37 tonnes Zn in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 2140 kg Zn in 2019 (VEAS 2020).

Berge *et al.* (2013b) estimated the discharges of Zn from various sources to the Inner Oslofjord; rivers (5397 kg Zn/year), atmosphere (792 kg Zn/year), impermeable surfaces (5534 kg Zn/year), wastewater treatment plants (WWTP) (4033 kg Zn/year) and overflow (502 kg Zn/year).

3.2.7 Silver (Ag)

Silver (Ag) is an element. In the present study, Ag was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

The concentrations of Ag in blue mussel were <0.050 mg/kg w.w. at all 22 blue mussel stations. This means that the mussel at all stations could have exceeded the Norwegian provisional high reference contaminant concentration (PROREF) of Ag by a factor of five to 10 (***Table 12***).

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Ag by a factor of five to 10. Cod liver from Bømlo (st. 23B) in the Outer Selbjørnfjord exceeded PROREF by a factor of two to five. Cod liver from Tjøme (st. 36B) in the Outer Oslofjord, Kristiansand harbour (st. 13B) and Skågskjera (st. 15B) at Farsund exceeded PROREF by a factor up to two.

Increase in PROREF factor since 2018

In 2018, the exceedance of PROREF for Ag in blue mussel was by a factor up to two in Gressholmen (st. 30A) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord and Vikingneset (st. 65A) in the Mid Hardangerfjord, while the exceedance was by a factor of five to 10 in 2019. At all other blue mussel stations, all concentrations of Ag were below PROREF in 2018, while all exceeded this value by a factor of five to 10 in 2019.

The Ag concentration in cod liver in the Inner Oslofjord (st. 30B) had increased from exceeding the PROREF by a factor of two to five in 2018 to a factor of five to 10 in 2019. In 2018, the Ag concentration in cod liver was below PROREF, but the exceedance was up to two at Kristiansand harbour (st. 13B) and between two and five times at Bømlo (st. 23B) in the Outer Selbjørnfjord in 2019.

Upward trends

There were both significant upward long-and short-term trends for Ag in cod liver from Skågskjera (st. 15B) in Farsund (***Figure 31 A***) and from Sandnessjøen area (st. 96B), also when adjusted for length (***Figure 31 B*** for Skågskjera in Farsund).

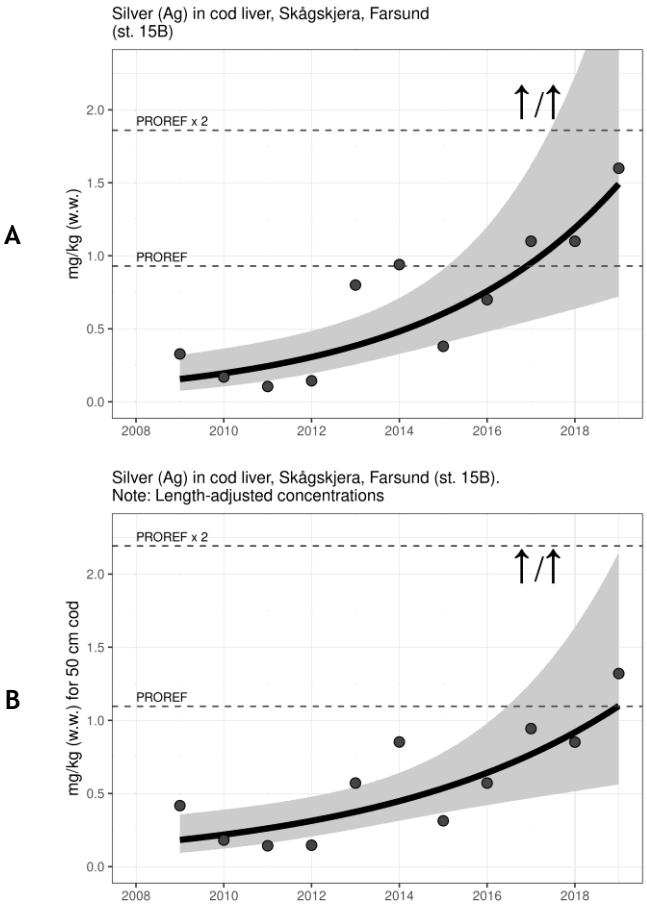


Figure 31. *Median concentrations (mg/kg w.w.) of silver (Ag) in cod liver from Skågskjera (st. 15B) in Farsund; no adjustment for length (***A***) and adjusted for length (***B***). (see* ***Figure 4*** *and* ***Appendix C****.)*

Downward trends

Both significant downward long- and short-term trends were found in cod liver from Bergen harbour (st. 24B).

Levels in flounder

In flounder at Sande (st. 33F) in the Mid Oslofjord, the Ag concentration in liver was 0.090 mg/kg w.w.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Ag concentrations were 0.001 mg/kg w.w. in blood and 0.007 mg/kg w.w. in eggs.

Comparison with other studies

In 2019, the highest Ag concentration in the present study was found in cod liver from the Inner Oslofjord (5.9 mg/kg w.w.), the similar result as in 2018 (2.9 mg/kg w.w.), in 2017 (5.4 mg/kg w.w.), in 2016 (2.4 mg/kg w.w.) and in 2015 (6.85 mg/kg w.w.). Literature is sparse but one investigation noted that equivalent concentration in the gills of Atlantic salmon was found to be lethal (Farmen *et al*. 2012), which indicates the need for a classification system to assess the possible effects in cod.

MILKYS samples of cod liver from the Inner Oslofjord collected in 2019 revealed a median Ag concentration of 5.9 mg/kg w.w. Cod liver from a comparable study from the Inner Oslofjord in 2019 showed mean concentration (5.3 mg/kg Ag w.w.) at the same level (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

Discharges of wastewater treatment plants and discharges from mine tailings are considered major and important sources for Ag to the aquatic environment (Tappin *et al*. 2010). The incorporation of Ag nanoparticles into consumer products is important in terms of inputs to wastewater treatment plants (Nowack 2010). Ag has very low toxicity to humans; however, this is not the case for microbe and invertebrate communities. There is increasing focus on the occurrence of Ag in both wastewater treatment plant effluent and sludge due to the increasing use of nanosilver in consumer products. Studies have shown that much of the Ag entering wastewater treatment plants is incorporated into sludge as Ag sulphide nanoparticles (Ag_2S), although little is known about the Ag-species that occurs in discharged effluent (Kim *et al*. 2010; Nowack 2010). From a study of eight Norwegian wastewater treatment plants, concentrations of Ag in effluent ranged from 0.01 to 0.49 µg/L, and concentrations in sludge ranged from <0.01 to 9.55 µg/g (Thomas 2011).

General, large scale

Discharges of Ag to water from land-based industries showed a decrease from 1998 (9.12 kg Ag/year) to 2019 (0.15 kg Ag/year) (***Figure 32***).

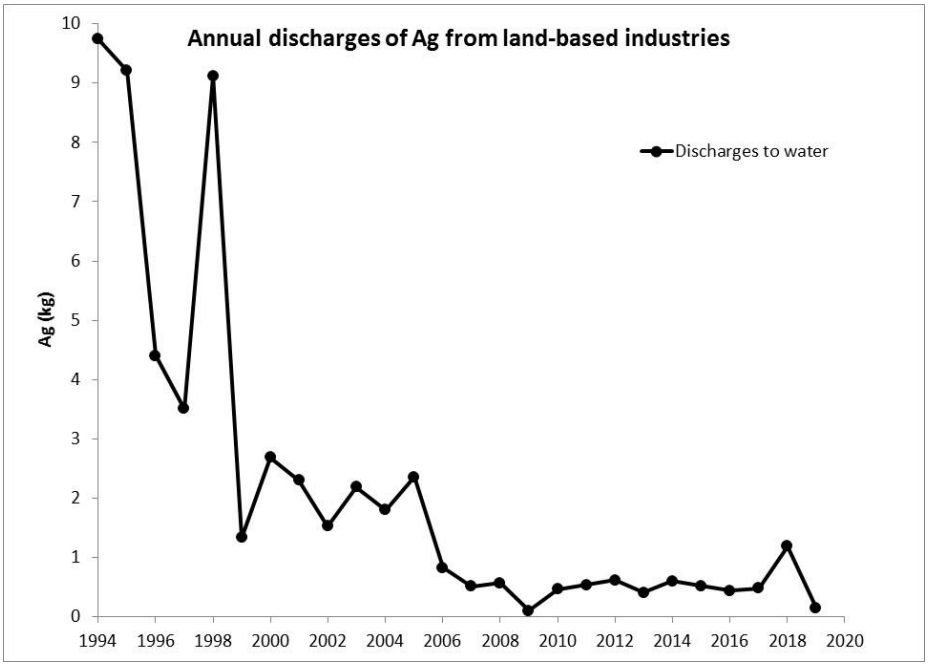


Figure 32. *Annual discharges of Ag to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

3.2.8 Arsenic (As)

Arsenic (As) is an element. In the past, wood was often impregnated with As. Today such use is prohibited, and the use of As has been significantly reduced[1]. In the present study, As was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for As by a factor of two to five at Vågsvåg (st. 26A2) in the Outer Nordfjord. The exceedance was by a factor up to two at Solbergstrand (st. 31A) in the Mid Oslofjord, Tjøme (st. 36A1) in the Outer Oslofjord, and at Utne (st. 64A) in the Outer Hardangerfjord and Vikingneset (st. 65A) in the Mid Hardangerfjord. This was also the result at Espevær (st. 22A) in the Outer Bømlafjord, Ålesund harbour (st. 28A2) and at Ørland (st. 91A2) in the Outer Trondheimfjord (***Table 12***). This was also the case at Mjelle (st. 97A2) in Bodø area.

Cod liver exceeded PROREF for As by a factor of up to two at the Inner Oslofjord (st. 30B).

Increase in PROREF factor since 2018

In 2019, the exceedance was between two and five times at Vågsvåg (st. 26A2) in the Outer Nordfjord, and by a factor up to two at Solbergstrand (st. 31A) in the Mid Oslofjord, Utne (st. 64A) in the Outer Sørfjord, Vikingneset (st. 65A) in the Mid Hardangerfjord, Espevær (st. 22A) in the Outer Bømlafjord and Mjelle (st. 97A2) in the Bodø area.

Upward trends

In cod liver, both significant upward long- and short-term trends were observed at Skågskjera (st. 15B) in Farsund.

Decrease in PROREF factor since 2018

In 2018, the As concentrations in blue mussel exceeded PROREF by a factor of up to two at Risøy (st. 76A2), while the concentration was below PROREF in 2019.

Downward trends

In blue mussel, both significant downward long- and short-term trends were observed at Gåsøya-Ullerøya in Farsund (st.15A). A significant downward long-term trend was found for As at Svolvær airport (st. 98A2) in Lofoten. Significant downward short-term trends were found in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and at Lastad (st. I131A) in Søgne.

In cod liver, a significant downward long-term trend was found for As in Bømlo (st. 23B) in the Outer Selbjørnfjord. A significant downward short-term trend was found in cod liver from Tromsø harbour (st. 43B2).

Levels in flounder

In flounder at Sande (st. 33F) in the Mid Oslofjord, the As concentration in liver was 2.3 mg/kg w.w.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the As concentrations were 0.023 mg/kg w.w. in blood and 0.123 mg/kg w.w. in eggs.

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/arsen-og-arsenforbindelser

Comparison with other studies

In the present study, cod liver from the Inner Oslofjord revealed median concentration of 19.00 mg/kg (w.w.) in 2019, 17.5 mg/kg (w.w.) in 2018, 11.5 mg/kg As (w.w.) in 2017 and 4.7 mg/kg As (w.w.) in 2016. Cod liver from a comparable study from the Inner Oslofjord in 2019 had higher mean concentration (22.6 mg/kg As w.w.) (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

In the present study, the As concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was 1.4 mg/kg w.w. Another recent survey in compliance with the EU Water Framework Directive, showed that As concentrations in blue mussel from the Kristiansandfjord in 2019 were below PROREF at all five stations (Schøyen 2019). The highest As concentration (1.8 mg/kg w.w.) was found at Kolsdalsbukta and Myrodden in that survey.

Concentrations of As in blue mussel from the Karmsundet in 2019 exceeded PROREF at two stations (Schøyen, Håvardstud, *et al*. 2019). The highest As concentration was 3.7 mg/kg w.w. in that survey. In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had As concentrations below PROREF (Øxnevad 2020d).

In the present study, As concentration (median 0.123 mg/kg w.w.) in eider eggs at Svalbard was on the same level as in a comparable study (median 0.12 mg/kg w.w.) (Hill 2018).

General, large scale trends

In 2017, 23 tons of As and compounds were released in Norway and there has been a 37 % decline since 1995 (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/arsen-og-arsenforbindelser/). In the past, wood was often impregnated with Cu, Cr and As. Today is it prohibited to use, and the use has been significantly reduced.

Discharges of As to water from land-based industries showed an increase from 2008 (501 kg As/year) to 2010 (2572 kg As/year) (***Figure 33***). Discharges to water was 2316 kg As/year in 2019.

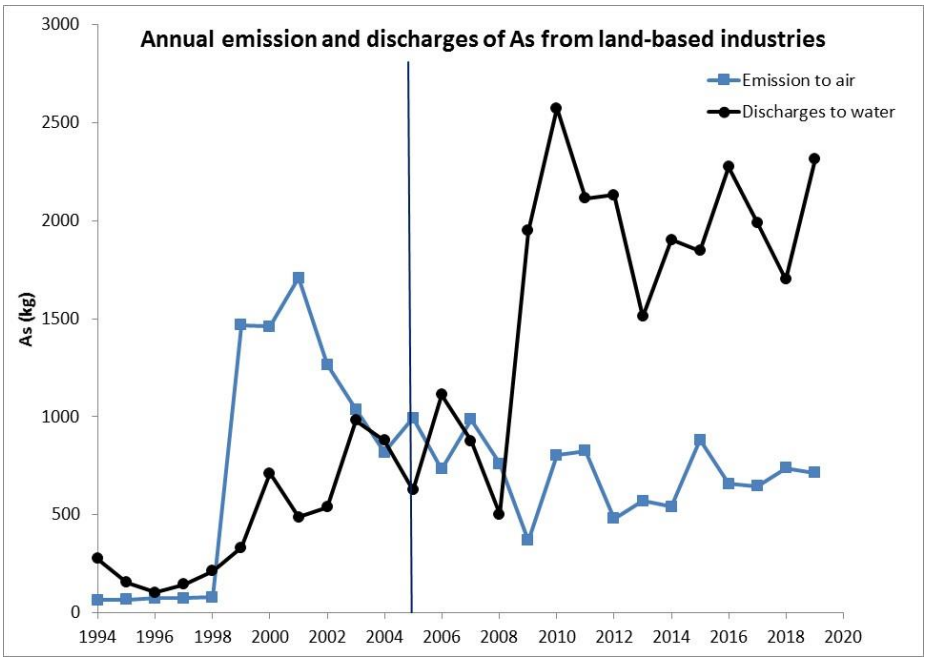


Figure 33. *Annual emissions of As to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). The vertical line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of As in Norway has been 24 tonnes in 2017 (Kaste 2018). Total riverine inputs of As were 11 tonnes to Skagerrak, 4 tonnes to the North Sea, 5 tonnes to the Norwegian Sea and 3 tonnes to the Lofoten/Barents Sea (Kaste 2018), indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from industrial effluents amounting to 2 tonnes or about 8 % of the total (26 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.01 tonnes As in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 51 kg As in 2019 (VEAS 2020).

3.2.9 Nickel (Ni)

Nickel (Ni) is an element. In the present study, Ni was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

Blue mussel at Kirkøy (st. I024) at Hvaler in the Outer Oslofjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Ni by a factor of 10 to 20 (***Table 12***). At Singlekalven (st. I023) at Hvaler, the exceedance was by a factor of five to 10. The exceedance was by a factor of two to five at Akershuskaia (st. I301) in the Inner Oslofjord, Risøy (st. 76A2) at Risør, Odderøya (st. I1333) in the Kristiansandfjord, Gåsøya-Ullerøya (st. 15A) in Farsund, Krossanes (st. 57A) in the Outer Sørfjord, Vikingneset (st. 65A) in the Mid Hardangerfjord, Bodø harbour (st. 97A3) and Mjelle (st. 97A2) in the Bodø area. The exceedances were by a factor less than two at

Gressholmen (st. 30A) and Gåsøya (st. I301) in the Inner Oslofjord, and at Solbergstrand (st. 31A) in the Mid Oslofjord.

Increase in PROREF factor since 2018

In 2018, blue mussel at Kirkøy (st. I024) at Hvaler exceeded the PROREF for Ni by a factor of two to five, while the exceedance was between 10 and 20 times in 2019. The exceedance of PROREF was by a factor of two to five at Singlekalven (st. I023) at Hvaler in 2018, while it was between five and 10 times in 2019. At Akershuskaia (st. I301) in the Inner Oslofjord, Gåsøya-Ullerø (st. 15A) at Farsund, and Krossanes (st. 57A) in the Outer Sørfjord the exceedances were by a factor up to two in 2018, while it was by a factor of two to five in 2019. In 2018, there were no exceedances at Vikingneset (st. 65A) in the Mid Hardangerfjord, Bodø harbour (st. 97A3) and at Mjelle (st. 97A2) in the Bodø area, while the exceedances were by a factor of two to five in 2019. In 2018, the concentrations were below PROREF at Solbergstrand (st. 31A) in the Mid Oslofjord, while the exceedance was by a factor up to two in 2019. The high concentrations of both Ni and Cr in blue mussel from Hvaler indicate contamination during sample preparation.

Upward trends

Both significant upward long- and short-term trends were found in blue mussel at Gressholmen (st. 30A) (***Figure 34* A**) in the Inner Oslofjord, at Risøy (st. 76A2) by Risør (***Figure 34* B**) and at and at Krossanes (st. 57A) in the Outer Sørfjord (***Figure 34* C**).

A significant upward short-term trends was found in cod liver from Skågskjera (st. 15B) in Farsund (***Figure 35***).

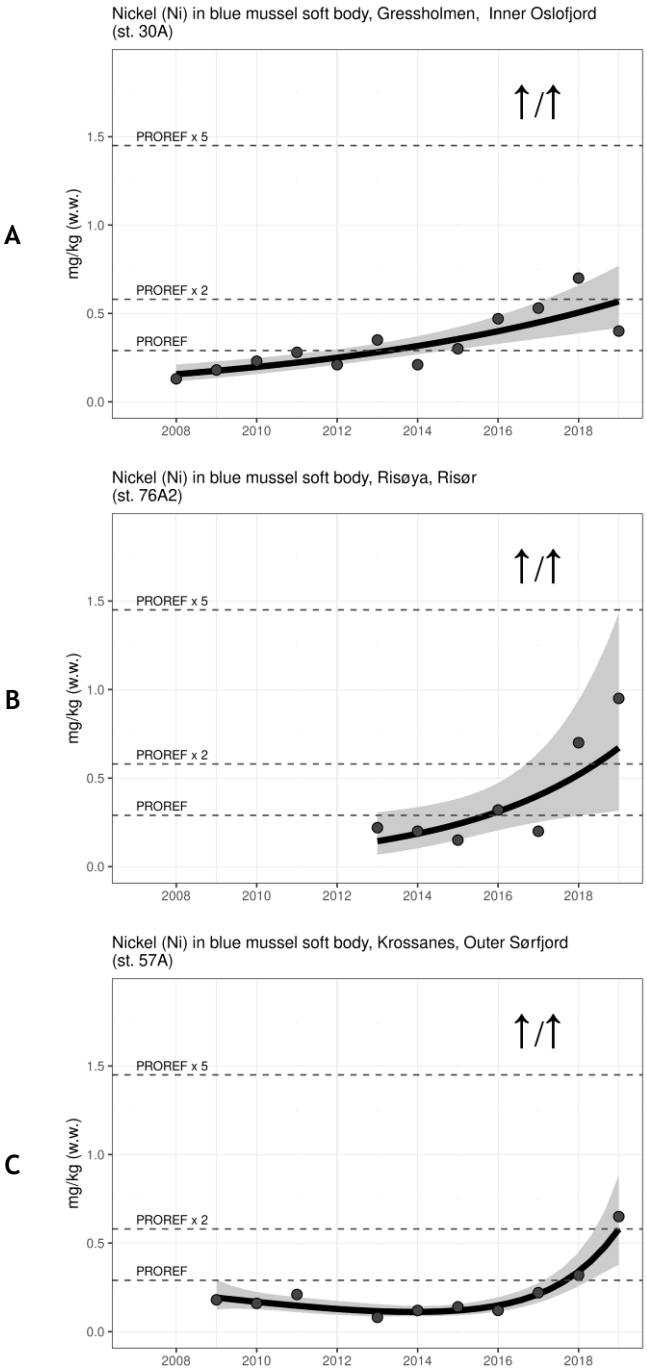


Figure 34. *Median concentrations (mg/kg w.w.) of nickel (Ni) in blue mussel from 2008 or 2009 to 2019 at Gressholmen (st. 30A) in the Inner Oslofjord (**A**), in mussel from Risøy (st. 76A2) at Risør (**B**) and in mussel from Krossanes (st. 57A) in the Outer Sørfjord (**C**). (see **Figure 4** and **Appendix C**.)*

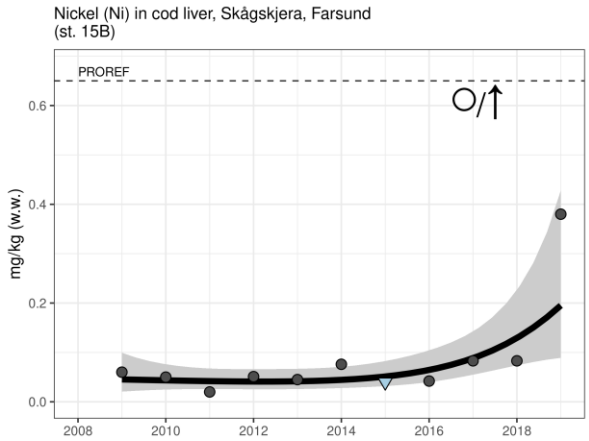


Figure 35. *Median concentrations (mg/kg w.w.) of nickel (Ni) in cod liver from Skågskjera in Farsund (st. 15B).* (*see* ***Figure 4*** *and* ***Appendix C.****)*

Decrease in PROREF factor since 2018
In 2018, the Ni concentrations in blue mussel exceeded the PROREF for Ni by a factor of two to five at Gressholmen (st. 30A), while the exceedance was by a factor up to two in 2019. In 2018, the exceedance was by a factor up to two at Utne (st. 64A) in the Outer Sørfjord and Ålesund harbour (st. 28A2), while the concentrations of Ni were below PROREF in 2019.

The Ni concentrations in cod liver at all stations were below the PROREF in 2019, as in 2018.

Downward trends
In cod liver, both significant downward long- and short-term trends were found for Ni at Tjøme (st. 36B) in the Outer Oslofjord. A significant downward long-term trend was found in the Kristiansand harbour (st. 13B).

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the Ni concentration in liver was 0.057 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Ni concentrations were <0.003 mg/kg w.w. in blood and 0.005 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord revealed a median concentration of 0.056 mg/kg Ni (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2019 showed a concentration of 0.082 mg/kg Ni w.w. (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

In the present study, the Ni concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was 1.3 mg/kg w.w. Another recent survey in compliance with the EU Water Framework Directive, showed that Ni concentrations in blue mussel from the Kristiansandfjord in 2019 exceeded PROREF at all five stations (Schøyen 2019). The highest Ni concentration (11 mg/kg w.w.) was found at Glencore harbour in that survey.

In the Inner Ranfjord in 2019, blue mussel of the former MILKYS station Bjørnbærviken (st. I969) had Ni concentrations below PROREF, while the level exceeded PROREF at Moholmen (st. I965) and north of Toraneskaien (st. I964) (Øxnevad 2020d) .

General, large scale

Discharges of Ni to water from land-based industries had decreased gradually from 2001 (21 463 kg Ni/year) to 2019 (5 672 kg Ni/year) (***Figure 36***).

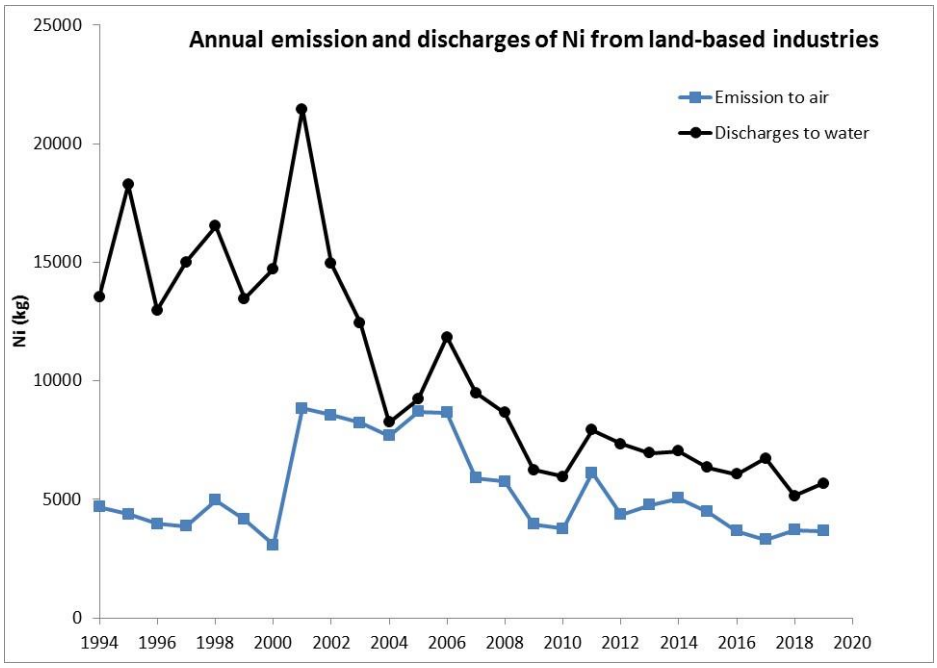


Figure 36. *Annual emissions of Ni to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Ni in Norway was 138 tonnes in 2017 (Kaste 2018). Total riverine inputs of Ni were 34 tonnes to Skagerrak, 13 tonnes to the North Sea, 29 tonnes to the Norwegian Sea and 62 tonnes to the Lofoten/Barents Sea. In addition to riverine inputs, comes the contribution by direct discharges from sewage (3 tonnes) and industrial (6 tonnes) effluents amounting to 9 tonnes or about 6 % of the total (147 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.03 tonnes Ni in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 231 kg Ni in 2019 (VEAS 2020).

Berge *et al.* (2013b) estimated the discharges of Ni from various sources to the Inner Oslofjord; rivers (684 kg Ni/year), atmosphere (37 kg Ni/year), impermeable surfaces (276 kg Ni/year), wastewater treatment plants (WWTP) (466 kg Ni/year) and overflow (40 kg Ni/year).

3.2.10 Chromium (Cr)

Chromium (Cr) is an element found in several forms that have different toxicities. In the past, wood was often impregnated with Cr. Today such use is prohibited, and the use of Cr has been significantly reduced (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/krom-og-kromforbindelser/). In the present study, Cr was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

In blue mussel, the exceedances of the Norwegian provisional high reference contaminant concentration (PROREF) of Cr were by a factor greater than 20 at Kirkøy (st. I204) at Hvaler (***Table 12***). The exceedance of PROREF was by a factor of 10 to 20 at Singlekalven (st. I023) at Hvaler and between five and 10 times at Akershuskaia (st. I301) and Mjelle (st. 97A2) in the Bodø area. Further, the exceedance was by a factor of two to five times at Solbergstrand (st. 31A) in the Mid Oslofjord, Risøy (st. 76A2) by Risør, Odderøya (st. I133) in the Kristiansandfjord and Gåsøya-Ullerøya (st. 15A) at Farsund. This was also the result at Krossanes (st. 57A) in the Mid Sørfjord, Vikingneset (st. 65A) in the Mid Hardangerfjord and in Bodø harbour (st. 97A3). The exceedance was up to a factor of two at Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord. The high concentrations of both Cr and Ni in blue mussel from Hvaler indicate contamination during sample preparation.

The concentration of Cr in cod liver from Skågskjera (st. 15B) exceeded the PROREF by a factor up to two.

Increase in PROREF factor since 2018

In 2018, blue mussel at Singlekalven (st. I023) at Hvaler exceeded PROREF for Cr by a factor of five to 10, compared to between 10 and 20 times at Kirkøy (st. I024). In 2018, the exceedance of the PROREF was up to two times, compared to greater than 20 at Kirkøy (st. I024) at Hvaler, between five and 10 times at Akershuskaia (st. I301) in the Inner Oslofjord, and between two and five times at Odderøya (st. I133) in the Kristiansandfjord, Gåsøya-Ullerøya (st. 15A) in Farsund and Krossanes (st. 57A) in the Outer Sørfjord. In 2018, the concentrations of Cr in blue mussel were below PROREF, while the exceedances were by a factor of five to 10 times at Mjelle (st. 97A2) in Bodø harbour, and between two and five times at Solbergstrand (st. 31A) in the Mid Oslofjord, Vikingneset (st. 65A) in the Mid Hardangerfjord and Bodø area (st. 97A3).

In 2018, the concentration of Cr in cod liver was below PROREF at Skågskjera (st. 15B) in Farsund, but the exceedance was by a factor up to two in 2019.

Upward trends

There were both significant upward long- and short-term trends in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and at Risøy (st. 76A2) close to Risør (***Figure 37 A*** *and* ***B****, respectively*). A significant upward long-term trend was observed at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, and at Singlekalven (st. I023) at Hvaler. A significant upward short-term trend was observed at Krossanes (st. 57A) in the Outer Sørfjord.

A significant upward short-term trend was found for Cr in cod liver from Skågskjera (st. 15B) in Farsund.

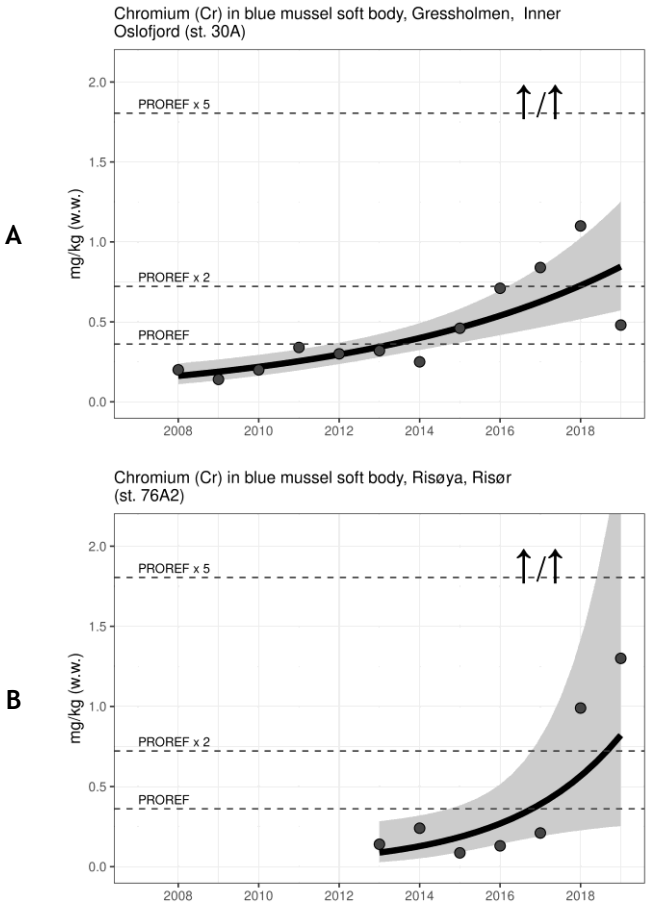


Figure 37. *Median concentrations (mg/kg w.w.) of chromium (Cr) in blue mussel from 2008 or 2009 to 2019 in Gressholmen in the Inner Oslofjord (st. 30A) (**A**) and Risøy (st. 76A2) at Risør (**B**). (see **Figure 4** and **Appendix C**.)*

Decrease in PROREF factor since 2018

Blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord had Cr concentration that exceeded PROREF by a factor of two to five in 2018, compared to an exceedance by a factor up to two in 2019. In 2018, the Cr concentration exceeded PROREF by a factor up to two at Utne (st. 64A) in the Outer Sørfjord, while the level was below PROREF in 2019.

Downward trends

Both significant downward long- and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B), Tjøme (st. 36B) in the Outer Oslofjord, Kristiansandfjord (st. 13B) and Trondheim harbour (st. 80B).

Levels in flounder

In flounder at Sande (st. 33F) in the Mid Oslofjord, the Cr concentration in liver was 0.081 mg/kg w.w.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cr concentrations were <0.005 mg/kg w.w. in blood and 0.011 mg/kg w.w. in eggs.

Comparison with other studies

In the present study, cod liver from the Inner Oslofjord revealed a median concentration of 0.015 mg/kg Cr (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2019 had mean concentration of 0.040 mg/kg Cr w.w. (Ruus 2020 In prep), which is 2.7 times higher. The collection of cod in both studies took place during the autumn.

Another recent survey in compliance with the EU Water Framework Directive, showed that Cr concentrations in blue mussel from the Karmsundet in 2019 were below PROREF at two stations (Schøyen, Håvardstud, *et al*. 2019). The highest Cr concentration was 0.26 mg/kg w.w. in that survey.

In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Cr concentrations that exceeded PROREF (Øxnevad 2020d).

General, large scale trends

In 2017, 39 tons of Cr and Cr compounds were released in Norway and there has been a 60 % decline since 1995 (https://miljostatus.miljodirektoratet.no/krom). Each year, 22 tons of Cr leak from contaminated soil. In the past, wood was often impregnated with Cu, Cr and As. Today is it prohibited to use, and the use has been significantly reduced.

Emissions of Cr to air and discharges to water from land-based industries had maintained stable levels the last years and are shown in ***Figure 38***. The discharges to water in 2019 was 1195 kg Cr/years.

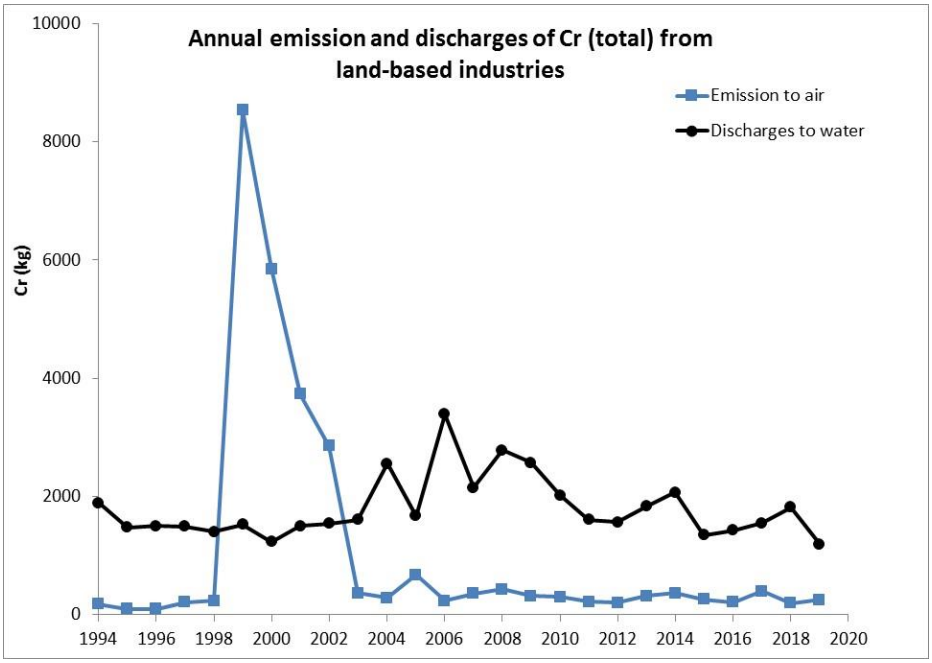


Figure 38. *Annual emissions of Cr to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Cr in Norway has been 31 tonnes in 2017 (Kaste 2018). The ranges of total riverine inputs of Cr were 11 tonnes to Skagerrak, 4 tonnes to the North Sea, 10 tonnes to the Norwegian Sea and 6 tonnes to the Lofoten/Barents Sea. In addition to riverine inputs, comes the contribution by direct discharges from sewage (1 tonnes) and industrial (1 tonnes) effluents amounting to 3 tonnes (Kaste 2018), or about 9 % of the total (34 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.02 tonnes Cr in 2018 (Gundersen 2019). VEAS sewage treatment plant reported a discharge of 65 kg Cr in 2019 (VEAS 2020).

Berge *et al.* (2013b) estimated the discharges of Cr from various sources to the Inner Oslofjord; rivers (398 kg Cr/year), atmosphere (24 kg Cr/year), impermeable surfaces (706 kg Cr/year), wastewater treatment plants (WWTP) (152 kg Cr/year) and overflow (50 kg Cr/year).

3.2.11 Cobalt (Co)

In the present study, cobalt (Co) was analysed in blue mussel at 22 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Levels exceeding PROREF

Blue mussel at Kirkøy (st. I024) in Hvaler in the Outer Oslofjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) by a factor of two to five (***Table 12***). Blue mussel at nine stations exceeded PROREF for Co by a factor of up to two. These stations were Gressholmen (st. 30A) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord, Singlekalven (st. I023) at Hvaler, Risøy (st. 76A2) at Risør and Odderøya (st. I133) in the Kristiansandfjord. This was also the result at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord, at Bodø harbour (st. 97A3) and Mjelle (st. 97A2) in Bodø area.

Increase in PROREF factor since 2018

In 2018, the Co concentration in blue mussel at Kirkøy (st. I024) at Hvaler exceeded PROREF by a factor up to two, compared to a factor of two to five in 2019. In 2018, the Co concentrations were below PROREF, compared to an exceedance by a factor up to two in 2019 at Solbergstrand (st. 31A) in the Mid Oslofjord, Risøy (st. 76A2) at Risør, Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord, at Bodø harbour (st. 97A3) and at Mjelle (st. 97A2) in the Bodø area.

Upward trends

Both significant upward long- and short-term trends were observed in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord.

Both significant upward long- and short-term trends were observed in cod liver from Skågskjera (st. 15B) in Farsund and in the Sandnessjøen area (st. 96B).

Decrease in PROREF factor since 2018

Blue mussel at Gåsøya (st. I304) in the Inner Oslofjord exceeded the PROREF of Co by a factor up to two in 2018, while there were no exceedance in 2019.

In 2018, the concentration of Co exceeded PROREF by a factor up to two at Skågskjera (st. 15B) in Farsund, compared to levels below PROREF in 2019.

Downward trends
Both significant downward long- and short-term trends were observed in blue mussel at Odderøya (st. I133) in the Kristiansandfjord. Significant downward long-term trends were found at Lastad (st. I131) at Søgne and Gåsøya-Ullerøya (st. 15A) at Farsund.

A significant downward short-term trend for Co was found in cod liver from the Austnesfjord (st. 98B1) in Lofoten.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the Co concentration in liver was 0.110 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Co concentrations were 0.003 mg/kg w.w. in blood and 0.005 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, the Co concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was 0.130 mg/kg w.w. Another recent survey in compliance with the EU Water Framework Directive, showed that Co concentrations in blue mussel from the Kristiansandfjord in 2019 exceeded PROREF at four of five stations (Schøyen 2019). The highest Co concentration (40 mg/kg w.w.) was found at Hanneviksbukta in that survey.

General, large scale trends
Discharges of Co to water from land-based industries showed increasing values from 2018 (552 kg Co/year) to 2019 (701 kg Co/year) (***Figure 39***).

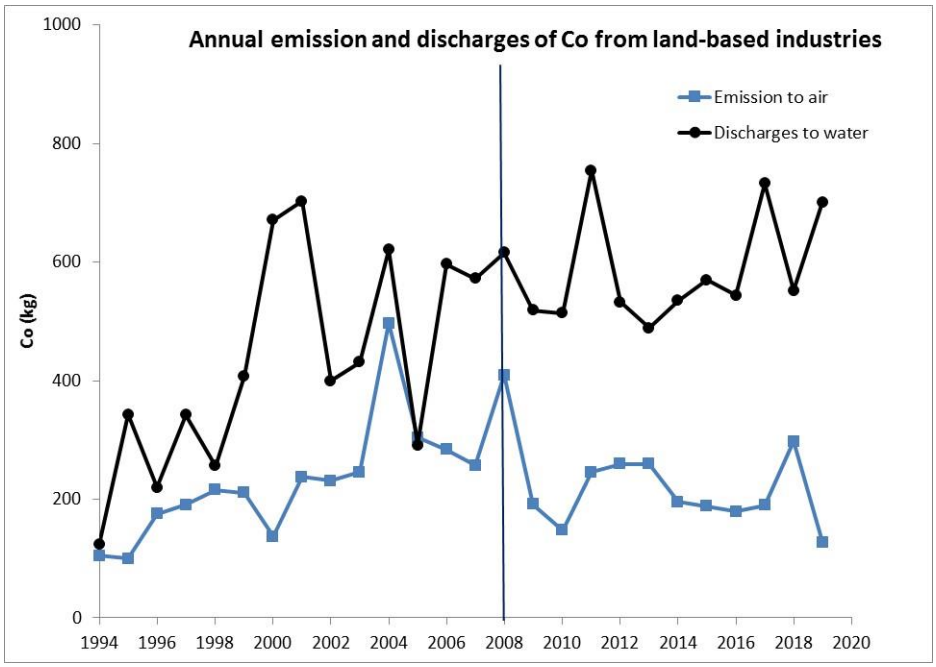


Figure 39. *Annual emissions of Co to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). The vertical grey line at 2008 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.12 Tributyltin (TBT)

Tributyltin (TBT) is an organic compound of tin used as a biocide especially in marine antifouling paints until the globally total ban in 2008. TBT is toxic to marine life and was first known used in the 1960s. Masculinized female marine snails was first described in the late sixties (Blaber 1970). TBT induces male sex characters onto females, such as imposex in dogwhelk and intersex in common periwinkle. In female dogwhelk, the TBT effect causes a vas deference and a penis that are superimposed onto female genital structures. Sterility and even death of individuals occur in the most advanced stages. In female common periwinkle, the TBT effect causes a pathological alteration in the oviduct, development of spermatocytes in ovary or oocytes in the testis and/or penis. Sterility, but not death, occur in the most advanced stages. Common periwinkle are less sensitive to TBT than dogwhelk, and may act as an alternative sentinel when dogwhelk are not found. This is the reason why common periwinkle have been monitored instead of dogwhelk at Fugløyskjær (st. 71G) in the Langesundfjord.

In the present study, TBT was analysed in blue mussel at seven stations, dogwhelk at eight stations and common periwinkle at one station. Imposex (VDSI) was investigated in dogwhelk at all eight stations, and intersex (ISI) was examined in common periwinkle at one station (***Table 3***).

Environmental Quality Standards (EQS) for priority substances

When applying the EQS for TBT (150 µg/kg w.w.) in biota ("for fish") on blue mussel (< 12.4 µg/kg w.w.), dogwhelk (< 2.3 µg/kg w.w.) and common periwinkle (< 1.8 µg/kg w.w.), all TBT-concentrations were below EQS in 2019 (***Table 11***), as in 2018.

Environmental Quality Standards (EQS) for river basin specific pollutants
When applying the EQS for triphenyltin (TPTIN) (152 µg/kg w.w.) in biota on blue mussel (<2.3 µg/kg w.w.), dogwhelk (<0.5 µg/kg w.w.) and common periwinkle (<0.5 µg/kg w.w.), all TPTIN-concentrations were below EQS in 2019, as in 2018 (***Table 11***).

Blue mussel
Levels exceeding PROREF
Blue mussel in the Inner Oslofjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for TBT by a factor up to two at Gressholmen (st. 30A) and Odderøya (st. I133) (***Table 12***).

Increase in PROREF factor since 2018
Blue mussel at Odderøya (st. I133) exceeded PROREF for TBT by a factor up to two in 2019, but did not exceeded this limit in 2018.

Downward trends
For blue mussel, there were both significant downward long- and short-term trends for TBT at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord. There were significant downward long-term trends at Gressholmen (st. 30A) in the Inner Oslofjord, Færder (st. 36A[1]) in the Outer Oslofjord, at Odderøya (st. I133) in the Kristiansandfjord and at Espevær (st. 22A) in the Outer Bømlafjord.

Dogwhelk
Levels of TBT
The TBT levels in dogwhelk were low (<2.3 µg/kg w.w.) at all seven stations.

Downward trends of TBT
There were significant downward long-term trends for TBT at all stations except for at Brashavn (st. 11G).

Biological effects of TBT (imposex/VDSI) in dogwhelk
The effects of TBT, the imposex parameter VDSI, were zero at all eight stations. All results were below the OSPARs Background Assessment Criteria (BAC=0.3) (OSPAR 2009) and the OSPARs Ecotoxicological Assessment Criteria (EAC=2) (OSPAR 2013) in 2019, as in 2018.

Decrease in VDSI since 2018
The effect of TBT in dogwhelk at Melandsholmen (st. 227G2) in the Mid Karmsundet in 2019 (VDSI=0) had decreased since 2018 (VDSI=0.129).

Downward trends of VDSI
In dogwhelk, both significant downward long- and short-term trends for VDSI were observed at Svolvær airport area (st. 98G) in Lofoten. Significant downward long-term trends were found at Færder (st. 36G) in the Outer Oslofjord, Risøy (st. 76G) at Risør, Lastad (st. 131G) at Søgne, Gåsøya-Ullerøya (st. 15G) in Farsund, in the Karmsundet (st. 227G) and at Espevær (st. 22G) in the Outer Bømlafjord.

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

Common periwinkle

Levels of TBT

The TBT concentration in common periwinkle at Fugløyskjær (st. 71G) in the Outer Langesundfjord was 1.8 µg/kg (w.w.).

Biological effects of TBT (intersex/ISI) in common periwinkle

The effect of TBT in common periwinkle, the intersex parameter ISI, was zero in 2019 at Fugløyskjær (st. 71G), as in 2018. ISI in common periwinkle is too sensitive for application of BAC and EAC (OSPAR 2013).

Trends of ISI

The data of ISI in common periwinkle at Fugløyskjær (st. 71G) showed a significant downward long-term trend.

Comparison with other studies

In another comparable study in a former TBT-polluted fjord arm, Vikkilen close to Grimstad, no intersex could be seen in common periwinkle in 2018 (Øxnevad 2018). Higher levels of TBT and intersex were measured close to the shipyard prior to the total ban in 2008 and the removal of the floating dry dock in 2012. Imposex in dogwhelk and intersex in common periwinkle, both aquatic living gastropods in the tidal zone, have shown a faster improvement than imposex in the sediment living netted dogwhelk (*Nassarius reticulatus*) and common whelk (*Buccinum undatum*) in the benthic zone (Schøyen In prep).

General, large scale trends

Long-term use of TBT has led to high concentrations in sediments in fjords and harbours along the coast. Today, contaminated sediments are the main source of TBT.

In the present program until 2017, synchronous decreases and significant downward long- and short-term trends in levels of TBT, VDSI and Relative Penis Size Index (RPSI) were found in dogwhelk, and the levels were low (Schøyen, Green, *et al*. 2019). The decreases in TBT concentrations and imposex parameters coincides with the TBT-bans. The results show that the Norwegian legislation banning application of organotin on ships shorter than 25 meters in 1990, longer than 25 meters in 2003 and the globally total ban for application and use in 2008, has been effective in reducing imposex. Populations of dogwhelk have recovered all along the Norwegian coastline after the introduction of bans on the use of TBT in antifouling paint. Former maximum levels of these markers were detected at coastal sites close to active shipping channels like Færder and the Karmsundet. In populations close to much ship traffic, the recovery took longer time than at remote stations. In the Karmsundet area, a maximum level of 46 % sterile females was measured in 2000, whereas there have not been detected any sterile females at any monitoring station after 2008, the year for the total ban. This recovery has also resulted in low levels of TBT and imposex in dogwhelk all along the Norwegian coast.

The international convention that was initiated by the International Maritime Organization (IMO) did not only ban application of organotin on ships after 2003 but also stated that organotin after 2008 could not be part of the system for preventing fouling on ships. VDSI in dogwhelk was around level 4 in all dogwhelk stations before the ban in 2003, except for the Varangerfjord where the VDSI had been low (<0.3) in the whole monitoring period. It was a clear decline in VDSI as well as TBT at all stations between 2003 and the total ban in 2008 (***Figure 40***, ***Figure 41***). In the post-ban period since 2008, the VDSI levels have been below PROREF (3.68) at all stations, and the levels have

gradually become zero. A typical example of a decreasing trend is shown for Færder in the Outer Oslofjord in ***Figure 42***.

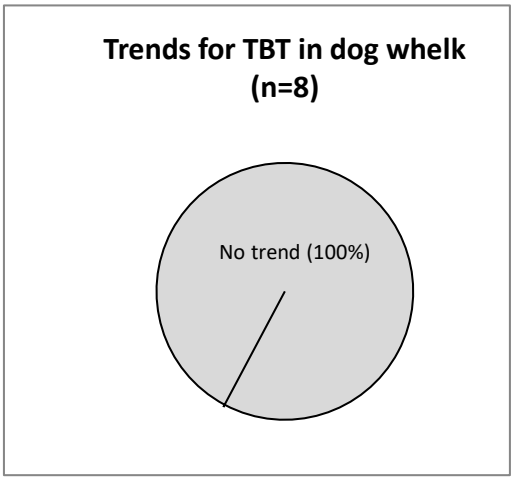


Figure 40. *Frequency of recent trends for the concentration of TBT in dogwhelk (n=8) (2010-2019). No upward trends were detected. Concerns about LOQ prevented some trend analyses.*

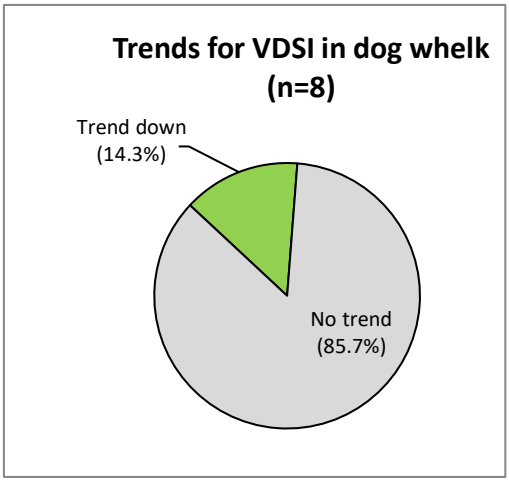


Figure 41. *Frequency of recent trends for VDSI in dogwhelk (n=8) (2010-2019). No upward trends were detected.*

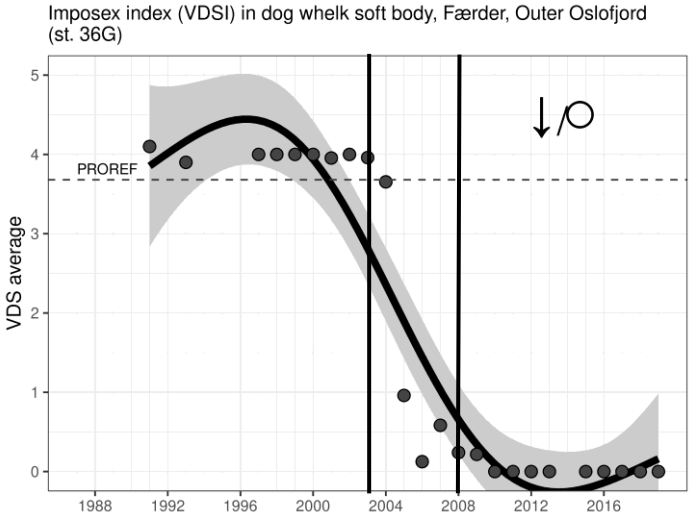


Figure 42. *Changes in VDSI for dogwhelk from Færder (st. 36G) (1991-2019). The vertical black lines indicate the ban of TBT in 2003 and total ban in 2008. (see* ***Figure 4*** *and* ***Appendix C****.)*

In the post-ban period since 2008, TBT concentrations in dogwhelk have been below PROREF (23.5 µg/kg w.w.) at all stations. Discharges of TBT and TPTIN to water from land-based industries from 1997 to 2019 is shown in ***Figure 43***, but do not adequately reflect loads to the marine environment because it does not include discharges from maritime activities for this period and do not include secondary inputs from organotin contaminated sediments. The values were high in 2003 (487 g TBT and TPTIN/year) and 2009 (504 g TBT and TPTIN/year), and these peaks were related to discharges to water from industry in Vestfold in the Outer Oslofjord. The annual discharges have decreased from 6.66 g TBT and TPTIN in 2018 to 2.4 g TBT and TPTIN/year in 2019.

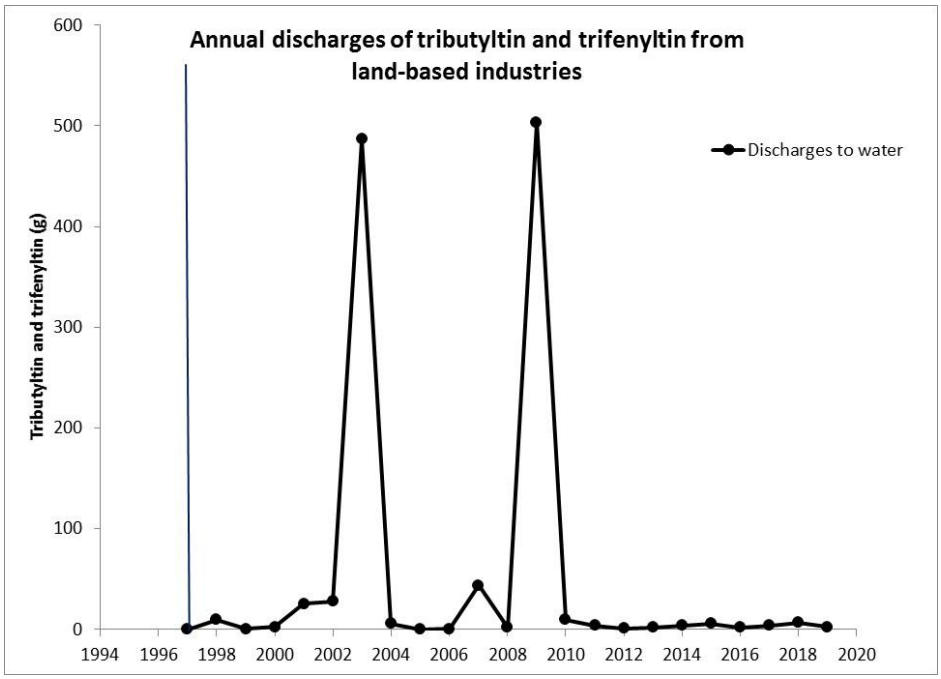


Figure 43. *Annual discharges of TBT and TPTIN to water from land-based industries in the period 1997-2019 (data from www.norskeutslipp.no, 3 June 2020). No data are reported for 1994-1996. The vertical grey line at 1997 marks when the MILKYS-measurements of TBT started. The MILKYS-measurements of VDSI started in 1991. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

3.2.13 Polychlorinated biphenyls (PCB-7)

Polychlorinated biphenyls (defined here as PCB-7, see ***Table 5***) are a group of chlorinated organic compounds that previously had a broad industrial and commercial application. There are more than 200 different PCBs. In 1980, an estimate of 1300 tons of PCBs were used in products and buildings, and an estimate of 100 tons remains in products and buildings today[1]. In the present study, PCB-7 was analysed in blue mussel at 22 stations, in cod liver at 15 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 3***).

Environmental Quality Standards (EQS) for river basin specific pollutants

When applying the EQS for PCB-7 (0.6 µg/kg w.w.) in biota on blue mussel (see ***Table 7***), the concentrations at all stations exceeded the limit (***Table 11***).

When applying the EQS for PCB-7 (0.6 µg/kg w.w.) on cod liver (see ***Table 7***), all stations exceed this value (***Table 11***).

Applying this EQS for flounder liver, the concentration of PCB-7 would have exceeded the EQS (***Table 11***).

Applying this EQS for eider blood and eggs, the concentrations of PCB-7 would have exceeded the EQS for eggs but not for blood (0.478 µg/kg w.w.) (***Table 11***).

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/polyklorerte-bifenyler-pcb/

Levels exceeding PROREF
Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for PCB-7 at all stations (***Table 12***). The mussels exceeded the limit by a factor of five to 10 at Gressholmen (st. 30A) in the Inner Oslofjord, at Nordnes (st. I241) in Bergen harbour and at Ålesund harbour (st. 28A2). The exceedance was by a factor of two to five at Akershuskaia (st. I301), Ørland area (st. 91A2) in the Outer Trondheimfjord and at Bodø harbour (st. 97A3). The exceedance was by a factor up to two at the remaining 16 blue mussel stations.

The PROREF in cod liver was exceeded by a factor of two to five in the Inner Oslofjord (st. 30B) and at Bergen harbour (st. 24B). The exceedance in cod liver was by a factor up to two at Kristiansand harbour (st. 13B). There were no exceedances at the remaining 12 cod stations.

Increase in PROREF factor since 2018
Blue mussel at two stations had increased PROREF for PCB-7 factors since 2018. The PROREF was exceeded by a factor of two to five in 2018, while the exceedance was between five and 10 times in 2019 at Nordnes (st. I241) close to Bergen. The exceedance was by a factor less than two in 2018, while it was between two and five times in 2019 at Bodø harbour (st. 97A3).

In 2018, the PROREF for PCB-7 in cod liver was exceeded by a factor less than two, while it exceeded this limit by a factor of two to five at Bergen Harbour (st. 24B) in 2019.

Upward trends
In blue mussel, there were both significant upward long- and short-term trends at Vågsvåg (st. 26A2) in the Outer Nordfjord. A significant upward short-term trend was found at Kvalnes (st. 56A) in the Mid Sørfjord, at Krossanes (st. 57A) in the Outer Sørfjord and at Vikingneset (st. 65A) in the Mid Hardangerfjord.

A significant upward short-time trend was found for PCB-7 in cod liver from the Austnesfjord (st. 98B1) in Lofoten.

Decrease in PROREF factor since 2018
The PROREF of PCB-7 was exceeded by a factor of two to five in 2018, while the exceedance was below a factor of two at Gåsøya (st. I304) in the Inner Oslofjord, at Solbergstrand (st. 31A) in the Mid Oslofjord, and at Vågsvåg (st. 26A2) in the Outer Nordfjord. The PROREF was exceeded by a factor up to two in 2018, compared to between two and five times at Bodø harbour (st. 97A3) in 2019.

In 2018, the PROREF for PCB-7 in cod liver was exceeded by a factor of two to five in Ålesund harbour (st. 28B), compared to levels below PROREF in 2019. In 2018, the exceedance of the PROREF was by a factor less than two at Tjøme (st. 36B) in the Outer Oslofjord, compared to levels below PROREF in 2019.

Downward trends
For blue mussel, there were significant downward long-term trends at 11 of the 22 stations (***Table 12***). These stations were Akershuskaia (st. I301) (***Figure 35 A***), Gressholmen (st. 30A) (***Figure 35 B***) and Gåsøya (st. 65A) (***Figure 35 C***) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord and Færder (st. 36A[1]) in the Outer Oslofjord. This was also the result at Singlekalven (st. I023) and Kirkøy (st. I024) at Hvaler, and Odderøya (st. I133) in the Kristiansandfjord. This was

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

also the case at Kvalnes (st. 56A) in the Mid Sørfjord, Espevær (st. 22A) in the Outer Bømlafjord and Nordnes (st. I241) in Bergen harbour.

For cod liver, there were significant downward long-term trends at five of the 15 stations. There were both significant downward long- and short-term trends in cod liver from Kirkøy (st. 02B) at Hvaler. There were significant downward long-term trends at Tjøme (st. 36B) in the Outer Oslofjord, Skågskjera in Farsund (st. 15B), Bømlo (st. 23B) in the Outer Selbjørnfjord and Trondheim harbour (st. 80B).

The Inner Oslofjord
Blue mussel at Gressholmen (st. 30A) exceeded PROREF by a factor of five to 10 in 2019. Mussels at Akershuskaia (st. I301) exceeded PROREF by a factor of two to five, while the exceedance was below a factor of two at Gåsøya (st. I304). Significant downward long-term trends were detected in 2019 for these stations (***Figure 44***).

Cod liver caught at 100 m depth in the Inner Oslofjord (st. 30B) exceeded PROREF by a factor of two to five in 2019.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the concentration of PCB-7 in liver was 59.63 µg/kg w.w., and a significant downward long-term trend was found.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PCB-7 were 0.478 µg/kg w.w. in blood and 9.404 µg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord revealed a median concentration of 1 836.5 µg PCB-7/kg (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2019 had almost the same mean concentration (1 698.1 µg PCB-7/kg w.w.) (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

Historical data on entry of PCB-7 to the Inner Oslofjord is not available. Present entry of PCB-7 to the fjord has however been calculated to be around 3.3 kg/year (Berge 2013a). Run-off from urban surfaces is the most important contributor (2.1 kg/year). It is also anticipated that sediments in the fjord store much of the historic inputs of PCBs, but their role as a current source of PCB-7 for uptake in biota is unclear. Parts of the Inner Oslofjord are densely populated with much urban activities. The high concentrations of PCB-7 observed in cod liver are probably related to these activities both in past and possibly also at present.

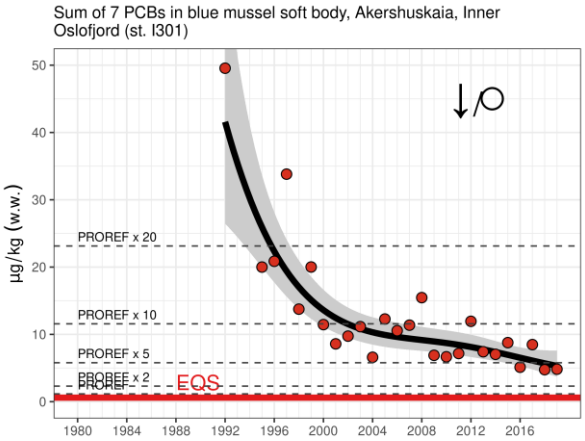
In the Inner Ranfjord in 2019, levels of PCB-7 exceeded EQS at the former MILKYS stations north of Toraneskaien (st. I964) and Moholmen (st. I965) (Øxnevad 2020d).

In the present study, the concentration of PCB-153 (median 0.200 µg/kg w.w.) in eider blood at Svalbard was nearly within the same range as in a comparable study from Svalbard (mean 0.187±0.023.8 µg/kg w.w. after five days of incubation) (Bustnes *et al*. 2010). A comparable study

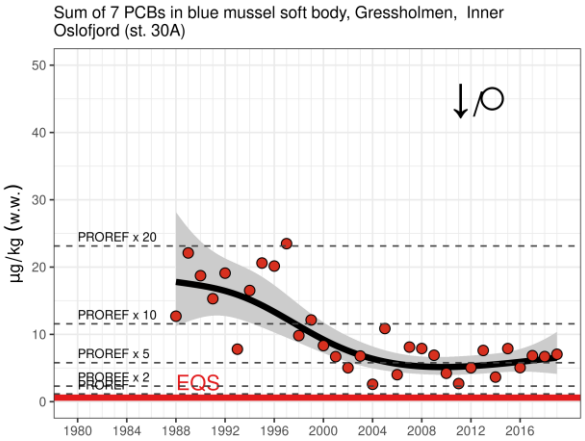
of eider duck from the Inner Oslofjord in 2017, found mean values of 4.697 µg PCB-153/kg w.w. in blood (Ruus 2018).

In the present study, the median concentrations were 0.478 µg PCB-7/kg w.w. in blood and 9.404 µg PCB-7/kg w.w. in eider eggs from Svalbard. A comparable study of eider duck from the Inner Oslofjord in 2017, found mean values of 10.519 µg PCB-7/kg w.w. in blood and 138.312 µg PCB-7/kg w.w. in eggs (Ruus 2018), which was 14-22 times higher concentrations in the Inner Oslofjord compared to results from Svalbard.

A



B



C

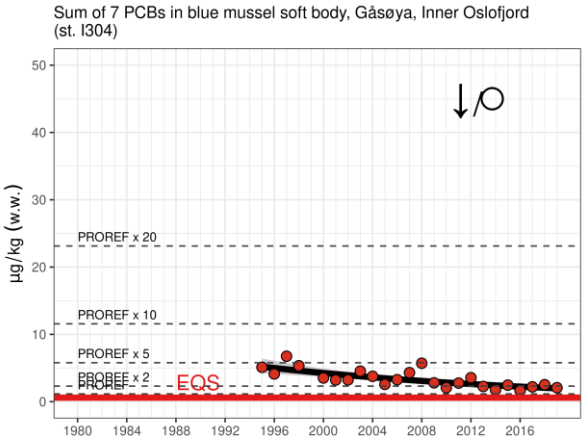


Figure 44. *Median concentrations (mg/kg w.w.) of PCB-7 in blue mussel in the Inner Oslofjord at Akershuskaia (st. I301) (***A***), Gressholmen (st. 30A) (***B***) and Gåsøya (st. I304) (***C***). (see* ***Figure 4*** *and* ***Appendix C****.)*

General, large scale trends

In Norway, the use of PCB-7 has been prohibited since 1980, but leakage from old products as well as landfills and natural deposits and contaminated sediments may still be a source of

contamination. Production and new use of PCB-7 are prohibited globally through the ECE-POPs protocol and the Stockholm Convention.

Emissions of PCB-7 to air and discharges to water from land-based industries are shown in ***Figure 45***. High emission to air was reported in 2008 (140 g PCBs/year), while the emission was 25.7 g PCBs/year in 2019. Investigations by Schuster *et al.* (2010) indicate that emissions in the northern Europe have declined during the period 1994-2008 by about 50 %.

Berge *et al.* (2013b) estimated the discharges of PCB-7 from various sources to the Inner Oslofjord; rivers (0.1 kg PCB-7/year), atmosphere (0.01 kg PCB-7/year), impermeable surfaces (2.1 kg PCB-7/year), wastewater treatment plants (WWTP) (0.8 kg PCB-7/year) and overflow (0.3 kg PCB-7/year).

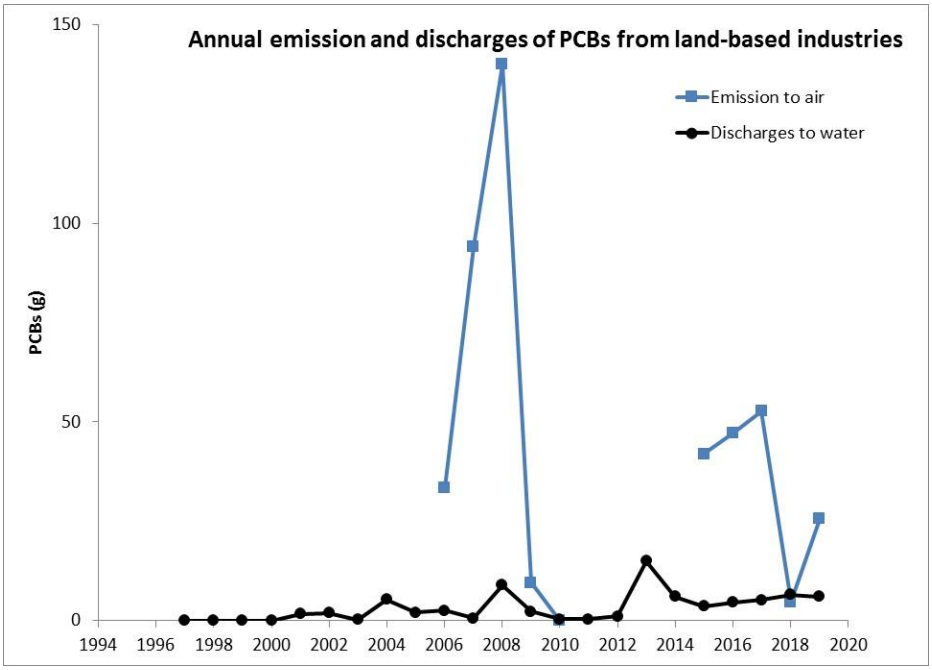


Figure 45. *Annual emissions of PCBs to air and discharges to water from land-based industries in the period 1997-2019 (data from www.norskeutslipp.no, 3 June 2020). No data for emissions to air are reported for 1994-2005 and 2011-2014. No data for discharges to water are reported for 1994-1996. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.14 Dichlorodiphenyldichloroethylene (DDE)

DDT (dichloro-diphenyl-trichloroethane) is the first modern synthetic pesticides developed in the 1940s. Dichlorodiphenyldichloroethylene (DDE) is a chemical compound formed by the loss of hydrogen chloride (dehydrohalogenation) from DDT, and DDE is one of the more common breakdown products. The compounds are used for insects and weed control. In the present study, dichlorodiphenyldichloroethylene (p,p'-DDE, referred to herein as DDE) was analysed in blue mussel at 12 stations and in cod liver at six stations and in flounder at one station (***Table 3***).

Environmental Quality Standards (EQS) for priority substances
EU has provided an EQS of 610 µg/kg w.w. for total DDT, but for the present study we apply the same limit to DDE in biota (see ***Table 7***). Applying this EQS for blue mussel and liver in cod and flounder, all concentrations were below EQS. In the present study DDE has been used as a proxy for the priority substance DDT.

Levels exceeding PROREF
Concentrations of DDE exceeded the Norwegian provisional high reference contaminant concentration (PROREF) at eight blue mussel stations (***Table 12***). The highest concentrations were found in the Sørfjord and Hardangerfjord. Blue mussel exceeded PROREF by a factor over 20 at Kvalnes (st. 56A) in the Mid Sørfjord and at Utne (st. 64A) in the Outer Sørfjord. Mussels exceeded PROREF by a factor of 10 to 20 at Krossanes (st. 57A) in the Outer Sørfjord. Mussel exceeded PROREF by a factor of five to 10 at Vikingneset (st. 65A) in the Mid Hardangerfjord. Mussels at Espevær (st. 22A) in the Outer Bømlafjord exceeded PROREF by a factor of two to five. At Gressholmen (st. 30A) and Gåsøya (st. I301) in the Inner Oslofjord and at Solbergstrand (st. 31A) in the Mid Oslofjord, the exceedance was by a factor of up to two.

Concentrations of DDE exceeded PROREF by a factor of two to five in the Inner Sørfjord (st. 53B).

Increase in PROREF factor since 2018
Blue mussel at Espevær (st. 22A) in the Bømlafjord exceeded the PROREF of DDE by a factor up to two in 2018, compared to a factor of two to five in 2019. The mussel at Gåsøya (st. I304) had concentrations of DDE below PROREF in 2018, while the exceedance was up to two in 2019.

Upward trends
There was a significant upward long-term trend in blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord. There was a significant upward short-term trend in mussel at Espevær (st. 22A) (***Figure 46***) in the Outer Bømlafjord.

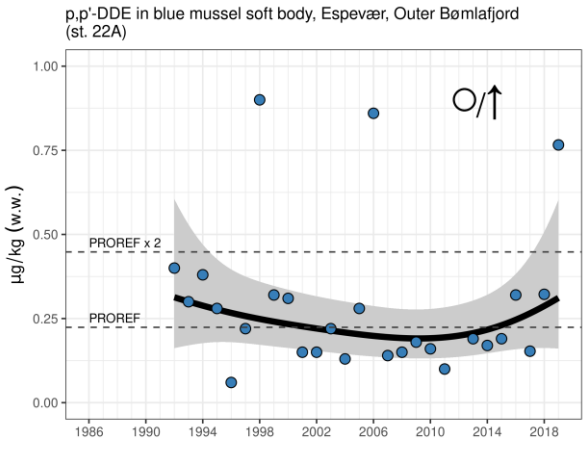


Figure 46. *Median concentrations (mg/kg w.w.) of pDDE (p,p'DDE) in blue mussel from 1992 to* 2019 at Espevær (st. 22A) on the West coast. *(see **Figure 4** and **Appendix C**.)*

Decrease in PROREF factor since 2018
In 2018, there was an exceedance of PROREF of DDE by a factor above 20 in mussel at Krossanes (st. 57A) compared to an exceedance by a factor of 10 to 20 in 2019. In 2018, there was an exceedance

of PROREF of DDE by a factor of two to five in blue mussel at Solbergstrand (st. 31A) in the Mid Oslofjord, compared to less than two in 2019.

In 2018, the DDE concentrations exceeded the PROREF by a factor less than two, compared to levels below PROREF in the Inner Oslofjord (st. 30B) and at Tjøme (st. 36B) in the Outer Oslofjord in 2019.

Downward trends
Significant downward long-term trends were found in blue mussel at four stations. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, and at Odderøya (st. I133) in the Kristiansand harbour.

Both significant downward long-term and short-term trends for DDE in cod liver were found at Skågskjera in Farsund (st. 15B). Significant downward long-term trends were found in the Inner Oslofjord (st. 30B), at Tjøme (st. 36B) in the Outer Oslofjord, and at Bømlo (st. 23B) in the Outer Selbjørnfjord.

Levels in flounder
In flounder at Sande (st. 33F) in the Mid Oslofjord, the concentration of DDE in liver was 21.5 µg/kg w.w., and a significant downward long-term trend was found.

Comparison with other studies, Sørfjord
In the present study, blue mussel from Krossanes had concentration of 2.8 µg/kg DDE (w.w.) and mussels from Utne, on the opposite side of the fjord, had concentration of 8.1 µg/kg DDE (w.w.). Mussels from a comparable study in the Sørfjord in 2015 had concentrations of 11.0 µg DDT/kg w.w. at Krossanes and 26.7 µg DDT/kg w.w. at Grimo, on the opposite side (Ruus 2016b).

The Sørfjord area has a considerable number of orchards. Earlier use and the persistence of DDT and leaching from contaminated soil is probably the main reason for the observed high concentrations of DDE in the Sørfjord area. It must however be noted that the use of DDT products has been prohibited in Norway since 1970. Green *et al.* (2004) concluded that the source of DDE in the Sørfjord was uncertain. Analyses of supplementary stations between Kvalnes and Krossanes in 1999 indicated that there could be local sources at several locations (Green 2001).

A more intensive investigation in 2002 with seven sampling stations confirmed that there were two main areas with high concentrations, one north of Kvalnes and the second near Urdheim south of Krossanes (Green 2004). The variations in concentrations of ΣDDT and the ratio between DDT/DDE (insecticide vs. metabolite) in blue mussel from Byrkjenes and Krossanes corresponds with periods with much precipitation, and it is most likely a result of wash-out from sources on shore) (Skei 2005). Botnen and Johansen (2006) deployed passive samplers (SPMD- and PCC-18 samplers) at 12 locations along the Sørfjord to sample for DDT and its derivates in sea water. Blue mussel and sediments were also taken at some stations. The results indicated that further and more detailed surveys should be undertaken along the west side of the Sørfjord between Måge and Jåstad, and that replanting of old orchards might release DDT through erosion. Concentrations of ΣDDT in blue mussel in the Sørfjord in 2008-2011 showed up to Class V (extremely polluted) at Utne (Ruus 2009, 2010, 2011, 2012). There was high variability in the concentrations of ΣDDT in replicate samples from Utne, indicating that this station was affected by DDT-compounds in varying degree, dependent on local conditions. The highest concentrations of DDE in sediment were observed in Mid Sørfjord (Green *et al.* 2010).

Increased ΣDDT-concentrations in blue mussel from the Sørfjord were discussed by Ruus *et al.* (2010). Possible explanations were increased transport and wash-out to the fjord of DDT sorbed to dissolved humus substances.

General, large scale trends
DDT is banned globally through the Stockholm convention, although with some exemptions. In Norway, the use of DDT was restricted in 1969 and the last approved use of DDT was discontinued in 1988. However, DDT from landfills and orchards can still be a problem and the possibility of some long-range transport cannot be excluded.

3.2.15 Hexachlorobenzene (HCB), pentachlorobenzene (QCB) and octachlorostyrene (OCS)

Hexachlorobenzene (HCB) is a fungicide. It is an animal carcinogen and is considered to be a probable human carcinogen. After its introduction as a fungicide in 1945, for crop seeds, this toxic chemical was found in all types of food. HCB is very toxic to aquatic organisms and is very persistent. HCB has been banned globally since 2004.

Pentachlorobenzene (QCB, quintochlorobenzene) was used as an intermediate in the manufacture of pesticides, particularly the fungicide pentachloronitrobenzene. QCB was a component of a mixture of chlorobenzenes added to products containing PCBs in order to reduce viscosity. QCB has also been used as a fire retardant. QCB is very toxic to aquatic organisms, it is persistent and accumulates in the food chain. OCB has been banned in the European Union since 2002 and globally since 2009.

Octachlorostyrene (OCS) I a by-product of normal industrial processes such as PVC-recycling activities and aluminium refining operations. OCS has bioconcentration factor values ranging from 8,100 to 1,400,000, which suggests bioconcentration in aquatic organisms is very high.

HCB, OCS and QCB were analysed in blue mussel from 11 stations, cod from six stations, flounder from one station and in eider from one station (***Table 15***).

All concentrations of HCB, OCS and QCB were low, and all median concentrations in blue mussel were below the limit of quantification (***Table 15***). Cod from the Austnesfjord in Lofoten (st. 98B1) had highest concentration of HCB, with 14.50 µg/kg w.w. (***Figure 49***). That same station also had highest concentration of OCS, with 1.5 µg/kg w.w. Five of six cod stations had median concentrations of QCB below the limit of quantification. Cod from the Sørfjord (st. 53B) had median QCB concentration of 1.5 µg/kg w.w. in the liver.

Environmental Quality standards (EQS) for priority substances
EQS for HCB is 10 µg/kg w.w. The median concentration of HCB in cod liver from the Austnesfjord in Lofoten (st. 98B1) exceeded the EQS for HCB. EQS for QCB is 50 µg/kg w.w. No concentrations exceeded the EQS for QCB.

Levels exceeding PROREF
The median concentration of HCB in cod liver from the Austnesfjord in Lofoten (st. 98B1) exceeded the PROREF by a factor of up to two.

Upward trends
There were no upward trends for concentrations of HCB, OCS or QCB.

Downward trends
Downward long-term trends were found for median concentration of HCB in liver of cod from the Inner Oslofjord (st. 30A, ***Figure 47***), Tjøme in the Outer Oslofjord (st. 36B), Skågskjera at Farsund (st. 15B, ***Figure 47***) and the Inner Sørfjord (st. 53B). Downward long-term trends were also found for HCB in blue mussels from Gressholmen in the Inner Oslofjord (st. 30A), Solbergstrand in the Mid Oslofjord (st. 31A), Færder in the Outer Oslofjord (st. 36A[1]) and Odderøya in Kristiansand (st. I133, ***Figure 47***). Downward long-term trends were also found for HCB in flounder from Sande in the Mid Oslofjord (st. 33F).

A downward tendency in concentration of QCB in cod from the Inner Sørfjord was observed, but there was no significant trend (***Figure 48***).

Levels in eider duck
Median concentration of HCB in blood of eider duck was 0.47 µg/kg w.w. Median concentration of HCB in eider duck eggs was 5.75 µg/kg w.w.

Levels in flounder
No median concentrations of OCS and QCB in flounder liver were above the limit of quantification. The concentration of HCB in flounder liver was lower than in cod liver. Median concentration of HCB in flounder liver from Sande in the Mid Oslofjord was 1.78 µg/kg w.w.

Comparison with other studies
Another study from the Inner Oslofjord in 2019 reported concentrations of HCB in cod liver in the range 1.8 to 10.7 µg/kg w.w., and concentrations of QCB in the range 0.2 to 1.3 µg/kg w.w. (Ruus 2020 In prep).

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

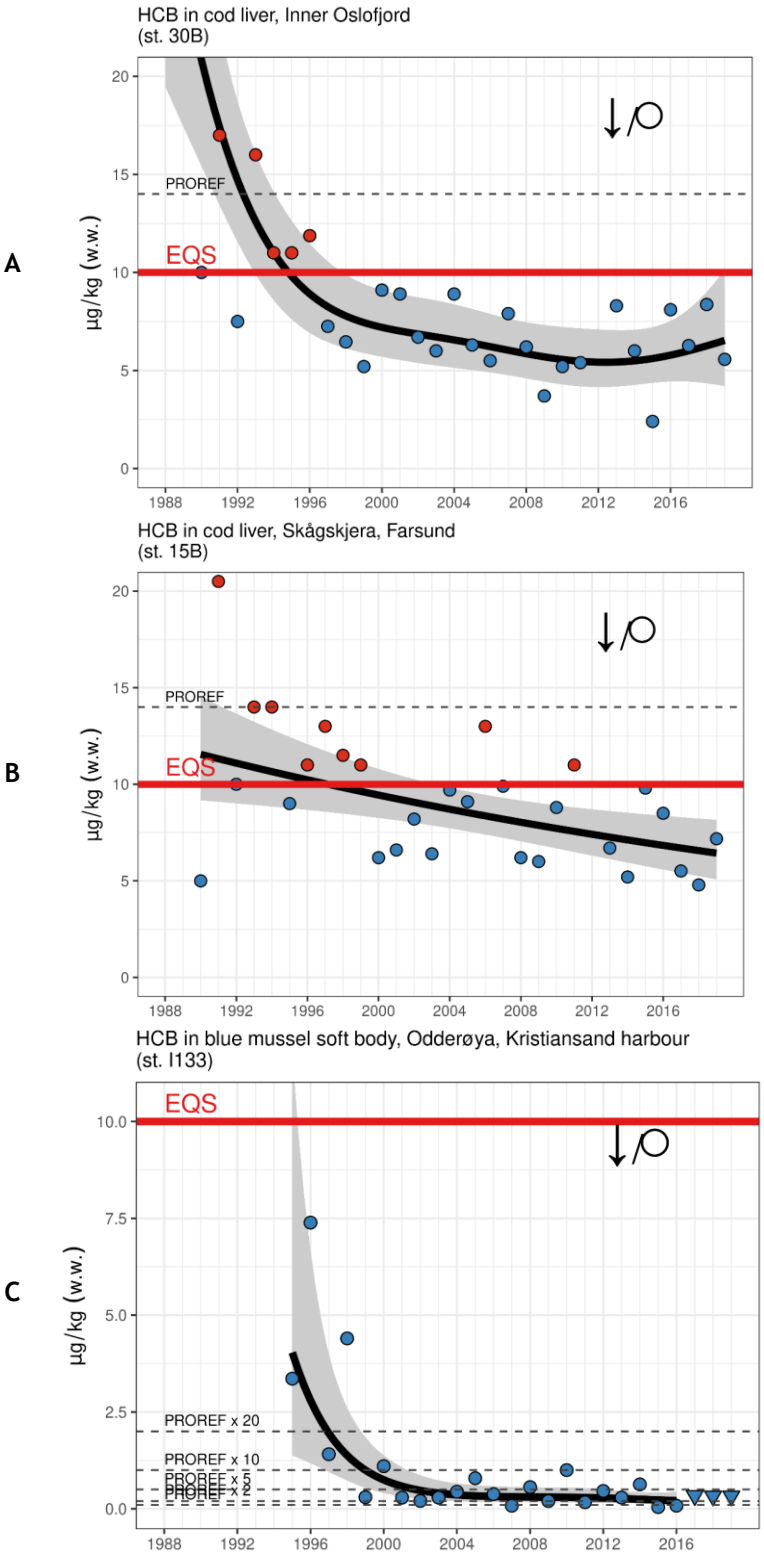


Figure 47. *Median concentrations (µg/kg w.w.) of HCB in cod liver from the Inner Oslofjord (st. 30B) (**A**), Skågskjera at Farsund (st. 15B) (**B**) and HCB in blue mussel from Odderøya in Kristiansand harbour (st. 13B) (**C**). (see **Figure 4** and **Appendix C**.)*

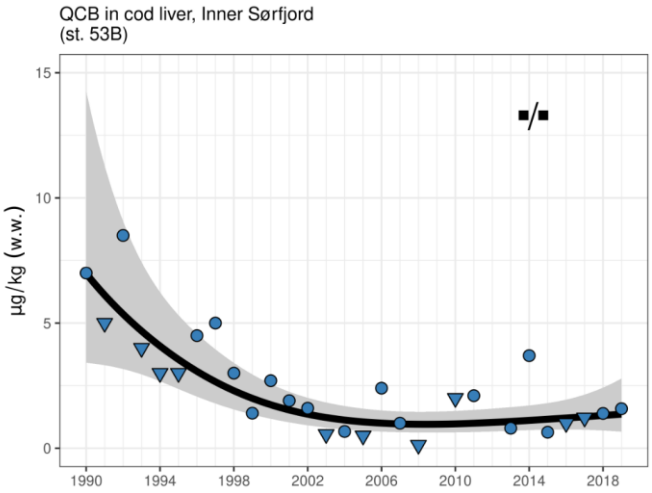


Figure 48**. Median concentrations (µg/kg w.w.) of QCB in cod liver from the Inner Sørfjord (st. 53B). (*see ***Figure 4 *and* ***Appendix C**.)*

***Table 15**.* Median concentrations (µg/kg w.w.) of HCB, OCS and QCB in blue mussel, cod liver flounder liver and eider blood and egg in 2019. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is the LOQ.

Component	Count	HCB			OCS			QCB		
Species and sampling locality	2019	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Blue mussel										
Akershuskaia, Inner Oslofjord (st. I301)	3 (3-50)	0.33	0.00	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.33	0.00	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Gåsøya, Inner Oslofjord (st. I304)	2 (2-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	0.33	0.00	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.34	0.01	0 [n.a.]	0.03	0.00	0 [n.a.]	0.34	0.00	0 [n.a.]
Risøya, Risør (st. 76A2)	3 (3-50)	0.34	0.10	0 [n.a.]	0.03	0.04	0 [n.a.]	0.34	0.00	0 [n.a.]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	0.33	0.00	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)	0.33	0.01	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	0.34	0.01	0 [n.a.]	0.03	0.00	0 [n.a.]	0.34	0.00	0 [n.a.]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	0.33	0.02	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.33	0.02	0 [n.a.]	0.03	0.00	0 [n.a.]	0.33	0.00	0 [n.a.]
Cod, liver										
Inner Oslofjord (st. 30B)	13 (10-3)	5.57	2.46	13 [1.42-10.5]	1.06	0.48	13 [0.379-2.27]	1.19	0.00	3 [1.27-1.46]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-2)	5.72	1.37	5 [2.91-6.23]	0.36	0.71	4 [0.351-1.89]	1.30	0.00	0 [n.a.]
Skågskjera, Farsund (st. 15B)	15 (0-1)	7.18	1.54	15 [3.58-9.74]	0.42	0.12	14 [0.271-0.659]	1.25	0.00	0 [n.a.]
Inner Sørfjord (st. 53B)	15 (6-2)	9.79	7.95	14 [1.84-34.6]	0.86	0.67	15 [0.246-3.09]	1.58	1.58	12 [1.2-3.02]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (0-1)	9.50	2.93	15 [5.34-15.2]	0.62	0.29	15 [0.241-1.09]	1.25	0.00	0 [n.a.]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	14.50	6.37	14 [7.78-26.1]	1.50	0.68	15 [0.187-2.51]	1.24	0.00	3 [1.25-1.34]
Flounder, liver										
Sande, Mid Oslofjord (st. 33F)	3 (3-5)	1.78	0.33	3 [1.3-1.92]	0.12	0.00	0 [n.a.]	1.22	0.00	0 [n.a.]
Eider, blood										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	0.47	0.48	14 [0.177-1.7]						
Eider, egg										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	5.75	1.84	15 [2.53-9.76]						

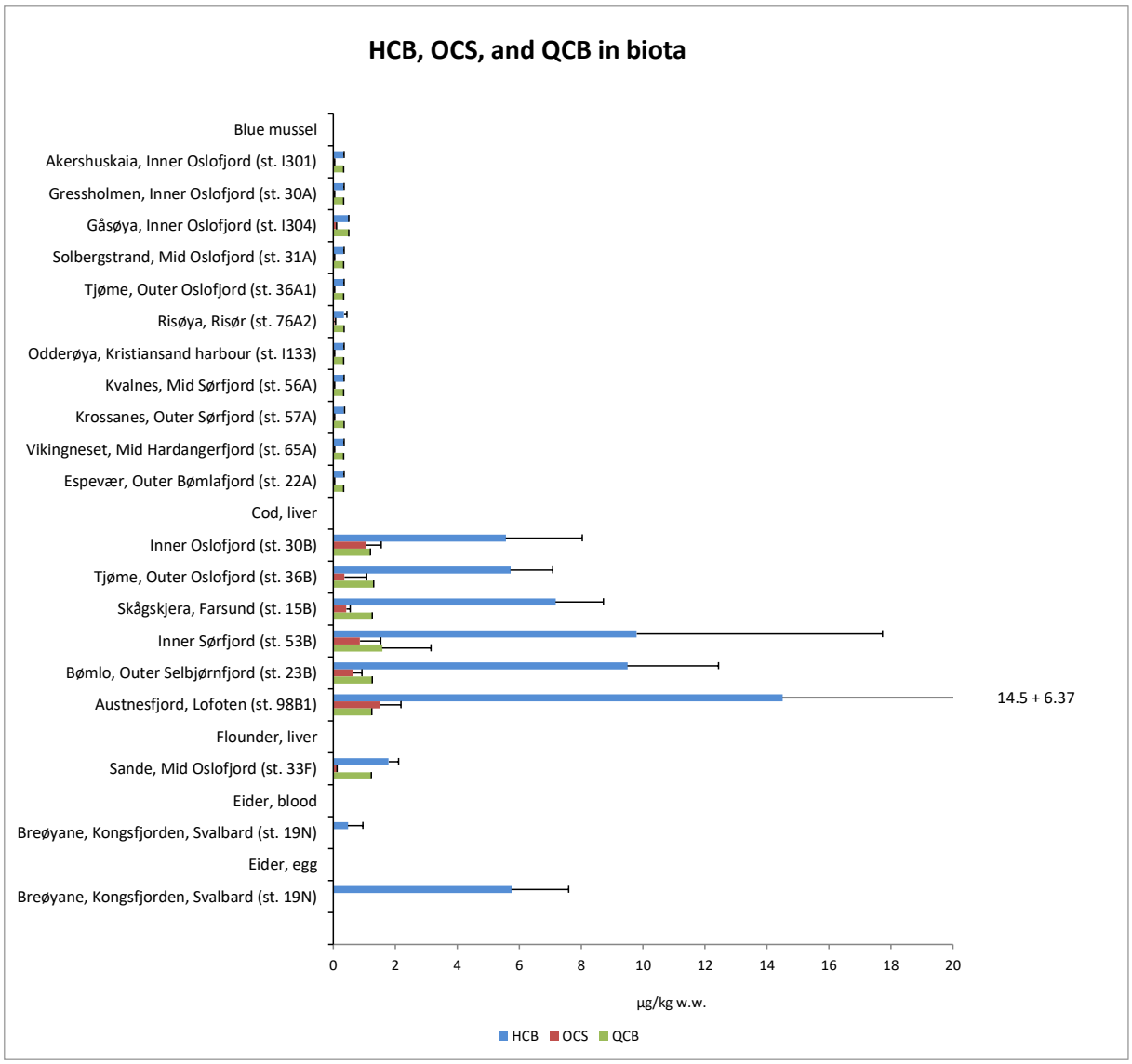


***Figure 49**. Median concentration (µg/kg w.w.) of HCB, OCS and QCB in blue mussel, cod liver, flounder liver and eider blood and egg in 2019. The error bar indicates one standard deviation above the median.*

3.2.16 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds produced by incomplete combustion or high-pressure processes. PAHs form when complex organic substances are exposed to high temperatures or pressures. The main sources of PAH in coastal waters include discharges from smelting industry and waste incinerators. Creosote impregnated wood is also an important source. In 2017, 77 tons of PAH was released in Norway, and there has been an 70 % reduction in discharges of PAH since 1995 (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/polysykliske-aromatiske-hydrokarboner-pah/). In the present study, PAHs[1] were analysed in blue mussel at six stations (***Table 3***).

PROREF

Blue mussel at all stations were below the Norwegian provisional high reference contaminant concentration (PROREF) for PAH-16 (***Table 12***).

Downward trends

Both significant downward long- and short-term trends were observed at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord. A significant downward short-term trend was also documented at Gåsøya (st. I304) in the Inner Oslofjord.

Comparison with other studies

In the Inner Ranfjord in 2019, significant downward trends were found for concentrations of several PAH compounds in blue mussels at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) (Øxnevad 2020d).

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries can be seen in ***Figure 50***. In 2019, the emission to air was 53 521 kg PAHs. In 2019, 35 850 kg PAHs originated from Agder, according to www.norskeutslipp. The discharges to water were 4 275 kg PAHs in 2019. In 2019, 1 319 kg PAHs was from Agder, according to www.norskeutslipp.

[1] For this report the total is the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic)-totalling 15 compounds, so that the classification system of the Norwegian Environment Agency can be applied (see ***Appendix B***).

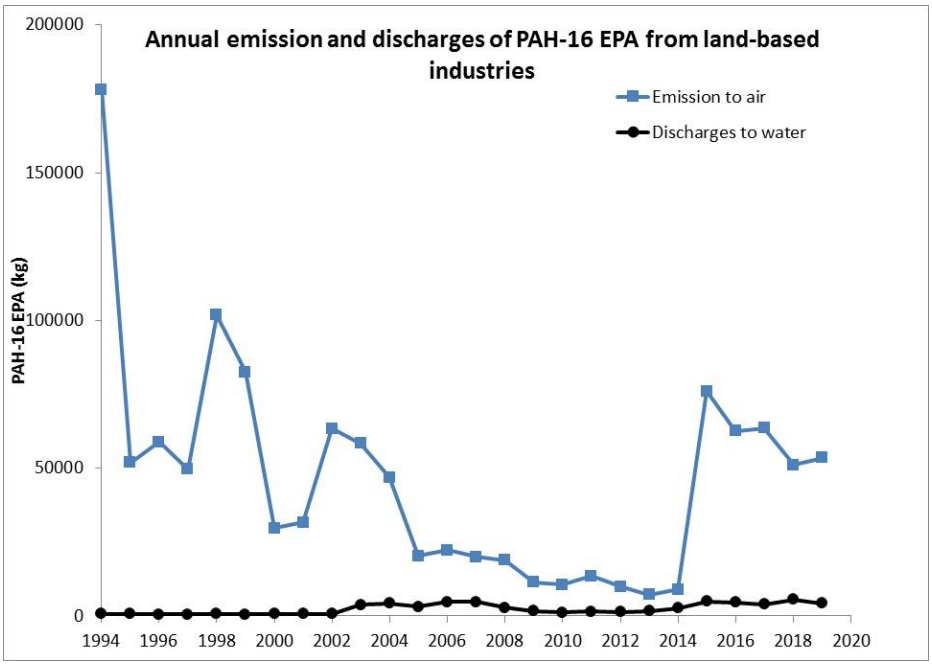


Figure 50. *Annual emissions of PAHs (PAH-16 EPA) to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Berge *et al.* (2013b) estimated the discharges of PAH-16 from various sources to the Inner Oslofjord; rivers (35.5 kg PAH-16/year), atmosphere (13.6 kg PAH-16/year), permeable surfaces (20.1 kg PAH-16/year), wastewater treatment plants (WWTP) (5.8 kg PAH-16/year) and overflow (2.5 kg PAH-16/year).

3.2.17 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

In the present study, sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs, see *Appendix B*) was analysed in blue mussel at six stations (***Table 3***).

Levels exceeding PROREF

Blue mussel at all six stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for KPAHs (***Table 12***). The exceedances were by a factor of five to 10 at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord and at Lastad (st. I131A) at Søgne. The concentrations of KPAHs were highest at Akershuskaia (4.667 µg/kg). The exceedances were by a factor of two to five at Gåsøya (st. I304) in the Inner Oslofjord, at Singlekalven (st. I023) at Hvaler and at Svolvær airport area (st. 98A2).

Increase in PROREF since 2018

Blue mussel at Gressholmen (st. 30A) exceeded the PROREF by a factor of two to five in 2018, compared to a factor of five to 10 in 2019. Mussel at Singlekalven (st. I023) exceeded the PROREF by a factor below two in 2018, compared to a factor of two to five in 2019.

Decrease in PROREF since 2018
Blue mussel at Akershuskaia (st. I301) and Lastad (st. I131A) exceeded the PROREF by a factor of 10 to 20 in 2018, compared to a factor of five to 10 in 2019.

Downward trends
There were both significant downward long- and short-term trends in blue mussel from Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler and at Svolvær airport (st. 98A2) in Lofoten.

3.2.18 Anthracene (ANT)
Anthracene is a PAH-compound and is *inter alia* used as an intermediate in industrial processes. In the present study, anthracene was analysed in blue mussel at six stations (***Table 3***).

Environmental Quality Standards (EQS) for priority substances
The EQS for anthracene is 2400 µg/kg w.w. in biota (relate to crustaceans and molluscs, see 2013/39/EU). Applying this EQS for blue mussel, all stations were below EQS in 2019 (***Table 11***), as in previous years.

Levels exceeding PROREF
Blue mussel at all stations had concentrations below the Norwegian provisional high reference contaminant concentration (PROREF) for anthracene.

Decrease in PROREF since 2018
In 2018, the concentration of anthracene in blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord exceeded the PROREF by a factor of less than two, compared to levels below the PROREF in 2019.

Downward trends
Both significant downward long- and short-term trends were found at Gressholmen (st. 30A) in the Inner Oslofjord. A significant downward short-term trend was found at Akershuskaia (st. I301) in the Inner Oslofjord.

Comparison with other studies
In the Kristiansandfjord in 2019, blue mussel had anthracene concentrations below EQS at all five stations (Næs 2020). In the Karmsundet close to Haugesund in 2019, blue mussel at three stations had anthracene concentrations below EQS (Øxnevad 2020c). One of these stations was the former MILKYS station at Høgevarde (st. 227A2). In the Sørfjord in 2019, blue mussel had anthracene concentrations below EQS at all three stations (Ruus 2020). In the Årdalsfjord in 2019, blue mussel at all four stations had anthracene concentrations below EQS (Øxnevad 2020b). In the Vefsnfjord in 2019, blue mussel at all six stations had anthracene concentrations below EQS (Øxnevad 2020e). In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had anthracene concentrations below EQS (Øxnevad 2020d).

General, large scale trends
Emissions of anthracene to air and discharges to water from land-based industries can be seen in ***Figure 51***. In 2019, the emission to air was 1 816 kg anthracene. The discharges to water were 4.2 kg anthracene in 2019.

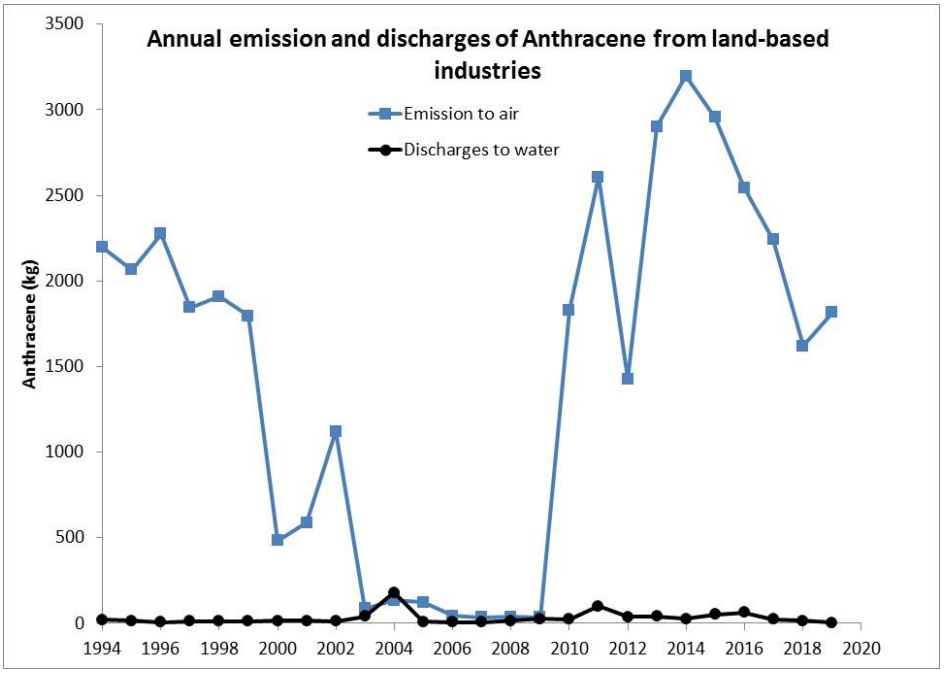


Figure 51. *Annual emissions of anthracene to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.19 Fluoranthene (FLU)

Fluoranthene is a PAH-compound. In the present study, fluoranthene was analysed in blue mussel at six stations (***Table 3***).

Environmental Quality Standards (EQS) for priority substances

The EQS for fluoranthene (30 µg/kg w.w.) in biota (relate to crustaceans and molluscs, see 2013/39/EU) was not exceeded in any of the mussel samples (***Table 11***).

Levels exceeding PROREF

Blue mussel at Akershuskaia (st. I301) exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for fluoranthene by a factor less than two (***Table 12***).

Downward trends

There were both significant downward long- and short-term trends at Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord.

Comparison with other studies

In the Kristiansandfjord in 2019, blue mussel had fluoranthene concentrations below EQS at three of five stations (Næs 2020). In the Karmsundet close to Haugesund in 2019, blue mussel at three stations had fluoranthene concentrations below EQS (Øxnevad 2020c). One of these stations was the former MILKYS station at Høgevarde (st. 227A2). In the Sørfjord in 2019, blue mussel had fluoranthene concentrations below EQS at all three stations (Ruus 2020). In the Årdalsfjord in 2019, blue mussel at one out of four stations had fluoranthene concentrations that exceeded the EQS (Øxnevad 2020b). In the Vefsnfjord in 2019, blue mussel at all six stations had fluoranthene

concentrations below EQS (Øxnevad 2020e). In the Inner Ranfjord in 2019, blue mussel at the former MILKYS station Bjørnbærviken (st. I969) had fluoranthene concentrations below EQS, while there were exceedances north of Toraneskaien (st. I964) and Moholmen (st. I965) (Øxnevad 2020d).

General, large scale trends

Emissions of fluoranthene to air and discharges to water from land-based industries can be seen in ***Figure 52***. In 2019, the emission to air was 3 430 kg fluoranthene. The discharges to water were 550 kg fluoranthene in 2019.

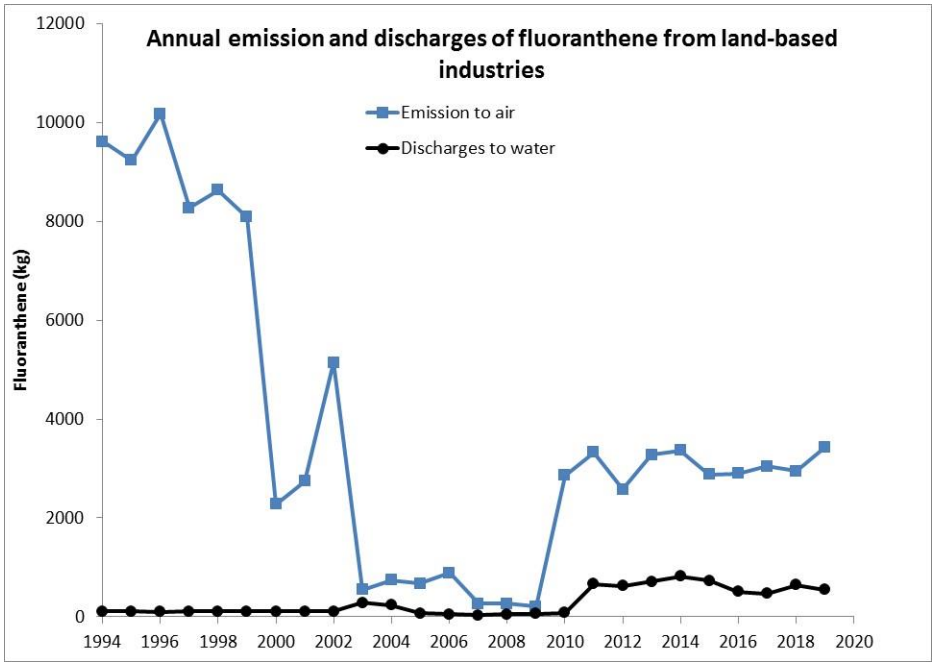


Figure 52. *Annual emissions of fluoranthene to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.20 Benzo(a)anthracene (B[a]A)

Benzo(a)anthracene is a PAH-compound, and the substance is used in industry. In the present study, benzo(a)anthracene was analysed in blue mussel at six stations (***Table 3***).

Environmental Quality Standards (EQS) for river basin specific pollutants

The EQS for benzo(a)anthracene is 304 µg/kg w.w. in biota (relate to crustaceans and molluscs, see 2013/39/EU). Applying this EQS for blue mussel, all concentrations were below EQS (***Table 11***).

Levels exceeding PROREF

Blue mussel at all stations had concentrations of benzo(a)anthracene below the Norwegian provisional high reference contaminant concentration (PROREF) (***Table 12***).

Decrease in PROREF factor since 2018
In 2018, blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord exceeded PROREF of benzo(a)anthracene by a factor up to two, compared to levels below PROREF in 2019.

Downward trends
There were both significant downward long- and short-term trends at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord. A significant downward long-term trend was seen at Lastad at Søgne (st. I131A). A significant downward short-term trend was seen at Gåsøya (st. I304) in the Inner Oslofjord.

Comparison with other studies
In the Kristiansandfjord in 2019, blue mussel had benzo(a)anthracene concentrations below EQS at all five stations (Næs 2020). In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had concentrations of benzo(a)anthracene below EQS (Øxnevad 2020d) .

3.2.21 Benzo[a]pyrene (B[a]P)
Benzo[a]pyrene (B[a]P) is a PAH-compound, and it is used as raw materials in industry. In the present study, B[a]P was analysed in blue mussel at six stations (***Table 3***).

Environmental Quality Standards (EQS) for priority substances
The EQS for B[a]P is 5 µg/kg w.w. in biota (relate to crustaceans and molluscs, 2013/39/EU). Applying this EQS for blue mussel, all concentrations of B[a]P were below EQS (***Table 11***).

Downward trends
Both significant downward long- and short-term trends for B[a]P were found in blue mussel from Akershuskaia (st. I301).

Comparison with other studies
In the Kristiansandfjord in 2019, blue mussel had B[a]P concentrations below EQS at two stations and exceeded PROREF at three stations (Næs 2020). In the Karmsundet close to Haugesund in 2019, blue mussel at two stations had anthracene concentrations below EQS, while the former MILKYS station at Høgevarde (st. 227A2) exceeded the EQS (Øxnevad 2020c). In the Sørfjord in 2019, blue mussel had B[a]P concentrations below EQS at all three stations (Ruus 2020). In the Årdalsfjord in 2019, blue mussel at two out of four stations had B[a]P concentrations that exceeded the EQS (Øxnevad 2020b). In the Vefsnfjord in 2019, blue mussel at one out of six stations had B[a]P concentrations that exceeded the EQS (Øxnevad 2020e). In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations Bjørnbærviken (st. I969) had B[a]P concentrations below EQS while there were exceedances north of Toraneskaien (st. I964) and Moholmen (st. I965) (Øxnevad 2020d).

General, large scale trends
Emissions of B[a]P to air and discharges to water from land-based industries can be seen in ***Figure 53***. In 2019, the emission to air was 645 885 kg B[a]P. The discharges to water were 62 484 kg B[a]P in 2019.

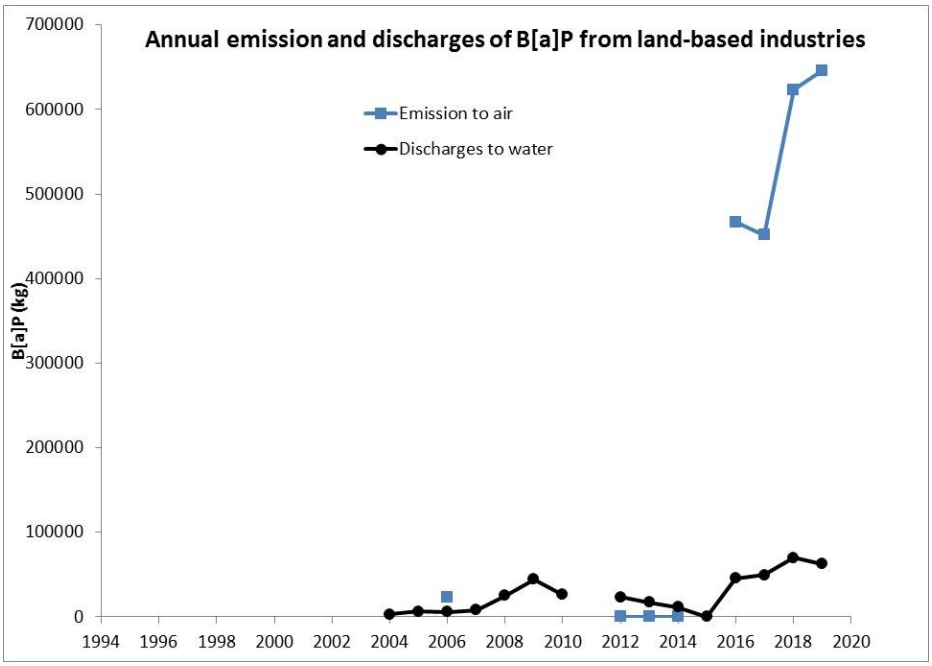


Figure 53. *Annual emissions of B[a]P to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.22 Naphthalene (NAP)

Naphthalene is a PAH-compound. Naphthalene was analysed in blue mussel at six stations (***Table 3***).

Environmental Quality Standards (EQS) for priority substances

The EQS for naphthalene is 2400 µg/kg w.w. in biota (relate to crustaceans and molluscs, see 2013/39/EU). Applying this EQS for blue mussel, all concentrations were below EQS (***Table 11***).

Decrease in PROREF factor since 2018

In 2019, the levels of naphthalene exceeded PROREF by a factor more than 20 at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, at Singlekalven (st. I023) at Hvaler and at Svolvær airport area (st. 98A2) in Lofoten, due to high detection limits. The concentrations at all blue mussel stations were below PROREF for naphthalene in 2018, due to lower detection limits. Changes in PROREF from 2018 to 2019 are due to changes in detection limits, considerably higher in 2019.

Comparison with other studies

In the Kristiansandfjord in 2019, blue mussel had naphthalene concentrations below EQS at all five stations (Næs 2019). In the Karmsundet close to Haugesund in 2019, blue mussel at three stations had naphthalene concentrations below EQS (Øxnevad 2020c). One of these stations was the former MILKYS station at Høgevarde (st. 227A2). In the Sørfjord in 2019, blue mussel had naphthalene concentrations below EQS at all three stations (Ruus 2020). In the Årdalsfjord in 2019, blue mussel at all four stations had naphthalene concentrations below EQS (Øxnevad 2020b). In the Vefsnfjord in 2019, blue mussel at all six stations had naphthalene concentrations below EQS (Øxnevad 2020e). In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien

(st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had naphthalene concentrations below EQS (Øxnevad 2020d).

General, large scale trends

Emissions of naphthalene to air and discharges to water from land-based industries can be seen in ***Figure 54***. In 2019, the emission to air was 11 801 kg naphthalene. The discharges to water were 1 858 kg naphthalene in 2019.

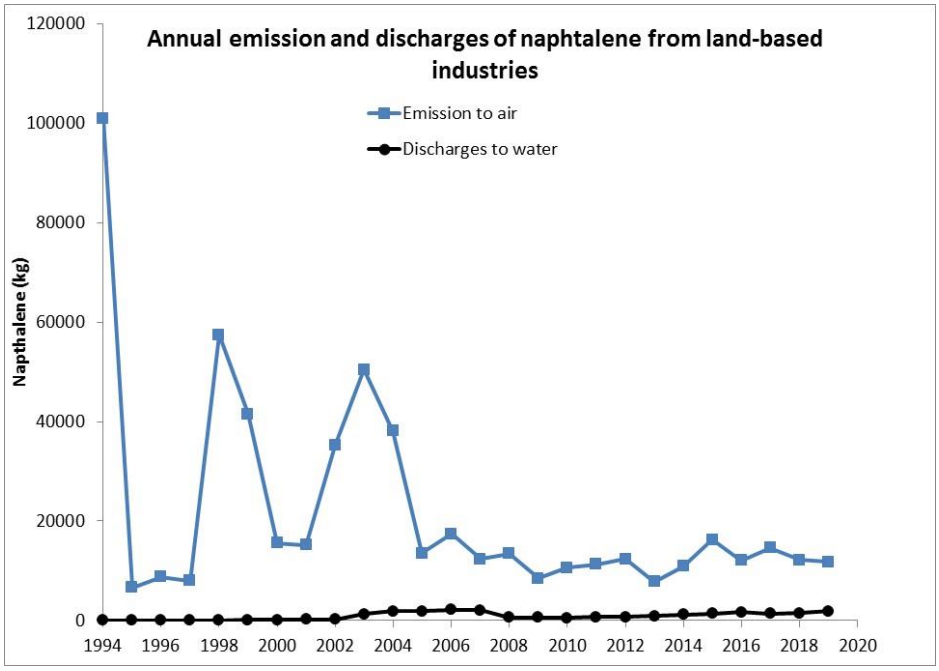


Figure 54. *Annual emissions* of *naphthalene* to *air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.23 Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (BDEs) are a group of brominated flame retardants used in a variety of consumer products. They are used in electrical and electronic products, textiles and cars. In 2013, the consumption of brominated flame retardants was 280 tons[1]. In Norway, there is a ban against all use, import and production of PBDEs. In the present study, BDEs were analysed in blue mussel at 10 stations, cod liver at 11 stations and in eider blood and eggs at one station (***Table 3***).

Environmental Quality Standards (EQS) for priority substances

The EQS for brominated diphenylethers (0.0085 µg/kg w.w.) in biota for "fish" is the sum of the concentrations of congener numbers BDE28, 47, 99, 100, 153 and 154 (sum BDEs). Applying this EQS for blue mussel, cod liver, and eider blood and eggs, the sum BDEs were above EQS at all stations (***Table 11***).

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/bromerte-flammehemmere/

The median concentration of BDE47 in blue mussel, cod liver, and eider blood and eggs exceeded this EQS at all stations except for blue mussel at Svolvær airport area (st. 98A2) (***Table 11***). These results, when one congener alone exceeds the EQS for the sum of six congeners, indicate that the EQS might not be a useful criterion to judge the condition of the environment with respect to this contaminant in biota. In the present study, additional assessments of the environmental quality were therefore conducted using BDE47 as a proxy for the PBDEs (included on the Norwegian List of Priority Substances[1]).

Levels exceeding PROREF

Blue mussel at all stations were below the Norwegian provisional high reference contaminant concentration (PROREF) for sum BDEs (28, 47, 99, 100, 153 and 154).

Cod liver from the Inner Oslofjord (st. 30B) and Bergen harbour (st. 30B) exceeded PROREF of sum BDEs (28, 47, 99, 100, 153 and 154) by a factor less than two (***Table 12***, ***Table 16***, ***Figure 57***).

Decrease in PROREF factor for sum BDEs since 2018

In 2018, cod liver exceeded PROREF by a factor of two to five for sum BDEs (28, 47, 99, 100, 153 and 154) in the Inner Oslofjord (st. 30B), while the exceedance was less than two in 2019. In 2018, the exceedance of the PROREF was by a factor of less than two in cod liver from Tjøme (st. 36B) in the Outer Oslofjord, compared to concentration below the PROREF in 2019.

Downward trends for sum BDEs

Both significant downward short- and long-term trends were found for sum BDEs (28, 47, 99, 100, 153 and 154) in blue mussel from Nordnes (st. I241) in Bergen harbour. A significant downward long-term trend was found for sum BDE levels in mussel from Gressholmen (st. 30A) in the Inner Oslofjord and at Svolvær (st. 98A2) in Lofoten.

Both significant downward long- and short-term trends were found in cod liver for sum BDE levels (28, 47, 99, 100, 153 and 154) from the Inner Oslofjord (st. 30B) (***Figure 55 A***), Bømlo (st. 23B) (***Figure 55 B***), Trondheim harbour (st. 80B) (***Figure 56 A***) and Tromsø harbour (st. 43B2) (***Figure 56 B***). A significant downward long-term trend was found for sum BDEs from the Kristiansand harbour (st. 13B). A significant downward short-term trend was found for sum BDEs from the Inner Sørfjord (st. 53B).

[1] https://www.environment.no/topics/hazardous-chemicals/list-of-priority-substances/

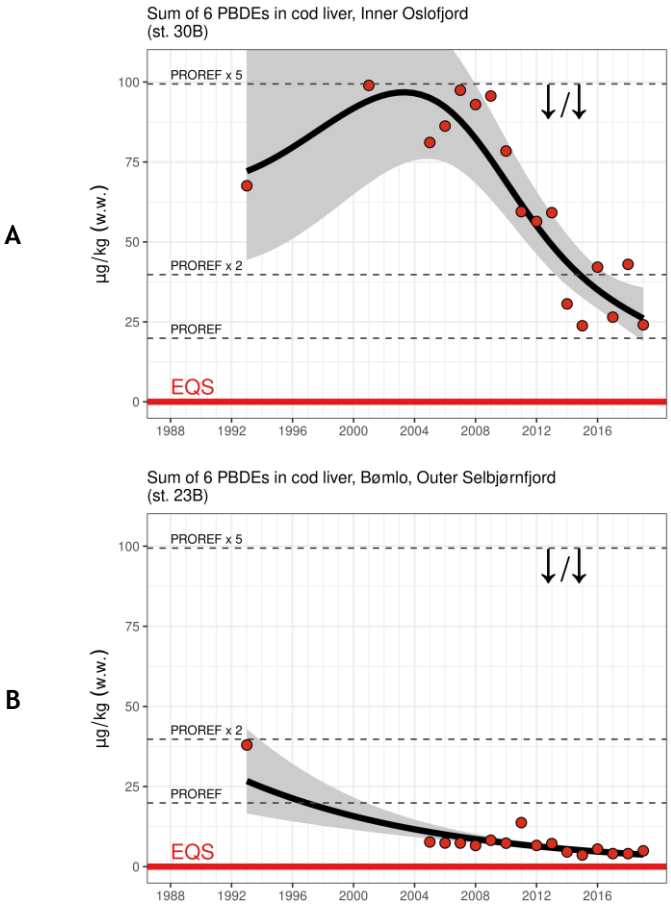


Figure 55. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 1993 or 2009 to 2019 in Inner Oslofjord (st. 30B) (**A**) and at Bømlo (st. 23B) (**B**). (see **Figure 4** and **Appendix C**.)*

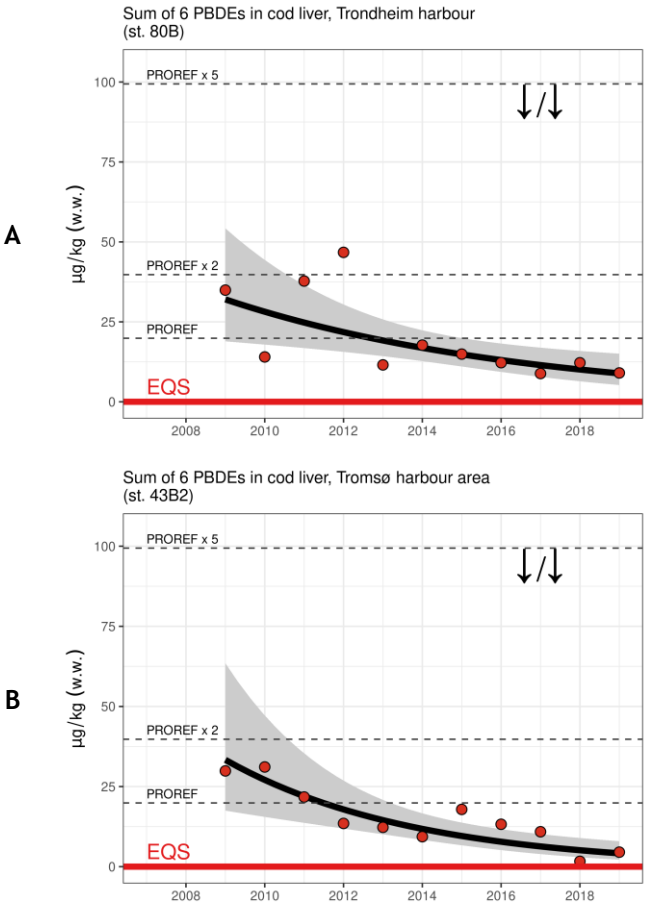


Figure 56. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 2009 to 2019 at Trond*heim harbour (st. 80B) ***(A)*** *and Tromsø harbour (*st. 43B2) ***(B)****. (see* ***Figure 4*** *and* ***Appendix C****.)*

Levels in blue mussel

In 2019, the most dominant congener in mussel was BDE47. BDE47 is a main constituent of the commercial flame retardant mixture pentabromocyclododecane or pentaBDE. It was detected in all blue mussel sampled in 2019. The 2019 findings are similar to the findings from 2018 which found BDE47 in all samples and showed it to be the predominant congener. The highest median concentrations of BDE47 were found in mussels from Vågsvåg (st. 26A2) in the Outer Nordfjord and Bodø harbour (st. 97A3) (0.110 µg BDE47/kg w.w.).

The congeners BDE28, 47, 99, 100, 154 and 209 showed concentrations above the LOQ for half or more of the samples at all stations (***Table 12***, ***Table 16***, ***Figure 58***).

The highest median concentration was BDE209 found in mussels from Ørland area (st. 91A2) in the Outer Trondheimfjord(st. 97A3) (0.342 µg BDE209/kg w.w.) (***Figure 58 B***). The second most dominant congener in 2019 was BDE47, which was also the case in 2018. BDE47 was detected at all stations in 2019, as in 2018. The highest median concentration was found in mussels from Vågsvåg (st. 26A2) in the Outer Nordfjord and in Bodø harbour (st. 97A3) (0.110 µg BDE47/kg w.w.).

Blue mussels from Nordnes (st. I241) in Bergen harbour, Bodø harbour (st. 97A3) and Vågsvåg (st. 26A2) showed significantly higher concentrations of BDE47 than mussels from all the other stations (Tukey-Kramer HSD test, see also ***Figure 58***).

Levels in cod liver

In 2019, the most dominant congener in cod liver was BDE47, as for blue mussel. It was detected at all cod stations sampled in 2019. The 2019 findings are similar to the findings from 2018 which found BDE47 in all samples and showed it to be the predominant congener. The highest median concentration of BDE47 was found in cod liver from Bergen harbour (25.5 µg BDE47/kg w.w.).

The standard deviation varied considerably among stations, also for other PBDEs. The highest standard deviation was found in Bergen harbour (st. 24B) for BDE47 (***Table 16***) in 2019. It seems like variation was highest in affected areas.

In the urban areas like Oslo and Bergen harbour, some of the BDE-congeners in cod liver showed higher levels than in remote areas. For example, the dominant congeners BDE47 and BDE100 were significantly higher in these two harbours than at Færder and Bømlo (Tukey-Kramer HSD test).

PBDEs have been investigated annually in cod liver since 2005. In the Inner Oslofjord (st. 30B), cod have also been analysed for PBDEs in 1993, 1996 and 2001 (***Figure 59***). Samples for similar analyses were also collected from Tjøme (st. 36B) in 1993 and 1996, and from Bømlo (st. 23B) on the west coast in 1996 and 2001. In 2019, PBDEs were analysed in cod from 11 stations (***Table 16***). Of the PBDEs, congeners BDE28, 47, 99, 100, 126 and 154 were above the limit of quantification (LOQ) in at least half of the samples from each station in cod liver.

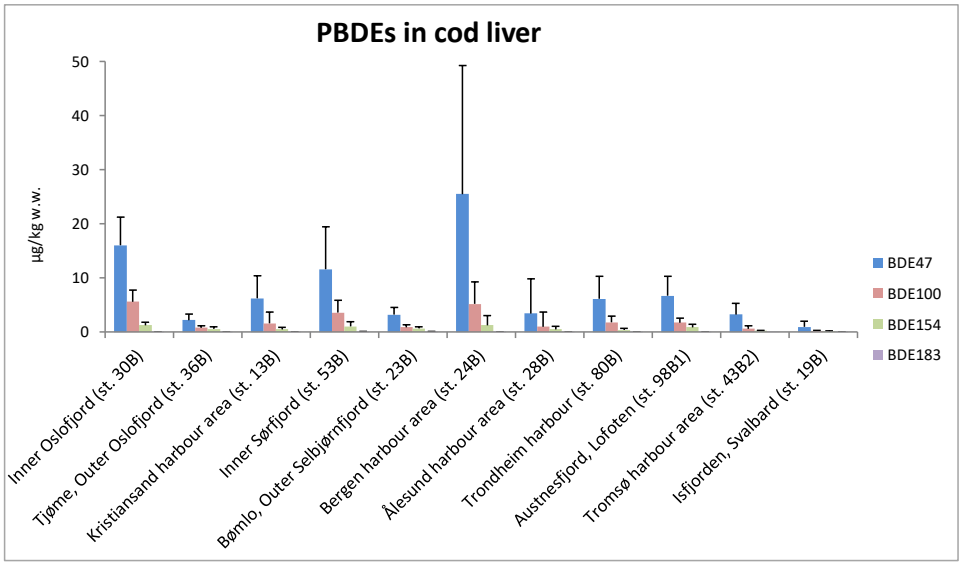
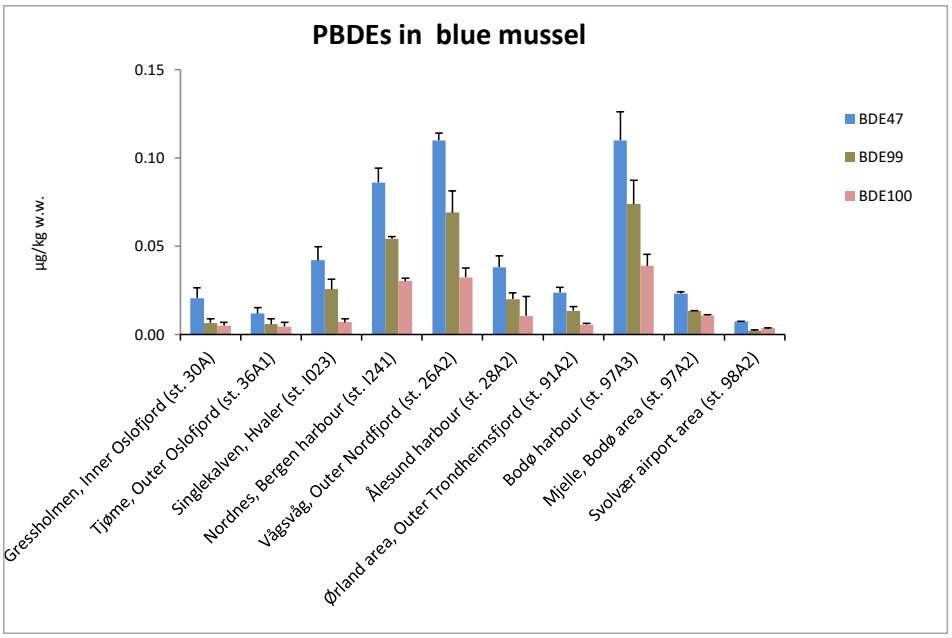


Figure 57*. Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2019. Only results where concentrations were above the limit of quantification (LOQ) for half or more of the samples are shown. The error bar indicates one standard deviation above the median.*

A



B

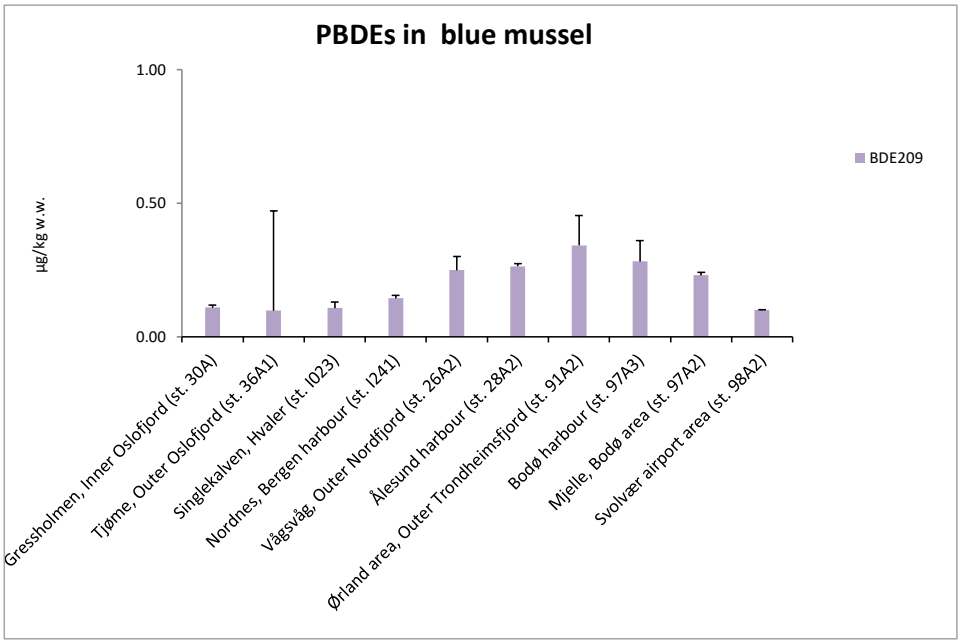


***Figure 58**. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2019; BDE47, BDE99 and BDE100 (**A**) and BDE209 (**B**). Only results where concentrations were above the limit of quantification (LOQ) for half or more of the samples are shown. The error bar indicates one standard deviation above the median.*

***Table 16**. Median concentrations (µg/kg w.w.) and standard deviations (S.d.) for PBDE congeners in blue mussel, cod liver, and eider blood and eggs in 2019. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. BDE6S is the sum of BDE -28, -47, -99, -100, -153 and -154 as used in the EQS, whereas BDESS is the sum of all PBDEs analysed (see **Table 7**, see also **Chapter 2.11** for more details and **Appendix B** for description of chemical codes).*

Component	Count	BDE28			BDE47			BDE99			BDE100			BDE126			BDE153		
Species and sampling locality	2019	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																			
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.001	0.000	1 [0.0012]	0.021	0.006	3 [0.0184-0.0292]	0.007	0.002	3 [0.0061-0.0103]	0.005	0.002	3 [0.0043-0.0076]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.001	0.000	2 [0.0011-0.0015]	0.012	0.003	3 [0.0103-0.0168]	0.006	0.003	3 [0.0048-0.0108]	0.005	0.002	3 [0.0037-0.0081]	0.002	0.001	1 [0.0035]	0.003	0.004	1 [0.0099]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.002	0.001	3 [0.0016-0.0031]	0.042	0.008	3 [0.0323-0.0474]	0.026	0.006	3 [0.0196-0.031]	0.007	0.002	3 [0.0063-0.0098]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.003	0.000	3 [0.0031-0.0035]	0.086	0.008	3 [0.0843-0.0995]	0.054	0.001	3 [0.0525-0.0552]	0.030	0.002	3 [0.0288-0.0321]	0.002	0.000	0 [n.a.]	0.005	0.000	3 [0.0044-0.0046]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.002	0.000	3 [0.0019-0.0023]	0.110	0.004	3 [0.103-0.11]	0.069	0.012	3 [0.0589-0.0833]	0.032	0.005	3 [0.0292-0.0394]	0.002	0.000	0 [n.a.]	0.005	0.000	3 [0.0042-0.0051]
Ålesund harbour (st. 28A2)	3 (3-50)	0.001	0.000	2 [0.0011-0.0014]	0.038	0.006	3 [0.0278-0.0396]	0.020	0.004	3 [0.0153-0.0224]	0.011	0.011	3 [0.0093-0.0291]	0.002	0.001	1 [0.003]	0.003	0.000	0 [n.a.]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.001	0.000	2 [0.0012-0.0012]	0.024	0.003	3 [0.0188-0.0241]	0.013	0.002	3 [0.0101-0.0147]	0.006	0.001	3 [0.0052-0.0063]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Bodø harbour (st. 97A3)	3 (3-50)	0.003	0.000	1 [0.0024]	0.110	0.016	3 [0.0917-0.124]	0.074	0.013	3 [0.06-0.0869]	0.039	0.007	3 [0.0335-0.0466]	0.005	0.001	0 [n.a.]	0.008	0.001	0 [n.a.]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.002	0.000	0 [n.a.]	0.023	0.001	3 [0.0217-0.0234]	0.013	0.000	3 [0.0129-0.0136]	0.011	0.000	3 [0.0104-0.011]	0.005	0.000	0 [n.a.]	0.007	0.000	0 [n.a.]
Svolvær airport area (st. 98A2)	3 (3-50)	0.001	0.000	0 [n.a.]	0.007	0.000	3 [0.007-0.0074]	0.002	0.000	3 [0.0022-0.0028]	0.004	0.000	3 [0.0034-0.0037]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Cod, liver																			
Inner Oslofjord (st. 30B)	14 (11-4)	0.322	0.108	14 [0.122-0.533]	16.050	5.180	14 [6.51-26]	0.560	0.311	14 [0.126-1.21]	5.610	2.152	14 [2.21-8.68]	0.052	0.074	14 [0.0199-0.305]	0.061	0.031	11 [0.0377-0.122]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-3)	0.092	0.039	5 [0.0632-0.152]	2.220	1.082	5 [1.15-4.14]	0.020	0.072	3 [0.0202-0.185]	0.798	0.352	5 [0.214-1.12]	0.081	0.081	4 [0.0738-0.237]	0.030	0.002	1 [0.0346]
Kristiansand harbour area (st. 13B)	9 (3-4)	0.191	0.263	9 [0.0699-0.936]	6.240	4.144	9 [1.71-16]	0.089	0.073	8 [0.0289-0.244]	1.610	2.075	9 [0.548-7.57]	0.028	0.019	7 [0.0231-0.0721]	0.033	0.014	5 [0.0334-0.0698]
Inner Sørfjord (st. 53B)	15 (6-4)	0.358	0.274	15 [0.0845-1.12]	11.600	7.892	15 [2.55-31.7]	0.118	0.227	13 [0.0299-0.838]	3.580	2.281	15 [0.714-9.79]	0.156	0.078	14 [0.0259-0.322]	0.031	0.034	8 [0.0305-0.141]
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.169	0.075	15 [0.0545-0.257]	3.230	1.300	15 [1.16-4.52]	0.026	0.023	11 [0.0193-0.104]	0.892	0.494	15 [0.246-1.98]	0.025	0.012	9 [0.0247-0.0629]	0.028	0.011	6 [0.0336-0.0655]
Bergen harbour area (st. 24B)	14 (4-4)	0.662	1.115	14 [0.358-4.69]	25.500	23.711	14 [12-94]	0.924	1.960	14 [0.0438-5.43]	5.210	4.101	14 [1.97-16.9]	0.048	0.040	13 [0.0307-0.149]	0.229	0.177	13 [0.0303-0.523]
Ålesund harbour area (st. 28B)	15	0.181	0.172	15 [0.07-0.793]	3.440	6.421	15 [1.23-27.6]	0.145	0.112	15 [0.0662-0.442]	0.994	2.700	15 [0.389-11.3]	0.042	0.051	14 [0.0229-0.229]	0.039	0.040	8 [0.0392-0.175]
Trondheim harbour (st. 80B)	11	0.230	0.255	11 [0.12-0.828]	6.160	4.139	11 [2.02-13.7]	0.095	0.159	11 [0.024-0.412]	1.800	1.112	11 [0.5-3.82]	0.076	0.046	8 [0.0402-0.151]	0.029	0.008	4 [0.0351-0.0517]
Austnesfjord, Lofoten (st. 98B1)	15	0.565	0.333	15 [0.0475-1.45]	6.690	3.587	15 [0.903-15.1]	0.081	0.031	13 [0.0325-0.114]	1.740	0.871	15 [0.208-3.64]	0.063	0.032	12 [0.0372-0.127]	0.028	0.001	0 [n.a.]
Tromsø harbour area (st. 43B2)	15	0.137	0.063	15 [0.0277-0.289]	3.260	2.031	15 [0.967-7.34]	0.060	0.048	14 [0.0305-0.199]	0.635	0.522	15 [0.276-2.19]	0.020	0.013	5 [0.0209-0.0602]	0.030	0.000	0 [n.a.]
Isfjorden, Svalbard (st. 19B)	15	0.056	0.062	15 [0.0321-0.273]	0.964	1.081	15 [0.36-4.9]	0.020	0.000	0 [n.a.]	0.175	0.183	15 [0.0504-0.832]	0.020	0.002	2 [0.0217-0.0279]	0.030	0.000	0 [n.a.]
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14	0.004	0.001	0 [n.a.]	0.020	0.006	14 [0.0117-0.0296]	0.009	0.006	13 [0.007-0.0275]	0.004	0.002	6 [0.0035-0.0083]	0.003	0.001	0 [n.a.]	0.007	0.002	0 [n.a.]
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.000	0 [n.a.]	0.045	0.014	15 [0.0181-0.0598]	0.016	0.015	9 [0.0157-0.0595]	0.026	0.016	13 [0.0129-0.0559]	0.003	0.001	0 [n.a.]	0.007	0.004	4 [0.0088-0.0165]

Table 16. *(cont.)*

Component	Count	BDE154			BDE183			BDE196			BDE209			BDE6S			BDESS		
Species and sampling locality	2019	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																			
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.109	0.010	0 [n.a.]	0.039	0.010	0 [n.a.]	0.256	0.017	3 [0.0358-0.0541]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.003	0.004	1 [0.01]	0.005	0.004	1 [0.0111]	0.010	0.003	1 [0.0159]	0.098	0.373	1 [0.745]	0.029	0.017	1 [0.745]	0.223	0.469	3 [0.0264-0.0567]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.003	0.001	3 [0.003-0.0044]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.108	0.021	2 [0.108-0.14]	0.083	0.016	2 [0.108-0.14]	0.279	0.038	3 [0.0659-0.0987]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.007	0.001	3 [0.0063-0.009]	0.005	0.000	1 [0.0057]	0.010	0.000	0 [n.a.]	0.144	0.011	3 [0.128-0.15]	0.184	0.011	3 [0.128-0.15]	0.472	0.023	3 [0.1827-0.202]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.007	0.000	3 [0.0057-0.0066]	0.005	0.000	0 [n.a.]	0.016	0.002	3 [0.013-0.0177]	0.249	0.052	3 [0.229-0.327]	0.218	0.019	3 [0.229-0.327]	0.680	0.069	3 [0.2103-0.2462]
Ålesund harbour (st. 28A2)	3 (3-50)	0.005	0.002	3 [0.0041-0.0078]	0.005	0.000	0 [n.a.]	0.017	0.006	2 [0.0112-0.024]	0.264	0.009	1 [0.249]	0.077	0.021	1 [0.249]	0.563	0.021	3 [0.0615-0.1033]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.001	0 [n.a.]	0.017	0.008	1 [0.0154]	0.342	0.112	2 [0.148-0.342]	0.049	0.005	2 [0.148-0.342]	0.612	0.178	3 [0.0431-0.0521]
Bodø harbour (st. 97A3)	3 (3-50)	0.010	0.001	2 [0.0095-0.0106]	0.013	0.001	0 [n.a.]	0.026	0.002	0 [n.a.]	0.282	0.079	3 [0.237-0.39]	0.243	0.037	3 [0.237-0.39]	0.779	0.070	3 [0.2039-0.2772]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.007	0.000	0 [n.a.]	0.012	0.001	0 [n.a.]	0.023	0.001	0 [n.a.]	0.230	0.012	0 [n.a.]	0.063	0.001	0 [n.a.]	0.505	0.023	3 [0.0615-0.0638]
Svolvær airport area (st. 98A2)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.100	0.001	0 [n.a.]	0.020	0.000	0 [n.a.]	0.214	0.001	3 [0.0197-0.0205]
Cod, liver																			
Inner Oslofjord (st. 30B)	14 (11-4)	1.280	0.553	14 [0.667-2.87]	0.050	0.008	1 [0.0762]	0.100	0.027	0 [n.a.]	1.000	0.266	0 [n.a.]	24.084	7.052	0 [n.a.]	27.996	8.213	14 [9.665-36.9643]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-3)	0.553	0.376	5 [0.152-1.15]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.013	0 [n.a.]	4.124	1.572	0 [n.a.]	6.568	2.005	5 [1.6388-6.0536]
Kristiansand harbour area (st. 13B)	9 (3-4)	0.533	0.362	9 [0.21-1.19]	0.050	0.003	0 [n.a.]	0.097	0.033	1 [0.158]	1.530	0.412	0 [n.a.]	8.368	6.701	0 [n.a.]	11.393	7.112	9 [2.7217-25.9172]
Inner Sørfjord (st. 53B)	15 (6-4)	1.060	0.898	15 [0.107-3.88]	0.050	0.003	2 [0.0488-0.0614]	0.101	0.017	0 [n.a.]	1.170	0.262	0 [n.a.]	16.758	11.082	0 [n.a.]	22.142	12.295	15 [3.5055-43.636]
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.651	0.290	15 [0.19-1.15]	0.047	0.002	0 [n.a.]	0.094	0.004	0 [n.a.]	0.935	0.151	2 [1.05-1.49]	4.938	2.077	2 [1.05-1.49]	7.328	2.326	15 [1.7606-7.8526]
Bergen harbour area (st. 24B)	14 (4-4)	1.275	1.743	14 [0.173-5.93]	0.045	0.109	5 [0.0712-0.45]	0.091	0.031	4 [0.106-0.192]	0.949	0.286	6 [1.05-1.71]	36.776	28.762	6 [1.05-1.71]	43.745	34.147	14 [16.9686-121.085]
Ålesund harbour area (st. 28B)	15	0.547	0.543	15 [0.221-2.47]	0.048	0.038	4 [0.0516-0.181]	0.132	0.039	9 [0.103-0.206]	1.450	0.281	0 [n.a.]	5.442	9.746	0 [n.a.]	9.374	10.197	15 [2.3761-42.2712]
Trondheim harbour (st. 80B)	11	0.392	0.334	11 [0.256-1.21]	0.049	0.002	0 [n.a.]	0.098	0.003	0 [n.a.]	1.000	0.163	4 [1.2-1.44]	9.029	5.883	4 [1.2-1.44]	15.260	7.482	11 [3.021-19.4651]
Austnesfjord, Lofoten (st. 98B1)	15	0.911	0.519	15 [0.182-1.99]	0.046	0.002	0 [n.a.]	0.093	0.004	0 [n.a.]	0.926	0.691	3 [0.911-3.61]	10.113	5.283	3 [0.911-3.61]	13.185	6.741	15 [1.4326-22.2452]
Tromsø harbour area (st. 43B2)	15	0.240	0.103	15 [0.138-0.475]	0.050	0.000	0 [n.a.]	0.100	0.018	1 [0.17]	1.320	0.848	3 [2.31-3.91]	4.532	2.591	3 [2.31-3.91]	8.009	2.722	15 [1.5611-9.4945]
Isfjorden, Svalbard (st. 19B)	15	0.138	0.112	15 [0.0624-0.52]	0.050	0.000	0 [n.a.]	0.100	0.022	0 [n.a.]	1.000	0.466	0 [n.a.]	1.342	1.427	0 [n.a.]	4.260	1.791	15 [0.5665-6.575]
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14	0.005	0.001	2 [0.0056-0.006]	0.005	0.001	0 [n.a.]	0.007	0.002	0 [n.a.]	0.428	0.117	14 [0.355-0.739]	0.051	0.014	14 [0.355-0.739]	0.606	0.154	14 [0.038-0.082]
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.023	0.012	13 [0.0108-0.0439]	0.005	0.001	0 [n.a.]	0.007	0.001	0 [n.a.]	0.194	0.127	11 [0.116-0.561]	0.143	0.049	11 [0.116-0.561]	0.447	0.127	15 [0.0644-0.1971]

The Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with several urban activities where PBDEs are involved. The high concentrations of PBDEs observed in cod are probably related to these activities, as well as reduced water exchange with the Outer fjord.

In the present study, cod liver from the Inner Oslofjord showed a median concentration of 16.1 µg BDE47/kg (w.w.), and the mean concentration in a comparable study in 2019 (Ruus 2020 In prep) was 22.2 µg BDE47/kg (w.w.). The median concentration of BDE100 was 5.6 µg /kg (w.w.) in the present study, while the mean concentration was 6.1 µg/kg (w.w.) in the study performed by Ruus *et al*. (Ruus). The median concentration of BDE154 was 1.3 µg/kg (w.w.) in the present study, while the mean concentration was 1.136 µg/kg (w.w.) in the comparable study (Ruus 2020 In prep). The collection of cod in both studies took place during the autumn.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of sum BDEs (28, 47, 99, 100, 153 and 154) were 0.051 µg/kg w.w. in blood and 0.143 µg/kg w.w. in eggs. The concentrations of BDE47 in eider were 0.020 µg/kg w.w. in blood and 0.045 µg/kg w.w. in eggs.

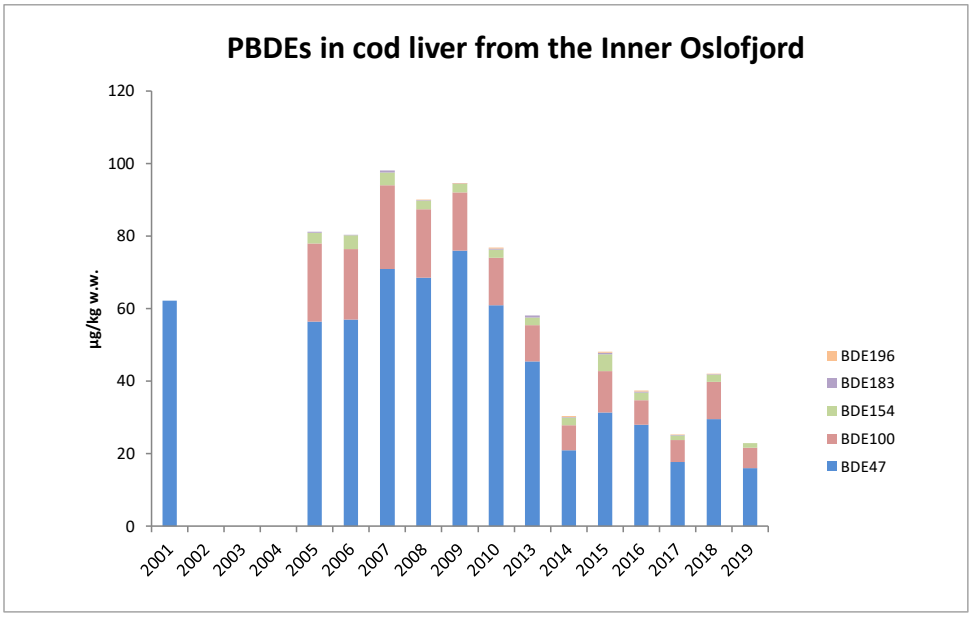


Figure 59. *Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2019 in the Inner Oslofjord (st. 30B).*

Comparison with other studies

Median concentrations for the sum BDEs (BDE28, 47, 66, 49+71, 77, 99, 100, 119, 153, 154, 183 and 209) found at presumed reference stations like Lofoten (8.49 µg/kg w.w.), Færder (9.61 µg/kg w.w.), Lista (12.9 µg/kg w.w.) and Bømlo-Sotra (23.8 µg/kg w.w.) indicate background levels in diffusely contaminated areas for cod liver (Fjeld 2005). This is lower than the sum BDEs (28, 47, 99, 100, 153 and 154) (24.1 µg/kg w.w.) found at MILKYS cod stations in the Inner Oslofjord (st. 30B) in 2019 (cf. ***Figure 57***).

The congeners BDE47 and 100 were the most dominant in 2019, as in previous years. The low concentrations of BDE99 could be due to the debromination to BDE47, because BDE99 is more prone to biotransformation than other common PBDE such as BDE47 (Streets *et al*. 2006). Furthermore, BDE47 is also reported to be a more stable congener than BDE99 (Benedict *et al*. 2007). Investigations of brown trout (*Salmo trutta)*, smelt (*Osmerus eperlanus*) and vendace (*Coregonus albula*) in lake Mjøsa showed that the decrease was greatest for BDE99, which probably is due to a biotransformation (debromination) to BDE47 (Fjeld 2012). In recent years, there has been a clear reduction of PBDE concentrations in freshwater fish from Mjøsa (Jartun 2020 In prep).

In the present study, the median concentration of PBDE47 (0.045 µg/kg w.w.) in eider eggs from Svalbard was lower than in another study of eider from three stations in northern Norway and one at Svalbard (mean 0.12 ± 0.06 µg/kg w.w.) (Harju 2013). A comparable study of eider duck from the Inner Oslofjord in 2017, found mean values of 0.385 µg PBDE47/kg w.w. in eggs (Ruus 2018), which was eight times higher than at Svalbard.

General, large scale trends

Time-trend analyses showed upward trends in concentrations of some PBDE congeners; both significant upward long- and short-term trends were found for BDE99 in cod liver from Bergen harbour (st. 24B). A significant upward short-term trends was found for BDE154 in cod liver from the Austnesfjord in Lofoten (st. 98B1). BDE99 is a main constituent of the penta-BDE flame retardant mixtures, while BDE154 is a main component of the hexa-BDE flame retardant mixtures.

There was a total of 40 significant downward long-term trends (sum BDE not included), 11 were found in blue mussel and 29 in cod liver. Of 28 significant downward short-term trends, five were found in blue mussel and 23 in cod liver.

These results of dominating downward trends are more in line with the general decreasing trends for the commercial penta-BDE mixture (that includes BDE100) (Law *et al*. 2014), declining European emissions of PBDE (Schuster *et al*. 2010) and lower concentrations of PBDEs in marine mammals in the Arctic and North Atlantic since 2000 (Rotander *et al*. 2012). It can be noted that after 2002 a sharp decline in concentrations of PBDEs (as well as PFASs) was observed in blood from newborns in New York state (Ma *et al*. 2013). Furthermore, both the penta- and octa PBDE mixtures were listed in the Stockholm Convention and has been regulated globally through since 2010.

Emissions of PBDEs to air and discharges to water from land-based industries can be seen in ***Figure 60***. In 2016, the emission to air was 0,03 kg brominated diphenyl ethers. The discharges to water were 1,7 kg brominated diphenyl ethers in 2017 and 0 kg in 2019.

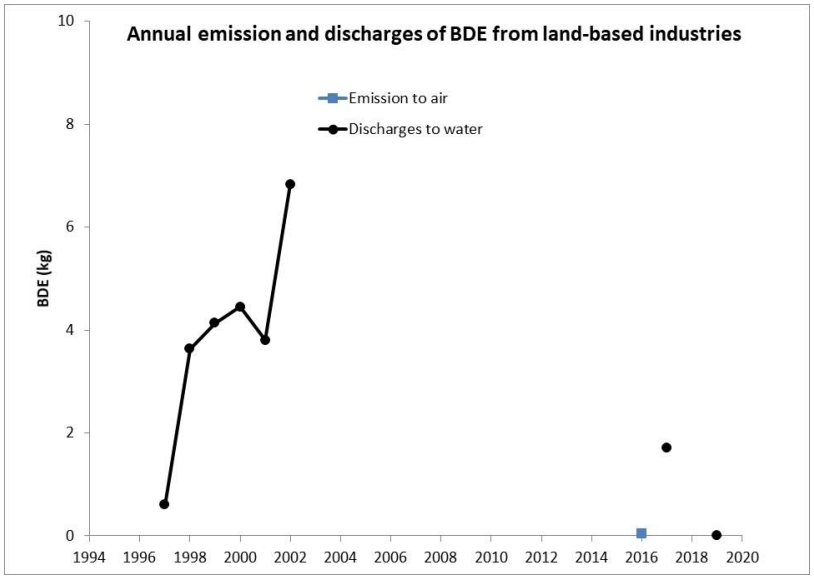


Figure 60. *Annual emissions* of *PBDEs to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 3 June 2020). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.24 Perfluorinated alkylated substances (PFAS)

Perfluorinated alkylated substances (PFAS) are organofluorine compounds used as oil-, stain- and water-repellent surfactants and in several other applications. There are approximately 6330 PFASs on the marked globally, and firefighting foam was the largest source to PFOS in the Norwegian environment until the ban in 2007[1]. In the present study, PFAS were analysed in blue mussel at six stations, cod liver at 10 stations, and in eider blood and eggs at one station (***Table 3***, ***Table 12***,

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/perfluorerte-stoffer-pfos-pfoa-og-andre-pfas-er/

Figure 62). PFAS have been analysed annually in cod liver since 2005, as well as in 1993 for the Inner Oslofjord (st. 30B) and Bømlo (st. 23B).

Environmental Quality Standards (EQS) for priority substances
The EQS for perfluorooctanesulfonic acid (PFOS) in biota (fish) is 9.1 µg/kg w.w. which applies to whole fish (Directive 2013/39/EU on priority substances in the field of water policy). Applying this for blue mussel, all stations were below the EQS (***Table 11***). The EQS cannot be directly compared to concentrations found in different tissues of fish. We have in the present study only measured PFOS in liver and have not considered converting liver to whole fish because this conversion is uncertain. If it is assumed, for this exercise, that the same concentration is found in cod liver as in the whole fish, then the results of PFOS would not be exceeded at any station (maximum concentration 4.1 µg/kg w.w. in the Inner Oslofjord (st. 30B) (***Table 11***). Applying this EQS for eider blood and eggs, the PFOS concentrations were below the EQS (***Table 11***).

Environmental Quality Standards (EQS) for river basin specific pollutants
The EQS for perfluorooctanoic acid (PFOA) is 91.3 µg/kg w.w. in biota (2013/39/EU). Applying this for blue mussel, cod liver, and eider blood and eggs, all concentrations of PFOA were below EQS (***Table 11***).

Increase in PROREF factor since 2018
In 2019, cod liver from the Inner Oslofjord (st. 30B) exceeded the Norwegian provisional high reference contaminant concentrations (PROREF) for perfluorooctanesulfonamide (PFOSA) by a factor up to two times. In 2018, there was no exceedance at this station.

Decrease in PROREF factor since 2018
In 2019, the level of PFAS in cod liver from Tjøme (st. 36B) in the Outer Oslofjord was below the PROREF. In 2018, the exceedance was by a factor of two to five. In 2018, PFOSA levels in cod at this station exceeded PROREF by a factor of five to 10, compared to no exceedance in 2019.

Downward trends in cod liver
For both PFOS and PFOSA, both significant downward long- and short-term trends were found in cod liver from Kristiansand harbour (st. 13B), the Austnesfjord (st. 98B1) in Lofoten and Tromsø harbour (st. 43B2). Both significant downward long- and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B) regarding PFOS, and in the Inner Sørfjord (st. 53B), at Bømlo (st. 23B) in the Outer Selbjørnfjord and in Trondheim harbour (st. 80B) for PFOSA. Significant downward long-term trends were found for PFOS in cod liver from Tjøme (st. 36B) in the Outer Oslofjord, the Inner Sørfjord (st. 53B) and Trondheim harbour (st. 80B). For PFOSA, both significant downward long- and short-term trends were found in cod liver from Bømlo (st. 23B) in the Outer Selbjørnfjord, the Inner Sørfjord (st. 53B) and Trondheim harbour (st. 80B). For PFOSA, a significant downward short-term trend was found in cod liver from the Inner Oslofjord (st. 30B). Both significant downward long- and short-term trends were also found in the Inner Sørfjord (st. 53B) for perfluorononanoic acid (PFNA).

Levels in cod
In cod liver, the highest median concentration of PFOS was found in the Inner Oslofjord (st. 30B) (4.1 µg/kg w.w.) and the lowest level was observed in Tromsø harbour (st. 43B2, 0.290 µg/kg w.w.) (***Figure 62***, ***Figure 63***, ***Table 17***). At Tjøme (st. 36B) the PFOS concentrations had decreased from 7.4 µg/kg (w.w.) in 2018 to 3.3 µg/kg (w.w.) in 2019. Maximum median concentration of PFOSA was 6.3 µg/kg (w.w.) in cod liver from the Inner Oslofjord (st. 30B), and a minimum level was found in Tromsø harbour (st. 43B2) (0.120 µg/kg w.w.) (***Figure 62***, ***Figure 63***). In 2019, the concentration of PFOSA was higher than PFOS in the Inner Oslofjord (st. 30B) and at Tjøme (st. 36B). PFOSA was

significantly higher in cod liver from the Inner Oslofjord (st. 30B) than any other station (Tukey-Kramer HSD test). In cod liver, all concentrations of PFNA (perfluorononanoic acid) were below LOQ (<0.500 µg/kg w.w.). The median concentrations of the remaining PFASs were mostly below LOQ (***Table 17***).

Levels in blue mussel

Data for PFAS in blue mussel are not sufficient to analyse trends or PROREF. In blue mussel, the concentration of PFOS at all six stations were below LOQ (<0.100 µg/kg w.w.). At Gressholmen (st. 30A), the concentration of PFOSA was 0.630 µg/kg w.w. The concentrations of PFOSA were 0.280 µg/kg w.w. at Tjøme (st. 36A1), 0.150 µg/kg w.w. at Nordnes (st. I241) in Bergen harbour, 0.130 µg/kg w.w. at Espevær (st. 22A) in the Outer Bømlafjord and 0.100 µg/kg w.w. in Svolvær airport area (98A2) in Lofoten. In blue mussel, all concentrations of PFNA (perfluorononanoic acid) were below LOQ (<0.500 µg/kg w.w.). The median concentrations of the remaining PFASs were mostly below LOQ (***Table 17***).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PFOS were 0.390 µg/kg w.w. in blood and 1.5 µg/kg w.w. in eggs. The concentrations of PFOA were <0.500 µg/kg w.w. in blood and <0.500 µg/kg w.w. in eggs.

The Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities including presence of PFOSA in certain products. PFOSA is a precursor compound in the production of fluorinated polymers but may also add to the exposure due to their degradation into PFOS. The high concentrations of PFOSA observed in cod are probably related to these activities, as well as reduced water exchange with the Outer Oslofjord.

In the present study, cod liver from the Inner Oslofjord had median concentrations of 4.1 µg PFOS/kg (w.w.) and 6.3 µg PFOSA/kg (w.w.) in 2019. Cod liver from a comparable study from the Inner Oslofjord in 2019 had mean concentrations of PFOS (4.5 µg/kg w.w.) within the same level, but higher concentrations of PFOSA (13.4 µg/kg w.w.) (Ruus 2020 In prep). There are major differences in PFAS accumulation at individual level in the comparable study. The collection of cod in both studies took place during the autumn, in the present study in November and in August in the comparable study. PFAS were analysed at NIVA in both studies.

Schøyen and Kringstad (2011) analysed PFAS in cod blood samples from the same individuals as were analysed in the MILKYS programme in 2009 from the Inner Oslofjord (Green *et al.* 2010). They found that PFOSA was the most dominant PFAS-compound with a median level six times higher than for PFOS. The median level of PFOSA in cod blood was about five times higher than in liver while the median level of PFOS in cod liver was about 1.5 times higher than in blood. Further, PFNA was also detected in cod blood. Rundberget *et al.* (2014) investigated cod from Inner Oslofjord (st. 30B) in the period 2009 to 2013 and found that blood was the preferred matrix for analysing PFAS. The levels of PFOS were roughly the same in blood as in liver and bile, but levels of other PFAS were higher in blood and therefore easier to detect. A study of cod liver from the Inner Oslofjord in 2012 showed higher median concentration of PFOS, than the median concentration of PFOSA which was lower in cod from 2012 (Ruus 2014) as opposed to what was observed in the present study.

The Outer Oslofjord

There were high levels in cod liver at Tjøme in the Outer Oslofjord in 2018 (7.4 µg PFOS/kg w.w. and 44 µg PFOSA/kg w.w.) compared to 2019 (3.6 µg PFOS/kg w.w. and 6.0 µg PFOSA/kg w.w.). In

2017, Ruus *et al.* (2018) reported that several PFAS compounds (e. g. PFOS) was found in higher concentrations in the seagulls of the Outer Oslofjord (both blood and eggs), possibly related to contamination in the area because of an earlier airport in proximity of the colony. Use of firefighting foam with PFOS at former Rygge Airport at Vansjø has caused contamination of surrounding terrestrial and aquatic environment (Fjeld 2017). Another study has also related PFAS concentrations in blue mussel to earlier use of firefighting foam in the area of Mossesundet (Øxnevad, Brkljacic, and Borgersen 2016).

Comparison with other studies

Valdersnes *et al.* (2017) found that the levels of PFAS in cod liver along the Norwegian coast was low. PFOS was the dominant PFAS and was quantified in 72 % of the liver samples. The highest concentration (21.8 µg PFOS /kg w.w.) was found at Kragerø in the eastern part of Norway. Valdernes *et al.* (2017) found geographical differences, with highest PFOS concentrations in the eastern part compared to the western and northern part. This was due to higher population density and closeness to urbanized and industrialized regions in the Baltic and Northern Europe. Further, cod from the northern part had significantly higher liver weight and liver somatic index. The study found that it is conceivable that both geographical and biological factors contribute to variations in PFOS levels (Valdersnes *et al.* 2017).

In the Inner Ranfjord in 2019, blue mussel at the former MILKYS stations north of Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had concentrations of PFOS and PFOA below EQS (Øxnevad 2020d).

In the present study, the median concentrations of PFOS (1.5 µg/kg w.w.) and PFOSA (<0.1 µg/kg w.w.) in eider eggs from Svalbard were within the same ranges as in another study of eider from three stations in northern Norway and one at Svalbard (mean 3.7±2.3 µg PFOS/kg w.w. and 0.26±0.14 µg PFOSA/kg w.w.) (Harju 2013).

In the present study, the median concentrations were 0.390 µg PFOS/kg w.w. in blood and 1.5 µg PFOS/kg w.w. in eider eggs from Svalbard. A comparable study of eider duck from the Inner Oslofjord in 2019, found mean values of 9.97 µg PFOS/kg w.w. in blood and 23.21 µg PFOS/kg w.w. in eggs (Ruus 2019). The PFOS concentrations in eider blood and eggs are 10 times higher in the Inner Oslofjord than at Svalbard.

Median concentrations of PFOS in cod liver from presumed reference stations like Lofoten, Kvænangen/Olderfjord north of Skjervøy and the Varangerfjord indicated that high background concentrations in diffusely contaminated areas might be around 10 µg/kg w.w. (Bakke 2007). All concentrations observed in this present study were lower (maximum 4.1 µg/kg w.w.). The average concentration of PFOS in cod liver from two stations in the North Sea was 1.55 and 0.95 µg/kg w.w. (Green 2011) and from three stations in the Norwegian Sea was 0.75, 0.82 and 11 µg/kg w.w. (Green 2012).

PFAS compounds in freshwater fish were investigated in 2016 (Fjeld 2017). The concentrations of long-chained compounds, like PFOS and PFOSA, increased with trophic levels with the highest levels in brown trout liver. The mean PFOS concentrations in liver from brown trout (*Salmo trutta*), European smelt (*Osmerus eperlanus*), charr (*Salvelinus alpinus*) and vendace (*Coregonus albula*) from the three main lakes (Mjøsa, Randsfjord and Femunden) were in the range of 0.9–10 µg/kg w.w. While in the same study, the PFOS levels were considerably elevated in perch (*Perca fluviatilis*) liver from the Tyrifjord and Vansjø with mean concentrations of 194 and 329 µg/kg w.w., respectively. Jartun *et al.* (Jartun) showed downward trends for PFOS for all fish in

Lake Mjøsa in 2019 compared to levels in 2013/2014, but the concentrations have seemed to stabilize the last four years.

PFOA has been strictly regulated nationally in consumer products from June 2014[1]. PFOA-data at all stations was inadequate for trend analysis due to concerns about the limit of quantifications.

General, large scale trends

Seven of the 10 cod liver stations showed significant downward long-term trends in PFOS (for the period 2010-2019). Significant downward trends for PFOS were dominating since 2013. The observed downward trends could reflect the overall reduction in production and use of PFOS and PFOA for the past 30 years (Nost *et al.* 2014; Axmon *et al.* 2014). A decrease in concentrations of PFOS in Sweden has been reported for food items (Johansson *et al.* 2014) and herring (Ullah *et al.* 2014). A sharp decline in concentrations of PFAS (as well as PBDEs) after 2002 was found in dried blood spots from newborns in New York state (Ma *et al.* 2013).

Discharges of PFAS (per- and polyfluorinated compounds, SPFAS[2]) to water from land-based industries are shown in ***Figure 61***. The discharges to water had increased from 330 g PFAS in 2013 to 4171 g PFAS in 2017, end then decreased to 2614 g PFAS in 2019.

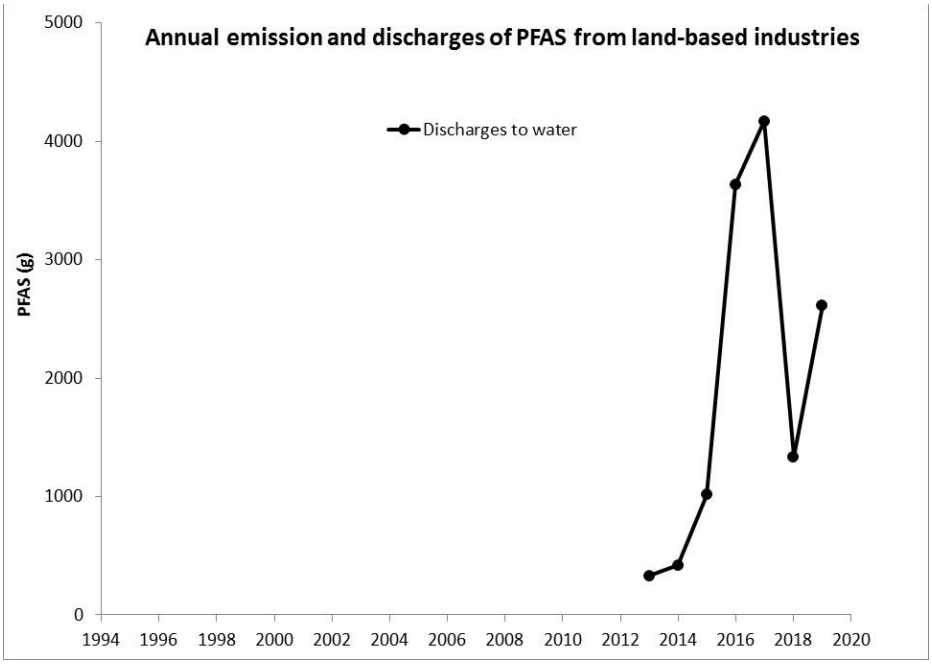


Figure 61. *Annual discharges of PFAS to water from land-based industries for 2013 to 2019 (data from www.norskeutslipp.no, 3. June 2020). No data for emissions to air are reported, and no data for discharges to water are reported for 1994-2012. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

[1] http://www.miljodirektoratet.no/no/Nyheter/Nyheter/2014/Mars-2014/Overgangsordning-for-miljogiften-PFOA-i-forbrukerprodukter/

[2] Inkluderer: PFOS, PFOA, 8:2 FTOH, 6:2FTS, C9 PFNA, C10PFDA, C11PFUnA, C12PFDoA, C13PFTrA, C14PFTeA, PFHxS, N-EtFOSA, N-Me FOSA, N-EtFOSE, N-Me FOSE. (See **Appendix B**.)

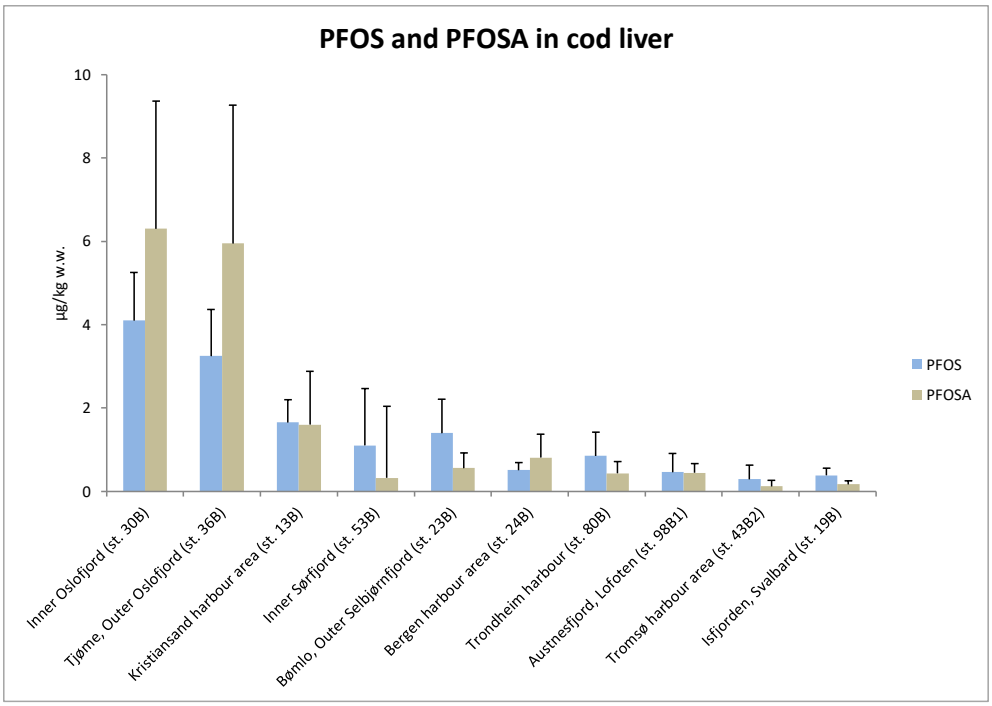


***Figure 62**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver in 2019. The error bar indicates one standard deviation above the median. (See also **Table 17**).*

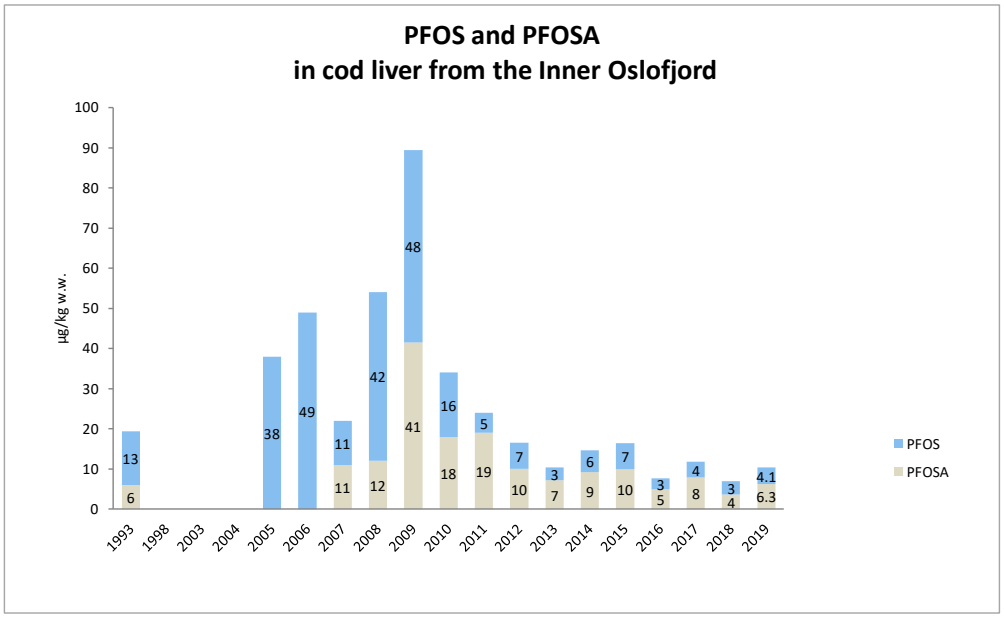


***Figure 63**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2019 in the Inner Oslofjord (st. 30B).*

***Table 17**. Median concentrations (µg/kg w.w.) and standard deviations (S.d.) of the PFAS-compounds analysed in blue mussel, cod liver, and eider blood and eggs in 2019. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter 2.11** for more details and **Appendix B** for description of chemical codes.)*

Component	Count	PFNA			PFOA			PFOS			PFOSA			PFUdA		
Species and sampling locality	2019	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Blue mussel																
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.63	0.0961	3 [0.51-0.7]	0.4	0	0 [n.a.]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.28	0.0208	3 [0.25-0.29]	0.4	0	0 [n.a.]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.13	0.0058	3 [0.12-0.13]	0.4	0	0 [n.a.]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.15	0.0058	3 [0.14-0.15]	0.4	0	0 [n.a.]
Ålesund harbour (st. 28A2)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.1	0.0058	1 [0.11]	0.4	0	0 [n.a.]
Svolvær airport area (st. 98A2)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.1	0	2 [0.1-0.1]	0.4	0	0 [n.a.]
Cod, liver																
Inner Oslofjord (st. 30B)	5 (5-3)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	4.1	1.1476	5 [2.6-5.6]	6.3	3.0705	5 [5.5-13]	1.5	0.4764	5 [1.2-2.4]
Tjøme, Outer Oslofjord (st. 36B)	6 (3-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	3.25	1.1089	6 [1.4-4.7]	5.95	3.3189	6 [2.8-10]	0.715	0.2225	5 [0.55-0.99]
Kristiansand harbour area (st. 13B)	10 (3-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.65	0.5421	10 [1-2.7]	1.6	1.2779	10 [0.35-4.7]	0.795	0.4158	10 [0.4-1.9]
Inner Sørfjord (st. 53B)	15 (6-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.1	1.3709	15 [0.67-5.2]	0.32	1.7141	14 [0.13-6.1]	1	0.5206	15 [0.52-2.1]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.4	0.8046	15 [0.65-3.7]	0.56	0.3543	15 [0.31-1.7]	0.5	0.1518	10 [0.44-0.96]
Bergen harbour area (st. 24B)	14 (4-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.51	0.1781	14 [0.19-0.78]	0.805	0.562	14 [0.27-2.1]	0.4	0	0 [n.a.]
Trondheim harbour (st. 80B)	11 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.85	0.5738	11 [0.27-2.2]	0.43	0.2835	11 [0.26-1.1]	0.42	0.1456	6 [0.42-0.8]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.46	0.4473	15 [0.17-2]	0.44	0.2246	15 [0.19-1]	0.4	0	0 [n.a.]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.29	0.3408	14 [0.13-1.3]	0.12	0.148	9 [0.1-0.61]	0.4	0.0319	2 [0.48-0.5]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.38	0.1759	15 [0.14-0.77]	0.17	0.0792	13 [0.1-0.39]	0.4	0.1001	6 [0.44-0.71]
Eider, blood																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.39	0.4026	14 [0.16-1.8]	0.1	0	0 [n.a.]	0.4	0	0 [n.a.]
Eider, egg																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.5	1.5289	15 [0.5-5.7]	0.1	0	0 [n.a.]	0.44	0.1129	8 [0.44-0.76]

3.2.25 PFAS emissions from contaminated sites - correlation between PFAS levels in a Norwegian coastal environment and distance to nearest airport

Perfluorinated compounds have attracted increased attention as hazardous substances in the environment in the last decade or more. Areas around industrial production, manufacturing, landfills and application sites (such as e.g. airports and firefighting training sites) have been found to be particularly contaminated by PFAS (Guelfo *et al*. 2018). There is therefore an increasing focus on regulating production and use of PFASs and PFAS related substances and to reduce their emissions in several countries (including in Norway), regions (e.g. EU[1] [2]) and on a global scale. According to information presented by the Norwegian Environment Agency (2020[3]), release of PFOS to the Norwegian environment have been associated with the following:

- Firefighting training sites[4] at
  - public airports (Avinor (n=45)
  - Norwegian Defence airports (n=10)
  - training sites used by municipal fire-fighters (n=248)
- Sites for industrial application and use (e.g. PFAS from a closed paper manufacturing site at Viul near Tyrifjorden, a freshwater lake near Oslo).
- Offshore industry (has historically employed PFOS in firefighting training, but PFOS has been phased out on nearly all platforms). In addition, the offshore industry has historically had some prePFOS detected (e.g. PFOSA).
- Landfills.

In addition, PFASs are present in many consumer products such as household items (including household dust), cosmetics[5] and textiles (Glüge *et al*. 2020). PFASs can therefore be released to wastewater, and PFASs are in general detected more frequently and in higher concentrations in urban areas than in remote areas. PFASs have never been produced in Norway, which means that all PFASs found in the environment comes from imported products/chemicals and are released during use e.g. of products.

As part of this study we investigated if PFAS concentrations found in biota samples correlated with the distance from airports since they allegedly are the most important sources to PFAS contamination. The distance was determined to the nearest airport or the nearest "upstream" airport (i.e. the airport with the shortest upstream distance). We assumed a negative correlation, i.e. the shorter the distance, the higher the concentrations.

Recent trends in PFAS levels in cod compared to historic MILKYS data
Figure 64 shows a comparison of historic MILKYS data for cod livers (2009 (PFOS and PFOSA) or 2012-2014 (PFUdA) with the latest data (2018 and/or 2019)) for all stations. It should be noted that this analysis is based on individual samples of cod, and hence, differs from the OSPAR method applied in ***section 3.2.24***, which is based on year-medians.

The yearly-median of PFOS concentrations in cod livers from five stations were approximately at or above the EQS of 9.1 µg/kg w.w. in 2009 (30B, 36B, 13B, 15B and 23B), while in 2019 the medians of all stations were below the EQS.

[1] https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe
[2] ECHA. 2020. Five European states call for evidence on broad PFAS restriction. [accessed 2020 Nov 3]. https://echa.europa.eu/-/five-european-states-call-for-evidence-on-broad-pfas-restriction.
[3] https://www.ngi.no/content/download/16940/1863001/file/#%206%20Nytt%20fra%20Milj%C3%B8direktoratet.pdf
[4] In general, the highest concentrations are found at firefighting training sites at airports. Norwegian airports have currently phased out PFOS and are now using fluorine free alternatives. However, other fire-fighting operations may still use PFAS (as indicated by Norconsult (2019)).
[5] https://www.framtiden.no/bilder/dokumenter/Notat2019_PFAS_i_kosmetikk_endelig.pdf

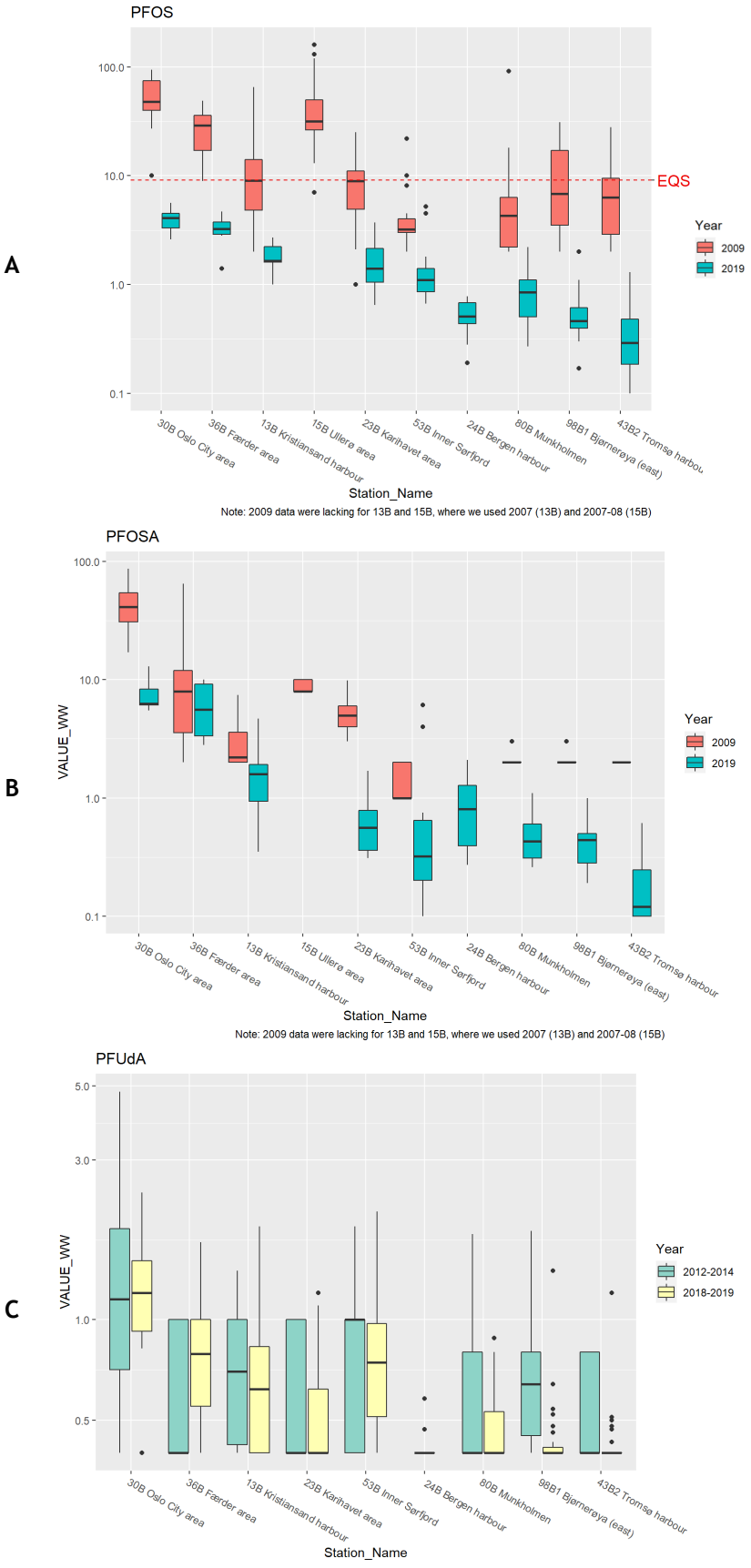


***Figure 64**. MILKYS historic concentrations (2009 (A,B) and 2012-14 (C)) of PFAS compared to current concentrations (2019). PFOS (**A**), PFOSA (**B**) and PFUdA (**C**). The EQS for PFOS are shown as*

a dotted red line. Please note the comments below figures A and B regarding the year presented for a few stations. Please also note that the scales (y-axes) are different.

In fact, almost all the cod samples analysed in 2019 were below the EQS. The exception was st. 36B in the Outer Oslofjord (n=6 samples above EQS) and st. 23B (n=1) at Bømlo where PFOS in cod was above the EQS in 2019. In general, there was approximately a 10-fold decrease for most stations. In general, stations with highest concentrations were stations south of 60 N (see also maps in ***Figure 89***, ***Appendix G***).

PFOSA had a lower detection frequency (see ***Table 32***, ***Appendix G***) than PFOS, and therefore inferences to trends are more difficult to make than for PFOS. PFOSA also had a downward trend, but less obvious than for PFOS for some stations. For stations st. 30B in the Inner Oslofjord and st. 23B there is a statistically significant decrease, while for st. 36B the decrease is not statistically significant (overlapping boxplots in ***Figure 64***). For three stations (80B, 98B1 and 43B2) the levels in 2009 were mostly below the LOQ. The LOQ has decreased with time because the analytical method has been improved.

PFUdA was not analysed until 2012, and therefore the time series for this PFAS is shorter than for PFOS and PFOSA. In addition, the concentrations of PFUdA is much lower than PFOS and PFOSA, and detection frequency was much lower. Therefore, any time trend is much more difficult to detect than for PFOS and PFOSA. Please note that the scale for concentrations of the boxplots for PFOS and PFOSA are the same, extending to 100 µg/kg w.w. in ***Figure 65***, while the scale for concentrations for PFUdA extends only to 5 µg/kg w.w. There were no stations with a clear upwards or downwards trend in concentrations of PFUdA. However, using the OSPAR-method based on yearly median concentrations, there were significant recent (2010-2019) downward trends for PFOS and PFOSA (see ***Chapter 3.2.24***).

Applying the OSPAR method on the PFOS values showed that the slopes (on a log scale) of the downward trends for PFOS are similar amongst the stations (***Table 18***) with a mean of -0.10 (see also ***Figure 90***, ***Appendix G***). This means that after a period of 10 years, the estimated means should be 1/10 of concentrations measured 10 years previously. This correlates well with the boxplots in ***Figure 65***. Even though the time trend for station 10B was upward, this station was only investigated twice (with sufficient samples) early in the period (2005 and 2007), and these results are therefore considered less reliable. For st. 15B in Farsund there were only three time-points investigated (2009-2011), and the results are therefore less reliable. The slopes are presented in ***Figure 65***, and apart from station 15B were comparable.

PFOS has been listed on EU's Chemical, Labelling and Packaging (CLP) register since 2008 and are included as a priority hazardous substance under the EU Water Framework Directive since 2013. A main of use PFOS was in firefighting foams. This use has been replaced by fluorine free alternatives at airports (2011[1]) and at offshore installations (Alling, 2020[2]) and might be one of the reasons for the decrease in concentrations found in fish along the coast. In an investigation of changes and the use of PFAS in chemicals in Norway over time, the use of PFAS in firefighting products has been significantly reduced since 2013 (Hovland, Steindal, and M. 2020 submitted). The reduction in the PFOS concentrations in cod livers as observed in this study, are therefore probably a result of stricter regulation of this compound.

PFOSA also showed a downward time trend for in cod livers at most stations investigated, with a mean slope of -0,073 (log scale). One slope was not significant (for st. 36B in the Outer Oslofjord)

[1] https://avinor.no/en/corporate/community-and-environment/pfos-i-fokus/pfos-i-fokus

[2] https://www.ngi.no/content/download/16940/1863001/file/#%206%20Nytt%20fra%20Milj%C3%B8direktoratet.pdf

and one slope was positive (for st. 24B in the Bergen harbour). The decrease of PFOSA concentrations was thereby smaller than for PFOS (-0.10) and was not observed at all stations. From ***Figure 65*** it can be observed that the spread in variation of the slopes for PFOSA is wider than for PFOS. The urban stations in the south of Norway near Oslo and Bergen (st. 36B and st. 24B, respectively) had the lowest decline, while the urban station near Tromsø (st. 43B) had the highest decline (high negative slope).

For PFUdA, the slope was significantly less negative than for PFOS and PFOSA (p=0.0002 and 0.0113 respectively), and the mean was only -0.0115. For five stations the time trend was not significant, and one station had a positive slope (st. 36B, not significant). This means that PFUdA was not decreasing as rapidly as PFOS and PFOSA. However, PFUdA have only been measured since 2012, and therefore the data are more limited than for PFOS and PFOSA.

Figure 65 shows a boxplot of the slopes for the three PFAS, and indicates that the slope of PFUdA is significantly different from those of PFOS and PFOSA (ANOVA, p=0.0003). The hypothesis of downward time trends for PFOS and PFOSA was confirmed, but not for PFUdA.

Table 18*. Slopes of time trends of concentrations of the three selected PFAS in cod livers. The years included in the time series are shown below the PFAS. Slopes with an upward trend are coloured in red. Time trends that are not significant are indicated in parentheses. Stations that are considered urban according to OSPAR classification are indicated in bold.*

Station	PFOS (2005-2019)	PFOSA (2005-2019)	PFUdA (2012-2019)
30B	-0.1005	-0.0476	(-0.0142)
36B	-0.0974	(-0.0039)	0.0077
13B	-0.1073	-0.0731	(-0.0167)
15B	-0.229	-0.1214	NA
23B	-0.0719	-0.0932	-0.0164
53B	-0.0777	-0.1049	(-0.0062)
24B	-0.0379	0.0025	(-0.0215)
80B	-0.0814	-0.0661	(-0.0119)
98B1	-0.108	-0.0832	-0.0298
43B2	-0.1101	-0.1386	-0.0221
10B	0.6415*	NA	NA
Mean	**-0.1**	**-0.073**	**-0.015**

* Only three time points (2005 - 2007) and several points below LOQ, therefore excluded from estimation of mean slope.

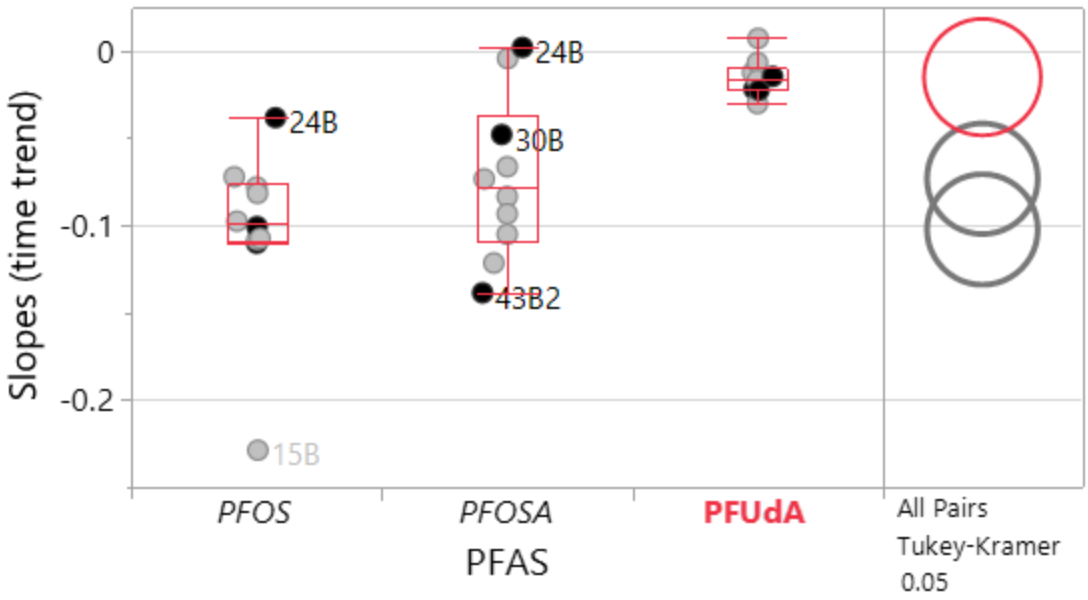


***Figure 65**. Comparison of time trend slopes between three PFASs. Urban stations (according to OSPAR, st. 30B, st. 24B and st. 43B) are indicated with black points. Selected stations are labelled. PFOS and PFOSA are significantly lower than PFUdA, but not from each other ((Tukey-Kramer all pairs test, p<0.05). The circles to the right represent the mean and confidence limits, and circles with different colours are significantly different from each other.*

PFAS concentration Distance to airports

The hypothesis that stations close to an airport had higher concentrations was tested for both 2019 data (***Figure 90***, ***Appendix G***) and the maximum concentration of any year (see red dots in ***Figure 91***, ***Appendix G*** for details of which year had the maximum concentration). The correlation plots are shown in ***Figure 66*** and ***Figure 67***, respectively. PFOS, PFOSA and PFudA were not significantly correlated with distance to the nearest airport, nor distance to the nearest upstream airport (***Figure 66***). PFOS and PFUdA increased with distance to the nearest airport but the trend was not significant, and the hypothesis could not be verified.

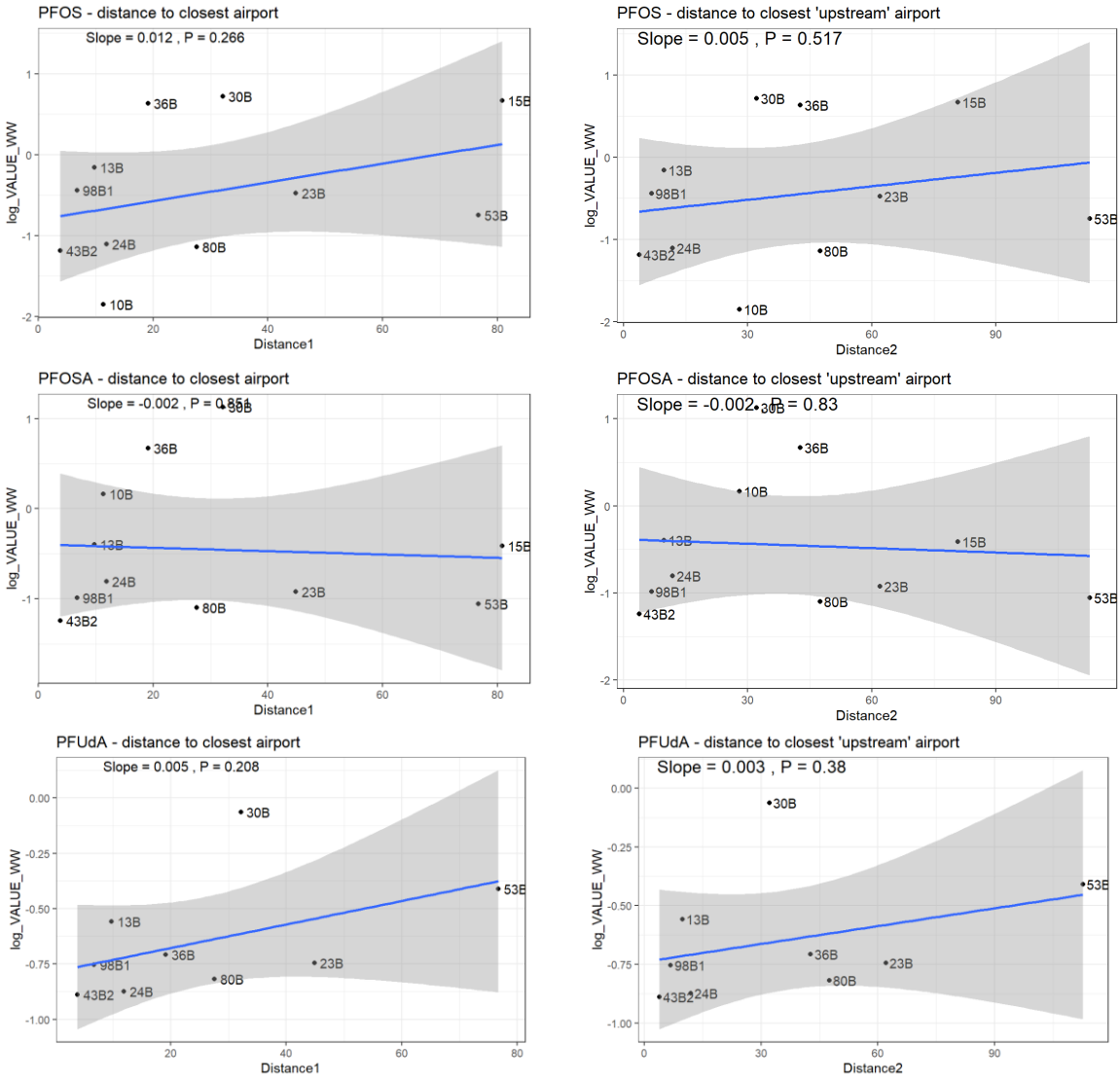


***Figure 66**. Correlations with distance to nearest airport (Distance1, upper panel) and nearest upstream airport (Distance2, lower panel) for three PFAS in 2019.*

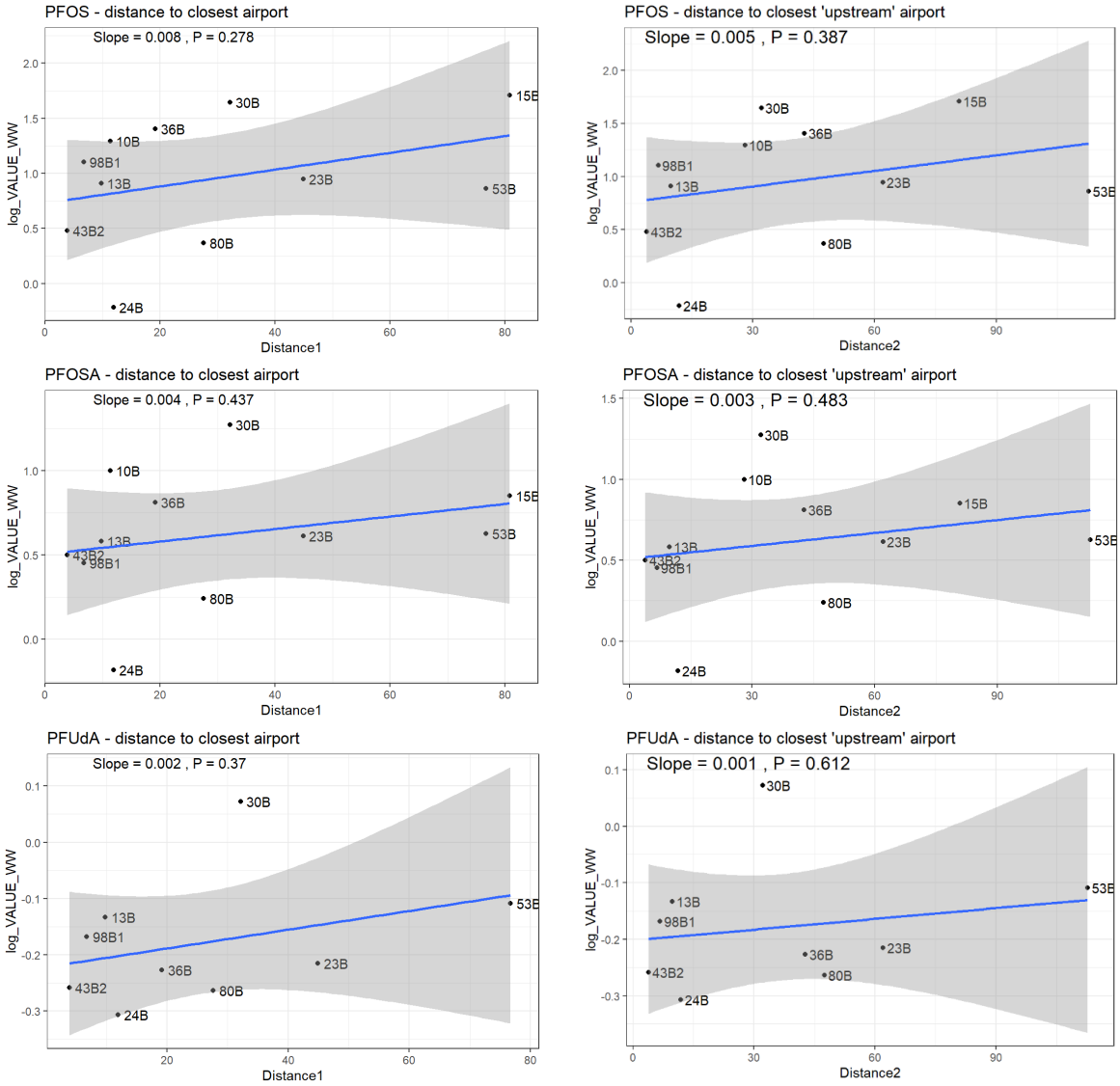


***Figure 67**. Correlations of maximum estimated concentrations (**Figure 91**) for each station with distance to nearest airport (Distance1) and nearest upstream airport (Distance2).*

In Norway, the amount of PFOS used for firefighting training purposes varies (Norconsult 2019). At some airports the amounts used were very high; up to 8900 kg (total) was reported for Tromsø (***Table* 19**). However, airports that have been required to remediate PFAS contaminated soil were not included in this overview (including e.g. Oslo airport Gardermoen, Harstad/Narvik, Kristiansand and Svalbard airports).

Table 19. Sum of PFOS and other PFAS used at Norwegian airports as reported by (Norconsult 2019).

Airport	PFOS + PFAS (kg)*
Tromsø	8 900
Ålesund	2 525
Bergen	2 460
Stavanger	1 790
Molde	1 730
Lakselv	950
Kristiansund	930
Alta	900
Røros	570
Sogndal	245
Fagernes	100
Florø	70
Haugesund	30
Leknes	22
Røst	10
Total	**21 232**

* Estimated from ***Table 31, Appendix G.***

Environmental concentrations of PFAS in organisms near the airports are elevated compared to more remote areas (Langberg *et al.* 2019), and several reports regarding this issue have been commissioned by AVINOR[1]. In Norway, freshwater fish in a lake close to airports have been used to as an indicator of PFAS exposure. There is currently advice from Norwegian Food Safety Authority (*Mattilsynet*) not to eat fish caught near Rygge, Evenes and Fagernes airports[2]. In contrast to other studies, e.g. Langberg (2019), this study does not indicate elevated concentrations in cod livers that can be attributed to PFAS emissions from nearby airports. This may have several explanations. The main reason is that MILKYS is not designed for the purpose of discovering differences in PFAS concentrations in biota at different distances from airports. In addition, a challenge with using cod, a somewhat migratory species, as an indicator species compared to some of the freshwater fish species in small freshwater lakes. Fish in small lakes have no opportunity to migrate and thereby escape exposure. Furthermore, the large volume of water in the fjords and sea combined with coastal current activity probably dilute PFAS more than in freshwater environments. The blue mussel on the other hand is a sessile species but is at a lower trophic level than cod which probably explains why lower levels of PFAS were detected in this species in MILKYS than in cod. Blue mussel data was therefore not included in this analysis.

A Norwegian Environment Agency study investigated the quantities of PFOS in firefighting foams used by different enterprises and releases from this use [3] (SFT 2005). The study showed that the offshore installations were estimated to have had a total release of 54 000 kg PFOS until 2005 (of an estimated total of 57 600 kg). Remaining stocks of unused of PFOS foam were estimated to be 15 600 kg (of a total of 21 500 kg). The offshore industry was therefore by far the largest consumer of PFAS, and probably the major source to PFAS emissions in Norway. Therefore, the PFAS observed in cod liver could just as likely have been the result of PFAS from oil installations. In addition to

[1] https://avinor.no/en/corporate/community-and-environment/pfos-i-fokus/rapporter

[2] https://www.matportalen.no/matvaregrupper/tema/fisk_og_skalldyr/oversikt_over_havner_fjorder_og_innsjoer_med_forurensning

[3] Offshore installations, mobile rigs, ships and ferries, petrochemical and other relevant industy, tank farms, airports, armed forces, fire-fighting training sites, fire- and rescue brigades.

the PFAS used as firefighting foams both at land and at sea, PFAS has been used in products mentioned earlier. The latter use of PFAS in consumer products will end up in wastewater[1] and from there be transported to the sea/oceans. We therefore believe that the concentrations found in cod along the Norwegian coast is probably a result of releases from many different sources.

3.2.26 Hexabromocyclododecanes (HBCD)

Hexabromocyclododecanes (HBCD) is a persistent pollutant which bioaccumulate and undergo long-range transports. HBCD is one of the substances identified as priority hazardous substances (2013/39/EU) and was globally regulated under the Stockholm convention in 2013.
HBCD was analysed in liver of cod from 10 stations, in blue mussel from 10 stations, and in blood and eggs of eider from one station (***Table 3***).

Environmental Quality Standards (EQS) for priority substances
When applying the EQS for HBCD (167 µg/kg w.w.), all concentrations in blue mussel, cod liver and eider (blood and eggs) were below EQS in 2019 (***Table 11***). In the present study α–HBCD (coded HBCDA in the present study) has been used as a proxy for the priority substance sum of the α–, β–, and γ–HBCD diastereomers (coded HBCDD in the present study).

Levels exceeding PROREF
The median concentration of HBCD in blue mussel from Bodø harbour (st. 97A3) exceeded the Norwegian provisional high reference contaminant concentration (PROREF) by a factor of two to five.

Upward trends
There were no upward trends for HBCD in cod or blue mussel in 2019.

Decrease in PROREF since 2018
The median concentration of HBCD in liver of cod from the Inner Oslofjord (st. 30B) decreased from 2018 to 2019. In 2018 the concentration of HBCD exceeded PROREF by a factor of up to two. In 2019 the median concentration of HBCD in liver of cod from the Inner Oslofjord did not exceed PROREF.

Downward trends
There were significant downward long-term and short-term trends for HBCD in cod liver from Stathelle area, Langesundfjord (st. 71B) (***Figure 69 A***), Kirkøy, Hvaler (st. 02B), Kristiansand harbour (st. 13B), Trondheim harbour (st. 80B), Tromsø harbour (st. 43B2) and Bømlo, Outer Selbjørnfjord (st. 23B). A significant downward short-term trend was also found for HBCD in liver of cod from Inner Oslofjord (st. 30B). Significant downward long-term and short-term trends were found for HBCD in blue mussel from Færder, Outer Oslofjord (st. 36A[2]), Nordnes, Bergen harbour (st. I241), Ørland area, Outer Trondheimfjord (st. 91A2), Mjelle, Bodø area (st. 97A2) and Svolvær airport (st. 98A2).

Levels in eider
The concentration of HBCD in eider egg increased from 0.133 µg/kg in 2018 to 0.183 µg/kg in 2019. The concentration of HBCD in eider blood was below the limit of quantification.

[1] As depicted in Figure 2 in https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe
[2] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

General, large scale trends

Cod from Bergen harbour (st. 24B) had the highest concentration of HBCD (here defined as the sum of the α–, β–, and γ–diastereomers) in liver (***Figure 68***, ***Table 20***). Median concentration of HBCD in cod liver from Bergen harbour was 5.838 µg/kg w.w.

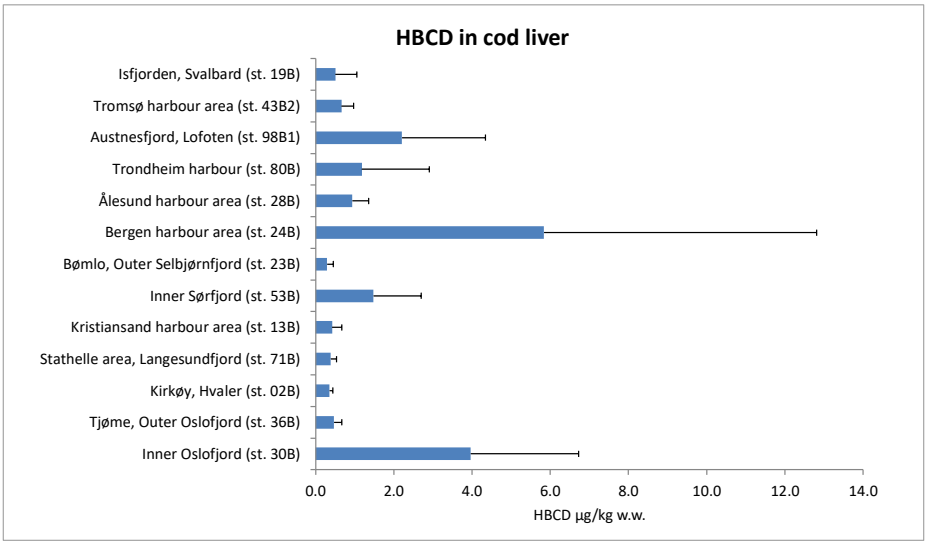


Figure 68*. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver in 2019. The error bar indicates one standard deviation above the median.*

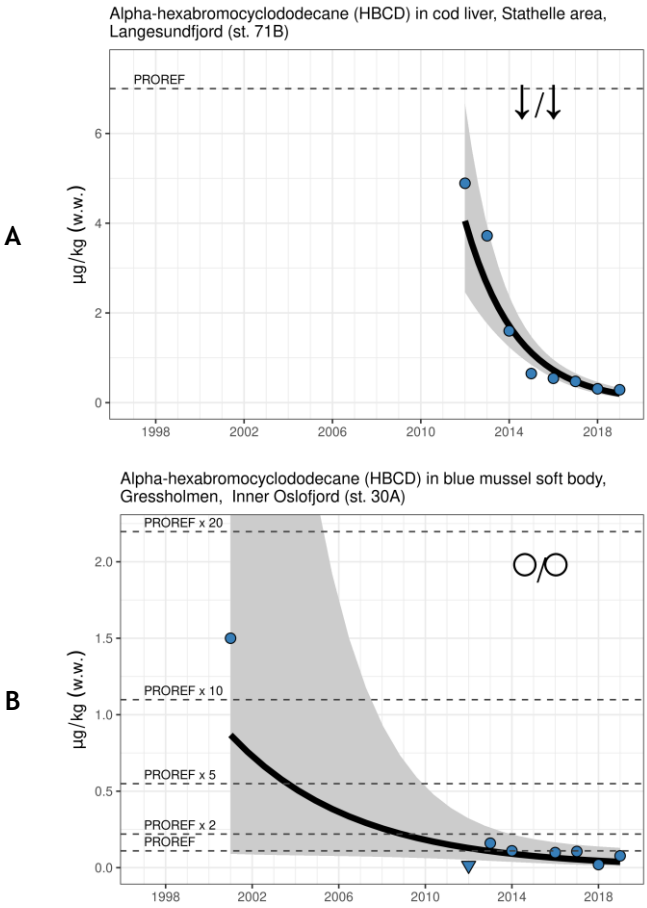


Figure 69. *Median concentrations (mg/kg w.w.) of α–HBCD (HBCDA) in cod liver from 2012 to 2019 in Stathelle area (st. 71B) in the Langesundfjord (**A**) and in blue mussel from Gressholmen (st. 30A) in the Inner Oslofjord (**B**). (see **Figure 4** and **Appendix C**.)*

***Table 20**. Median concentration (µg/kg w.w.) with standard deviation (S.d.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver, blue mussel and eider in 2019. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter** 2.11 for more details and Appendix B for description of chemical codes.)*

Component	Count	a-HBCD		g-HBCD		b-HBCD		HBCD	
Species and sampling locality	2019	Med.	S.d. D.d.i.	Med.	S.d. D.d.i.	Med.	S.d. D.d.i.	Med.	S.d. D.d.i.
Blue mussel									
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.077	0.017 3 [0.0617-0.0952]	0.006	0.006 1 [0.0161]	0.006	0.000 0 [n.a.]	0.089	0.012 3 [0.0839-0.1072]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.016	0.004 3 [0.0142-0.0221]	0.006	0.000 0 [n.a.]	0.006	0.000 0 [n.a.]	0.029	0.004 3 [0.0262-0.0345]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.062	0.005 3 [0.0571-0.0672]	0.008	0.002 2 [0.0082-0.0105]	0.006	0.000 0 [n.a.]	0.076	0.007 3 [0.0693-0.0837]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.113	0.003 3 [0.109-0.114]	0.016	0.002 3 [0.0139-0.0174]	0.009	0.001 3 [0.0083-0.0103]	0.136	0.002 3 [0.1347-0.1391]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.084	0.014 3 [0.0609-0.0863]	0.020	0.000 0 [n.a.]	0.007	0.001 0 [n.a.]	0.111	0.015 3 [0.087-0.1153]
Ålesund harbour (st. 28A2)	3 (3-50)	0.081	0.008 3 [0.0679-0.0814]	0.027	0.010 3 [0.0266-0.0449]	0.007	0.001 0 [n.a.]	0.114	0.017 3 [0.1013-0.1345]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.014	0.002 2 [0.0138-0.0164]	0.015	0.003 0 [n.a.]	0.006	0.000 0 [n.a.]	0.035	0.004 2 [0.0348-0.037]
Bodø harbour (st. 97A3)	3 (3-50)	0.234	0.007 3 [0.224-0.237]	0.049	0.009 3 [0.0351-0.0524]	0.013	0.003 0 [n.a.]	0.287	0.007 3 [0.2857-0.2988]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.013	0.001 0 [n.a.]	0.015	0.002 0 [n.a.]	0.006	0.000 0 [n.a.]	0.033	0.001 0 [n.a.]
Svolvær airport area (st. 98A2)	3 (3-50)	0.009	0.002 0 [n.a.]	0.006	0.000 0 [n.a.]	0.006	0.000 0 [n.a.]	0.021	0.002 0 [n.a.]
Cod, liver									
Inner Oslofjord (st. 30B)	14 (11-3)	3.855	2.727 14 [1.09-10.2]	0.066	0.052 5 [0.102-0.247]	0.030	0.021 2 [0.0338-0.069]	3.965	2.760 14 [1.29-10.516]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-2)	0.364	0.217 5 [0.102-0.701]	0.085	0.015 0 [n.a.]	0.028	0.002 0 [n.a.]	0.470	0.203 5 [0.2195-0.7803]
Kirkøy, Hvaler (st. 02B)	11 (4-3)	0.236	0.087 11 [0.103-0.373]	0.090	0.001 0 [n.a.]	0.029	0.000 0 [n.a.]	0.354	0.087 11 [0.2236-0.4936]
Stathelle area, Langesundfjord (st. 71B)	13 (9-3)	0.288	0.145 13 [0.145-0.562]	0.072	0.009 0 [n.a.]	0.029	0.001 0 [n.a.]	0.385	0.146 13 [0.2463-0.6652]
Kristiansand harbour area (st. 13B)	9 (3-2)	0.321	0.238 9 [0.129-0.896]	0.066	0.006 0 [n.a.]	0.030	0.003 0 [n.a.]	0.424	0.243 9 [0.228-1.0003]
Inner Sørfjord (st. 53B)	15 (6-2)	1.260	1.208 15 [0.0666-4.79]	0.190	0.050 0 [n.a.]	0.028	0.002 0 [n.a.]	1.478	1.216 15 [0.2993-5.0055]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (0-1)	0.232	0.157 15 [0.151-0.702]	0.029	0.001 0 [n.a.]	0.029	0.001 0 [n.a.]	0.290	0.157 15 [0.209-0.7608]
Bergen harbour area (st. 24B)	14 (4-2)	5.700	6.893 14 [0.446-26.3]	0.075	0.164 7 [0.0771-0.505]	0.029	0.002 0 [n.a.]	5.838	6.977 14 [0.5325-26.6195]
Ålesund harbour area (st. 28B)	15 (0-1)	0.837	0.415 15 [0.367-1.69]	0.074	0.021 5 [0.044-0.134]	0.029	0.001 0 [n.a.]	0.939	0.420 15 [0.4719-1.762]
Trondheim harbour (st. 80B)	11 (0-1)	1.090	1.705 10 [0.133-5.52]	0.069	0.059 3 [0.0945-0.111]	0.028	0.002 0 [n.a.]	1.185	1.725 10 [0.2338-5.6442]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	2.150	2.134 14 [0.375-8.38]	0.029	0.005 1 [0.0462]	0.029	0.001 0 [n.a.]	2.209	2.138 14 [0.4276-8.4553]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.567	0.312 15 [0.282-1.4]	0.090	0.007 0 [n.a.]	0.028	0.002 0 [n.a.]	0.662	0.313 15 [0.3872-1.5194]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.387	0.566 14 [0.132-2.38]	0.060	0.020 0 [n.a.]	0.060	0.025 0 [n.a.]	0.507	0.552 14 [0.22-2.44]
Eider, blood									
Brøøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	0.009	0.005 0 [n.a.]	0.009	0.002 0 [n.a.]	0.029	0.008 0 [n.a.]	0.047	0.013 0 [n.a.]
Eider, egg									
Brøøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.008	0.004 0 [n.a.]	0.148	0.086 15 [0.0599-0.365]	0.029	0.000 0 [n.a.]	0.183	0.086 15 [0.0989-0.4119]

Analysis of cod liver showed that α–HBCD was about-100 times higher than in blue mussel on a wet weight basis (compare ***Figure 70*** and ***Figure 71***). The difference was smaller on a lipid basis. There are some indications of biomagnification for specific diastereomers of HBCD (Haukås 2009). Cod liver from the Inner Oslofjord (st. 30B) and Bergen harbour area (st. 24B) had concentrations of α–HBCD that were significantly higher than for all the other stations except Austnesfjord (st. 98B1) and Trondheim harbour (st. 80B) (Tukey-Kramer HSD test, see also ***Figure 70***).

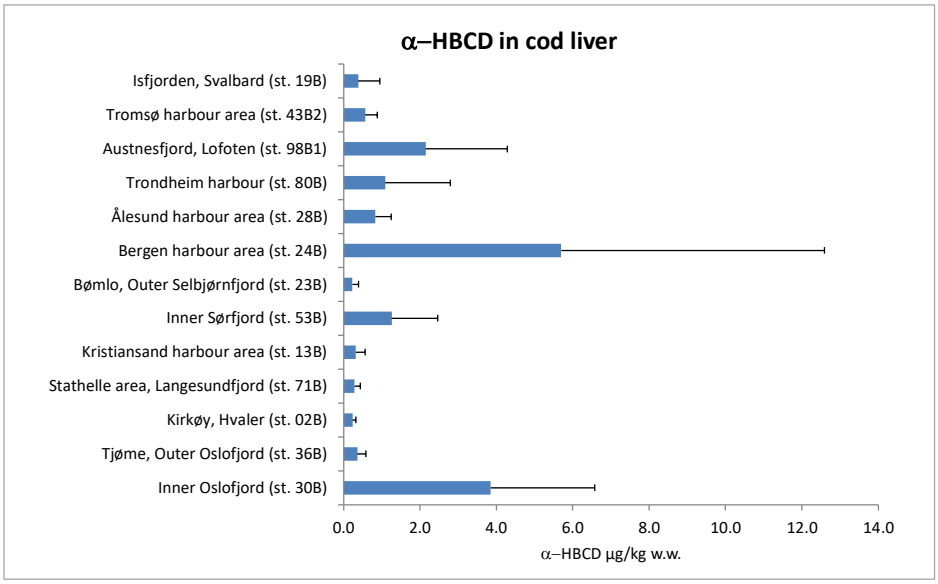


Figure 70*. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2019. The error bar indicates one standard deviation above the mean.*

Blue mussel from Bodø harbour (st. 97A3) had concentrations of α–HBCD that were significantly higher than for all the other stations (Tukey-Kramer HSD test, see also ***Figure 71***).

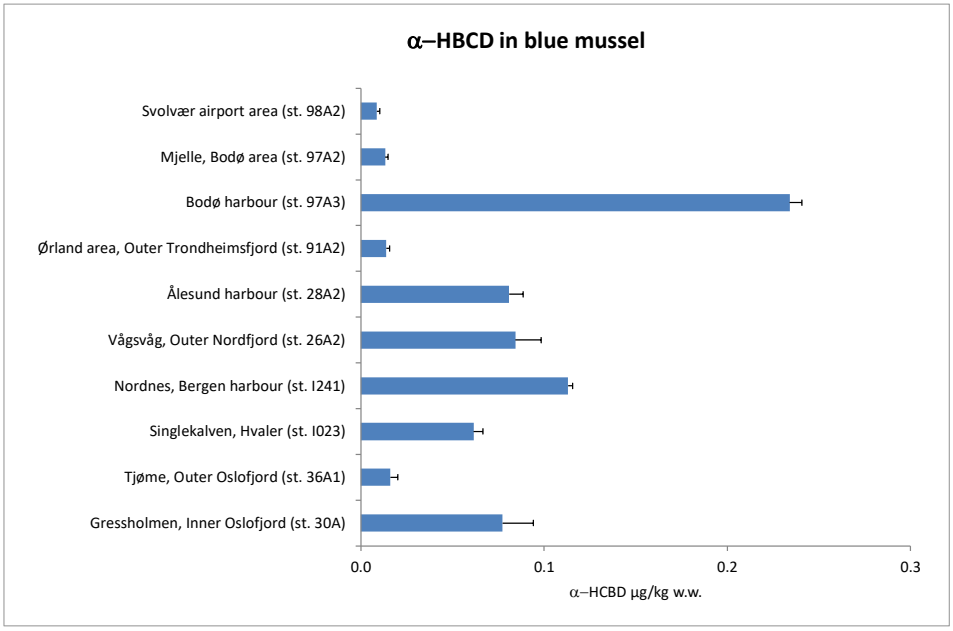


Figure 71*. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2019. The error bar indicates one standard deviation above the mean.*

General, large scale trends

The discharges of HBCD to water from land-based industries showed a decrease from 2004 (12.90 kg HBCD/year) to 2005 (1.50 kg HBCD/year) (***Figure 72***). In 2006, the discharge to water was 0.51 kg and during the following years the discharges have gradually decreased to 0 kg[1] in 2016.

Riverine loads for HBCD isomers for 2016 have been estimated to be in the range 0.63-1.8 g/year for river Alna (Inner Oslofjord), 135-468 g/year for river Drammenselva (Mid Oslofjord) and 70-776 g/year for river Glomma (Outer Oslofjord) (Skarbøvik *et al*. 2017).

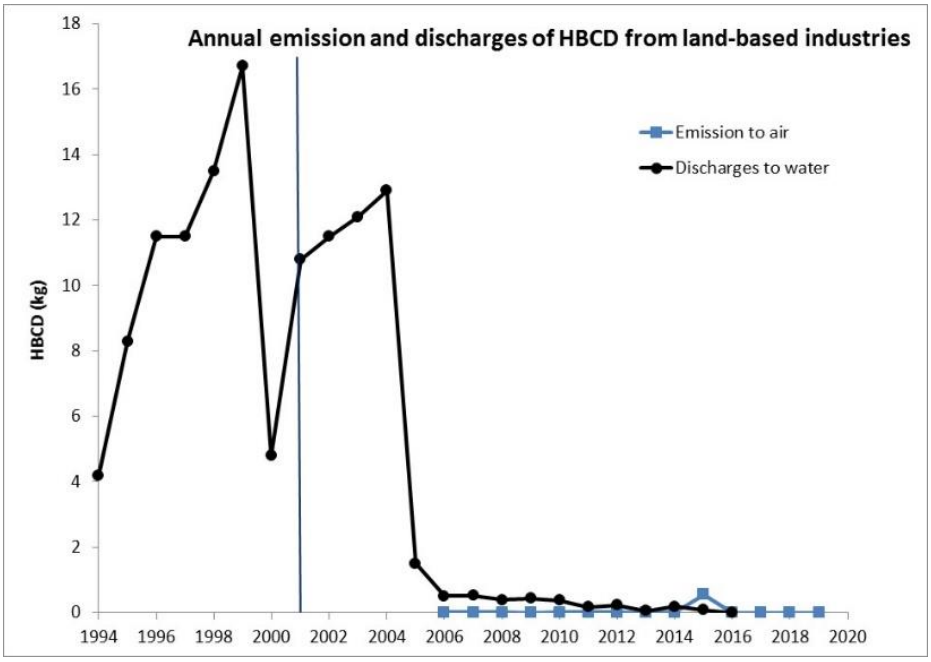


Figure 72. *Annual emissions of HBCD* to air and discharges to water from land-based industries in the period 1994-2019 (data from *www.norskeutslipp.no*, 3 June 2020). HBCD has been monitored in this project since 2001 (indicated with a vertical line). No data for emissions to air are reported for 2002-2005. Discharges to water in 2017-2019 is not reported. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.

Comparison with other studies

In 2017, HBCD was found in freshwater fish in 13 lakes in Norway, in the range 0.00[2] (below LOQ) to 11.89 ng/g w.w. (Jartun 2018).

3.2.27 Chlorinated paraffins (SCCP and MCCP)

Chlorinated paraffins are complex mixtures of polychlorinated organic compounds. They are mainly used in metal working fluids, sealants, as flame-retardants in rubbers and textiles, in leather processing and in paints and coatings. Their persistence, bioaccumulation, potential for long-ranged environmental transport and toxicity imply that they may have harmful environmental effects at a global level. A global regulation of SCCP has been in place since the end of 2019

[1] No LOQ was provided in www.norskeutslipp.no

[2] No LOQ was provided by Jartun *et al*. (2018).

through the Stockholm Convention. In the present study, chlorinated paraffins were analysed in liver of cod from 13 stations, in blue mussel from 10 stations, and in blood and eggs of eider from one station (***Table 3***).

Chlorinated paraffins are subdivided according to their carbon chain length into short chain chlorinated paraffins (SCCPs, C_{10-13}) and medium chain chlorinated paraffins (MCCPs, C_{14-17}). The EQS for SCCP and MCCP in biota are 6000 and 170 µg/kg w.w., respectively (Norwegian_Environment_Agency 2016a). SCCPs and MCCPs are classified as persistent with a high potential for bioaccumulation and they are toxic to aquatic organisms (Tomy *et al*. 1998). Use and production of SCCPs are prohibited in Norway. However, emission from old- or imported products cannot be excluded. MCCPs are largely used as a flame retardant and as an additive to plastics, such as PVC, to increase flexibility. To a lesser degree MCCPs are used as a lubricant in machinery for manufacturing metal products. MCCPs are mainly released to water in effluent from industry using them as metal working fluids. MCCP has been used to a limited extent in Norwegian production (as flame retardants, in plastics and as lubricants), but may be found in imported products. There is, however, considerable uncertainty about the quantities in products used in Norway, and there is an indication that the discharges from the use of MCCP have been reduced by 40 % from 1995 to 2017[1]. In 2013 there were emissions of 880 kg MCCP to air, discharges of 11340 kg MCCP to water and 5250 kg MCCP to soil (reported on www.norskeutslipp.no).

Environmental Quality standards (EQS) for priority substances

When applying the EQS for SCCP (6000 µg/kg w.w.) in biota, all concentrations in cod liver, blue mussel and eider were below the EQS (***Table 11***). Cod from Kirkøy, Hvaler (st. 02B) had highest concentration of SCCP, with median concentration of 98 µg/kg w.w., and high individual variation. Blue mussel from Ørland area, Outer Trondheimfjord (st. 91A2) had highest concentration of SCCP, with median concentration of 13 µg/kg w.w. Cod from Svalbard had concentrations of SCCP at same level as cod from some of the urban areas along the coast of Norway.

Environmental Quality Standards (EQS) for river basin specific pollutants

When applying the EQS for MCCP (170 µg/kg w.w.) in biota, median concentrations of MCCP exceeded EQS in cod liver from Kirkøy, Hvaler (st. 02B), Inner Sørfjord (st. 53B), Bømlo, Outer Selbjørnfjord (st. 23B), Bergen Harbour area (st. 24B), Ålesund harbour area (st. 28B) and Trondheim harbour (st. 80B). Cod from Kirkøy, Hvaler (st. 02B) had highest concentration of MCCPs with median concentration of 320 µg/kg w.w. High individual variation was observed (***Figure 77***, ***Table 21***). There were higher concentrations of MCCP in cod liver in 2019 than in 2018. No median concentrations of MCCPs in blue mussel or eider were above the EQS.

Levels exceeding PROREF

No median concentrations of SCCPs and MCCPs in cod liver, blue mussel and eider exceeded the PROREF.

Upward trends

There was a significant short term upward trend for SCCP in blue mussel from Singlekalven (no data series over 10 years), Hvaler (st. I023) (***Figure 73***). However, the concentrations of SCCPs on this station were low.

A significant long-term upward trend was found for MCCP in liver of cod from Bømlo, Outer Selbjørnfjord (st. 23B). The trend in cod was also significant when the data was adjusted for fish length.

[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/klorerte-parafiner-sccp-og-mccp//

Downward trends

There was a significant long-term downward trend for SCCPs in blue mussel from Færder, Outer Oslofjord (st. 36A[1]). There were significant short- and long-term downward trends for SCCPs in liver of cod from Bergen harbour area (st. 24B) (***Figure 74 A***), and there was a significant long-term downward trend for SCCPs in liver of cod from the Inner Sørfjord (st. 53B) (***Figure 74 B***).

Decrease in PROREF factor since 2018

The median concentration of SCCPs in blue mussel from Ålesund (st. 28A2), Nordnes, Bergen harbour (st. I241) decreased from 2018 to 2019. In 2018 blue mussels from these two stations exceeded PROREF for SCCP by a factor of up to two. The median concentration of SCCPs in blue mussel from Bodø harbour exceeded PROREF by a factor of two to five. Blue mussels from Bodø harbour (st. 97A3) exceeded PROREF by a factor of up to two.

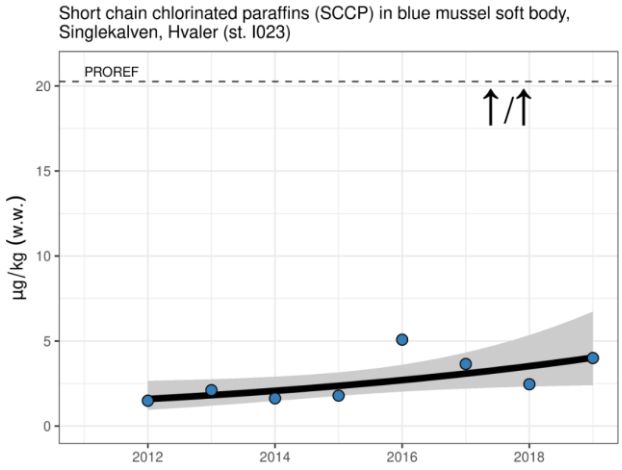


Figure 73. *Median concentrations (µg/kg w.w.) of SCCP in blue mussel from Singlekalven, Hvaler (st. I023). (see* ***Figure 4*** *and* ***Appendix C****.)*

[1] Timeseries includes altnerate station at Tjøme, Outer Oslofjord (st. 36A1).

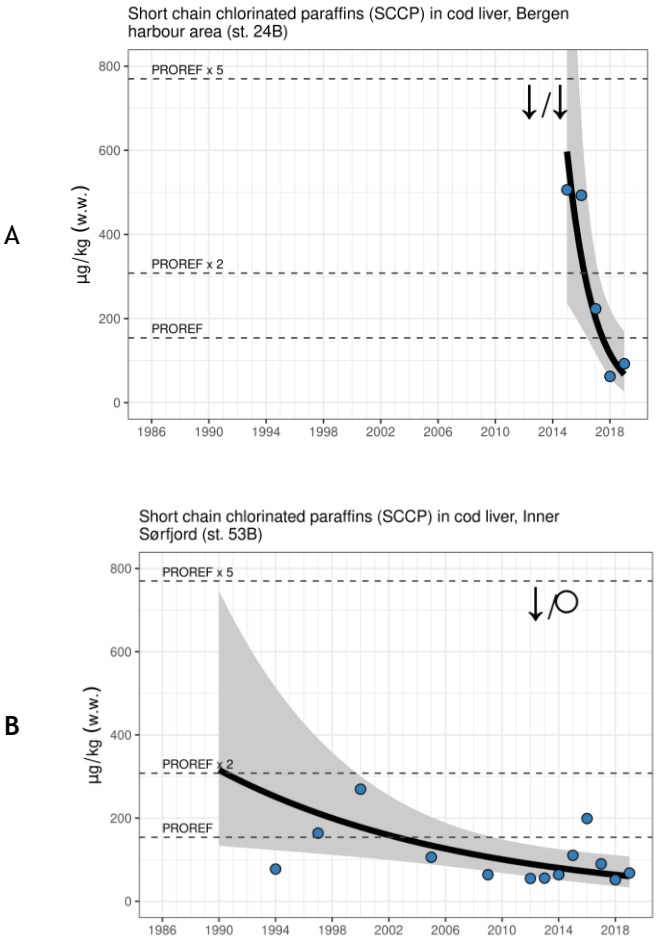


Figure 74**. Median concentration of SCCPs in cod liver from Bergen harbour area (st. 24B) (A) and the Inner Sørfjord (**B**).* (see ***Figure 4 *and* ***Appendix C**.)*

Levels in eider

Median concentration of SCCP was 15.48 µg/kg w.w. in eider blood, and 4.31 µg/kg w.w. in eider egg from Kongsfjord, Svalbard (st. 19N). This was a decrease from 2018. Median concentration of MCCP was 30.51 µg/kg w.w. in eider blood and 12.84 µg/kg w.w. in eider egg from the same station, a decrease from 2018.

General, large scale trends

Cod from Kirkøy, Hvaler (st. 02B) had highest concentration of SCCPs, with median concentration of 98 µg/kg w.w., and high individual variation (***Figure 75***). Cod from Bergen harbour had also high median concentration of SCCPs (92.5 µg/kg w.w.). The median concentration of SCCP in blue mussel ranged from 4.0 to 13.0 µg/kg w.w. in the present study and the highest concentration was found in the samples from Ørland area; Outer Trondheimfjord, (***Figure 76***).

Cod from Kirkøy, Hvaler and Bergen harbour also had highest concentrations of MCCPs, with median concentration of 320 µg/kg w.w. in cod from Kirkøy and median concentration of 265 µg/kg w.w. in cod from Bergen harbour (***Figure 77***). The concentrations of MCCPs in blue mussel were lower than in cod, and ranged from 13.0 to 62.0 µg/kg w.w. Blue mussel from Bodø harbour (st. 97A3) had the highest concentrations of MCCPs (***Figure 78***). Runoff from local airports might be a source for the high levels of MCCPs and SCCPs found in blue mussels from these areas.

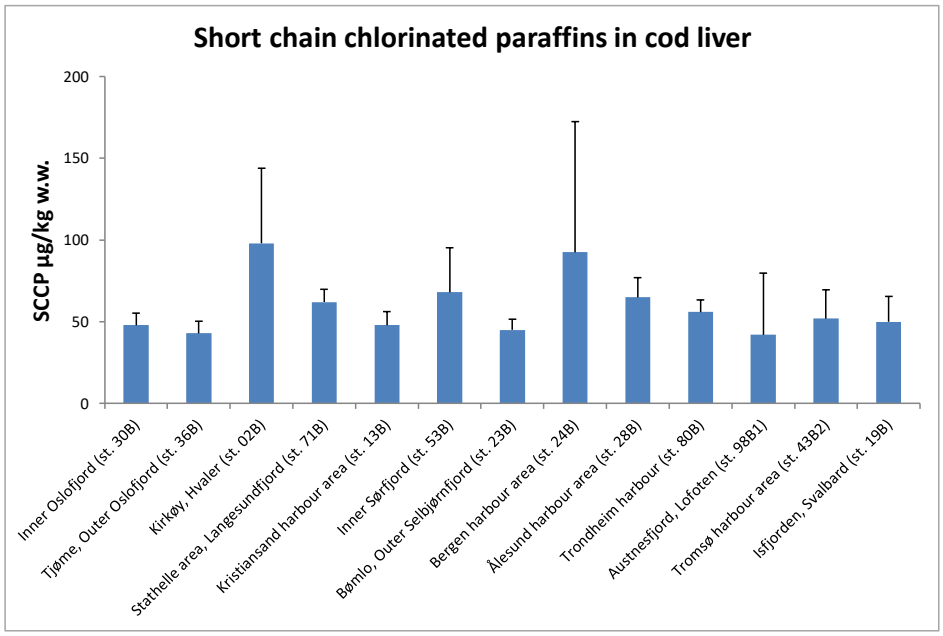


***Figure 75**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in cod liver in 2019. The error bar indicates one standard deviation above the median.*

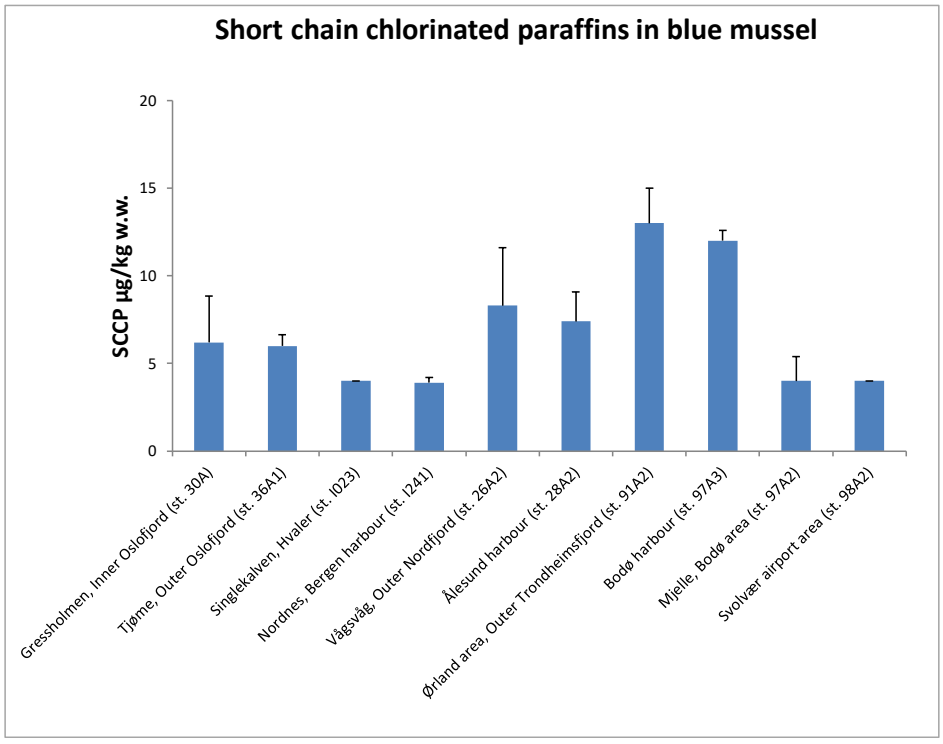


***Figure 76**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in blue mussel in 2019. The error bar indicates one standard deviation above the median.*

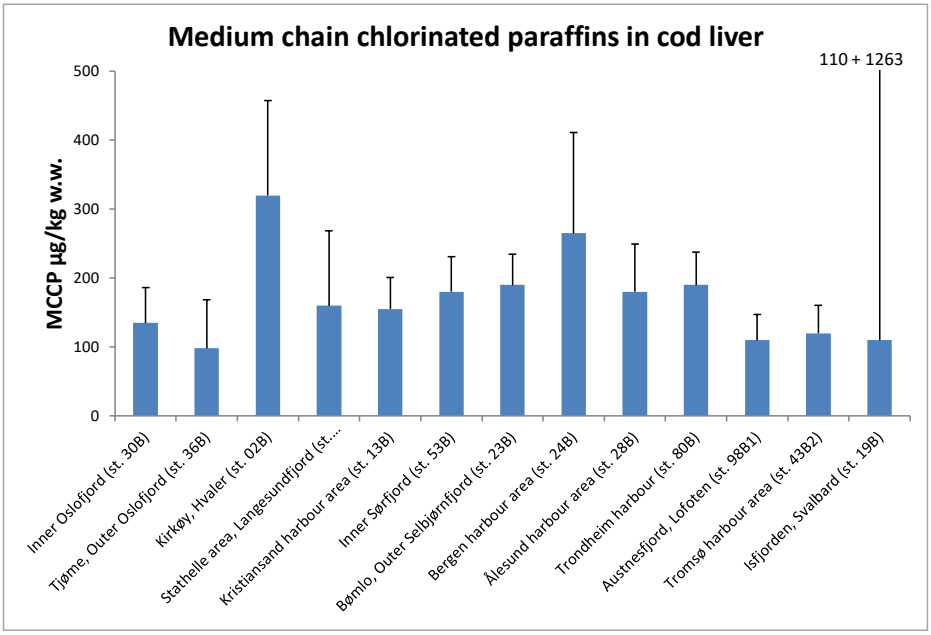


***Figure 77**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in cod liver in 2019. The error bar indicates one standard deviation above the median.*

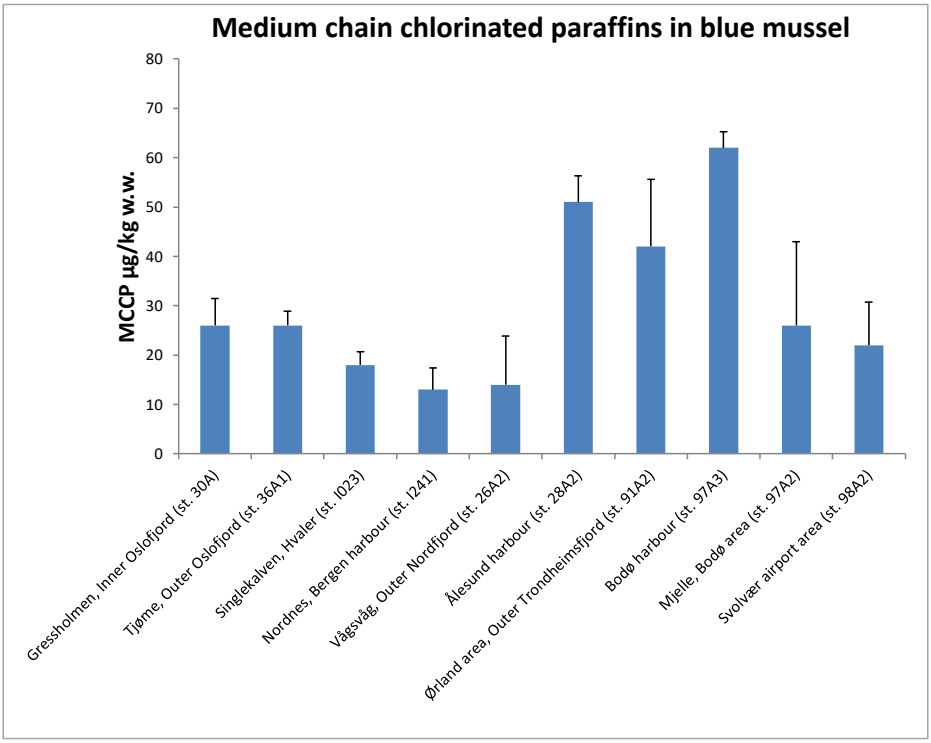


***Figure 78**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in blue mussel in 2019. The error bar indicates one standard deviation above the median.*

Comparison with other studies

Cod from the Inner Oslofjord had median concentration of SCCP in liver of 48.0 µg/kg w.w. and ranging between 35 to 59 µg/kg w.w. Median concentration of MCCP in cod liver from the Inner Oslofjord was 135 µg/kg w.w. , and ranged between 44 to 200 µg/kg w.w. Ruus *et al.* (2020 In prep) found higher levels of SCCP in cod from the Inner Oslofjord (268.7 to 1100.4 µg/kg w.w.). The concentrations of MCCP in cod liver found by Ruus et al (2020 In prep) were in the range 422.2 to 1697.6 µg/kg w.w. Those samples were analysed with the same method by the same lab. The

observed differences in concentrations of SCCPs and MCCPs in cod from the Inner Oslofjord cannot be explained by analytical differences. The cod reported by Ruus *et al.* (2020 In prep) were caught in August 2019, and the cod in this project were caught in November 2019. The impact of seasonal variation on concentration of SCCPs and MCCPs should not be disregarded.

SCCPs and MCCPs have also been found in freshwater fish in Norway. In 2017 SCCPs were found in the range 3.21 to 12.76 ng/g w.w., and MCCPs were found in the range 8.24 to 51.50 ng/g w.w. (Jartun 2018). Cod from Svalbard had the same level of SCCP and MCCP as cod from some urban areas along the coast of Norway.

In the present study, the median concentration of SCCP (15 µg/kg w.w.) in eider egg from Svalbard was higher than in another study of eider from three stations in northern Norway and one at Svalbard (3.2±1.8 µg/kg w.w.) (Harju 2013). The similar pattern was seen for the median concentration of MCCP (12.84 µg/kg w.w.) in the present study compared to the other study (4.2±4.1 µg/kg w.w.).

Riverine loads for SCCPs for 2016 have been estimated to 0.21 kg/year for river Alna (Inner Oslofjord), 9.7 kg/year for river Drammenselva (Mid Oslofjord) and 71 kg/year for river Glomma (Outer Oslofjord) (Skarbøvik *et al.* 2017). Riverine loads for MCCPs for 2016 have been estimated to 0.25 kg/year for river Alna, 19 kg/year for river Drammenselva and 420 kg/year for river Glomma.

***Table 21**. Median concentrations (µg/kg w.w.) with standard deviation of short chain chlorinated paraffins (SCCPs) and medium chain chlorinated paraffins (MCCPs) in blue mussel, cod and eider blood and eggs in 2019. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. -Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter** 2.11 for more details.*)

Component	Count	SCCP		MCCP	
Species and sampling locality	2019	Med.	S.d. D.d.i	Med.	S.d. D.d.i
Blue mussel					
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	6.20	2.66 3 [1.6-6.2]	26.00	5.51 3 [17-27]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	6.00	0.62 3 [5.7-6.9]	26.00	2.89 3 [21-26]
Singlekalven, Hvaler (st. I023)	3 (3-50)	4.00	0.00 3 [4-4]	18.00	2.65 3 [17-22]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	3.90	0.30 3 [3.6-4.2]	13.00	4.36 3 [12-20]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	8.30	3.29 3 [8.3-14]	14.00	9.87 3 [12-30]
Ålesund harbour (st. 28A2)	3 (3-50)	7.40	1.66 3 [6.9-10]	51.00	5.29 3 [49-59]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	13.00	2.00 3 [11-15]	42.00	13.58 3 [26-53]
Bodø harbour (st. 97A3)	3 (3-50)	12.00	0.58 3 [11-12]	62.00	3.21 3 [57-63]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	4.00	1.39 3 [1.6-4]	26.00	17.01 3 [10-44]
Svolvær airport area (st. 98A2)	3 (3-50)	4.00	0.00 3 [4-4]	22.00	8.78 3 [9.2-26]
Cod, liver					
Inner Oslofjord (st. 30B)	12 (9-3)	48.00	7.18 12 [35-59]	135.00	51.29 12 [44-200]
Tjøme, Outer Oslofjord (st. 36B)	5 (3-2)	43.00	7.26 5 [33-51]	98.00	70.29 5 [48-220]
Kirkøy, Hvaler (st. 02B)	11 (4-3)	98.00	45.95 11 [89-250]	320.00	137.73 11 [260-760]
Stathelle area, Langesundfjord (st. 71B)	13 (9-3)	62.00	7.86 13 [53-76]	160.00	108.31 13 [26-500]
Kristiansand harbour area (st. 13B)	10 (3-2)	48.00	8.18 10 [40-66]	155.00	45.81 10 [28-190]
Inner Sørfjord (st. 53B)	15 (6-2)	68.00	27.21 15 [46-160]	180.00	51.02 15 [96-270]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (0-1)	45.00	6.55 15 [33-56]	190.00	45.11 15 [100-270]
Bergen harbour area (st. 24B)	14 (4-2)	92.50	79.89 14 [63-320]	265.00	145.97 14 [130-580]
Ålesund harbour area (st. 28B)	15 (0-1)	65.00	12.03 15 [58-100]	180.00	69.64 15 [51-340]
Trondheim harbour (st. 80B)	11 (0-1)	56.00	7.46 11 [45-69]	190.00	48.06 11 [47-220]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	42.00	37.69 15 [20-180]	110.00	37.26 15 [50-190]
Tromsø harbour area (st. 43B2)	15 (0-1)	52.00	17.69 15 [32-94]	120.00	40.84 15 [26-170]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	50.00	15.55 15 [21-80]	110.00	1262.96 15 [36-5000]
Eider, blood					
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	15.48	6.94 12 [12.664-33.9716]	30.51	10.81 14 [22.2204-55.5368]
Eider, egg					
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	3.24	5.87 3 [15.8143-17.3532]	8.76	25 7 [19.4931-98.0165]

3.2.28 Siloxanes (D4, D5 and D6)

Siloxanes are chemical compounds consisting of silicon and oxygen substituted with various organic side chains, and they exist both as linear and cyclic substances. Siloxanes are chemicals used as synthetic intermediates in silicone polymer productions and can be ingredients in cosmetic and personal care products. Siloxanes have properties that affect the consistency of personal care products such as deodorants, skin and hair products to facilitate their use. The chemicals are also used in mechanical fluids and lubricants, biomedical products, cleaning and surface treatment agents, paint, insulation materials and cement. Since 01.02.2020, there are restrictions for D4 and D5 for wash-off cosmetic products in concentrations above 0.1 %[1].

Siloxanes, i.e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver at the four stations (***Table 3***); in the Inner Oslofjord (st. 30B), Bergen harbour (st. 24B), Tromsø harbour (st. 43B2) and the Isfjord (st. 19B) at Svalbard (***Table 22***, ***Figure 79***). Siloxanes were also analysed in eider blood and eggs at one station at Svalbard (st. 19N Breøyane).

[1] https://www.miljodirektoratet.no/aktuelt/nyheter/2020/februar-2020/nytt-forbud-mot-bruk-av-miljogifter/

Environmental Quality Standards (EQS) for river basin specific pollutants
When applying the EQS for D5 (15 217 µg/kg w.w.) in biota on cod liver, D5-concentrations were below EQS at all five stations (***Table 11***). No individual D5-concentration exceeded EQS (***Table 22***).

The EQS for D5 in biota (15 217 µg/kg w.w.) is provided for fish and are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in the present study only measured D5 in liver. Converting concentrations in liver to concentrations in whole fish is uncertain. If it is assumed, for this exercise, that the same concentration is found in all fish tissue types, then the results of D5 in cod liver would have been below the EQS for all 2019-samples (***Table 11***).

Levels in cod liver
Data for D4, D5 or D6 in cod liver are not sufficient to analyse trends or PROREF. D5 was the most dominant cVMS in the Inner Oslofjord (st. 30B) (876.1 µg/kg w.w.) and Bergen harbour area (st. 24B) (184 µg/kg w.w.). Median D5-concentrations in cod liver were lowest at Svalbard (3.96 µg/kg w.w.). The same pattern was found for D4 and D6.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of D4, D5 and D6 in blood were <1.4, <1.2 and 1.5 µg/kg, respectively. The concentrations of D4, D5 and D6 in eggs were <1.3, 2.9 and <2.8 µg/kg, respectively.

Comparison with other studies
The Inner Oslofjord
D5 were the dominating compound in cod from the Inner Oslofjord (st. 30B) inn all studies reported by Powell (2009), Powell *et al.* (2010; 2018), Ruus *et al.* (2016a; 2017; 2018, 2019), Schlabach *et al.* (2008) and Schøyen *et al.* (2016).

In 2019, median D5 concentration in cod liver from the Inner Oslofjord was 819.0 µg/kg w.w., while the mean D5 concentration was 1204.4 µg/kg w.w. in the study performed by Ruus *et al.* (Ruus). In the current study, median concentrations of D4 and D6 in cod liver from the Inner Oslofjord were 56.8 and 107.0 µg/kg w.w., respectively, while the mean concentrations were 92.2 and 169.5 µg/kg w.w., respectively, in the comparable study. The concentrations of D4, D5 and D6 in the Urban fjord program (mean values) were 1.5-1.6 times higher than in the MILKYS study (median values). The collection of cod in both studies took place during the autumn, in August for the Urban fjord program and in November for the MILKYS program. Furthermore, Ruus *et al.* (2018) found approximately 20 % higher mean D5-concentrations in cod liver in 2017 (2518.3 µg/kg w.w.) than in 2016 (2065.1 µg/kg w.w.) (Ruus *et al.* 2017). In 2015, the median D5 concentration was 1083.3 µg/kg w.w. (Ruus 2016a).

For the period 2011 to 2014, concentrations of D4, D5 and D6 were higher in herring than in cod (both whole fish) from the Inner Oslofjord (st. 30B) (Schøyen 2016). There was a positive correlation between lipid content and lipid-normalized concentrations of D4, D5 and D6 in cod, but a negative correlation in herring. Lipid-normalized concentrations of D4, D5 and D6 in cod, herring and shrimp were lowest in 2014 compared to the period 2011 to 2013.

In 2008, the mean concentrations of D4, D5 and D6 in cod (whole fish) from the Inner Oslofjord (st. 30B) were 2.6, 61.7 and 4.2 µg/kg w.w., respectively (Powell 2010). In 2006, the concentration ranges of D4, D5 and D6 in cod liver from the Inner Oslofjord (st. 30B) were 81.2-134.4, 1490.8-

1978.5 and 109.1-151.5 µg/kg w.w., respectively (Schlabach 2008). In 2005, the concentrations of D4, D5 and D6 in cod liver from the Inner Oslofjord (st. 30B) were 70, 2200 and 74 µg/kg w.w., respectively (Kaj 2005).

A literature overview and possible EQS derivation for D5 in biota (fish) is estimated to 833 µg/kg w.w. to protect the environment from secondary poisoning via the food chain (Sahlin 2018).

In Mjøsa, D5 was detected in highest concentrations (Jartun 2020 In prep). The mean concentrations were highest in brown trout (*Salmo trutta*) (38 µg/kg w.w.), European smelt (*Osmerus eperlanus*) (34 µg/kg w.w.), vendace (*Coregonus albula*) (26 µg/kg w.w.), zooplankton (1.7 µg/kg w.w.) and Mysis (*Mysis relicta*) (5.1 µg/kg w.w.) (Jartun 2020 In prep). There was a slight decline in D5 concentration in brown trout from 2013-2019.

The Arctic

At Svalbard, the highest concentrations of cVMS were found in cod liver from the Adventfjord (close to Longyearbyen), when compared to the Kongsfjord (close to Ny-Ålesund) and the Liefdefjord (north-west of Spitsbergen) in 2009 (Warner *et al.* 2010). The wastewaters from Longyearbyen are released into the Adventfjord. D5 was the dominant compound in all fjords. In the Adventfjord, mean concentrations were 57 µg/kg w.w. for D5 and 3.1 µg/kg w.w. for D6, while D4 not was detected in any cod. Warner *et al.* (2014) found that concentrations of D4 and D6 were negatively correlated with fish length and weight, indicating a greater elimination capacity compared to uptake processes with increasing fish size. Similar correlations were not detected for D5.

Freshwater

The median D5-concentration in cod liver (876.1 µg/kg w.w.) from the Inner Oslofjord was higher than the mean concentration in trout liver from Lake Mjøsa in 2019 (38 µg/kg w.w.) (Jartun 2020 In prep).

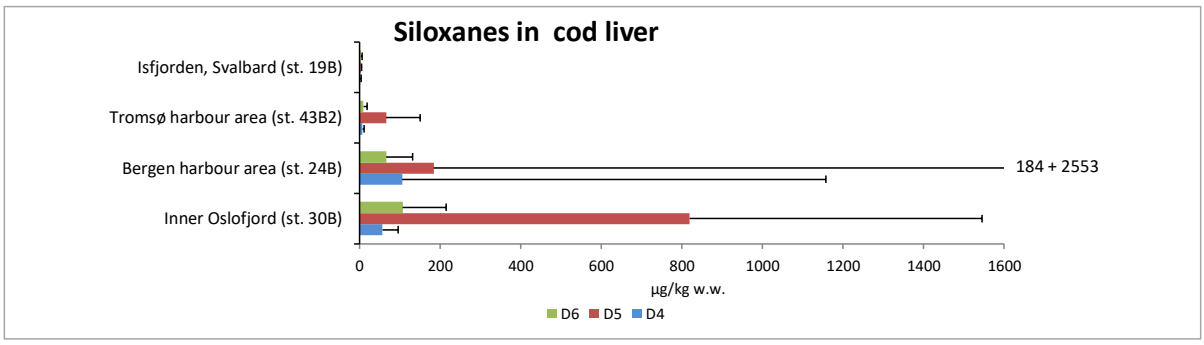


***Figure 79**. Median concentration (µg/kg w.w.) of siloxanes D4, D5 and D6 in cod liver in 2019. The error bar indicates one standard deviation above the median.*

***Table 22**. Median concentrations (µg/kg w.w.) with standard deviation of siloxanes (D4, D5 and D6) in cod liver and eider in 2019. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter** 2.11 for more details.)*

Component	Count	D4			D5			D6		
Species and sampling locality	2019	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Cod, liver										
Inner Oslofjord (st. 30B)	15 (0-1)	56.80	38.60	15 [14.8-174]	819.00	725.61	15 [73.5-2360]	107.00	107.00	15 [25.5-215]
Bergen harbour area (st. 24B)	15 (0-1)	105.91	1050.80	15 [12.5698-4047.671]	184.03	2553.28	15 [8.8454-9922.1252]	65.98	65.98	15 [13.8958-312.9549]
Tromsø harbour area (st. 43B2)	15 (0-1)	7.03	3.88	15 [3.8295-18.0101]	65.83	84.46	15 [26.6715-345.0966]	9.14	9.14	15 [3.0171-41.7286]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	2.17	1.17	14 [1.7253-6.1941]	3.43	1.50	15 [1.5385-7.6984]	2.93	2.93	15 [1.7812-10.5242]
Eider, blood										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	14 (0-1)	1.44	0.39	6 [1.6111-2.4565]	1.24	0.30	4 [1.4686-1.8157]	1.51	0.35	6 [1.508-2.2364]
Eider, egg										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	1.34	0.21	3 [1.3419-1.664]	2.89	0.68	15 [1.9529-4.7027]	2.76	0.45	2 [3.0568-4.0256]

General, large scale trends

These chemicals are highly volatile, and most of emissions occur to the atmosphere. Release to aquatic environment can also occur through wastewater. In Norway, cosmetics and personal care products cause the main source of siloxane emission (www.Miljostatus.no). Estimated emissions of siloxanes (D4 and D5) have increased gradually from 200 tons in 2000, to 387 tons in 2015 (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/siloksaner/).

3.3 Biological effects methods for cod in the Inner Oslofjord

Biological effect methods (BEM) are included in the monitoring program to assess the potential pollution effects on organisms. This can hardly be done solely on the basis of tissue concentrations of chemicals. There are three BEM methods used on cod liver samples (including analyses of degradation products of PAH in bile). Each method is in theory specific for individual or groups of chemicals. One of the advantages of these methods used at the individual level is the ability to integrate biological and chemical endpoints, since both approaches are performed on the same individuals. The results can be seen in relation to established reference values (OSPAR 2013).

3.3.1 OH-pyrene metabolites in bile

Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs and is thus a marker of exposure. Quantification methods for OH-pyrene have been improved two times since the initiation of these analyses in the CEMP/MILKYS programme. In 1998, the support/normalisation parameter was changed from biliverdine to absorbance at 380 nm. In 2000, the use of single-wavelength fluorescence for quantification of OH-pyrene was replaced with HPLC separation proceeding fluorescence quantification. The single wavelength fluorescence method is much less specific than the HPLC method. Although there is a good correlation between results from the two methods, they cannot be compared directly.

PAH compounds are effectively metabolized in vertebrates. As such, when fish are exposed to and take up PAHs, the compounds are biotransformed into polar metabolites which enhances the efficiency of excretion. It is therefore not suitable to analyse fish tissues for PAH parent compounds as a measure of exposure. However, since the bile is a dominant excretion route of PAH metabolites, and since the metabolites are stored for some time in the gall bladder, the bile is regarded as a suitable matrix for analyses of PAH metabolites as a measure of PAH exposure.

In 2019 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) was similar to 2018 and resembled the concentrations most recent years. Median OH-pyrene bile concentration in 2019 was above the ICES/OSPAR assessment criterion (background assessment criteria, BAC) in this area as well as in fish from the Inner Sørfjord (st. 53B). Also, at Farsund (st. 15B) and at Bømlo (st. 23B, reference station), median OH-pyrene bile concentrations exceeded the ICES/OSPAR assessment criterion in 2019, however only barely. Note that the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380 nm. In the Inner Sørfjord (st. 53B), the median concentration of OH-pyrene metabolites in bile from cod was significantly higher (by a factor of ~5) than in 2018 (Tukey-Kramer HSD test). Among the four stations, OH-pyrene concentrations were highest in the Inner Sørfjord (st. 53B) (Tukey-Kramer HSD test) (***Appendix F***).

3.3.2 ALA-D in blood cells

Inhibited activity of ALA-D indicates exposure to lead. Although ALA-D inhibition is lead-specific, it is not possible to rule out interference by other metals or organic contaminants. Note that the protocol for ALA-D analysis was slightly altered (to avoid Hg-containing reagents) in 2017.

The median ALA-D activity at the reference station (Bømlo area; 23B) appeared similar as observed in the years 2013-2017.

As previously noted, most years up to 2011 the activity of ALA-D in cod was somewhat inhibited in the Inner Oslofjord (st. 30B), compared to reference stations, i.e. Outer Oslofjord (st. 36B; only data to 2001), Bømlo (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Green *et al*. 2016). The median ALA-D activity in the Inner Oslofjord (st. 30B) in 2019 was lower (significantly so, Tukey-Kramer HSD test) than in the Bømlo (st. 23B, reference station, ***Appendix F***). Also, in the Inner Sørfjord (st. 53B), the median activity of ALA-D was significantly lower than the reference station (st. 23B) as well as the Inner Oslofjord (Tukey-Kramer HSD test). The frequent lower activities of ALA-D in cod from the Inner Oslofjord and Inner Sørfjord compared to the reference station (basis for comparison prior to 2007, 2009-2011 and 2013-2019) indicate the contamination of lead. Higher concentrations of lead in cod liver have generally been observed in the Inner Oslofjord and Inner Sørfjord compared to Bømlo, though with a relatively large individual variation. Median concentrations of lead in cod liver from the Inner Oslofjord (st. 30B) and the Sørfjord (st. 53B) were 0.096 mg/kg and 0.043 mg/kg, respectively, in 2019. In the Bømlo (st. 23B) the median concentration was 0.006 mg/kg. In cod liver, significant downward long-term trends were found for Pb in cod liver at all three stations (***Table 12***).

3.3.3 EROD-activity

High activity of hepatic cytochrome P4501A activity (EROD-activity) normally occurs as a response to the contaminants indicated in ***Table 6***. It was expected that higher activity would be found at the stations that were presumed to be most impacted by planar PCBs, PCNs, PAHs or dioxins such as the Inner Oslofjord (st. 30B). Since 2000, the median EROD-activity has generally been higher in the Inner Oslofjord compared to the reference station on the west coast (Bømlo, st. 23B). In 2018, EROD activities in neither the Inner Oslofjord (st. 30B), nor the Inner Sørfjord (st. 53B) were higher than at the reference station (st. 23B). In 2019, the median EROD activity appeared slightly higher in the Inner Oslofjord (st. 30B) and slightly lower in the Inner Sørfjord (st. 53B), compared to Bømlo (st. 23B), but these differences were not statistically different. Statistically significant downward trends in EROD activity were observed on both a long-term basis (whole data series) and

a short-term basis (last 5 years) at all three stations (***Figure 80***). Median EROD-activities were below the ICES/OSPAR assessment criterion (background assessment criteria, BAC).

No adjustment for water temperature has been made. Fish are sampled at the same time of year (September-November) when differences between the sexes should be at a minimum. Previous statistical analyses indicated no clear difference in activity between the sexes (Ruus, Hylland, and Green 2003). It has been shown that generally higher activity occurs at more contaminated stations (Ruus, Hylland, and Green 2003). However, the response is inconsistent (cf. ***Appendix F***), perhaps due to sampling of populations with variable exposure history. Besides, there is evidence from other fish species that continuous exposure to e.g. PCBs may cause adaptation, i.e. decreased EROD-activity response.

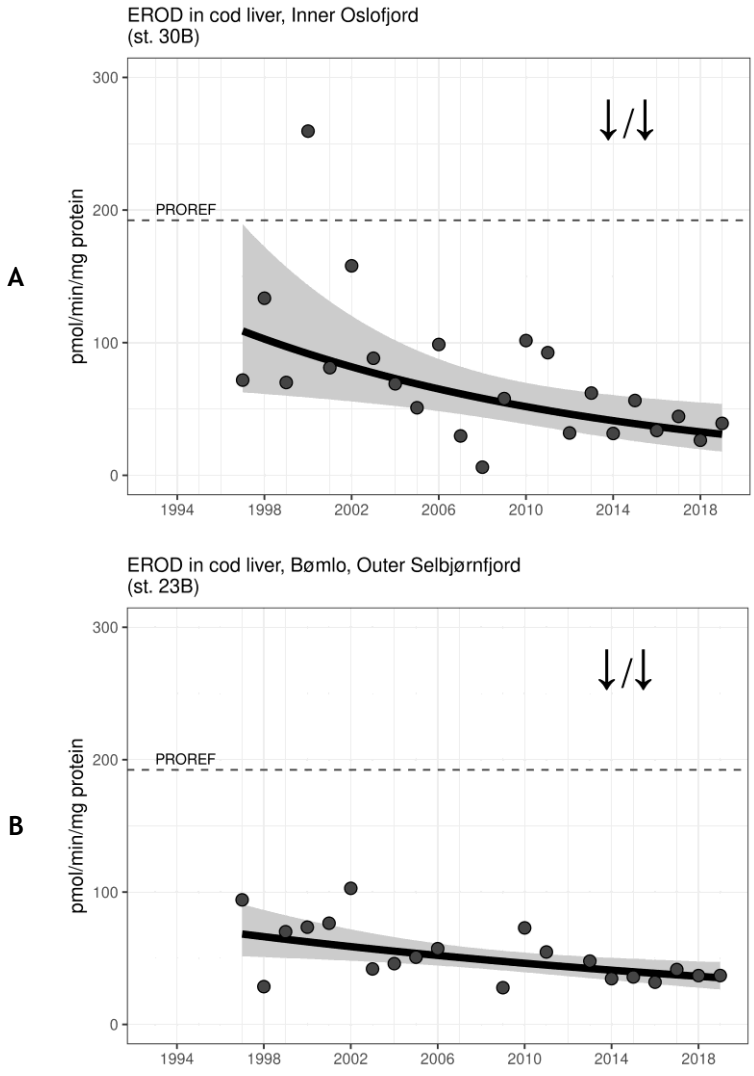


Figure 80. *Median activity (pmol/min/mg-protein) of EROD in cod liver from 1990 to 2019 in the Inner Oslofjord (st. 30B) (***A***) and from 1997 to 2019 in Bømlo (st. 23B) (***B***). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* ***Figure 4*** *and* ***Appendix C****.)*

3.4 Analysis of stable isotopes

3.4.1 General description of method

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 of 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) than the autochthonous. 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, Åberg, and Skei 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 ($\delta^{15}N$) is 3-5 ‰ per trophic level (Layman *et al*. 2012; Post 2002). It thus offers a continuous descriptor of trophic position. As such, it is also the basis for Trophic Magnification Factors (TMFs). TMFs give the factor of increase in concentrations of contaminants per trophic level. If the concentration increase per trophic level can be expressed as:

Log Concentration = $a + b * ($Trophic Level)

Then:

TMF = 10^b

TMFs has recently 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 applied to elucidate if spatial differences in contaminant concentrations may partially be attributed to different energy sources between stations, or that the same species (cod) may inhabit different trophic levels on different stations (***Table* 23**). Analysis of stable isotopes was included in the programme in 2012, thus the database now includes eight years. In the present report, The $\delta^{15}N$ data were scrutinized further by deducing the trophic position of the cod, based on a known baseline in the area, given by the isotopic profile of blue mussel, inhabiting trophic position 2 (primary consumer, feeding on particulate matter; see ***Chapter 3.4.3***). So far for the period 2012-2018 (Green *et al*. 2019) the results of the stable isotope analysis (of both blue mussel and cod) have shown a continual geographical pattern, suggesting a spatial trend persistent in time, and the isotopic signatures in mussels thus provide valuable information about the isotopic baselines along the Norwegian coast. This information has e.g. earlier been used to normalize trophic positions of herring gulls, when geographic comparisons have been made (Keilen 2017).

3.4.2 Results and discussion

The results of the stable isotope analysis in 2019 generally show the same pattern as observed in 2012-2018 (Green *et al*. 2019) i.e. a continual geographical pattern, suggesting a spatial trend persistent in time (***Figure 81***). The pattern for cod resembles that in blue mussel, in terms of isotopic signatures in the different geographical areas along the coast, indicating that there are geographical differences in the baseline isotopic signatures.

As previously, it can be noted that individual cod from the Sørfjord (st. 53B) and Bergen harbour (station 24B; both in Hordaland County) stand out with particularly low $\delta^{15}N$ signature (***Figure 81***); Bergen harbour, station 24B, was introduced in 2015). The same is shown for mussels from the

Sørfjord (stations 56A and 57A), indicating that the $\delta^{15}N$ -baseline of the food web in the Sørfjord is lower. The reason for this is unknown, but a higher influence of allochthonous nitrogen is possible. Likewise, isotope signatures of both fish (30B) and mussels (30A and I304) from the Oslofjord are among the highest observed (***Figure 81***) indicating a high baseline. These geographic differences were also observed 2012-2018 (Green *et al.* 2019). Interestingly, cod from stations from the North of Norway (Lofoten, 98B1) and Svalbard (19B) show intermediate $\delta^{15}N$ values and low $\delta^{13}C$ values (***Figure 81***). The same can be observed in mussels from Northern Norway (98A2). As previously pointed out, the stations generally show very similar patterns from year to year in terms of isotopic signatures, indicating a geographical trend, persistent in time.

Table 23. *Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ in blue mussel, cod and eider, 2019. Statistics shown are count (n), mean and standard deviation. Vienna Pee Dee Belemnite (VPDB) and atmospheric air (AIR) are standards.*

		$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$		
Station ID		**n**	**mean**	**s.d.**	**n**	**mean**	**s.d.**
Presumed less impacted:							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**3**	**-21.02**	**0.24**	**3**	**5.68**	**0.32**
Tjøme, Outer Oslofjord (st. 36A1)		3	-20.41	0.54	3	7.05	0.25
Singlekalven, Hvaler (st. I023)		3	-20.41	0.18	3	6.39	0.15
Gåsøya-Ulleröya, Farsund (st. 15A)		3	-21.15	0.42	3	6.68	0.36
Krossanes, Outer Sørfjord (st. 57A)		3	-20.19	0.17	3	3.54	0.89
Espevær, Outer Bømlafjord (st. 22A)		3	-21.81	0.04	3	5.72	0.21
Vågsvåg, Outer Nordfjord (st. 26A2)		3	-21.21	0.15	3	3.96	0.07
Ørland area, Outer Trondheimsfjord (st. 91A2)		3	-20.16	0.14	3	5.66	0.25
Mjelle, Bodø area (st. 97A2)		3	-21.04	0.32	3	6.60	0.24
Svolvær airport area (st. 98A2)		3	-22.75	0.21	3	5.52	0.43
Atlantic cod (*Gadus morhua*)	**statistics >>**	**14**	**-19.72**	**0.67**	**14**	**14.13**	**0.72**
Tjøme, Outer Oslofjord (st. 36B)		9	-18.70	0.60	9	15.71	0.77
Kirkøy, Hvaler (st. 02B)		15	-19.69	0.78	15	14.49	0.67
Skågskjera, Farsund (st. 15B)		15	-19.27	0.94	15	14.90	0.43
Bømlo, Outer Selbjørnfjord (st. 23B)		15	-19.61	1.04	15	13.80	0.68
Sandnessjøen area (st. 96B)		15	-19.68	0.62	15	13.71	1.44
Austnesfjord, Lofoten (st. 98B1)		15	-20.13	0.33	15	14.06	0.54
Isfjorden, Svalbard (st. 19B)		15	-20.92	0.41	15	12.23	0.48
Common eider (*Somateria mollissima*), blood	**statistics >>**	**14**	**-21.94**	**0.97**	**14**	**10.97**	**0.96**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		14	-21.94	0.97	14	10.97	0.96
Common eider (*Somateria mollissima*), egg	**statistics >>**	**15**	**-23.17**	**0.53**	**15**	**10.24**	**0.54**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-23.17	0.53	15	10.24	0.54
Presumed more impacted:							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**3**	**-20.75**	**0.24**	**3**	**5.85**	**0.27**
Gressholmen, Inner Oslofjord (st. 30A)		3	-19.27	0.04	3	7.86	0.11
Gåsøya, Inner Oslofjord (st. I304)		2	-19.59	0.31	2	7.29	0.33
Kirkøy, Hvaler (st. I024)		2	-21.81	0.80	2	6.89	0.23
Odderøya, Kristiansand harbour (st. I133)		3	-21.98	0.17	3	6.62	0.10
Kvalnes, Mid Sørfjord (st. 56A)		3	-20.02	0.10	3	2.70	0.29
Nordnes, Bergen harbour (st. I241)		3	-20.97	0.03	3	3.49	0.22
Ålesund harbour (st. 28A2)		3	-20.68	0.38	3	5.93	0.50
Bodø harbour (st. 97A3)		3	-21.72	0.08	3	6.06	0.34
Atlantic cod (*Gadus morhua*)	**statistics >>**	**14**	**-19.19**	**0.91**	**14**	**13.44**	**0.89**
Inner Oslofjord (st. 30B)		15	-18.93	1.19	15	16.79	0.73
Stathelle area, Langesundfjord (st. 71B)		15	-18.45	1.13	15	13.07	0.55
Kristiansand harbour area (st. 13B)		13	-18.23	0.62	13	14.65	0.48
Inner Sørfjord (st. 53B)		15	-18.59	1.30	15	10.56	0.76
Bergen harbour area (st. 24B)		14	-19.66	1.17	14	11.06	1.82
Ålesund harbour area (st. 28B)		15	-20.20	0.84	15	13.55	1.12
Trondheim harbour (st. 80B)		11	-18.82	0.45	11	13.74	0.70
Tromsø harbour area (st. 43B2)		15	-19.47	0.76	15	14.49	1.16
Hammerfest harbour area (st. 45B2)		15	-20.36	0.68	15	13.02	0.73
Mean of all blue mussel	**statistics >>**	**3**	**-20.88**	**0.24**	**3**	**5.77**	**0.29**
Mean of all Atlantic cod	**statistics >>**	**14**	**-19.45**	**0.79**	**14**	**13.78**	**0.81**

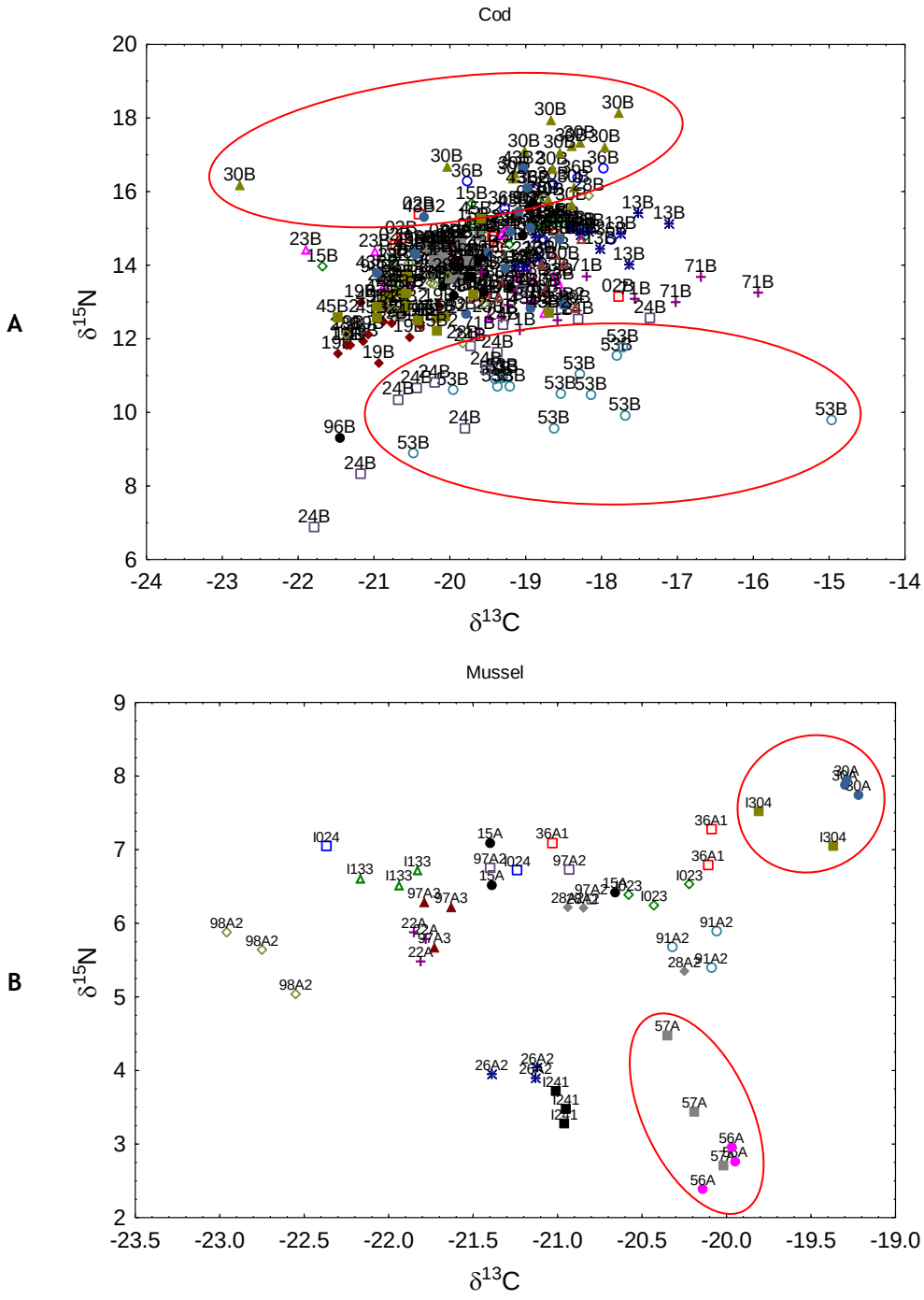


***Figure 81**. δ13C plotted against δ15N in for cod (**A**) and blue mussel (**B**). Station codes are superimposed. Red ellipses indicate the position of the majority of the samples of cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.*

δ^{15}N ratio in eiders from Svalbard (blood and egg) sampled in 2019 resembled those in 2018 (***Figure 82***), however δ^{13}C and δ^{15}N in blood and δ^{15}N in eggs were lower in 2019. The values are similar as those measured in eiders (pectoral muscle) from Kongsfjorden (Svalbard), October 2007 (Evenset *et al.* 2016). Evenset *et al.* (2016) estimated the trophic level of these birds to 3.1-3.4. The δ^{13}C ratio in the eiders differed between the two matrices (blood and egg). The δ^{13}C ratio was higher in blood than in eggs (***Figure 82***) 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 to 5.13 ± 0.63 in blood and 9.53 ± 0.42 in egg, and a C:N ratio of >3.5 implies the presence of lipids, which may somewhat confound δ^{13}C interpretation, since lipids are δ^{13}C-

depleted relative to proteins (Sweeting, Polunin, and Jennings 2006). The $\delta^{13}C$ ratio in the eiders (egg and blood) was also lower than in pectoral muscle of eider from Svalbard collected in 2007 (Evenset *et al.* 2016).

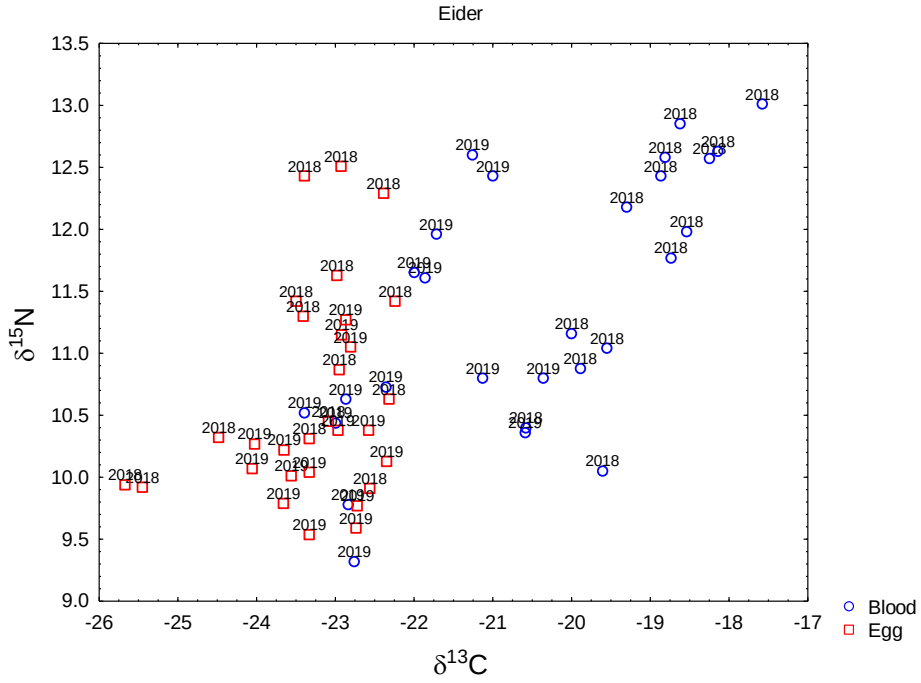


Figure 82. *$\delta^{15}C$ plotted against $\delta^{15}N$ in blood and egg of eider from Svalbard in 2018 and 2019. Sampling years are superimposed.*

3.4.3 Geographical differences in trophic levels

As described in ***Chapter 3.4.2***, the results of the stable isotope analysis in 2019 generally show the same pattern as observed in 2012-2018 (Green *et al.* 2019), i.e. a continual geographical pattern, suggesting a spatial trend persistent in time. For $\delta^{15}N$ in cod, this is also evident from ***Figure 83***. This figure shows that through the years stable isotopes have been analysed (2015-2019) the lowest $\delta^{15}N$ values are found in cod from stations 53B (Inner Sørfjord) and 24B (Bergen harbour area) in Vestland County, and the highest $\delta^{15}N$ values are found in cod from The Inner Oslofjord (30B).

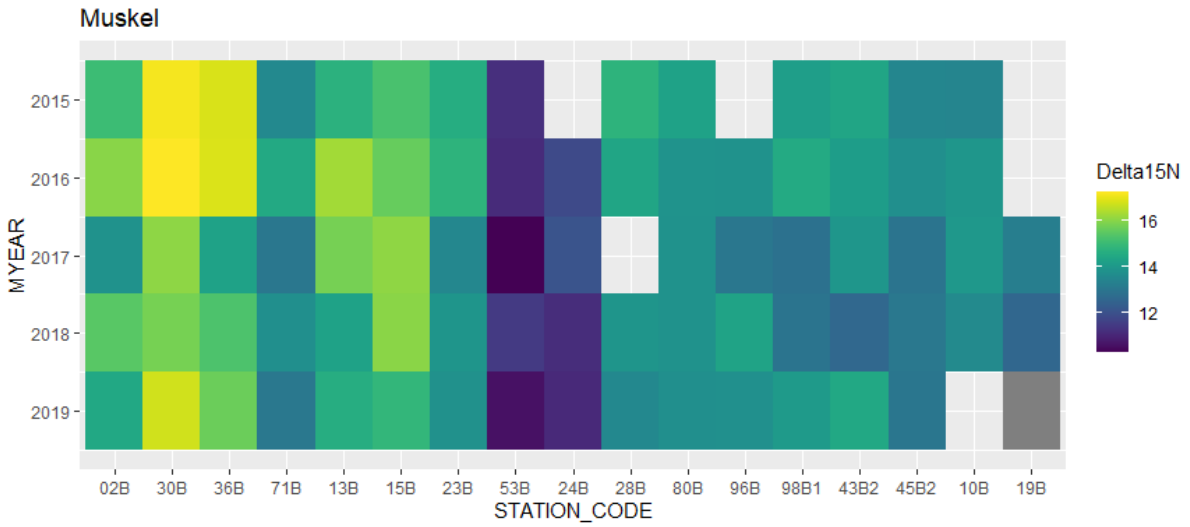


Figure 83. *Tile plot for $\delta^{15}N$ in cod along the Norwegian coast (and Svalbard; 19B), 2015-2019.*

This year, we set out to investigate if these differences in $\delta^{15}N$ in cod from the different areas imply differences in trophic position of the cod at the different places. If so, parts of the differences in concentrations of contaminants that biomagnify may be attributed to different trophic positions of the cod, and not merely differences in exposure. To accomplish such an exercise, a measure of the $\delta^{15}N$ baseline in the food web is needed for all the different localities. The $\delta^{15}N$ measured in blue mussel serves this purpose. ***Figure 84*** shows that, like for cod, the lowest $\delta^{15}N$ values are found in blue mussel from the Sørfjord/Hardangerfjord (69A, 51A, 52A, 56A, 57A, 63A) and Bergen harbour (I241) area in Vestland County, while the $\delta^{15}N$ values in blue mussel from the Inner Oslofjord (30A and I304) are among the highest.

Everywhere, blue mussel feeds by filtering particulate matter and are primary consumers that can be defined as inhabitants of trophic level 2. Assuming an increase in $\delta^{15}N$ of 3.8 ‰ (Layman *et al.* 2012; Post 2002) per (integer) trophic level, the trophic position (TP) of cod may be calculated as:

$$TP_{Cod} = 2 + (\delta^{15}N_{Cod} - \delta^{15}N_{Blue\ mussel})/3.8$$

An overview of which blue mussel station that is used as baseline for the different cod stations is given in ***Table 24***. The blue mussel station in the nearest proximity to the cod station is chosen, but note that for the cod stations 43B2 (Tromsø) and 45B2 (Hammerfest), the blue mussel stations are 300 km and 500 km, respectively, away.

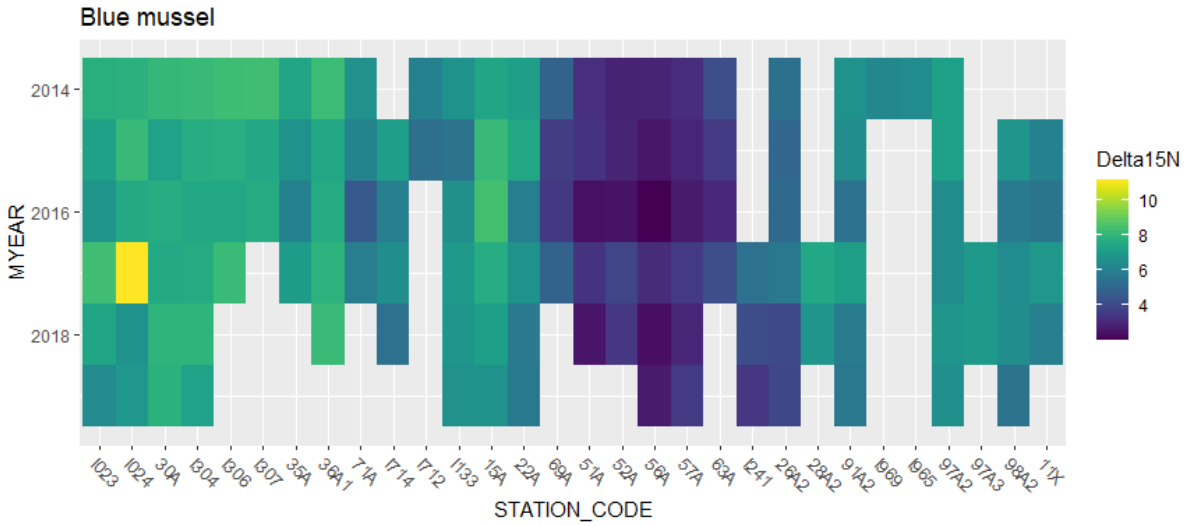


Figure 84. *Tile plot for $\delta^{15}N$ in blue mussel along the Norwegian coast, 2014-2019.*

***Table 24**. Overview of which blue mussel station that is used as baseline for the different cod stations in calculations of Cod trophic position.*

Cod station	Cod station name	Mussel station	Mussel station name
02B	Kirkøy, Hvaler	I024	Kirkøy, Hvaler
30B	Inner Oslofjord	I304	Gåsøya, Inner Oslofjord
36B	Tjøme, Outer Oslofjord	36A1	Tjøme, Outer Oslofjord
71B	Stathelle area, Langesundfjord	I712	Croftholmen, Langesundfjord
13B	Kristiansand harbour area	I133	Odderøya, Kristiansand harbour
15B	Skågskjera, Farsund	15A	Gåsøya-Ullerøya, Farsund
23B	Bømlo, Outer Selbjørnfjord	22A	Espevær, Outer Bømlafjord
53B	Inner Sørfjord	56A	Kvalnes, Mid Sørfjord
24B	Bergen harbour area	I241	Nordnes, Bergen harbour
28B	Ålesund harbour area	28A2	Ålesund harbour
80B	Trondheim harbour	91A2	Ørland area, Outer Trondheimfjord
96B	Sandnessjøen area	I969	Bjørnbærviken, Inner Ranfjord
98B1	Austnesfjord, Lofoten	98A2	Svolvær airport area
43B2	Tromsø harbour area	98A2	Svolvær airport area
45B2	Hammerfest harbour area	98A2	Svolvær airport area
10B	Kjøfjord, Outer Varangerfjord	11X	Brashavn, Outer Varangerfjord

The calculations of cod trophic position showed that, despite the similar geographical pattern in $\delta^{15}N$ between cod and blue mussel, there are geographical differences in the trophic position of cod (***Figure 85***).

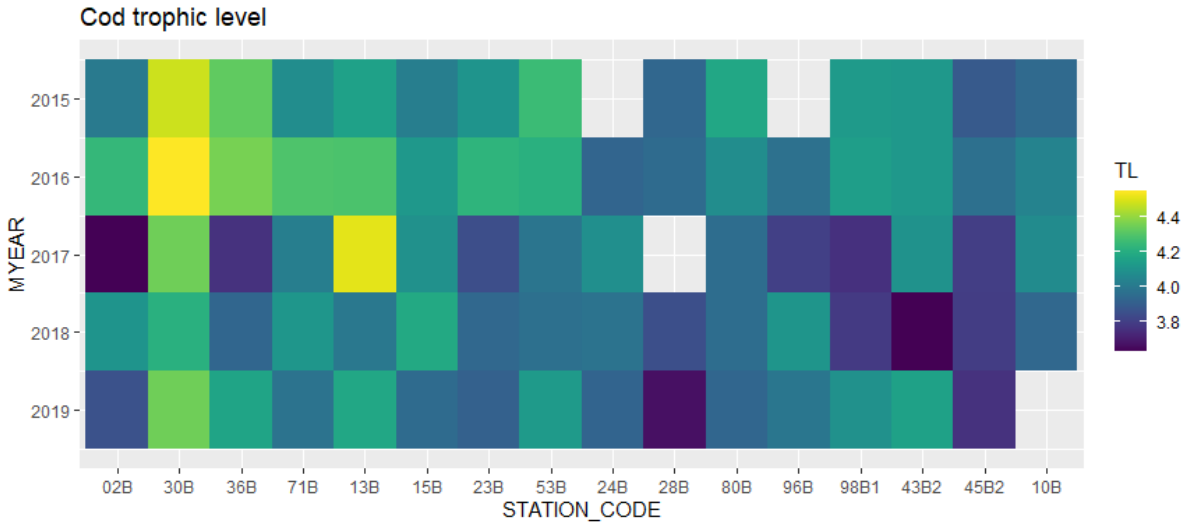


***Figure 85**. Tile plot for trophic position of cod along the Norwegian coast, 2015-2019.*

Figure 85 shows that the trophic position of cod (length-adjusted) from the Oslofjord appears particularly high. The trophic position of a fish is affected by its age, and thus size, as it may feed on larger organisms (higher trophic organisms) as it grows older/larger. To account for the possibility of having caught fish of different sizes at the different stations, a model with station and length (40 cm normalized fish) was run (***Figure 86***). Here, "year" us a random factor and station effect is estimated on the year level. The confidence intervals are estimated using Bolker

(2020[1]) method, and are based on fixed-effects uncertainty only, i.e. the confidence interval for the station effect. The model showed significant differences in trophic position.

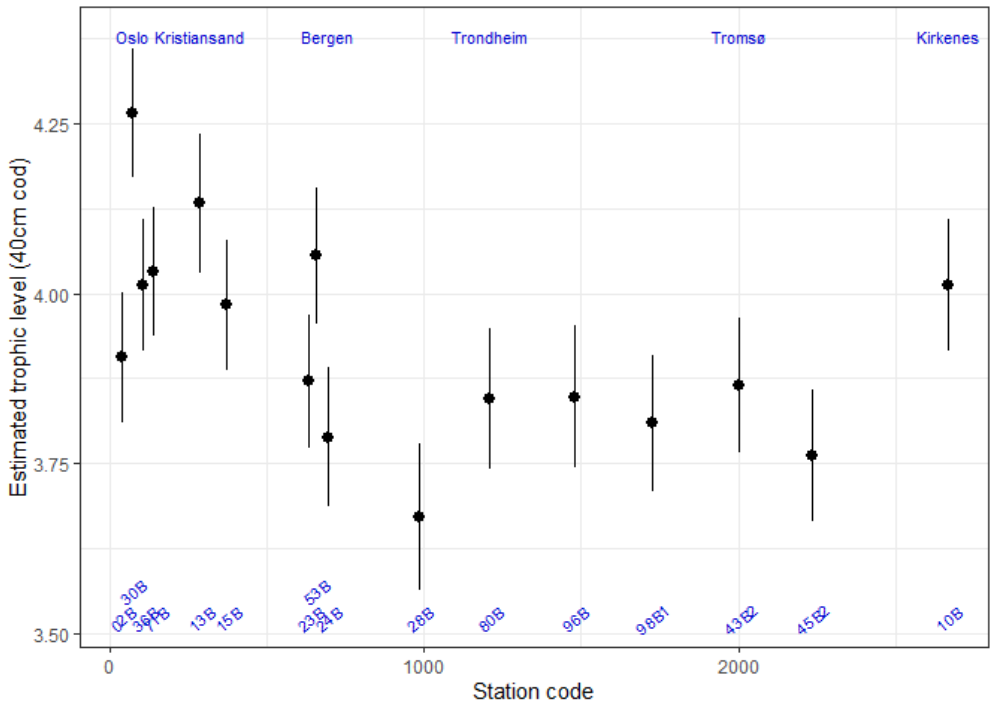


***Figure 86**. Estimated trophic level of cod normalised to 40 cm length, along the Norwegian coast.*

These findings may suggest that parts of the differences in concentrations of contaminants that biomagnify may be attributed to different trophic positions of the cod, and not merely differences in exposure at the different stations. PCB-153 and Hg are compounds that are known to biomagnify. ***Figure 87*** and ***Figure 88*** show the logarithmic concentrations of PCB-153 and Hg, respectively, plotted against the trophic position of the cod. Both show a significant linear relationship, although with poor goodness-of-fit (p=0.04, R^2=0.03 and p<0.0001, R^2=0.19, respectively). The slopes of these regressions correspond to trophic magnification factors (TMF) of 1.86 and 3.10 for PCB-153 and Hg, respectively. Linear regressions isolated for each station produced significant positive linear relationships between trophic position and Log[PCB153], with better goodness-of-fit, at the following stations:

15B: p=0.016, R^2=0.37
96B: p=0.011, R^2=0.49
13B: p=0.020, R^2=0.70
24B: p=0.006, R^2=0.69
80B: p=0.005, R^2=0.60
43B2: p=0.0005, R^2=0.62

Furthermore, linear regressions isolated for each station produced significant positive linear relationships between trophic position and Log[Hg] at the following stations:

15B: p=0.002, R^2=0.53
96B: p=0.002, R^2=0.64
98B1: p=0.012, R^2=0.40
13B: p=0.001, R^2=0.62
24B: p=0.0001, R^2=0.72

[1] Bolker, Ben 2020. The GLMM FAQ. https://bbolker.github.io/mixedmodels-misc/glmmFAQ.html (visited 19.10.2020)

28B: p=0.0039, R^2=0.49
80B: p=0.0029, R^2=0.65
43B2: p=0.00004, R^2=0.74

As such, parts of the differences in concentrations of other contaminants with known biomagnifying properties may also be attributed to different trophic positions of the cod, and not merely differences in exposure at the different stations.

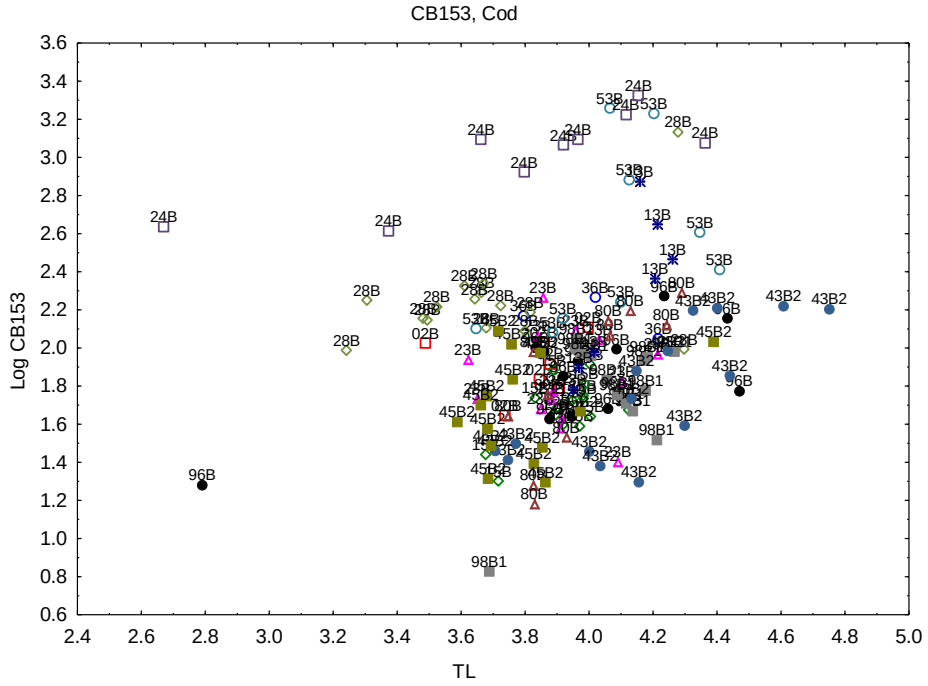


Figure 87. *Trophic position of cod plotted against the log-transformed concentration of CB153 in cod. Station codes are superimposed.*

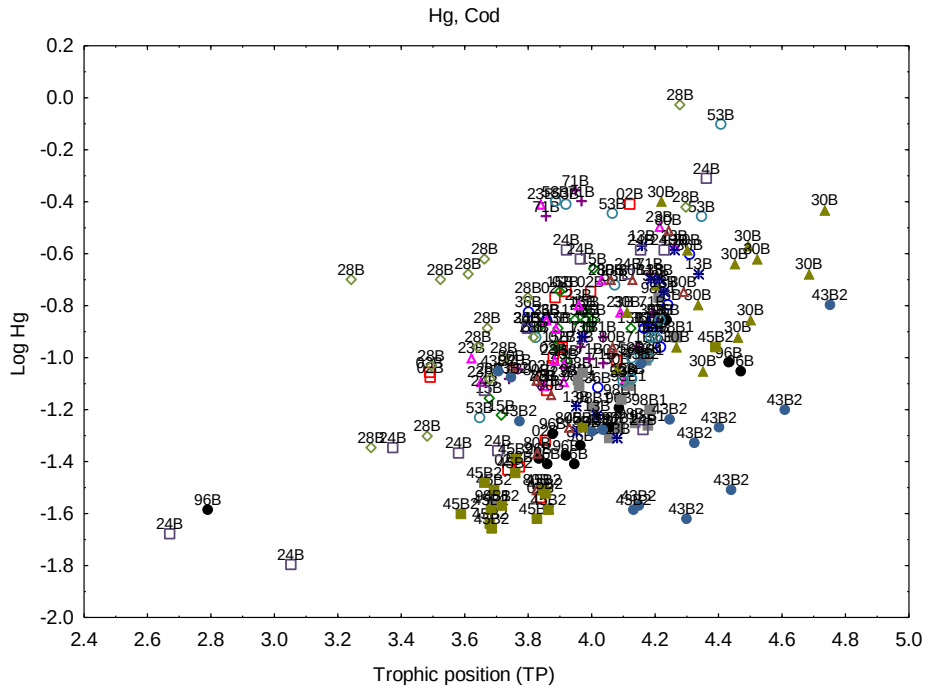


Figure 88. *Trophic position of cod plotted against the log-transformed concentration of Hg in cod. Station codes are superimposed.*

3.5 Summary of results from Svalbard

Investigation of contaminants in samples from Svalbard was included in the MILKYS programme in 2018. Contaminant levels are monitored in two species from two different locations; fillet and liver from cod caught in the Isfjord (st. 19B) and blood and eggs from the eider duck found in the Kongsfjord (st. 19N) (***Table 25***). The results are reported in the preceding sections (see **Chapters 3.1.2** and **3.3**) and summarized here. Where possible, concentrations in cod are compared to the EQS and PROREF. However, for the eider samples, comparison to the EQS was not considered justified, and values for PROREF have not yet been established.

Levels in cod
As for cod from most of the other stations, the median concentrations in cod liver at Svalbard exceeded the EQS for Hg (in fillet), PCB-7, BDE6S and BDE47, but were below the EQS for PFOA, PFOS, D5, α–HBCD, SCCP and MCCP (***Table 11***). Median concentrations of contaminants in cod liver and cod fillet were generally low (below PROREF), the exception being for Cd which exceeded PROREF by a factor below two. (***Table 12***).

Siloxanes, i.e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5) and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver for the third time at the four stations, including Svalbard. D5, the most dominant cVMS, as well as D4 and D6 were lowest at Svalbard compared to the other sampling stations included in the study (***Figure 79***).

The correlation between δ^{15}N and contaminant concentration in cod could suggest higher concentrations in individuals with higher δ^{15}N.

Levels in eider
The median concentrations in eider blood and egg from Svalbard exceeded the EQS for Hg, PCB-7 (in egg), BDE6S and BDE47, but were below the EQS for PCB-7 (in blood), α–HBCD, SCCP, MCCP, PFOA, PFOS, D5 and HCB (***Table 11***).

Median concentrations of Hg, Pb and As in eider eggs from Svalbard were similar (within 60 %) as also observed in a comparable study (Hill 2018). The median concentration of PCB-153 (0.200 µg/kg w.w.) in eider blood at Svalbard was nearly within the same range as in another study from Svalbard (mean 0.187±0.023.8 µg/kg w.w. after five days of incubation) (Bustnes *et al*. 2010). The Hg concentrations in eider blood and eggs at Svalbard in 2019 was almost within the same range as a study in the Inner Oslofjord in 2017 (Ruus 2018) (see ***Chapter 3.2.2***).

In the present study, the median concentration of PBDE47, PFOS and PFOSA was almost within the same ranges as average concentrations found in another study of eider from three stations in northern Norway and one at Svalbard (Harju 2013). However, for SCCP and MCCP, median concentrations were higher (up to five times) compared to the same study. The PFOS concentrations in eider eggs and blood are 15 and 26 times higher, respectively, in the Inner Oslofjord than at Svalbard (see ***Chapter 3.2.24***).

The δ^{15}N ratios in eider (blood and eggs) from Svalbard were fairly similar to that observed in 2007 (Evenset *et al*. 2016).

***Table 25**. Median concentrations and standard deviations for contaminant levels in cod livers (unless otherwise specified) from the Isfjord (st. 19B) and eider blood and eggs from Breøyane in Kongsfjord (st. 19N) from 2019. Units are: percent for dry and lipid weight, permille for stabile isotopes, mg/kg (w.w.) for metals and µg/kg (w.w.) for the remaining substances. Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter 2.11** for more details.)*

Parameter Code	Gadus morhua, Liver Isfjorden, Svalbard (st. 19B)			Somateria mollissima, Blood Breøyane, Kongsfjorden, Svalbard (st. 19N)			Somateria mollissima, Egg Breøyane, Kongsfjorden, Svalbard (st. 19N)		
	Median	S.d.	D.d.i.	Median	S.d.	D.d.i.	Median	S.d.	D.d.i.
Dry weight (%)	49.000	7.968	15 [26-62]						
Lipid content (%)	37.600	9.049	15 [14.3-50.8]	0.240	0.076	12 [0.13-0.355]	8.383	0.635	15 [7.4025-9.875]
AG	0.230	0.222	13 [0.06-0.77]	0.001	0.001	14 [2e-04-0.0048]	0.007	0.006	15 [0.0016-0.0218]
AS	2.800	1.513	15 [1.6-6.4]	0.023	0.017	14 [0.0161-0.0786]	0.123	0.052	15 [0.0587-0.2941]
CD	0.170	0.212	15 [0.075-0.71]	0.006	0.002	14 [0.0021-0.0089]	0.000	0.000	15 [1e-04-4e-04]
CO	0.017	0.007	15 [0.01-0.036]	0.003	0.002	14 [8e-04-0.0057]	0.005	0.001	15 [0.0041-0.0085]
CR	0.010	0.008	6 [0.013-0.032]	0.005	0.000	0 [n.a.]	0.011	0.009	12 [0.0073-0.0408]
CU	1.500	1.779	15 [0.63-7.5]	0.520	0.100	14 [0.331-0.7462]	1.442	0.194	15 [1.0559-1.7509]
HG (in muscle)	0.026	0.031	15 [0.014-0.14]	0.125	0.059	14 [0.0382-0.2442]	0.094	0.030	15 [0.0546-0.1723]
NI	0.034	0.024	15 [0.025-0.12]	0.003	0.000	0 [n.a.]	0.005	0.004	12 [0.0033-0.0182]
PB	0.005	0.013	15 [0.003-0.051]	0.049	0.165	14 [0.0318-0.6655]	0.008	0.016	14 [0.002-0.0568]
SN	0.027	0.016	15 [0.013-0.077]	0.006	0.059	2 [0.0246-0.2281]	0.006	0.016	4 [0.0063-0.0615]
ZN	17.000	3.127	15 [13-23]	5.269	0.612	14 [4.2908-6.3741]	17.006	1.736	15 [15.1164-20.7933]
CB_S7	32.664	33.476	15 [15.024-152.37]	0.478	0.556	10 [0.4033-1.9687]	9.404	3.069	15 [5.1474-15.1637]
CB18				0.017	0.001	1 [0.02]	0.017	0.000	0 [n.a.]
CB28	0.601	0.475	13 [0.408-2.3]	0.020	0.010	5 [0.0237-0.0537]	0.176	0.102	15 [0.098-0.367]
CB31				0.015	0.000	1 [0.0155]	0.022	0.006	11 [0.0172-0.0317]
CB33				0.010	0.000	1 [0.0097]	0.010	0.000	0 [n.a.]
CB37				0.005	0.000	0 [n.a.]	0.005	0.002	0 [n.a.]
CB47				0.012	0.007	3 [0.0121-0.0369]	0.071	0.049	15 [0.0387-0.157]
CB52	2.260	1.879	15 [0.984-8.77]	0.016	0.010	1 [0.0522]	0.037	0.008	15 [0.0233-0.0489]
CB66				0.051	0.007	2 [0.0699-0.0729]	0.188	0.164	15 [0.0844-0.535]
CB74				0.028	0.013	5 [0.0299-0.0774]	0.246	0.156	15 [0.15-0.568]
CB99				0.027	0.040	9 [0.0243-0.151]	0.669	0.341	15 [0.344-1.31]
CB101	4.630	5.064	15 [2.2-23.1]	0.036	0.013	1 [0.0831]	0.069	0.020	15 [0.0357-0.11]
CB105				0.021	0.026	8 [0.0194-0.0893]	0.366	0.156	15 [0.21-0.649]
CB114				0.003	0.002	4 [0.0058-0.0089]	0.042	0.018	15 [0.0176-0.07]
CB118	4.780	4.912	15 [1.89-22.4]	0.068	0.090	9 [0.0593-0.298]	1.350	0.572	15 [0.787-2.53]
CB122				0.003	0.001	1 [0.005]	0.004	0.001	0 [n.a.]
CB123				0.005	0.001	3 [0.0052-0.0082]	0.024	0.009	15 [0.0124-0.0401]
CB128				0.016	0.022	10 [0.0106-0.0729]	0.358	0.135	15 [0.182-0.66]
CB138	7.180	7.907	15 [2.89-34.5]	0.100	0.134	8 [0.0986-0.46]	2.240	0.838	15 [1.2-3.84]
CB141				0.010	0.001	1 [0.0156]	0.013	0.006	8 [0.013-0.0266]
CB149				0.063	0.000	0 [n.a.]	0.176	0.105	15 [0.0898-0.425]
CB153	11.300	11.191	15 [4.99-50]	0.200	0.291	10 [0.159-1.05]	4.810	1.350	15 [2.62-6.94]
CB156				0.007	0.011	14 [0.0041-0.0377]	0.139	0.043	15 [0.0695-0.199]
CB157				0.002	0.003	8 [0.0017-0.0098]	0.046	0.013	15 [0.0233-0.061]
CB167				0.007	0.010	11 [0.0037-0.034]	0.121	0.036	15 [0.0655-0.176]
CB170				0.010	0.014	14 [0.0054-0.0508]	0.157	0.067	15 [0.066-0.305]
CB180	2.620	2.556	15 [0.996-11.3]	0.037	0.040	10 [0.0294-0.138]	0.666	0.279	15 [0.341-1.35]
CB183				0.012	0.020	8 [0.0112-0.0718]	0.225	0.089	15 [0.0991-0.382]
CB187				0.033	0.052	7 [0.0343-0.19]	0.659	0.377	15 [0.35-1.86]
CB189				0.002	0.001	2 [0.0032-0.0071]	0.013	0.012	11 [0.0066-0.0544]
CB194				0.003	0.004	9 [0.0027-0.0154]	0.045	0.022	15 [0.0221-0.11]
CB206				0.002	0.003	4 [0.0032-0.0133]	0.019	0.021	15 [0.0074-0.0948]
CB209				0.001	0.004	4 [0.0033-0.0162]	0.013	0.020	15 [0.0077-0.0885]
HCB				0.469	0.484	14 [0.177-1.7]	5.750	1.843	15 [2.53-9.76]
HBCDA	0.387	0.566	14 [0.132-2.38]	0.009	0.005	0 [n.a.]	0.008	0.004	0 [n.a.]
HBCDG	0.060	0.020	0 [n.a.]	0.009	0.002	0 [n.a.]	0.148	0.086	15 [0.0599-0.365]
HBCDB	0.060	0.025	0 [n.a.]	0.029	0.008	0 [n.a.]	0.029	0.000	0 [n.a.]
HBCDD	0.507	0.552	14 [0.22-2.44]	0.047	0.013	0 [n.a.]	0.183	0.086	15 [0.0989-0.4119]
Sum HBCD	0.353	0.588	14 [0.132-2.38]						

Table 25. *(cont.)*

Parameter Code	Gadus morhua, Liver Isfjorden, Svalbard (st. 19B)			Somateria mollissima, Blood Breøyane, Kongsfjorden, Svalbard (st. 19N)			Somateria mollissima, Egg Breøyane, Kongsfjorden, Svalbard (st. 19N)		
	Median	S.d.	D.d.i.	Median	S.d.	D.d.i.	Median	S.d.	D.d.i.
BDESS	4.260	1.791	15 [2.9303-9.9111]	0.606	0.154	14 [0.5303-1.0671]	0.447	0.127	15 [0.264-0.7481]
BDE6S	1.342	1.427	15 [0.5665-6.575]	0.051	0.014	14 [0.038-0.082]	0.143	0.049	15 [0.0644-0.1971]
BDE17	0.010	0.006	5 [0.012-0.0353]	0.003	0.001	2 [0.0036-0.0043]	0.003	0.000	0 [n.a.]
BDE28	0.056	0.062	15 [0.0321-0.273]	0.004	0.001	0 [n.a.]	0.004	0.000	0 [n.a.]
BDE47	0.964	1.081	15 [0.36-4.9]	0.020	0.006	14 [0.0117-0.0296]	0.045	0.014	15 [0.0181-0.0598]
BDE49	0.179	0.226	15 [0.0828-0.96]	0.003	0.001	1 [0.0039]	0.004	0.009	13 [0.0032-0.0372]
BDE66	0.010	0.004	5 [0.0123-0.0228]	0.003	0.001	0 [n.a.]	0.003	0.010	2 [0.0073-0.0401]
BDE71	0.010	0.001	1 [0.0142]	0.002	0.001	3 [0.0021-0.0025]	0.002	0.009	2 [0.0043-0.0361]
BDE77	0.010	0.000	0 [n.a.]	0.002	0.001	4 [0.002-0.0025]	0.002	0.000	1 [0.0029]
BDE85	0.020	0.000	0 [n.a.]	0.003	0.001	0 [n.a.]	0.005	0.002	0 [n.a.]
BDE99	0.020	0.000	0 [n.a.]	0.009	0.006	13 [0.007-0.0275]	0.016	0.015	9 [0.0157-0.0595]
BDE100	0.175	0.183	15 [0.0504-0.832]	0.004	0.002	6 [0.0035-0.0083]	0.026	0.016	13 [0.0129-0.0559]
BDE119	0.020	0.007	6 [0.0203-0.042]	0.003	0.001	1 [0.0034]	0.005	0.002	1 [0.0076]
BDE126	0.020	0.002	2 [0.0217-0.0279]	0.003	0.001	0 [n.a.]	0.003	0.001	0 [n.a.]
BDE138	0.030	0.000	0 [n.a.]	0.007	0.002	0 [n.a.]	0.007	0.001	0 [n.a.]
BDE153	0.030	0.000	0 [n.a.]	0.007	0.002	0 [n.a.]	0.007	0.004	4 [0.0088-0.0165]
BDE154	0.138	0.112	15 [0.0624-0.52]	0.005	0.001	2 [0.0056-0.006]	0.023	0.012	13 [0.0108-0.0439]
BDE156	0.030	0.000	0 [n.a.]	0.009	0.003	0 [n.a.]	0.009	0.002	0 [n.a.]
BDE183	0.050	0.000	0 [n.a.]	0.005	0.001	0 [n.a.]	0.005	0.001	0 [n.a.]
BDE184	0.050	0.000	0 [n.a.]	0.004	0.001	0 [n.a.]	0.004	0.000	1 [0.0043]
BDE191	0.050	0.000	0 [n.a.]	0.004	0.001	0 [n.a.]	0.004	0.002	0 [n.a.]
BDE196	0.100	0.022	0 [n.a.]	0.007	0.002	0 [n.a.]	0.007	0.001	0 [n.a.]
BDE197	0.100	0.019	0 [n.a.]	0.005	0.001	0 [n.a.]	0.005	0.001	0 [n.a.]
BDE202				0.008	0.002	1 [0.0098]	0.008	0.002	0 [n.a.]
BDE206	0.400	0.255	0 [n.a.]	0.037	0.015	13 [0.0294-0.075]	0.010	0.007	6 [0.0152-0.0294]
BDE207	0.224	0.093	0 [n.a.]	0.026	0.011	11 [0.0184-0.0468]	0.008	0.007	5 [0.0108-0.0301]
BDE209	1.000	0.466	0 [n.a.]	0.428	0.117	14 [0.355-0.739]	0.194	0.127	11 [0.116-0.561]
SCCP	50.000	15.546	15 [21-80]	15.484	6.940	12 [12.664-33.9716]	3.236	5.874	3 [15.8143-17.3532]
MCCP	110.000	1262.957	15 [36-5000]	30.511	10.808	14 [22.2204-55.5368]	8.761	25.249	7 [19.4931-98.0165]
PFAS	0.560	0.215	15 [0.24-1.1]	0.490	0.403	14 [0.26-1.9]	1.600	1.529	15 [0.6-5.8]
PFDcA	0.400	0.000	0 [n.a.]	0.400	0.000	0 [n.a.]	0.400	0.078	2 [0.57-0.66]
PFHpA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFHxA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFHxS	0.200	0.000	0 [n.a.]	0.215	0.179	13 [0.17-0.85]	0.150	0.109	13 [0.12-0.5]
PFNA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFOA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFOS	0.380	0.176	15 [0.14-0.77]	0.390	0.403	14 [0.16-1.8]	1.500	1.529	15 [0.5-5.7]
PFOSA	0.170	0.079	13 [0.1-0.39]	0.100	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]
PFUdA	0.400	0.100	6 [0.44-0.71]	0.400	0.000	0 [n.a.]	0.440	0.113	8 [0.44-0.76]
TBA				0.016	0.008	0 [n.a.]	0.050	0.038	12 [0.0281-0.135]
D4	2.168	1.171	14 [1.7253-6.1941]	1.440	0.389	6 [1.6111-2.4565]	1.340	0.206	3 [1.3419-1.664]
D5	3.429	1.502	15 [1.5385-7.6984]	1.240	0.298	4 [1.4686-1.8157]	2.887	0.677	15 [1.9529-4.7027]
D6	2.933	2.345	15 [1.7812-10.5242]	1.510	0.347	6 [1.508-2.2364]	2.760	0.449	2 [3.0568-4.0256]
Delta13C (in muscle)	-20.940	0.405	15 [-21.48--20.14]	-21.930	0.966	14 [-23.39--20.36]	-22.970	0.530	15 [-24.06--22.35]
Delta15N (in muscle)	12.160	0.480	15 [11.35-13]	10.765	0.955	14 [9.32-12.6]	10.130	0.538	15 [9.54-11.27]
C/N (in muscle)	3.330	0.057	15 [3.28-3.49]	5.005	0.635	14 [4.17-6.4]	9.540	0.422	15 [8.73-10.11]

4. Conclusions

This monitoring programme examines long- and short-term changes for 30 selected contaminants in biota along the coast of Norway in point-source areas and in areas remote from point sources. In this report the state of the environment in Norwegian coastal waters is assessed based on measured contaminant levels and changes in contaminant concentrations over time, and by relating these concentrations to environmental quality standards (EQS) and the Norwegian provisional high reference contaminant concentrations (PROREF). The main conclusions from the 2019 investigations were (based on wet weight basis) that:

The environmental quality in Norwegian coastal waters are generally good, with some exceptions

- The majority (67.1 %) of the median concentrations that could be assessed against the EQS were below the EQS.
- The majority (69.9 %) of the median concentrations that could be assessed against the PROREF were below the PROREF.
- Statistical analyses showed that most contaminants had a downward short-term trend, e.g. for metals, TBT and imposex (VDSI), PFOS and PFOSA. However, upward time-trends were also found for, *inter alia*, Cr and Hg.
- A south to north gradient was found for some contaminants. Median concentraions of contaminants in blue mussel and cod from less impacted stations showed statistically significant geographical trends for some of the contaminants. For Ag, Co, PCB-7, DDE, BDE100, PFOS, PFOSA, TBT and TPT concentrations were found to decrease by 20 % or more from South to North. For Ag, Cd, and HCB an increase in concentrations of 20 % or more was observed from South to North.
- In cod fillet from the Inner Oslofjord and Tromsø harbour, significant upward long-term trends for Hg were found. Significant upward long- and short-term trends for Hg were also found in the harbour of Kristiansand, at Farsund (Skågskjera) and at Bømlo. While Hg concentration is strongly linked to fish length, these trends were significant also after adjusting for cod length for the Inner Oslofjord, Kristiansand harbour and Farsund.
- The highest concentrations of PBDEs, predominantly BDE47, were found in the Inner Oslofjord and Bergen harbour for cod liver, and in the Outer Nordfjord and the harbours of Bergen and Bodø for blue mussel.
- The highest PCB-7 concentrations were found in blue mussel from the Inner Oslofjord and in cod liver from the harbour of Bergen.
- Blue mussel from two stations in the Sørfjord had concentrations exceeding PROREF for DDE (degradation product of DDT) by a factor of over 20, presumably related to the earlier use of DDT as pesticide in this orchard district.
- Cod liver from the Outer Oslofjord had high concentrations of PFOSA.
- PFOS, PFOSA and PFUdA concentrations in cod were not found to correlate with the distance from the nearest airport.
- The dominant HBCD isomer in cod liver was α–HBCD. The concentration of α–HBCD was highest in cod liver from Bergen harbour, and in blue mussel from Bodø harbour; probably related to urban activities.
- In cod liver, the highest SCCP and MCCP median concentrations were found at Kirkøy in Hvaler. Blue mussel samples indicated highest SCCP and MCCP concentrations at Ørland in Bodø harbour, respectively. Significant upward short-term and long-term trends were found for SCCP in blue mussel from Singlekalven, and a significant upward long-term trend for MCCP was found in cod liver from Bømlo in the Outer Selbjørnfjord.
- The median concentration of HCB in cod liver from the Austnesfjord in Lofoten, exceeded the EQS for this substance.

- In livers from flounder caught at Sande in the Mid Oslofjord, significant downward long-term trends were found for Pb, Cu, PCB-7, DDE and HCB.

Contaminant levels at Svalbard are generally low and declining, but Hg levels in common eider and HCB are of potential concern

- Median concentrations of contaminants in cod liver and cod fillet from Svalbard were generally low (below the PROREF).
- D5 was the most dominant siloxane found in cod liver, and the concentrations were highest in the Inner Oslofjord and lowest in the Isfjord at Svalbard. The same patterns were found for D4 and D6.
- Contaminants were analyzed in the blood and eggs (homogenate of yolk and albumin) of the eider duck from Svalbard. This was the third time this species was used under the MILKYS programme. Concentrations of Hg, Pb, As, PCB153, BDE47, PFOS and PFOSA in eggs were in the range as found in comparable studies from the Svalbard region. The Hg concentrations in eider blood and eggs at Svalbard in 2019 was almost within the same range as reported in a comparable study in the Inner Oslofjord in 2017. The concentrations of PCB-7, BDE47 and PFOS were higher in eider blood and eggs in the Inner Oslofjord in 2017 than at Svalbard in 2019.

Biological effect parameters found no effects of TBT but confirm exposure PAH, lead and planar halogenated hydrocarbons and other structurally similar compounds

- No observable biological effects of TBT were found in this study; the effects of TBT on dogwhelk as measured by the imposex parameter VDSI, were zero at all eight stations where dogwhelk was sampled. The less sensitive intersex parameter ISI was assessed in common periwinkle at only one station and was found to be zero, indicating no effect of TBT also at this station.
- The ICES/OSPAR Background Assessment Criteria (BAC) for OH-pyrene in cod bile was exceeded at all stations investigated, however only barely at Farsund and at the reference station at Bømlo.
- Inhibited ALA-D activity in cod liver from the Inner Oslofjord and Inner Sørfjord indicated exposure to Pb.
- Median EROD-activities were below the ICES/OSPAR assessment criterion at all stations investigated, and downward long-term and short-term trends in EROD activities could be observed at all stations investigated.

Elevated levels in coastal waters near urban centres suggests that these hot-spots are of concern

- The Inner Oslofjord, and to a lesser degree the harbour areas of Bergen, Kristiansand, Trondheim and Bodø seem on the whole to be an area where contaminant concentrations tend to be higher. This is probably due to high population in the relevant watershed areas, a multitude of urban activities, and former and present use of products containing contaminants. A reduced water exchange in the Inner Oslofjord with the outer fjord will also contribute to higher contaminant concentrations in water and biota.
- High concentrations of PCB-7 and Hg in cod are reasons for concern, particularly in the Inner Oslofjord. There is some evidence that elevated concentrations may result from increased fish length due to poor recruitment of cod in recent years in this area. Although no trends (either for long- or short-term trends) were observed for PCB-7, and also neither for concentrations adjusted for fish length nor for concentrations without such adjustment.
- Results from stable isotopes of C and N indicate that the stations show very similar patterns from 2012 to 2019 in terms of isotopic signatures, indicating a geographical difference consistent over time.
- Baseline adjusted trophic position of cod differed between stations along the Norwegian coast, suggesting that that parts of the differences in concentrations of contaminants that biomagnify

may be attributed to different trophic positions of the cod, and not merely differences in exposure at the different stations.

- Some legacy contaminants are still present in elevated levels in Norwegian coastal waters and gives reason for concern.

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Appendix A
Quality assurance programme

Information on Quality Assurance

The laboratories (NIVA and subcontractor Eurofins) have participated in the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME), International Food Analysis Proficiency Testing Services (FAPAS), international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, round 2018-1 apply to the 2019-samples. The results are acceptable. These QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this programme. The quality assurance programme is corresponding to the analyses of the 2018 samples, cf. Green *et al. (2018)*.

NIVA participated in the QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" in July-September 2017. Shell height, penis-length-male, penis-length-female, average-shell-height and female-male-ratio were measured. NIVA got the score satisfactory for all parameters except number of females for one sample, which got the score questionable. The score for VDSI was satisfactory for both samples tested.

In addition to the QUASIMEME exercises, certified reference materials (CRM) and in-house reference materials are analysed routinely with the MILKYS samples. It should be noted that for biota, the type of tissue used in the CRMs does not always match the target tissue for analysis. Uncertain values identified by the analytical laboratory or the reporting institute are flagged in the database. The results are also "screened" during the import to the database at NIVA and ICES.

The laboratories used for the chemical testing are accredited according to ISO 17025:2005, except for the PFCs.

Summary of quality control results
Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly (***Table 26***). Apple juice was used as an in-house reference material for the quality control of the determination of metals. The reference material for determination of BDEs, HBCDDs and PAHs in blue mussel, as well as BDEs and PAHs in liver, was an internal reference (fish oil). Fish reference material (EDF-2525) was used as SRM for the quality assurance of PCBs in blue mussel and fish liver, and for tin organic compounds the reference material ZRM 81 was used as SRM in mussel tissue. For the determination of dieldrin, trans-nonachlor and DDTs in blue mussel, internal reference materials provided by EF GfA Lab services were used, these consisted of fish meal and feedingstuff. For the quality assurance of chlorinated paraffines spiked fish was used as an in-house reference material, and spiked fish liver was used for quality control of PFCs.

Table 26. Summary of the quality control of results for the 2019 biota samples analysed in 2019-2019. The Standard Reference Materials (SRM) were EDF-2525 in blue mussel, fish liver and fish fillet, and ZRM 81 (mussel tissue). The in-house reference materials were apple juice, spiked fish oil, spiked fish meal and spiked fish liver. The SRMs and in-house reference materials and quality assurance standards were analysed in series with the MILKYS samples and measured several times (N) over a number of weeks (W). The values are reported in the following units: metals (µg/kg), BDE (pg/g), PCB (ng/kg), DDTs (ng/kg), SCCPs and MCCPs (ng/sample), HBCDDs (ng/g), PAH (ng/kg), tin organic compounds (mg/kg), PFCs (% recovery), dieldrin and trans-nonachlor (ng/g). Tissue types were: mussel soft body (SB), fish liver (LI) and fish fillet (MU).

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
Ag	**Silver**	-	-	-	-	-	-	-
As	**Arsenic**	SB/MU/LI	Apple juice	108 ± 14	45	11	108	7,10
Cd	**Cadmium**	SB/MU/LI	Apple juice	107 ± 12	45	12	108	6,10
Cr	**Chromium**	SB/MU/LI	Apple juice	108 ± 12	45	12	108	6,30
Co	**Cobalt**	-	-	-	-	-	-	-
Cu	**Copper**	SB/MU/LI	Apple juice	6182 ± 418	45	12	6182	209
Hg	**Mercury**	SB/MU/LI	Apple juice	19,4 ± 2,5	45	12	19,4	1,23
Ni	**Nickel**	SB/MU/LI	Apple juice	112 ± 16	45	12	112	8,10
Pb	**Lead**	SB/MU/LI	Apple juice	105 ± 10	45	12	105	4,70
Zn	**Zinc**	SB/MU/LI	Apple juice	1341 ± 280	45	12	1341	140
Sn	**Tin**	-	-	-	-	-	-	-
BDE-28	**2,2,4' Tribromodiphenylether**	SB	Internal RM (fish oil)	85,55 ± 37,74	74	17	92,43	4,85
BDE-47	**2,2',4,4',-Tetrabromodiphenylether**	SB	Internal RM (fish oil)	161,50 ± 567,64	74	17	1630,71	48,12
BDE-100	**2,2',4,4',6-Pentabromodiphenylether**	SB	Internal RM (fish oil)	333,71 ± 118,76	66	17	347,34	38,06
BDE-99	**2,2',4,4',5-Pentabromodiphenylether**	SB	Internal RM (fish oil)	252,90 ± 86,43	74	17	256,40	10,62
BDE-154	**2,2',4,4',5,6'-Hexabromodiphenylether**	SB/MU/LI	Internal RM (fish oil)	189,48 ± 105,32	53	17	232,70	42,46
BDE-153	**2,2',4,4'5,5'-Hexabromodiphenylether**	SB/MU/LI	Internal RM (fish oil)	62,19 ± 52,79	74	17	61,90	5,66
BDE-209	**Decabromodiphenylether**	-	-	-	-	-	-	-
BDE-49	**2,2',4,5'-tetrabromodiphenyleter**	SB	Internal RM (fish oil)	419,22 ± 191,33	68	17	471,42	54,87
BDE-66	**2,3',4,4'-Tetrabromodiphenyleter**	-	-	-	-	-	-	-
BDE-119	**2,3',4,4',6-Pentabromodiphenyl ether**	-	-	-	-	-	-	-
PCB 77	**PCB congener CB-77**	-	-	-	-	-	-	-
PCB 52	**PCB congener CB-52**	SB/MU/LI	EDF-2525	27100 ± 12100	14	17	38189	2916
PCB 28	**PCB congener CB-28**	SB	EDF-2525	7100 ± 1260	14	17	6917	815
PCB 189	**PCB congener CB-189**	-	-	-	-	-	-	-
PCB 180	**PCB congener CB-180**	SB/MU/LI	EDF-2525	108000 ± 23600	14	17	153576	15394
PCB 169	**PCB congener CB-169**	-	-	-	-	-	-	-
PCB 167	**PCB congener CB-167**	-	-	-	-	-	-	-
PCB 157	**PCB congener CB-157**	-	-	-	-	-	-	-
PCB 156	**PCB congener CB-156**	-	-	-	-	-	-	-
PCB 153	**PCB congener CB-153**	SB/MU/LI	EDF-2525	226000 ± 71200	14	17	304188	36621
PCB 138	**PCB congener CB-138**	SB/MU/LI	EDF-2525	178000 ± 27800	14	17	231179	25628
PCB 126	**PCB congener CB-126**	-	-	-	-	-	-	-
PCB 123	**PCB congener CB-123**	-	-	-	-	-	-	-
PCB 118	**PCB congener CB-118**	SB	EDF-2525	122000 ± 38000	14	17	145730	18012
PCB 114	**PCB congener CB-114**	-	-	-	-	-	-	-
PCB 105	**PCB congener CB-105**	-	-	-	-	-	-	-
PCB 101	**PCB congener CB-101**	SB/MU/LI	EDF-2525	82700 ± 21400	14	17	113014	10691
DDEOP	**o,p'-DDE**	-	-	-	-	-	-	-
TDEOP	**o,p'-DDD**	-	-	-	-	-	-	-
DDTOP	**o,p'-DDT**	-	-	-	-	-	-	-
DDEPP	**p,p'-DDE**	SB	Internal RM (feed)	5,04 ± 3,77	21	17	4,88	0,74
TDEPP	**p,p'-DDD**	SB	Internal RM (feed)	1,48 ± 1,02	20	17	1,50	0,37
DDTPP	**p,p'-DDT**	-	-	-	-	-	-	-
SCCP	Short-chain chlorinated Paraffins (C10-C13)	SB/MU/LI	Internal RM (spiked fish)	10000	12	7	10240	1830
MCCP	Medium-chain chlorinated Paraffins (C14-C17)	SB/MU/LI	Internal RM (spiked fish)	10000	14	7	9980	1470
α-HBCDD	**α-Hexabromocyclododecane**	SB	Internal RM (fish oil)	1,21 ± 0,25	46	17	1,19	0,13
ß-HBCDD	**ß- Hexabromocyclododecane**	SB	Internal RM (fish oil)	0,08 ± 0,05	49	17	0,07	0,02
γ-HBCDD	**γ- Hexabromocyclododecane**	SB	Internal RM (fish oil)	0,32 ± 0,09	24	17	0,34	0,05
BGHIP	**Benzo[ghi]perylene**	SB/MU/LI	Internal RM (fish oil)	196 ± 120	10	17	283	82
ICDP	**Indeno[1,2,3-cd]pyrene**	-	-	-	-	-	-	-
BBJF	**Benzo[b+j]fluoranthene**	SB	Internal RM (fish oil)	500 ± 339	14	17	540	91
DBA3A	**Dibenzo[ac,ah]anthracene**	-	-	-	-	-	-	-
BKF	**Benzo[k]fluoranthene**	SB	Internal RM (fish oil)	127 ± 62	11	17	153	29
ACNLE	**Acenaphthylene**	SB/MU/LI	Internal RM (fish oil)	1310 ± 878	13	17	1475	494
ANT	**Anthracene**	SB	Internal RM (fish oil)	1030 ± 665	11	17	959	251
BAA	**Benzo[a]anthracene**	SB/MU/LI	Internal RM (fish oil)	511 ± 348	11	17	420	107
BAP	**Benzo[a]pyrene**	SB/MU/LI	Internal RM (fish oil)	230 ± 144	11	17	279	45
CHR	**Chrysene**	SB/MU/LI	Internal RM (fish oil)	496 ± 339	10	17	592	51
FLU	**Fluoranthene**	SB/MU/LI	Internal RM (fish oil)	3120 ± 2330	10	17	4358	281
FLE	**Fluorene**	SB/MU/LI	Internal RM (fish oil)	4460 ± 2609	11	17	6766	744
NAP	**Naphthalene**	SB/MU/LI	Internal RM (fish oil)	16100 ± 15359	14	17	19788	5506
PA	**Phenanthrene**	SB/MU/LI	Internal RM (fish oil)	8950 ± 6077	10	17	12615	1454

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
PYR	**Pyrene**	SB/MU/LI	Internal RM (fish oil)	2060 ± 1507	15	17	2592	274
ACNE	**Acenaphthene**	SB/MU/LI	Internal RM (fish oil)	2120 ± 1830	11	17	2542	738
TBBPA	**Tetrabromobisphenol-A**	-	-	-	-	-	-	-
BPA	**Bisphenol-A**	-	-	-	-	-	-	-
BPA	**Bisphenol-A**	-	-	-	-	-	-	-
BPA	**Bisphenol-A**	-	-	-	-	-	-	-
APO	**4-tert-oktylfenol**	-	-	-	-	-	-	-
APO	**4-n-oktylfenol**	-	-	-	-	-	-	-
APO	**4-n-nonylfenol**	-	-	-	-	-	-	-
MBT	**Monobutyltinn (MBT)**	-	-	-	-	-	-	-
DBT	**Dibutyltinn (DBT)**	-	-	-	-	-	-	-
TBT	**Tributyltinn (TBT)**	-	-	-	-	-	-	-
TPhT	**Trifenyltinn (TPhT)**	SB	ZRM 81 (mussel)	1,4 ± 0,7	7	17	1,40	0,23
PFBS	**Perfluorobutane sulphonate**	LI*	In-house spiked liver*	100%[1)]	12	11	96	1,8%
PFHxA	**Perfluorohexane acid**	LI*	In-house spiked liver*	100%[1)]	12	11	102	2,7%
PFHpA	**Perfluoroheptane acid**	LI*	In-house spiked liver*	100%[1)]	12	11	103	3,0%
PFOA	**Perfluorooctane acid**	LI*	In-house spiked liver*	100%[1)]	12	11	97	3,3%
PFNA	**Perfluorononane acid**	LI*	In-house spiked liver*	100%[1)]	12	11	101	3,5%
PFOS	**Perfluorooctane sulphonate**	LI*	In-house spiked liver*	100%[1)]	12	11	99	2,9%
PFOSA	**Perfluorooctane sulphone amide**	LI*	In-house spiked liver*	100%[1)]	12	11	98	4,6%
PFHxS	**Perfluorohexane sulphonate**	LI*	In-house spiked liver*	100%[1)]	12	11	94	2,9%
PFDA	**Perfluorodecanoic acid**	LI*	In-house spiked liver*	100%[1)]	12	11	102	2,9%
PFUDA	**Perfluoroundecanoic acid**	LI*	In-house spiked liver*	100%[1)]	12	11	98	1,3%
PFDS	**Perfluorodecanesulphonate**	LI*	In-house spiked liver*	100%[1)]	12	11	83	1,8%
	Dieldrin	SB	Internal RM (feed)	1,44 ± 0,74	19	17	1,35	0,35
	Trans-Nonachlor	SB	Internal RM (feed)	1,35 ± 1,17	21	17	1,46	0,44

* For some PFCs the tissue type also contained blue mussels, sea gull egg and blood

[1)] Recovery of spiked control sample

Appendix B
Abbreviations

(Includes all abbreviations used in MILKYS and forerunner programmes,
and not just those used in the present study.)

Abbreviation[1]	English	*Norwegian*	Param. group
ELEMENTS			
Al	aluminium	*aluminium*	I-MET
Ag	silver	*sølv*	I-MET
As	arsenic	*arsen*	I-MET
Ba	barium	*barium*	I-MET
Cd	cadmium	*kadmium*	I-MET
Ce	cerium	*serium*	I-MET
Co	cobalt	*kobolt*	I-MET
Cr	chromium	*krom*	I-MET
Cu	copper	*kobber*	I-MET
Fe	iron	*jern*	I-MET
Hg	mercury	*kvikksølv*	I-MET
La	lanthanum	*lantan*	I-MET
Li	lithium	*litium*	I-MET
Mn	manganese	*mangan*	I-MET
Mo	molybdenum	*molybden*	I-MET
Nd	neodymium	*neodym*	I-MET
Ni	nickel	*nikkel*	I-MET
Pb	lead	*bly*	I-MET
Pb210	lead-210	*bly-210*	I-RNC
Pr	praseodymium	*praseodym*	I-MET
Se	selenium	*selen*	I-MET
Sn	tin	*tinn*	I-MET
Ti	titanium	*titan*	I-MET
V	vanadium	*vanadium*	I-MET
Zn	zinc	*sink*	I-MET
METAL COMPOUNDS			
TBT	tributyltin (formulation basis =TBTIN*2.44)	*tributyltinn (formula basis =TBTIN*2.44)*	O-MET
MBTIN (MBT)	Monobutyltin	*monobutyltinn*	O-MET
MBTIN (MBT)	Monobutyltin	*monobutyltinn*	O-MET
MOT	Monooctyltin	*monooktyltinn*	O-MET
MPTIN	Monophenyltin	*monofenyltinn*	O-MET
DBT	dibutyltin (di-n-butyltin)	*dibutyltinn (di-n-butyltinn)*	O-MET
DBTIN	dibutyltin (di-n-butyltin)	*dibutyltinn (di-n-butyltinn)*	O-MET
DOT	dioctyltin	*dioktyltinn*	O-MET
DPTIN	diphenyltin	*difenyltinn*	O-MET
TBTIN	tributyltin (=TBT*0.40984)	*tributyltinn (=TBT*0.40984)*	O-MET
TCHT	tricyclohexyl-stannylium	*tricyclohexyl-stannylium*	O-MET
TPT	Triphenyltin (=TPTIN/3)	*Trifenyltinn (=TPTIN/3)*	O-MET
TPTIN	Triphenyltin (=TPT*3)	*Trifenyltinn (=TPT*3)*	O-MET
TTBT	tetrabutyltin	*tetrabutyltinn*	O-MET
PAHs			
PAH	polycyclic aromatic hydrocarbons	*polysykliske aromatiske hydrokarboner*	

Abbreviation[1]	English	*Norwegian*	Param. group
ACNE [3]	acenaphthene	*acenaften*	PAH
ACNLE [3]	acenaphthylene	*acenaftylen*	PAH
ANT [3]	anthracene	*antracen*	PAH
BAA [3, 4]	benzo[*a*]anthracene	*benzo[a]antracen*	PAH
BAP [3, 4]	benzo[*a*]pyrene	*benzo[a]pyren*	PAH
BBF [3, 4]	benzo[*b*]fluoranthene	*benzo[b]fluoranten*	PAH
BKF [3, 4]	benzo[*k*]fluoranthene	*benzo[k]fluoranten*	PAH
BJF [3, 4]	benzo[*j*]fluoranthene	*benzo[j]fluoranten*	PAH
BBJKF [3, 4]	benzo[*b,j,k*]fluoranthene	*benzo[b,j,k]fluoranten*	PAH
BBJKF [3, 4]	benzo[b+j,k]fluoranthene	*benzo[b+j,k]fluoranten*	PAH
BBKF [3, 4]	benzo[*b+k*]fluoranthene	*benzo[b+k]fluoranten*	PAH
BEP	benzo[*e*]pyrene	*benzo[e]pyren*	PAH
BGHIP [3]	benzo[*ghi*]perylene	*benzo[ghi]perylen*	PAH
BIPN [2]	biphenyl	*bifenyl*	PAH
BJKF [3, 4]	benzo[*j,k*]fluoranthene	*benzo[j,k]fluorantren*	PAH
BKF [3, 4]	benzo[*k*]fluoranthene	*benzo[k]fluorantren*	PAH
CHR [3, 4]	chrysene	*chrysen*	PAH
CHRTR [3, 4]	chrysene+triphenylene	*chrysen+trifenylen*	PAH
COR	coronene	*coronen*	PAH
DBAHA [3, 4]	dibenz[*a,h*]anthracene	*dibenz[a,h]anthracen*	PAH
DBA3A [3, 4]	dibenz[*a,c/a,h*]anthracene	*dibenz[a,c/a,h]antracen*	PAH
DBP [4, 6]	dibenzopyrenes	*dibenzopyren*	PAH
DBT	dibenzothiophene	*dibenzothiofen*	PAH
DBTC1	C_1-dibenzothiophenes	*C_1-dibenzotiofen*	PAH
DBTC2	C_2-dibenzothiophenes	*C_2-dibenzotiofen*	PAH
DBTC3	C_3-dibenzothiophenes	*C_3-dibenzotiofen*	PAH
FLE [3]	fluorene	*fluoren*	PAH
FLU [3]	fluoranthene	*fluoranten*	PAH
ICDP [3, 4]	indeno[*1,2,3-cd*]pyrene	*indeno[1,2,3-cd]pyren*	PAH
NAP [2, 4]	naphthalene	*naftalen*	PAH
NAPC1 [2]	C_1-naphthalenes	*C_1-naftalen*	PAH
NAPC2 [2]	C_2-naphthalenes	*C_2-naftalen*	PAH
NAPC3 [2]	C_3-naphthalenes	*C_3-naftalen*	PAH
NAP1M [2]	1-methylnaphthalene	*1-metylnaftalen*	PAH
NAP2M [2]	2-methylnaphthalene	*2-metylnaftalen*	PAH
NAPD2 [2]	1,6-dimethylnaphthalene	*1,6-dimetylnaftalen*	PAH
NAPD3 [2]	1,5-dimethylnaphthalene	*1,5-dimetylnaftalen*	PAH
NAPDI [2]	2,6-dimethylnaphthalene	*2,6-dimetylnaftalen*	PAH
NAPT2 [2]	2,3,6-trimethylnaphthalene	*2,3,6-trimetylnaftalen*	PAH
NAPT3 [2]	1,2,4-trimethylnaphthalene	*1,2,4-trimetylnaftalen*	PAH
NAPT4 [2]	1,2,3-trimethylnaphthalene	*1,2,3-trimetylnaftalen*	PAH
NAPTM [2]	2,3,5-trimethylnaphthalene	*2,3,5-trimetylnaftalen*	PAH
NPD	collective term for naphthalenes, phenanthrenes and dibenzothiophenes	*Samme betegnelse for naftalen, fenantren og dibenzotiofens*	PAH
PA [3]	phenanthrene	*fenantren*	PAH
PAC1	C_1-phenanthrenes	*C_1-fenantren*	PAH

Abbreviation[1]	English	*Norwegian*	Param. group
PAC2	C_2-phenanthrenes	*C_2-fenantren*	PAH
PAC3	C_3-phenanthrenes	*C_3-fenantren*	PAH
PAM1	1-methylphenanthrene	*1-metylfenantren*	PAH
PAM2	2-methylphenanthrene	*2-metylfenantren*	PAH
PADM1	3,6-dimethylphenanthrene	*3,6-dimetylfenantren*	PAH
PADM2	9,10-dimethylphenanthrene	*9,10-dimetylfenantren*	PAH
PER	perylene	*perylen*	PAH
PYR [3]	pyrene	*pyren*	PAH
DI-Σn	sum of "n" dicyclic "PAH"s (footnote 2)	*sum "n" disykliske "PAH" (fotnote 2)*	
P-Σn/P_S	sum "n" PAH (DI-Σn not included, footnote 3)	*sum "n" PAH (DI-Σn ikke inkludert, fotnote 3)*	
PK-Σn/PK_S	sum carcinogen PAHs (footnote 4)	*sum kreftfremkallende PAH (fotnote 4)*	
PAHΣΣ	dI-Σn + P-Σn etc.	*dI-Σn + P-Σn mm.*	
SPAH	"total" PAH, specific compounds not quantified (outdated analytical method)	*"total" PAH, spesifikke forbindelser ikke kvantifisert (foreldet metode)*	
BAP_P	% BAP of PAHΣΣ	*% BAP av PAHΣΣ*	
BAPPP	% BAP of P-Σn	*% BAP av P-Σn*	
BPK_P	% BAP of PK_Sn	*% BAP av PK_Sn*	
PKn_P	% PK_Sn of PAHΣΣ	*% PK_Sn av PAHΣΣ*	
PKnPP	% PK_Sn of P-Σn	*% PK_Sn av P-Σn*	
PCBs			
PCB	**polychlorinated biphenyls**	***polyklorerte bifenyler***	
CB	individual chlorobiphenyls (CB)	*enkelte klorobifenyl*	
CB28	CB28 (IUPAC)	*CB28 (IUPAC)*	OC-CB
CB31	CB31 (IUPAC)	*CB31 (IUPAC)*	OC-CB
CB44	CB44 (IUPAC)	*CB44 (IUPAC)*	OC-CB
CB52	CB52 (IUPAC)	*CB52 (IUPAC)*	OC-CB
CB77 [5]	CB77 (IUPAC)	*CB77 (IUPAC)*	OC-CB
CB81 [5]	CB81 (IUPAC)	*CB81 (IUPAC)*	OC-CB
CB95	CB95 (IUPAC)	*CB95 (IUPAC)*	OC-CB
CB101	CB101 (IUPAC)	*CB101 (IUPAC)*	OC-CB
CB105	CB105 (IUPAC)	*CB105 (IUPAC)*	OC-CB
CB110	CB110 (IUPAC)	*CB110 (IUPAC)*	OC-CB
CB118	CB118 (IUPAC)	*CB118 (IUPAC)*	OC-CB
CB126 [5]	CB126 (IUPAC)	*CB126 (IUPAC)*	OC-CB
CB128	CB128 (IUPAC)	*CB128 (IUPAC)*	OC-CB
CB138	CB138 (IUPAC)	*CB138 (IUPAC)*	OC-CB
CB149	CB149 (IUPAC)	*CB149 (IUPAC)*	OC-CB
CB153	CB153 (IUPAC)	*CB153 (IUPAC)*	OC-CB
CB156	CB156 (IUPAC)	*CB156 (IUPAC)*	OC-CB
CB169 [5]	CB169 (IUPAC)	*CB169 (IUPAC)*	OC-CB
CB170	CB170 (IUPAC)	*CB170 (IUPAC)*	OC-CB
CB180	CB180 (IUPAC)	*CB180 (IUPAC)*	OC-CB
CB194	CB194 (IUPAC)	*CB194 (IUPAC)*	OC-CB

Abbreviation[1]	English	*Norwegian*	Param. group
CB209	CB209 (IUPAC)	*CB209 (IUPAC)*	OC-CB
CB-Σ7	CB: 28+52+101+118+138+153+180	*CB: 28+52+101+118+138+153+180*	
CB-ΣΣ	sum of PCBs, includes PCB-Σ7	*sum PCBer, inkluderer PCB-Σ7*	
TECBW	sum of PCB-toxicity equivalents after WHO model, see **TEQ**	*sum PCB- toksisitets ekvivalenter etter WHO modell, se **TEQ***	
TECBS	sum of PCB-toxicity equivalents after SAFE model, see **TEQ**	*sum PCB-toksisitets ekvivalenter etter SAFE modell, se **TEQ***	
PCN	polychlorinated naphthalenes	*polyklorerte naftalen*	
DIOXINs			
TCDD	2, 3, 7, 8-tetrachloro-dibenzo dioxin	*2, 3, 7, 8-tetrakloro-dibenzo dioksin*	OC-DX
CDDST	sum of tetrachloro-dibenzo dioxins	*sum tetrakloro-dibenzo dioksiner*	
CDD1N	1, 2, 3, 7, 8-pentachloro-dibenzo dioxin	*1, 2, 3, 7, 8-pentakloro-dibenzo dioksin*	OC-DX
CDDSN	sum of pentachloro-dibenzo dioxins	*sum pentakloro-dibenzo dioksiner*	
CDD4X	1, 2, 3, 4, 7, 8-hexachloro-dibenzo dioxin	*1, 2, 3, 4, 7, 8-heksakloro-dibenzo dioksin*	OC-DX
CDD6X	1, 2, 3, 6, 7, 8-hexachloro-dibenzo dioxin	*1, 2, 3, 6, 7, 8-heksakloro-dibenzo dioksin*	OC-DX
CDD9X	1, 2, 3, 7, 8, 9-hexachloro-dibenzo dioxin	*1, 2, 3, 7, 8, 9-heksakloro-dibenzo dioksin*	OC-DX
CDDSX	sum of hexachloro-dibenzo dioxins	*sum heksakloro-dibenzo dioksiner*	
CDD6P	1, 2, 3, 4, 6, 7, 8-heptachloro-dibenzo dioxin	*1, 2, 3, 4, 6, 7, 8-heptakloro-dibenzo dioksin*	OC-DX
CDDSP	sum of heptachloro-dibenzo dioxins	*sum heptakloro-dibenzo dioksiner*	
CDDO	Octachloro-dibenzo dioxin	*Oktakloro-dibenzo dioksin*	OC-DX
PCDD	sum of polychlorinated dibenzo-p-dioxins	*sum polyklorinaterte-dibenzo-p-dioksiner*	
CDF2T	2, 3, 7, 8-tetrachloro-dibenzofuran	*2, 3, 7, 8-tetrakloro-dibenzofuran*	OC-DX
CDFST	sum of tetrachloro-dibenzofurans	*sum tetrakloro-dibenzofuraner*	
CDFDN	1, 2, 3, 7, 8/1, 2, 3, 4, 8-pentachloro-dibenzofuran	*1, 2, 3, 7, 8/1, 2, 3, 4, 8-pentakloro-dibenzofuran*	OC-DX
CDF2N	2, 3, 4, 7, 8-pentachloro-dibenzofuran	*2, 3, 4, 7, 8-pentakloro-dibenzofuran*	OC-DX
CDFSN	sum of pentachloro-dibenzofurans	*sum pentakloro-dibenzofuraner*	
CDFDX	1, 2, 3, 4, 7, 8/1, 2, 3, 4, 7, 9-hexachloro-dibenzofuran	*1, 2, 3, 4, 7, 8/1, 2, 3, 4, 7, 9-heksakloro-dibenzofuran*	OC-DX

Abbreviation[1]	English	*Norwegian*	Param. group
CDF6X	1, 2, 3, 6, 7, 8-hexachloro-dibenzofuran	*1, 2, 3, 6, 7, 8-heksakloro-dibenzofuran*	OC-DX
CDF9X	1, 2, 3, 7, 8, 9-hexachloro-dibenzofuran	*1, 2, 3, 7, 8, 9-heksakloro-dibenzofuran*	OC-DX
CDF4X	2, 3, 4, 6, 7, 8-hexachloro-dibenzofuran	*2, 3, 4, 6, 7, 8-heksakloro-dibenzofuran*	OC-DX
CDFSX	sum of hexachloro-dibenzofurans	*sum heksakloro-dibenzofuraner*	
CDF6P	1, 2, 3, 4, 6, 7, 8-heptachloro-dibenzofuran	*1, 2, 3, 4, 6, 7, 8-heptakloro-dibenzofuran*	OC-DX
CDF9P	1, 2, 3, 4, 7, 8, 9-heptachloro-dibenzofuran	*1, 2, 3, 4, 7, 8, 9-heptakloro-dibenzofuran*	OC-DX
CDFSP	sum of heptachloro-dibenzofurans	*sum heptakloro-dibenzofuraner*	OC-DX
CDFO	octachloro-dibenzofurans	*octakloro-dibenzofuran*	OC-DX
PCDF	sum of polychlorinated dibenzo-furans	*sum polyklorinated dibenzo-furaner*	
CDDFS	sum of PCDD and PCDF	*sum PCDD og PCDF*	
TCDDN	sum of TCDD-toxicity equivalents after Nordic model, see **TEQ**	*sum TCDD- toksisitets ekvivalenter etter Nordisk modell, se **TEQ***	
TCDDI	sum of TCDD-toxicity equivalents after international model, see **TEQ**	*sum TCDD-toksisitets ekvivalenter etter internasjonale modell, se **TEQ***	
BIOICIDES			
ALD	aldrin	*aldrin*	OC-DN
DIELD	dieldrin	*dieldrin*	OC-DN
ENDA	endrin	*endrin*	OC-DN
CCDAN	cis-chlordane (=α-chlordane)	*cis-klordan (=α-klordan)*	OC-DN
TCDAN	trans-chlordane (=γ-chlordane)	*trans-klordan (=γ-klordan)*	OC-DN
OCDAN	oxy-chlordane	*oksy-klordan*	OC-DN
TNONC	trans-nonachlor	*trans-nonaklor*	OC-DN
TCDAN	trans-chlordane	*trans-klordan*	OC-DN
Triclosan	5-chloro-2-2,4-dichlorophenoxy)phenol	*5-kloro-2-2,4-diklorofenoxy)fenol*	OC-CL
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	*3-(3,4-diklorofenyl)-1,1-dimetylurea*	OC-CL
Irgarol	a triazine (nitrogen containing heterocycle)	*en triazin (nitrogen holdig heterosykle)*	
OCS	octachlorostyrene	*oktaklorstyren*	OC-CL
QCB	pentachlorobenzene	*pentaklorbenzen*	OC-CL
DDD	dichlorodiphenyldichloroethane 1,1-dichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyldikloretan* *1,1-dikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDE	dichlorodiphenyldichloroethylene (principle metabolite of DDT) 1,1-*bis*-(4-chlorophenyl)-2,2-dichloroethene*	*diklordifenyldikloretylen (hovedmetabolitt av DDT)* *1,1-bis-(4-klorofenyl)-2,2-dikloroeten*	OC-DD

Abbreviation[1]	English	*Norwegian*	Param. group
DDT	dichlorodiphenyltrichloroethane 1,1,1-trichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyltrikloretan* *1,1,1-trikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDEOP	o,p'-DDE	*o,p'-DDE*	OC-DD
DDEPP	p,p'-DDE	*p,p'-DDE*	OC-DD
DDTOP	o,p'-DDT	*o,p'-DDT*	OC-DD
DDTPP	p,p'-DDT	*p,p'-DDT*	OC-DD
TDEPP	p,p'-DDD	*p,p'-DDD*	OC-DD
DDTEP	p,p'-DDE + p,p'-DDT	*p,p'-DDE + p,p'-DDT*	OC-DD
DD-nΣ	sum of DDT and metabolites, n = number of compounds	*sum DDT og metabolitter, n = antall forbindelser*	OC-DD
HCB	hexachlorobenzene	*heksaklorbenzen*	OC-CL
HCHG	Lindane γ HCH = gamma hexachlorocyclohexane (γ BHC = gamma benzenehexachloride, outdated synonym)	*Lindan* *γ HCH = gamma heksaklorsykloheksan* *(γ BHC = gamma benzenheksaklorid, foreldet betegnelse)*	OC-HC
HCHA	α HCH = alpha HCH	*α HCH = alpha HCH*	OC-HC
HCHB	β HCH = beta HCH	*β HCH = beta HCH*	OC-HC
HC-nΣ	sum of HCHs, n = count	*sum av HCHs, n = antall*	
EOCl	extractable organically bound chlorine	*ekstraherbart organisk bundet klor*	OC-CL
EPOCl	extractable persistent organically bound chlorine	*ekstraherbart persistent organisk bundet klor*	OC-CL
PBDEs			
PBDE	**polybrominated diphenyl ethers**	***polybromerte difenyletere***	OC-BR
BDE	brominated diphenyl ethers		OC-BR
BDE28	2,4,4'-tribromodiphenyl ether	*2,4,4'-tribromdifenyleter*	OC-BR
BDE47	2,2',4,4'-tetrabromodiphenyl ether	*2,2',4,4'-tetrabromdifenyleter*	OC-BR
BDE49*	2,2',4,5'- tetrabromodiphenyl ether	*2,2',4,5'- tetrabromdifenyleter*	OC-BR
BDE66*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE71*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE77	3,3',4,4'-tetrabromodiphenyl ether	*3,3',4,4'-tetrabromdifenyleter*	OC-BR
BDE85	2,2',3,4,4'-pentabromodiphenyl ether	*2,2',3,4,4'-pentabromdifenyleter*	OC-BR
BDE99	2,2',4,4',5-pentabromodiphenyl ether	*2,2',4,4',5-pentabromdifenyleter*	OC-BR
BDE100	2,2',4,4',6-pentabromodiphenyl ether	*2,2',4,4',6-pentabromdifenyleter*	OC-BR
BDE119	2,3',4,4',6-pentabromodiphenyl ether	*2,3',4,4',6-pentabromdifenyleter*	OC-BR

Abbreviation[1]	English	*Norwegian*	Param. group
BDE126	3,3',4,4',5'-pentabromodiphenyl ether	*3,3',4,4',5'-pentabromdifenyleter*	OC-BR
BDE138	2,2',3,4,4',5'-hexabromodiphenyl ether	*2,2',3,4,4',5'-heksabromdifenyleter*	OC-BR
BDE153	2,2',4,4',5,5'-hexabromodiphenyl ether	*2,2',4,4',5,5'-heksabromdifenyleter*	OC-BR
BDE154	2,2',4,4',5,6'-hexabromodiphenyl ether	*2,2',4,4',5,6'-heksabromdifenyleter*	OC-BR
BDE183	2,2',3,4,4',5',6-heptabromodiphenyl ether	*2,2',3,4,4',5',6-heptabromdifenyleter*	OC-BR
BDE196	2,2',3,3',4,4',5',6-octabromodiphenyl ether	*2,2',3,3',4,4',5',6-octabromdifenyleter*	OC-BR
BDE205	2,2',3,3',4,4',5,5',6'-nonabromodiphenyl ether	*2,2',3,3',4,4',5,5',6'-nonabromdifenyleter*	OC-BR
BDE209	decabromodiphenyl ether	*Dekabromdifenyleter*	OC-BR
BDE4S	sum of BDE -85, -99, -100, -119	*sum av BDE -85, -99, -100, -119*	OC-BR
BDE6S	sum of BDE -28, -47, -99, -100, -153, -154	*sum av BDE -28, -47, -99, -100, -153, -154*	OC-BR
BDESS	sum of all BDEs	*sum av alle BDEer*	OC-BR
HBCDD	hexabromocyclododecane (1 2 5 6 9 10 hexabromocyclododecane)	*heksabromsyklododekan (1 2 5 6 9 10 heksabromsyklododekan)*	OC-BR
HBCDA	α–hexabromocyclododecane	*α–heksabromsyklododekan*	OC-BR
HBCDB	β-hexabromocyclododecane	*β-heksabromsyklododekan*	OC-BR
HBCDG	γ-hexabromocyclododecane	*γ-heksabromsyklododekan*	OC-BR
TBBPA	tetrabrombisphenol A	*tetrabrombisfenol A*	OC-CP
BPA	bisphenol A	*bisfenol A*	OC-CP
HCBD	hexachlorobutadiene	*hexaklorobutadien*	OC-CL
PFAS	**perfluorinated alkylated substances**	***Perfluoralkylerte stoffer***	
PFBS	perfluorobutane sulfonate	*perfluorbutan sulfonat*	PFAS
PFDCA	perfluorodecanoic acid	*perfluordekansyre*	PFAS
PFDCS	ammonium henicosafluorodecanesulphonate	*ammonium henikosafluordekansulfonat*	PFAS
PFHxA	perfluorohexanoic acid	*perfluorhexansyre*	PFAS
PFHpA	perfluoroheptanoic acid	*perfluorheptansyre*	PFAS
PFOA	perfluorooctanoic acid	*perfluoroktansyre*	PFAS
PFNA	perfluorononanoic acid	*perfluornonansyre*	PFAS
PFOS	Perfluorooctanesulfonic acid	*Perfluorooktansulfonatsyre*	PFAS
PFOSA	perfluorooctanesulfonamide	*perfluorooktansulfonamid*	PFAS
PFUDA	perfluoroundecanoic acid	*perfluorundekansyre*	PFAS
SCCP	short chain chlorinated paraffins, C_{10-13}	*kortkjedete klorerte parafiner, C_{10-13}*	

Abbreviation[1]	English	*Norwegian*	Param. group
MCCP	medium chain chlorinated, C_{14-17} paraffins	*mediumkjedete klorerte parafiner, C_{14-17}*	
Alkylphenols	**phenols/chlorophenols**	***fenoler/klorfenoler***	
4-n-NP	4-n-nonylphenol	*4-n-nonylfenol*	
4-n-OP	4-n-octylphenol	*4-n-oktylfenol*	
4-t-NP	4-tert-nonylphenol	*4-tert-nonylfenol*	
4-t-OP	4-tert-octylphenol	*4-tert-oktylfenol*	
	stable isotopes	***stabile isotoper***	
C/N	$\delta^{13}C$ /$\delta^{15}N$	*$\delta^{13}C$ /$\delta^{15}N$*	
Delta15N	$\delta^{15}N$	*$\delta^{15}N$*	
Delta13C	$\delta^{13}C$	*$\delta^{13}C$*	
	phthalates/organic esters	***phtalater/organiske estere***	
BBP	benzylbutylphthalate	*benzylbutylftalat*	
DBP[6]	dibutylphthalate	*dibutylftalat*	
DBPA	dibutyladipat	*dibutyladipat*	
DEHA	diethylhexcyladipate	*dietylheksyladipat*	
DEHP	di(2-ethylhexyl)-phthalate	*di(2-etylhexyl)-ftalat*	
DEP	dietylphthale	*dietylftalat*	
DEPA	diethyladipat	*dietyladipat*	
DIBP	diisobutylphthalate	*diisobutylftalat*	
DIDP	diisodectylyphthalate	*diisodekylftalat*	
DIHP	diisoheptylphthalate	*diisoheptylftalat*	
DINCH	1,2-Cyclohexane dicarboxylic acid diisononyl ester	*1,2-sykloheksan dikarboksyl syre diisononyl ester*	
DIPA	diisobutyl adipate	*diisobutyladipat*	
DMP	dimethylphthalate	*dimetylftalat*	
DNOP	di-n-octylphthalte	*di-n-oktylftalt*	
DPF	diphenylphthalate	*difenylftalat*	
SDD	dinonylphthalte+diisononylphthalate	*dinonylftalat+diisononylftalat*	
TBP	tributylphosphate	*tributylfosfat*	
TOA	tributyl-o-acetylcitrate	*tributyl-o-acetylcitrate*	
Triclosan	triclosan	*triklosan*	
[not defined]	dodecylfenol	*dodecylfenol*	
Diuron	Duiron	*Durion*	
Irgarol	Irgarol	*Irgarol*	
Siloxanes			
D4	octamethylcyclotetrasiloxane		
D5	decamethylcyclopentasiloxane		
D6	dodecamethylcyclohexasiloxane		
Dechlorane Plus			
DBALD	dibromoaldrin	*Dibromoaldrin*	
DDC_ANT	dechlorane 603	*dekloran 603*	

Abbreviation[1]	English	*Norwegian*	Param. group
DDC_BBF	dechlorane 601	*dekloran 601*	
DDC_CO	dechlorane A	*dekloran A*	
DDC_DBF	dechlorane 602	*dekloran 602*	
DDC_PA	Dechlorane Plus anti	*Dekloran Plus anti*	
DDC_PS	Dechlorane Plus syn	*Dekloran Plus syn*	
HCTBPH	dechlorane 604	*dekloran 604*	
NTOT	total organic nitrogen	*total organisk nitrogen*	I-NUT
CTOT	total organic carbon	*total organisk karbon*	O-MAJ
CORG	organic carbon	*organisk karbon*	O-MAJ
GSAMT	grain size	*kornfordeling*	P-PHY
MOCON	moisture content	*vanninnhold*	P-PHY
Specific biological effects methods			
ALAD	δ-aminolevulinic acid dehydrase inhibition	*δ-aminolevulinsyre dehydrase*	BEM
CYP1A	cytochrome P450 1A-protein	*cytokrom P450 1A-protein*	BEM
EROD-activity	Cytochrome P4501A-activity (CYP1A/P4501A1, EROD)	*cytokrom P450 1A-aktivitet*	BEM
OH-pyrene	Pyrene metabolite	*pyren metabolitt*	BEM
VDSI	Vas Deferens Sequence Index		BEM
INSTITUTES			
EFDH	Eurofins [DK]	*Eurofins [DK]*	
EFNO	Eurofins [N, Moss]	*Eurofins [N, Moss]*	
EFGFA	Eurofins [DE, GFA]	*Eurofins [DE, GFA]*	
EFSofia	Eurofins [DE, Sofia]	*Eurofins [DE, Sofia]*	
FIER	Institute for Nutrition, Fisheries Directorate	*Fiskeridirektoratets Ernæringsinstitutt*	
FORC	FORCE Institutes, Div. for Isotope Technique and Analysis [DK]	*FORCE Institutterne, Div. for Isotopteknik og Analyse [DK]*	
GALG	GALAB Laboratories Gmbh [D]	*GALAB Laboratories Gmbh [D]*	
IFEN	Institute for Energy Technology	*Institutt for energiteknikk*	
IMRN	Institute of Marine Research (IMR)	*Havforskningsinstituttet*	
NACE	Nordic Analytical Center	*Nordisk Analyse Center*	
NILU	Norwegian Institute for Air Research	*Norsk institutt for luftforskning*	
NIVA	Norwegian Institute for Water Research	*Norsk institutt for vannforskning*	
SERI	Swedish Environmental Research Institute	*Institutionen för vatten- och luftvårdsforskning*	

Abbreviation[1]	English	*Norwegian*	Param. group
SIIF	Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology-SINTEF (a division, previously: Center for Industrial Research SI)	*Stiftelsen for industriell og teknisk forskning ved Norges tekniske høgskole- SINTEF (en avdeling, tidligere: Senter for industriforskning SI)*	
VETN	Norwegian Veterinary Institute	*Veterinærinstituttet*	
VKID	Water Quality Institute [DK]	*Vannkvalitetsintitutt [DK]*	

[1]) After: ICES Environmental Data Reporting Formats. International Council for the Exploration of the Sea. July 1996 and supplementary codes related to non-ortho and mono-ortho PCBs and "dioxins" (ICES pers. comm.)

[2]) Indicates "PAH" compounds that are dicyclic and not truly PAHs typically identified during the analyses of PAH, include naphthalenes and "biphenyls".

[3]) Indicates the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 (often called PAH-16) minus naphthalene (dicyclic), so that the Norwegian Environmental Agency classification system can be applied

[4]) Indicates PAH compounds potentially cancerogenic for humans according to IARC (1987), updated 14 August 2007), i.e., categories 1, 2A, and 2B (are, possibly and probably carcinogenic). NB.: the update includes Chrysene as cancerogenic.

[5]) Indicates non ortho- co-planer PCB compounds i.e., those that lack Cl in positions 1, 1', 5, and 5'

[6]) DBP is ambiguous; a code for both a PAH and an phthalate. DBP as a PAH was only measured in 1992 whereas DBP as an phthalate has been measure in 2012 and 2013. A correction in the data base is needed in this regard.

*) The Pesticide Index, second edition. The Royal Society of Chemistry, 1991.

Other abbreviations *andre forkortelser*

	English	*Norwegian*
TEQ	"Toxicity equivalency factors" for the most toxic compounds within the following groups: • polychlorinated dibenzo-p-dioxins and dibenzofurans (**PCDD/PCDFs**). Equivalents calculated after Nordic model (Ahlborg 1989) [1] or international model (Int./EPA, cf. Van_den_Berg *et al.* (1998) [2] • non-ortho and mono-ortho substituted chlorobiphenyls after WHO model (Ahlborg *et al.* 1994) [3] or Safe (1994, cf. NILU pers. comm.)	*"Toxisitetsekvivalentfaktorer" for de giftigste forbindelsene innen følgende grupper.* • *polyklorerte dibenzo-p-dioksiner og dibenzofuraner (**PCDD/PCDF**). Ekvivalentberegning etter nordisk modell (Ahlborg 1989) [1] eller etter internasjonal modell (Int./EPA, cf. Van_den_Berg et al.* (1998) [2] • *non-orto og mono-orto substituerte klorobifenyler etter WHO modell (Ahlborg et al. 1994) [3] eller Safe (1994, cf. NILU pers. medd.)*
ppm	parts per million, mg/kg	*deler pr. milliondeler, mg/kg*
ppb	parts per billion, μg/kg	*deler pr. milliarddeler, μg/kg*
ppp	parts per trillion, ng/kg	*deler pr. tusen-milliarddeler, ng/kg*
d.w.	dry weight basis	*tørrvekt basis*
w.w.	wet weight or fresh weight basis	*våtvekt eller friskvekt basis*

[1]) Ahlborg, U.G., 1989. Nordic risk assessment of PCDDs and PCDFs. Chemosphere 19:603-608.

[2]) Van den Berg, Birnbaum, L, Bosveld, A. T. C. and co-workers, 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Hlth. Perspect. 106:775-792.

[3]) Ahlborg, U.G., Becking G.B., Birnbaum, L.S., Brouwer, A, Derks, H.J.G.M., Feely, M., Golor, G., Hanberg, A., Larsen, J.C., Liem, A.K.G., Safe, S.H., Schlatter, C., Wärn, F., Younes, M., Yrjänheikki, E., 1994. Toxic equivalency factors for dioxin-like PCBs. Report on a WHO-ECEH and IPSC consultation, December 1993. Chemosphere 28:1049-1067.

Appendix C
Norwegian provisional high reference contaminant concentrations (PROREF) revised 2019

Table 27. *Norwegian provisional high reference contaminant concentrations* (PROREF) for contaminants in blue mussel (*Mytilus edulis*), perwinkle (*Littorina littorea*), dogwhelk (*Nucella lapillus)* and Atlantic cod (*Gadus* morhua) for whole soft body, liver and fillet based on MILYKYS data (see **Chapter 2.7**). All values are on a wet weight basis. The stations, count and total number of values used to determine PROREF are indicated. Also indicated for comparison to PROREF used previously in MILKYS reports, e.g. Green *et al*. (2018), and the risk-based standards (e.g. EU EQS and Water Region Specific Substances) used in this report (Norwegian_Environment_Agency 2016a) The yellow indicates where PROREF has increased or decreased over 20 %, and green and pink cells indicate where PROREF is below or above the EQS, respectively.

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
AG	Mytilus edulis	**soft body**	26A2,22A,I241,I023,I712,I131A,63A,97A2	**8**	162	mg/kg	0.009	0.0080	0.9340		
AS	Mytilus edulis	**soft body**	31A,I301,I023,30A,I712	**5**	116	mg/kg	2.503	3.3150	1.3247		
CD	Mytilus edulis	**soft body**	I241,26A2,I969	**3**	106	mg/kg	0.180	0.1800	1.0000		
CO	Mytilus edulis	**soft body**	26A2,I241	**2**	34	mg/kg	0.080	0.0791	0.9890		
CR	Mytilus edulis	**soft body**	52A,15A,26A2,I131A,64A	**5**	100	mg/kg	0.361	0.3610	1.0000		
CU	Mytilus edulis	**soft body**	I307,I712,63A,I306,I304,57A,51A,64A,I023	**9**	353	mg/kg	1.400	1.4200	1.0143		
HG	Mytilus edulis	**soft body**	36A,46A,10A2	**3**	137	mg/kg	0.012	0.0100	0.8197	0.020	1.6393
MO	Mytilus edulis	**soft body**	B7,B11,B2,B3,B6,B10,35A,B5	**8**	207	mg/kg	0.220				
NI	Mytilus edulis	**soft body**	I241,I131A,52A,57A,26A2	**5**	101	mg/kg	0.290	0.2900	1.0000		
PB	Mytilus edulis	**soft body**	11X,48A	**2**	75	mg/kg	0.195	0.1950	1.0000		
SN	Mytilus edulis	**soft body**	10A2,11X,15A,22A,26A2,30A,31A,35A,57A,63A,64A,65A,69A,71A,91A2,97A2,98A2,I023,I131A,I133,I301,I304,I306,I965,I969,I241,52A,I307,I712	**29**	625	mg/kg	0.300	0.3000	1.0000		
ZN	Mytilus edulis	**soft body**	43A,I712,48A	**3**	49	mg/kg	17.660	17.6600	1.0000		
PCB-7	Mytilus edulis	**soft body**	10A2,41A,11X,98A2,64A,97A2	**6**	194	µg/kg	1.157	0.4891	0.4228	0.600	0.5187
CB28	Mytilus edulis	**soft body**	10A2,11X,15A,22A,36A,41A,43A,44A,46A,48A,56A,57A,63A,65A,69A,84A,91A2,92A1,98A2	**19**	910	µg/kg	0.120	0.1200	1.0000		
CB52	Mytilus edulis	**soft body**	10A2,11X,15A,26A2,41A,43A,64A,65A,69A,84A,97A2,98A2	**12**	480	µg/kg	0.200	0.2000	1.0000		
CB77	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg	0.010	0.0111	1.1054		
CB81	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg		0.0005			
CB101	Mytilus edulis	**soft body**	43A,48A,98A2,97A2,10A2,64A,26A2,11X,41A	**9**	245	µg/kg	0.200	0.2000	1.0000		
CB105	Mytilus edulis	**soft body**	10A2,11X,15A,41A,43A,46A,48A	**7**	208	µg/kg	0.150	0.1500	1.0000		
CB118	Mytilus edulis	**soft body**	43A	**1**	15	µg/kg	0.070	0.0730	1.0429		
CB126	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg		0.0010			
CB138	Mytilus edulis	**soft body**	43A,10A2,11X,41A	**4**	153	µg/kg	0.200	0.2040	1.0200		
CB153	Mytilus edulis	**soft body**	43A,11X,10A2,41A	**4**	153	µg/kg	0.260	0.2600	1.0000		
CB156	Mytilus edulis	**soft body**	10A2,11X,15A,22A,35A,36A,41A,43A,44A,46A,48A	**11**	399	µg/kg	0.150	0.1500	1.0000		
CB169	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg		0.0001			
CB180	Mytilus edulis	**soft body**	10A2,11X,15A,22A,26A2	**5**	282	µg/kg	0.100	0.1000	1.0000		
DDEPP	Mytilus edulis	**soft body**	43A,41A,10A2,11X	**4**	147	µg/kg	0.224	0.2240	1.0000	610.000	2 723.2143
DDTEP	Mytilus edulis	**soft body**	84A,36A,71A,31A	**4**	107	µg/kg	3.000				
DDTPP	Mytilus edulis	**soft body**	10A2,11X,15A,22A,30A,31A,36A,71A,76A,98A2,I022,I023,I024,I131A,I132,I133,I304,I306,I307,I712	**20**	644	µg/kg	0.600	0.6000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
TDEPP	Mytilus edulis	**soft body**	41A,43A,44A,46A,48A,92A1	**6**	93	µg/kg	0.100	0.1000	1.0000		
HCB	Mytilus edulis	**soft body**	48A,43A,15A,22A,46A,41A,98A2,11X,30A,10A2,36A	**11**	473	µg/kg	0.100	0.1000	1.0000	10.000	100.0000
HBCDA	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.110	0.1099	1.0000	167.000	1 520.2549
HBCDG	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.030	0.0317	1.0577		
HBCDB	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.020	0.0199	0.9925		
HBCDD	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.147	0.1396	0.9513		
BDESS	Mytilus edulis	**soft body**	98A2	**1**	16	µg/kg	0.193	0.193	1.0000		
BDE6S	Mytilus edulis	**soft body**	98A2,26A2,91A2,71A,I023,97A2,30A	**7**	109	µg/kg	0.408	0.1900	0.4657	0.009	0.0208
BDE47	Mytilus edulis	**soft body**	98A2,26A2,71A,I023,91A2,30A	**6**	94	µg/kg	0.171	0.1410	0.8270	0.009	0.0499
BDE99	Mytilus edulis	**soft body**	98A2,91A2,26A2,I023	**4**	61	µg/kg	0.060	0.0600	1.0000		
BDE100	Mytilus edulis	**soft body**	98A2,26A2,I023,91A2,71A	**5**	79	µg/kg	0.050	0.0510	1.0200		
BDE126	Mytilus edulis	**soft body**	71A,97A2,26A2,I023,91A2	**5**	75	µg/kg	0.050	0.0500	1.0000		
BDE153	Mytilus edulis	**soft body**	97A2,26A2,I023,91A2,71A,98A2,30A	**7**	109	µg/kg	0.050	0.0500	1.0000		
BDE154	Mytilus edulis	**soft body**	97A2,26A2,I023,91A2,71A,98A2,30A	**7**	109	µg/kg	0.050	0.0500	1.0000		
BDE183	Mytilus edulis	**soft body**	71A,97A2,26A2,I023,91A2,98A2	**6**	92	µg/kg	0.300	0.3000	1.0000		
BDE196	Mytilus edulis	**soft body**	71A,97A2,26A2,I023,91A2	**5**	75	µg/kg	0.300	0.3000	1.0000		
BDE209	Mytilus edulis	**soft body**	71A,97A2,91A2,I023,26A2	**5**	75	µg/kg	1.290	1.2920	1.0016		
SCCP	Mytilus edulis	**soft body**	I023,71A,91A2,97A2,26A2,30A	**6**	90	µg/kg	20.260	20.2600	1.0000	6 000.000	296.1500
MCCP	Mytilus edulis	**soft body**	I023,26A2,71A,91A2,97A2,30A	**6**	89	µg/kg	87.600	87.6000	1.0000	170.000	1.9406
PAH16	Mytilus edulis	**soft body**	98A2,I023	**2**	32	µg/kg	33.828	33.8280	1.0000		
PAH-sum	Mytilus edulis	**soft body**	98A2,I023	**2**	32	µg/kg	30.050				
KPAH	Mytilus edulis	**soft body**	98A2	**1**	17	µg/kg	0.622				
ACNE	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A	**5**	177	µg/kg	0.800	0.8000	1.0000		
ACNLE	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A,I132,I133	**7**	266	µg/kg	1.000	1.0000	1.0000		
ANT	Mytilus edulis	**soft body**	98A2,I131A,I307,I915,I913,71A	**6**	208	µg/kg	0.800	1.1000	1.3750	2 400.000	3 000.0000
BAA	Mytilus edulis	**soft body**	I023,98A2	**2**	32	µg/kg	1.490	1.4900	1.0000	300.000	201.3423
BAP	Mytilus edulis	**soft body**	98A2,I307,I131A,I306,I304,30A,I913	**7**	354	µg/kg	1.200	1.3000	1.0833	5.000	4.1667
BBJF	Mytilus edulis	**soft body**	98A2,I023,I304,I306,I307	**5**	107	µg/kg	6.240	6.2400	1.0000		
BBJKF	Mytilus edulis	**soft body**	I304,I306,I307,30A	**4**	96	µg/kg	3.925				
BGHIP	Mytilus edulis	**soft body**	98A2,I023,I304,I306,I307,I913,71A	**7**	254	µg/kg	2.070	2.0700	1.0000		
BKF	Mytilus edulis	**soft body**	30A,98A2,I023,I304,I306,I307,I913	**7**	167	µg/kg	1.500	1.5000	1.0000		
CHR	Mytilus edulis	**soft body**	98A2	**1**	17	µg/kg	0.520	0.5180	0.9962		
DBA3A	Mytilus edulis	**soft body**	30A,I131A	**2**	117	µg/kg	0.500	0.5000	1.0000		
FLE	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A,I304,I306,I307,I915	**9**	364	µg/kg	1.600	1.6000	1.0000		
FLU	Mytilus edulis	**soft body**	98A2,I023	**2**	32	µg/kg	5.350	5.3500	1.0000	30.000	5.6075
ICDP	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A	**5**	176	µg/kg	1.730	1.7250	0.9971		
NAP	Mytilus edulis	**soft body**	I023,98A2,71A	**3**	47	µg/kg	17.300	17.3000	1.0000	2 400.000	138.7283
PA	Mytilus edulis	**soft body**	98A2,I023,71A	**3**	47	µg/kg	2.280	2.2800	1.0000		
PYR	Mytilus edulis	**soft body**	98A2	**1**	17	µg/kg	1.020	1.0200	1.0000		
TBT	Mytilus edulis	**soft body**	11X	**1**	20	µg/kg	7.107	7.1065	1.0000	150.000	21.1074
TCHT	Mytilus edulis	**soft body**	I301,I133,22A,30A	**4**	65	µg/kg	2.000	2.0000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
MBTIN	Mytilus edulis	**soft body**	22A	**1**	14	µg/kg	0.860	0.8638	1.0044		
DBTIN	Mytilus edulis	**soft body**	30A,I131A,I201,I205,I304,I306,I307	**7**	317	µg/kg	4.770	4.7680	0.9996		
TBEP	Mytilus edulis	**soft body**	26A2,I023,91A2,97A2,30A	**5**	71	µg/kg	11.300	11.3000	1.0000		
TBP	Mytilus edulis	**soft body**	30A,I023,97A2,26A2,91A2	**5**	71	µg/kg	5.960	5.9550	0.9992		
TCEP	Mytilus edulis	**soft body**	26A2,I023,91A2,97A2,30A	**5**	71	µg/kg	55.500	55.5000	1.0000		
TCPP	Mytilus edulis	**soft body**	30A,26A2,97A2,91A2	**4**	56	µg/kg	40.250	40.2500	1.0000		
TDCP	Mytilus edulis	**soft body**	26A2,91A2,97A2,I023,30A	**5**	71	µg/kg	8.930	8.9250	0.9994		
TEHP	Mytilus edulis	**soft body**	26A2,I023,91A2,97A2,30A	**5**	71	µg/kg	23.950	23.9500	1.0000		
TIBP	Mytilus edulis	**soft body**	30A,I023,26A2,97A2,91A2	**5**	71	µg/kg	9.900	9.9000	1.0000		
EHDPP	Mytilus edulis	**soft body**	30A,26A2,I023,91A2,97A2	**5**	71	µg/kg	11.050	11.0500	1.0000		
BPA	Mytilus edulis	**soft body**	30A,97A2,I023	**3**	45	µg/kg	7.450	7.4460	0.9995		
TBBPA	Mytilus edulis	**soft body**	30A,97A2,26A2,I023,71A,91A2	**6**	87	µg/kg	0.270	0.2669	0.9885		
Delta13C	Mytilus edulis	**soft body**	97A2,22A,26A2,15A	**4**	60	‰	20.450	-20.4470	-0.9999		
Delta15N	Mytilus edulis	**soft body**	56A,51A	**2**	30	‰	3.770	3.7743	1.0011		
C/N	Mytilus edulis	**soft body**	15A,71A,I304,22A,30A,I023,97A2,56A	**8**	120	%	4.980	4.9810	1.0002		
DOT	Mytilus edulis	**soft body**	I301,I133,22A,30A	**4**	65	µg/kg	0.990	0.9900	1.0000		
MOT	Mytilus edulis	**soft body**	I301,I133,22A,30A	**4**	65	µg/kg	0.990	0.9900	1.0000		
MBT	Littorina littorea	**soft body**	71G	**1**	5	µg/kg	1.344				
DBT	Littorina littorea	**soft body**	71G	**1**	5	µg/kg	1.964				
TTBT	Nucella lapillus	**soft body**	15G,76G,22G,131G,36G,11G,227G	**7**	35	µg/kg	1.015				
TBT	Nucella lapillus	**soft body**	11G,131G,15G,98G	**4**	66	µg/kg	23.540	23.5350	0.9998	150.000	6.3721
TCHT	Nucella lapillus	**soft body**	76G,22G,131G,11G,36G,15G,98G,227G1	**8**	55	µg/kg	2.330	2.3300	1.0000		
MBTIN	Nucella lapillus	**soft body**	22G,98G,36G,11G,15G,76G,131G,227G1	**8**	47	µg/kg	2.180	2.1770	0.9986		
DBTIN	Nucella lapillus	**soft body**	11G,131G,15G,98G,36G,22G,76G	**7**	42	µg/kg	1.200	1.2000	1.0000		
MPTIN	Nucella lapillus	**soft body**	71G	**1**	5	µg/kg	2.624				
DPTIN	Nucella lapillus	**soft body**	71G	**1**	5	µg/kg	1.940				
TPTIN	Nucella lapillus	**soft body**	71G	**1**	6	µg/kg	1.650	1.6463	0.9977		
VDSI	Nucella lapillus	**soft body**	11G,15G,131G,76G	**4**	63	Index	3.680	3.6832	1.0009		
DOT	Nucella lapillus	**soft body**	76G,22G,131G,36G,15G,11G,98G,227G1	**8**	55	µg/kg	1.200	1.2000	1.0000		
MOT	Nucella lapillus	**soft body**	76G,22G,131G,36G,15G,11G,98G,227G1	**8**	55	µg/kg	1.200	1.2000	1.0000		
AG	Gadus morhua	**Liver**	80B,10B	**2**	229	mg/kg	0.930	0.9256	0.9953		
AS	Gadus morhua	**Liver**	10B,13B,80B,43B2,71B,15B	**6**	721	mg/kg	12.800	12.8000	1.0000		
CD	Gadus morhua	**Liver**	80B,67B,15B,23B	**4**	1655	mg/kg	0.137	0.1365	1.0000		
CO	Gadus morhua	**Liver**	43B2	**1**	145	mg/kg	0.060	0.0584	0.9733		
CR	Gadus morhua	**Liver**	10B,15B,71B,43B2,80B,13B,36B,30B,98B1	**9**	1176	mg/kg	0.400	0.4025	1.0063		
CU	Gadus morhua	**Liver**	10B,15B,80B	**3**	1101	mg/kg	14.000	14.0000	1.0000		
NI	Gadus morhua	**Liver**	15B,23B,43B2,10B,71B,80B,53B,36B	**8**	973	mg/kg	0.650	0.6500	1.0000		
PB	Gadus morhua	**Liver**	92B,36B,67B,43B,15B,43B2,98B1,10B,23B,80B	**10**	3588	mg/kg	0.050	0.0500	1.0000		
SN	Gadus morhua	**Liver**	10B,15B,23B,36B,43B2,53B,71B,80B,13B,98B1,30B	**11**	1381	mg/kg	0.300	0.3000	1.0000		
ZN	Gadus morhua	**Liver**	98B1,10B,92B,43B2,80B	**5**	1351	mg/kg	35.000	35.0000	1.0000		
PCB-7	Gadus morhua	**Liver**	98B1,10B,92B,43B	**4**	1229	µg/kg	614.000	614.0000	1.0000	0.600	0.0010

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
CB28	Gadus morhua	**Liver**	80B,98B1,23B,67B,10B,43B,92B,53B,43B2	**9**	3039	µg/kg	8.000	8.0000	1.0000		
CB52	Gadus morhua	**Liver**	67B,23B,98B1	**3**	1385	µg/kg	16.000	16.0000	1.0000		
CB101	Gadus morhua	**Liver**	23B	**1**	554	µg/kg	32.350	32.3500	1.0000		
CB118	Gadus morhua	**Liver**	98B1,23B,10B,92B,43B,67B,80B	**7**	2359	µg/kg	100.000	100.0000	1.0000		
CB138	Gadus morhua	**Liver**	98B1,10B,43B,92B	**4**	1282	µg/kg	157.950	157.9500	1.0000		
CB153	Gadus morhua	**Liver**	98B1,10B,92B,43B	**4**	1282	µg/kg	189.950	189.9500	1.0000		
CB180	Gadus morhua	**Liver**	98B1,10B,92B	**3**	1165	µg/kg	45.800	45.8000	1.0000		
DDEPP	Gadus morhua	**Liver**	23B,10B,98B1	**3**	1498	µg/kg	160.750	160.7500	1.0000	610.000	3.7947
DDTPP	Gadus morhua	**Liver**	10B,23B,36B,98B1	**4**	885	µg/kg	13.000	13.0000	1.0000		
TDEPP	Gadus morhua	**Liver**	23B,92B,36B	**3**	1303	µg/kg	32.000	32.0000	1.0000		
HCHA	Gadus morhua	**Liver**	53B,15B,36B,10B,23B,30B,67B,92B,43B,98B1	**10**	4071	µg/kg	8.000	8.0000	1.0000		
HCHG	Gadus morhua	**Liver**	53B,10B,92B,36B	**4**	1602	µg/kg	11.000	12.0000	1.0909	61.000	5.5455
HCB	Gadus morhua	**Liver**	36B,53B	**2**	1079	µg/kg	14.000	14.0000	1.0000	10.000	0.7143
4-N-NP	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	131.000	131.0000	1.0000	3 000.000	22.9008
4-N-OP	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	23.500	23.5000	1.0000	0.004	0.0002
4-T-NP	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	240.900	240.9000	1.0000	3 000.000	12.4533
4-T-OP	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	20.000	20.0000	1.0000	0.004	0.0002
CYP1A	Gadus morhua	**Liver**	23B,53B	**2**	487		2.070	2.0669	0.9985		
EROD	Gadus morhua	**Liver**	23B,53B,36B,30B	**4**	1303	pmol/min/mg protein	192.290	192.2861	1.0000		
HBCDA	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	7.000	7.0000	1.0000	167.000	23.8571
HBCDG	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	0.890	0.8948	1.0054		
HBCDB	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	0.400	0.4030	1.0075		
HBCDD	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	7.180	7.1960	1.0022		
BDESS	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	21.420	21.4200	1.0000		
BDE6S	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	19.882	19.8800	1.0000	0.009	0.0004
BDE28	Gadus morhua	**Liver**	36B,13B,98B1,23B,43B2	**5**	701	µg/kg	1.400	1.4000	1.0000		
BDE47	Gadus morhua	**Liver**	98B1,36B,23B	**3**	557	µg/kg	16.000	16.0000	1.0000	0.009	0.0005
BDE49	Gadus morhua	**Liver**	23B,98B1	**2**	266	µg/kg	3.950				
BDE66	Gadus morhua	**Liver**	23B,98B1	**2**	266	µg/kg	0.595				
BDE71	Gadus morhua	**Liver**	98B1,23B,53B,30B	**4**	553	µg/kg	0.400				
BDE77	Gadus morhua	**Liver**	30B	**1**	122	µg/kg	1.690				
BDE85	Gadus morhua	**Liver**	98B1,53B,23B,30B	**4**	536	µg/kg	1.725				
BDE99	Gadus morhua	**Liver**	13B,23B	**2**	363	µg/kg	0.750	0.7540	1.0053		
BDE100	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	2.600	2.6000	1.0000		
BDE126	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,80B	**6**	419	µg/kg	0.100	0.1000	1.0000		
BDE138	Gadus morhua	**Liver**	30B,23B,53B,98B1	**4**	561	µg/kg	0.300				
BDE153	Gadus morhua	**Liver**	13B,23B	**2**	363	µg/kg	0.150	0.1490	0.9933		
BDE154	Gadus morhua	**Liver**	98B1,36B	**2**	323	µg/kg	1.500	1.5000	1.0000		
BDE183	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,53B,80B,98B1	**8**	1360	µg/kg	0.600	0.6005	1.0008		
BDE196	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,53B,80B,98B1	**8**	1142	µg/kg	1.000	1.0000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
BDE205	Gadus morhua	**Liver**	23B,30B,98B1,53B	**4**	559	µg/kg	1.500				
BDE209	Gadus morhua	**Liver**	13B	**1**	131	µg/kg	2.000	2.0000	1.0000		
SCCP	Gadus morhua	**Liver**	23B,43B2,80B	**3**	245	µg/kg	154.000	154.0000	1.0000	6 000.000	38.9610
MCCP	Gadus morhua	**Liver**	23B,43B2	**2**	174	µg/kg	392.800	392.8000	1.0000	170.000	0.4328
PFAS	Gadus morhua	**Liver**	43B2,80B	**2**	251	µg/kg	11.000	20.0000	1.8182		
PFNA	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,80B,98B1,53B	**8**	1315	µg/kg	5.000	5.0000	1.0000		
PFOA	Gadus morhua	**Liver**	43B2,13B,80B,53B,36B,98B1,23B,30B	**8**	1289	µg/kg	10.000	10.0000	1.0000	91.000	9.1000
PFOS	Gadus morhua	**Liver**	43B2,80B	**2**	251	µg/kg	10.250	10.2500	1.0000	9.100	0.8878
PFOSA	Gadus morhua	**Liver**	43B2,98B1,53B,80B,23B	**5**	718	µg/kg	6.245	6.2450	1.0000		
PFBS	Gadus morhua	**Liver**	13B,36B,43B2,53B,80B,23B,30B,98B1	**8**	1316	µg/kg	8.000	8.0000	1.0000		
TBEP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
TBP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
TCEP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	477.200	477.2000	1.0000		
TCPP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	67.600	67.6000	1.0000		
TDCP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	71.120	71.1200	1.0000		
TEHP	Gadus morhua	**Liver**	43B2	**1**	64	µg/kg	334.150	334.1500	1.0000		
TIBP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
EHDPP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	66.420	66.4200	1.0000		
BPA	Gadus morhua	**Liver**	43B2,80B	**2**	134	µg/kg	2.000	2.0000	1.0000		
TBBPA	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	0.570	0.5675	0.9956		
HG	Gadus morhua	**Fillet**	10B	**1**	504	mg/kg	0.056	0.0600	1.0714	0.020	0.3571
ALAD	Gadus morhua	**Blood**	53B	**1**	395	ng/min/mg protein	34.940	34.9390	1.0000		
BAP3O	Gadus morhua	**Bile**	30B,15B	**2**	305	µg/kg	2.780	2.7828	1.0010		
PA1O	Gadus morhua	**Bile**	23B,15B,30B,53B	**4**	800	µg/kg	6.150	6.1542	1.0007		
PYR1O	Gadus morhua	**Bile**	23B	**1**	398	µg/kg	15.840	15.8370	0.9998		
TBT	Littorina/Nucella	**soft body**	11G,15G,131G,98G	**4**	66	µg/kg	23.535				

Appendix D
Maps of stations

Nominal station positions 1981-2019
(cf. Appendix E)

Appendix D (cont.) Map of stations

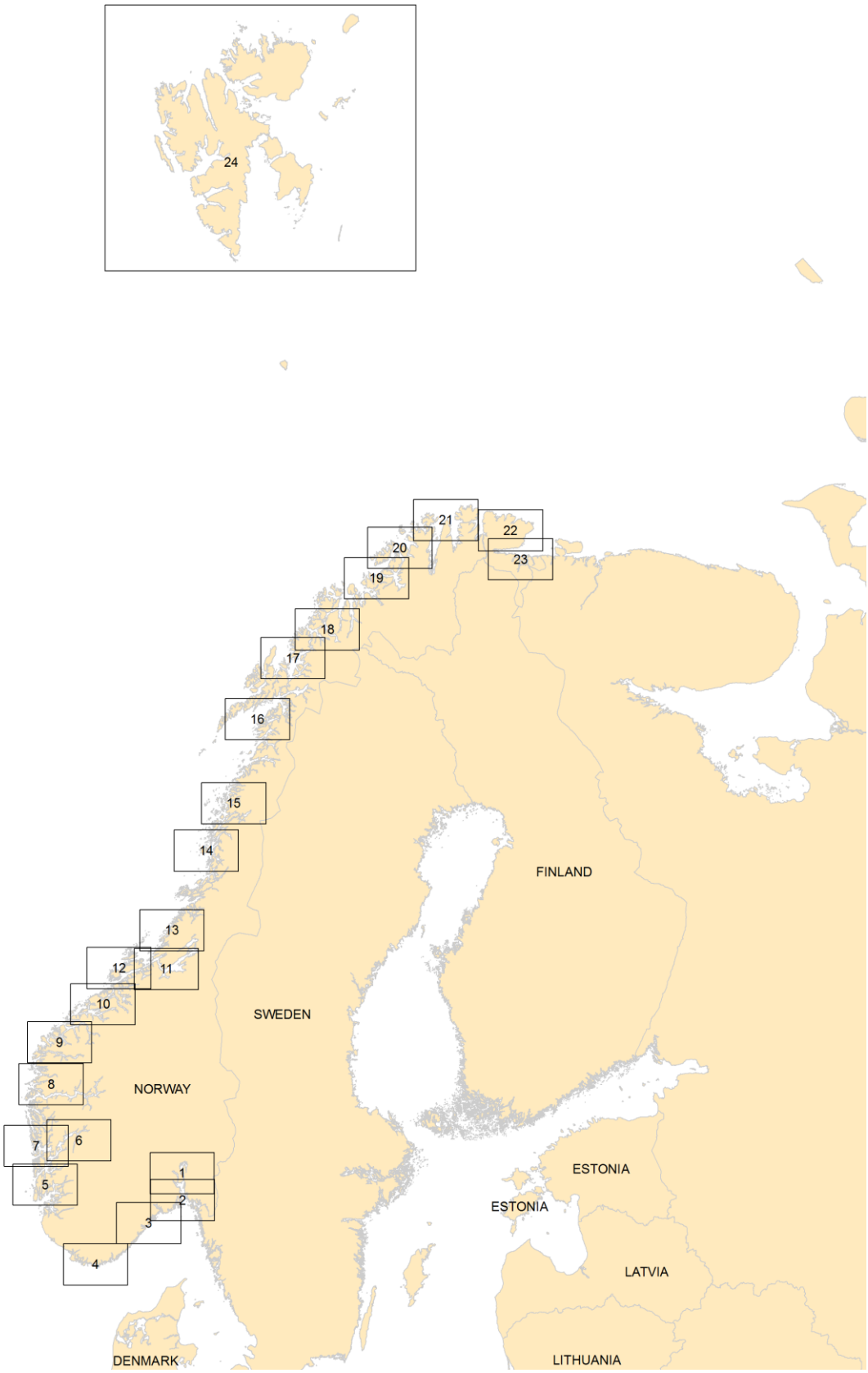
NOTES

The station's nominal position is plotted, and not the specific positions that may have differed from one year to another. The maps are generated using ArcGIS version 9.1.

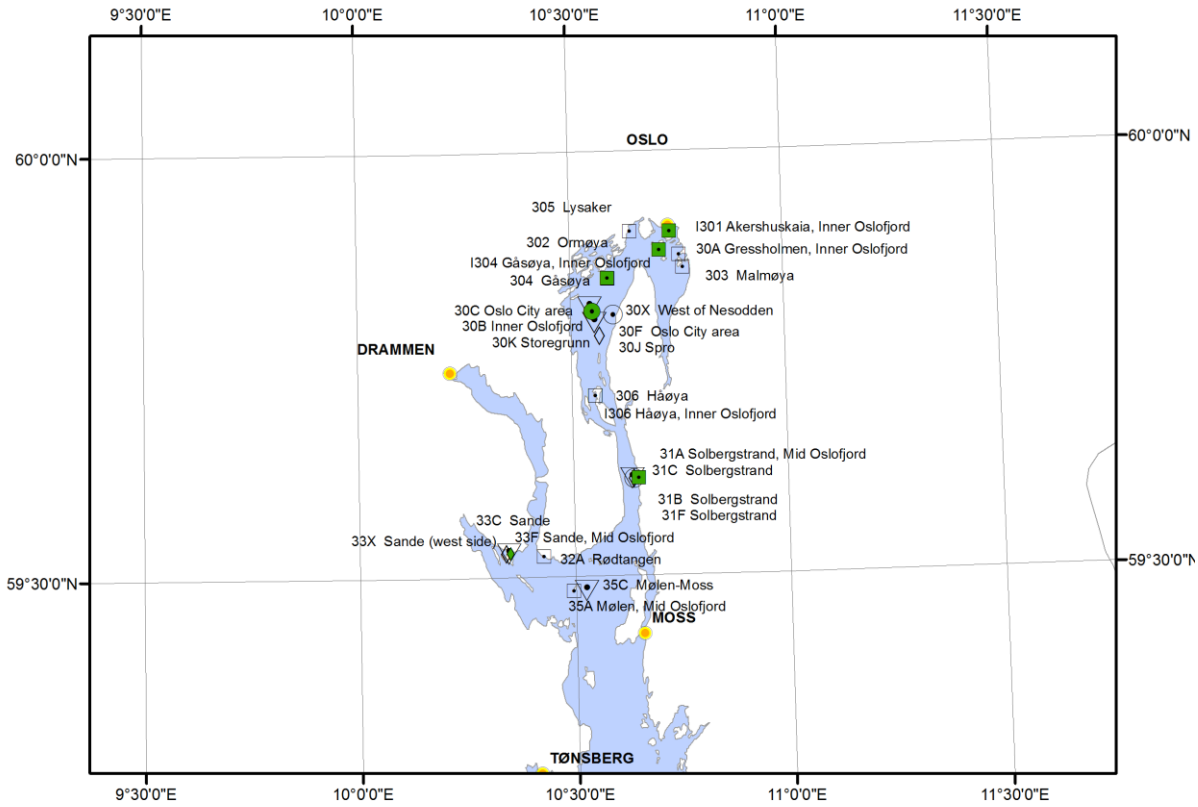
The following symbols and codes apply:

All years	2019	Explanation	Station code
		Sediment	<number>S
		Blue mussel	<number>A
		Blue mussel	I<number/letter> [1]
		Blue mussel	R<number/letter> [1]
		Dogwhelk/periwinkle	<number>G
		Prawn	<number>C
		Atlantic cod	<number>B
		Flatfish	<number>F
		Other round fish	
		Common eider duck	<number>N
		Town or city	

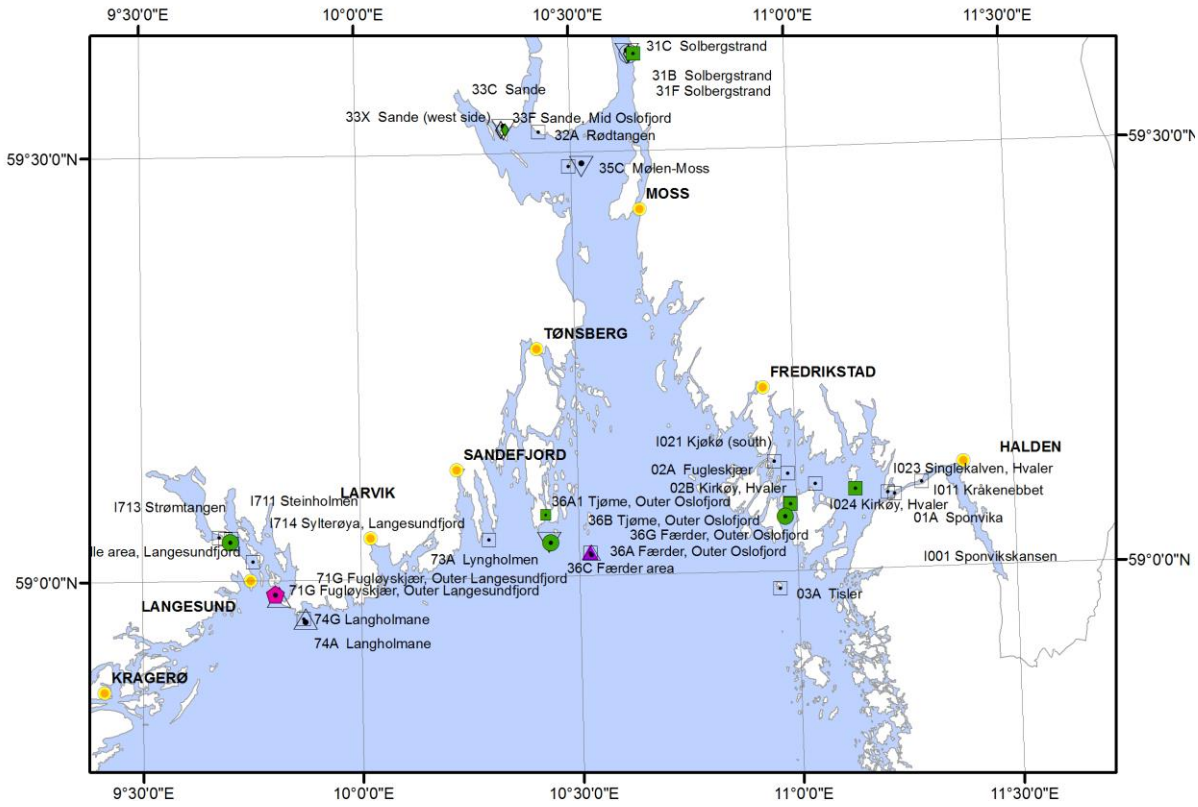
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (Green *et al*. 2011).



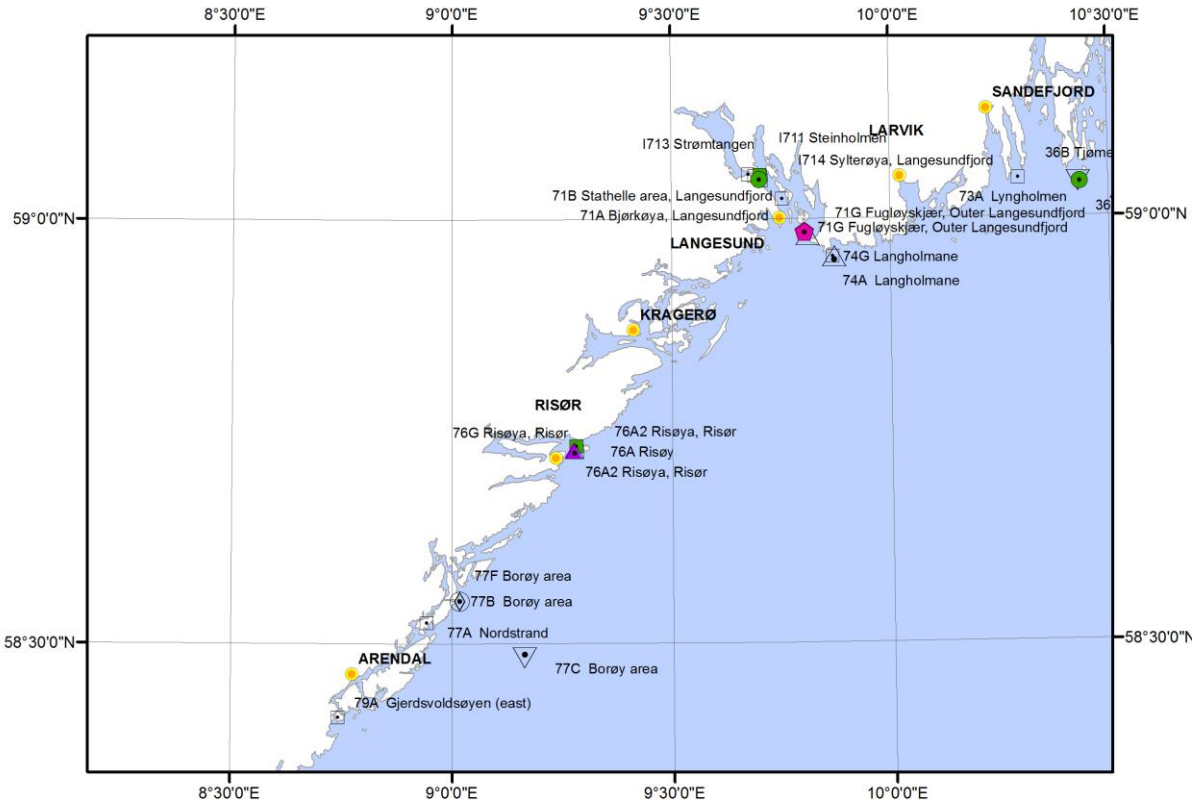
Maps presenting MILKYS stations in Norway. Numbers refer to map references that follow. Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
60°0'0"N
59°30'0"N
OSLO
DRAMMEN
MOSS
TØNSBERG
305 Lysaker
I301 Akershuskaia, Inner Oslofjord
302 Ormøya
30A Gressholmen, Inner Oslofjord
I304 Gåsøya, Inner Oslofjord
303 Malmøya
304 Gåsøya
30C Oslo City area
30X West of Nesodden
30B Inner Oslofjord
30F Oslo City area
30K Storegrunn
30J Spro
306 Håøya
I306 Håøya, Inner Oslofjord
31A Solbergstrand, Mid Oslofjord
31C Solbergstrand
31B Solbergstrand
31F Solbergstrand
33C Sande
33X Sande (west side)
33F Sande, Mid Oslofjord
32A Rødtangen
35C Mølen-Moss
35A Mølen, Mid Oslofjord

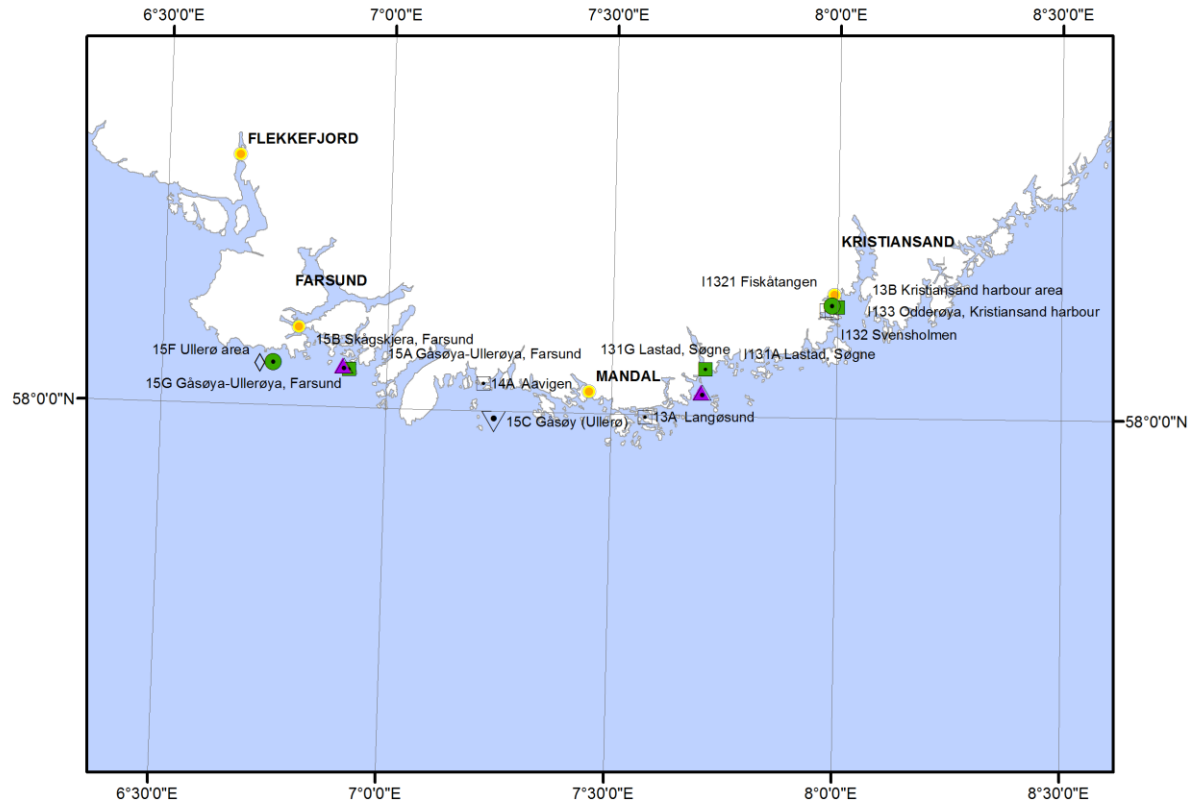
MAP 1


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
59°30'0"N
59°0'0"N
31C Solbergstrand
31B Solbergstrand
31F Solbergstrand
33C Sande
33X Sande (west side)
33F Sande, Mid Oslofjord
32A Rødtangen
35C Mølen-Moss
MOSS
TØNSBERG
FREDRIKSTAD
I021 Kjøkø (south)
HALDEN
SANDEFJORD
02A Fugleskjær
I023 Singlekalven, Hvaler
02B Kirkøy, Hvaler
I011 Kråkenebbet
LARVIK
I713 Strømtangen
I711 Steinholmen
36A1 Tjøme, Outer Oslofjord
I024 Kirkøy, Hvaler
01A Sponvika
I714 Sylterøya, Langesundfjord
36B Tjøme, Outer Oslofjord
36G Færder, Outer Oslofjord
73A Lyngholmen
36A Færder, Outer Oslofjord
I001 Sponvikskansen
36C Færder area
71G Fugløyskjær, Outer Langesundfjord
03A Tisler
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ

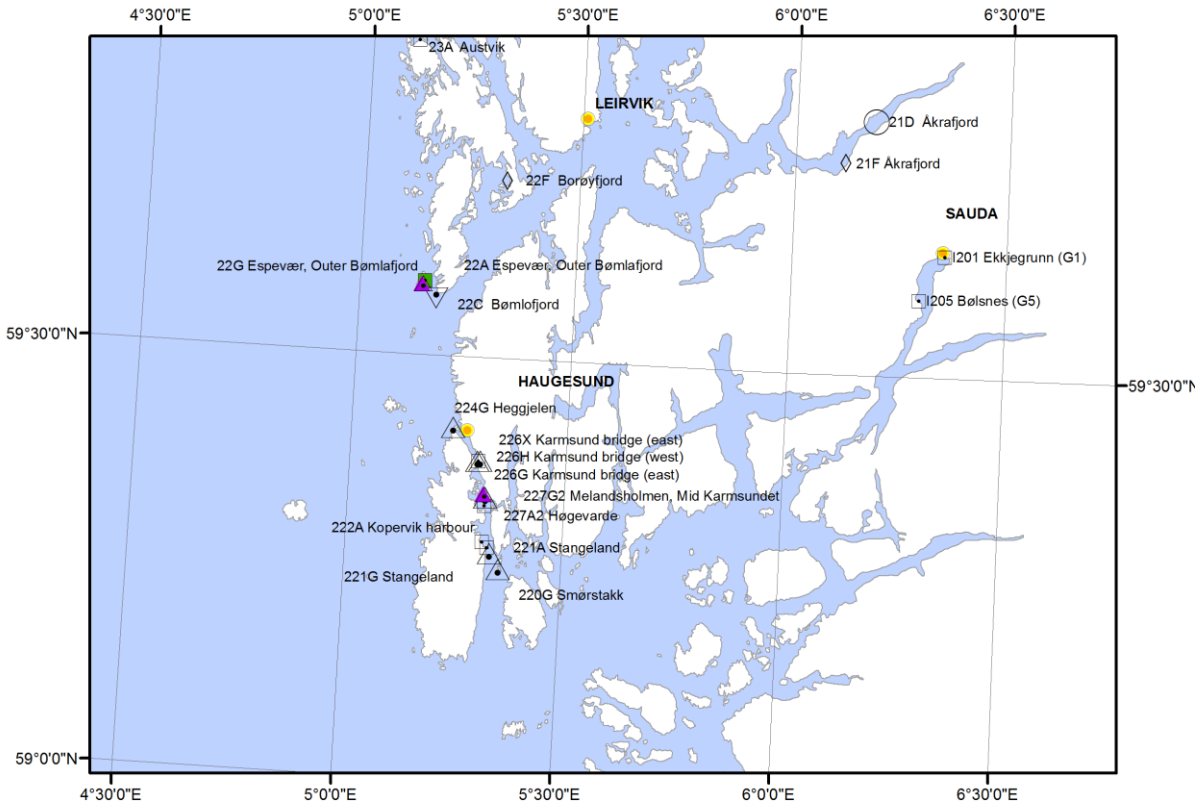
MAP 2


8°30'0"E
9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
59°0'0"N
58°30'0"N
SANDEFJORD
LARVIK
I713 Strømtangen
I711 Steinholmen
I714 Sylterøya, Langesundfjord
36B Tjøme
71B Stathelle area, Langesundfjord
71A Bjørkøya, Langesundfjord
73A Lyngholmen
71G Fugløyskjær, Outer Langesundfjord
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ
RISØR
76G Risøya, Risør
76A2 Risøya, Risør
76A Risøy
77F Borøy area
77B Borøy area
77A Nordstrand
ARENDAL
77C Borøy area
79A Gjerdsvoldsøyen (east)

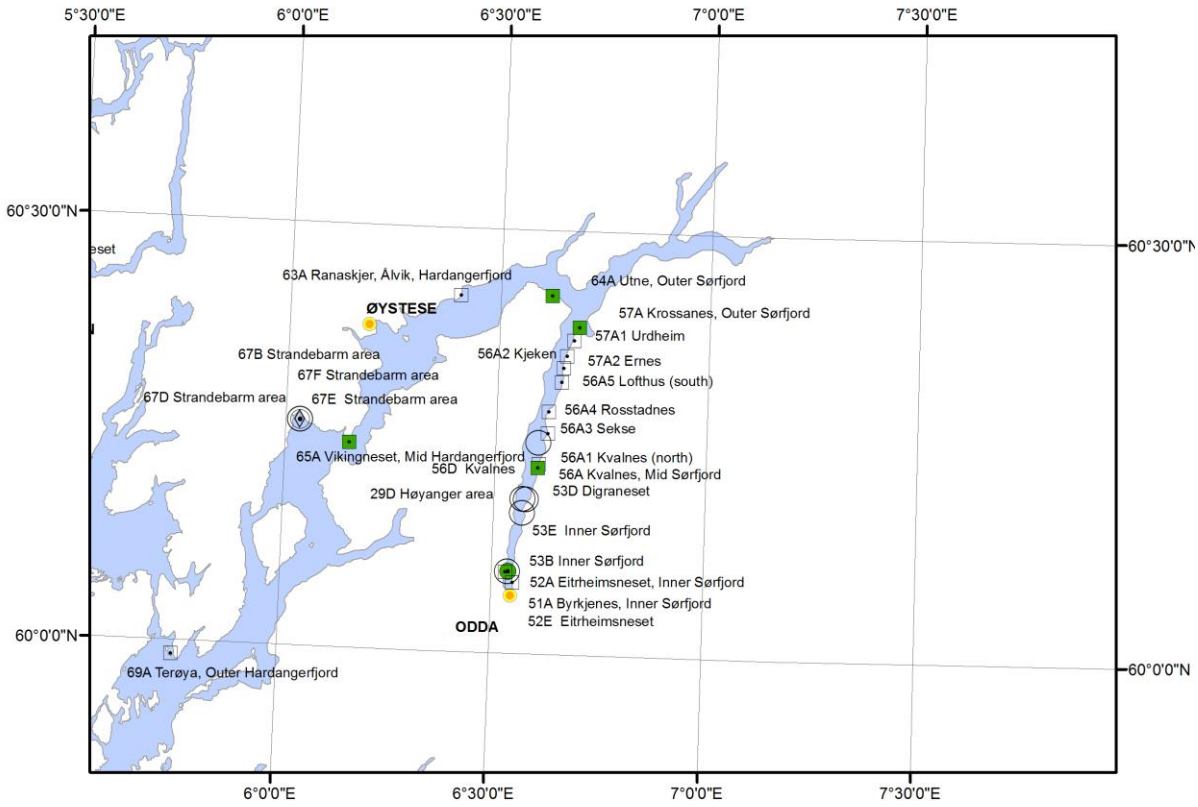
MAP 3


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
58°0'0"N
FLEKKEFJORD
KRISTIANSAND
FARSUND
I1321 Fiskåtangen
13B Kristiansand harbour area
I133 Odderøya, Kristiansand harbour
I132 Svensholmen
15B Skågskjera, Farsund
15F Ullerø area
15A Gåsøya-Ullerøya, Farsund
131G Lastad, Søgne
I131A Lastad, Søgne
15G Gåsøya-Ullerøya, Farsund
14A Aavigen
MANDAL
15C Gåsøy (Ullerø)
13A Langøsund

MAP 4


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
59°30'0"N
59°0'0"N
23A Austvik
LEIRVIK
21D Åkrafjord
21F Åkrafjord
22F Borøyfjord
SAUDA
22G Espevær, Outer Bømlafjord
22A Espevær, Outer Bømlafjord
I201 Ekkjegrunn (G1)
22C Bømlofjord
I205 Bølsnes (G5)
HAUGESUND
224G Heggjelen
226X Karmsund bridge (east)
226H Karmsund bridge (west)
226G Karmsund bridge (east)
227G2 Melandsholmen, Mid Karmsundet
227A2 Høgevarde
222A Kopervik harbour
221A Stangeland
221G Stangeland
220G Smørstakk

MAP 5


5°30'0"E
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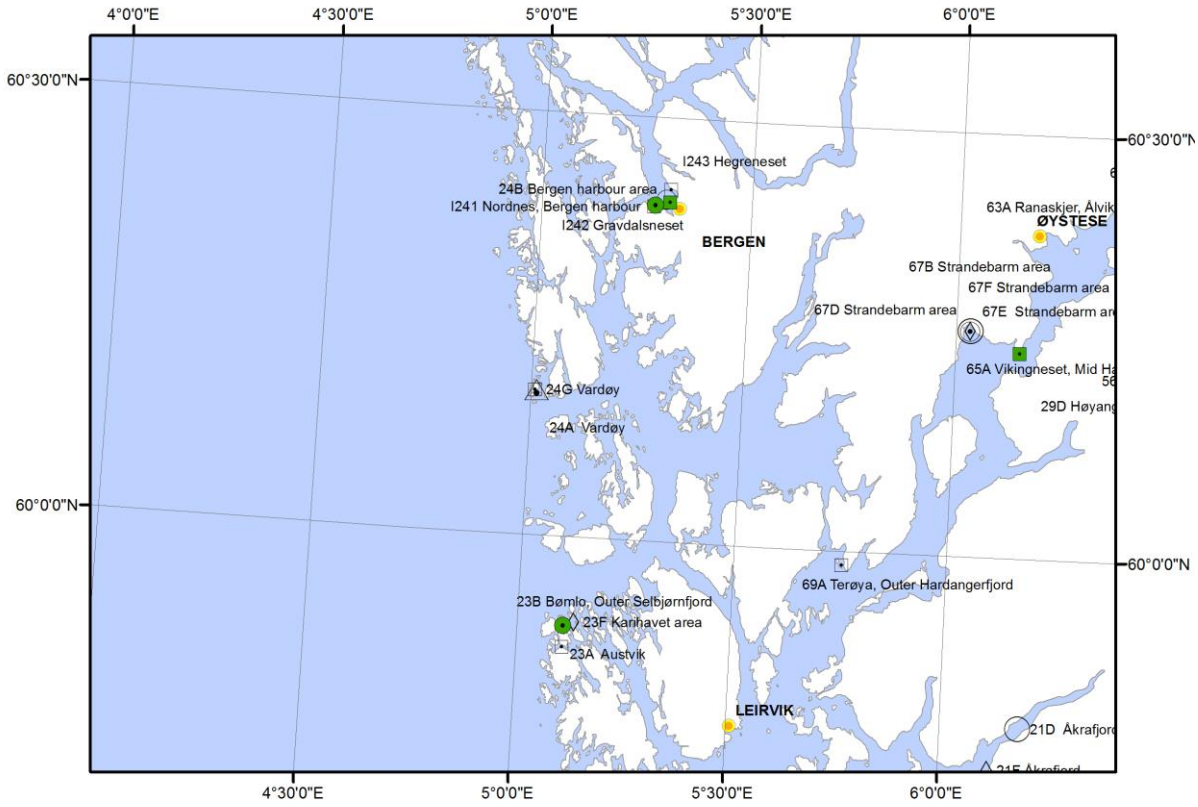
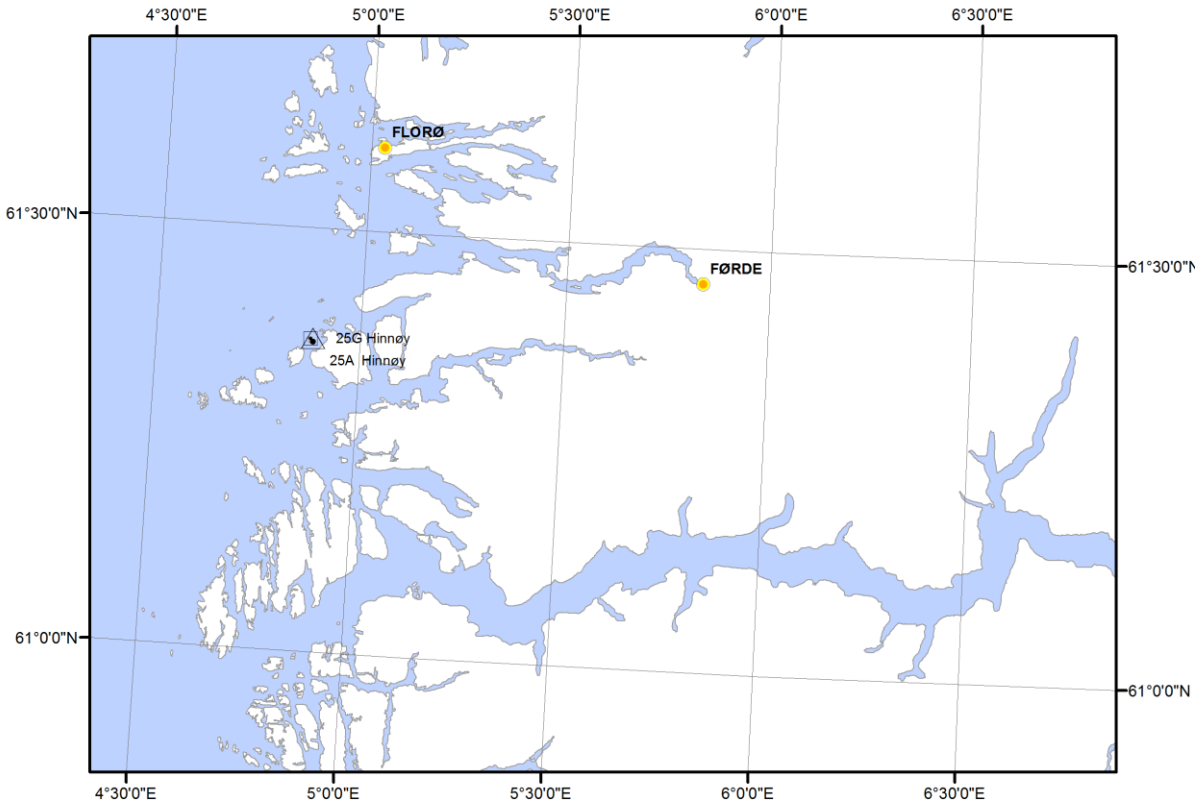
6°30'0"E
7°0'0"E
7°30'0"E
60°30'0"N
60°0'0"N
63A Ranaskjer, Ålvik, Hardangerfjord
64A Utne, Outer Sørfjord
ØYSTESE
57A Krossanes, Outer Sørfjord
57A1 Urdheim
67B Strandebarm area
56A2 Kjeken
57A2 Ernes
67F Strandebarm area
56A5 Lofthus (south)
67D Strandebarm area
67E Strandebarm area
56A4 Rosstadnes
56A3 Sekse
65A Vikingneset, Mid Hardangerfjord
56A1 Kvalnes (north)
56D Kvalnes
56A Kvalnes, Mid Sørfjord
29D Høyanger area
53D Digraneset
53E Inner Sørfjord
53B Inner Sørfjord
52A Eitrheimsneset, Inner Sørfjord
51A Byrkjenes, Inner Sørfjord
52E Eitrheimsneset
ODDA
69A Terøya, Outer Hardangerfjord

MAP 6


4°0'0"E
4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
60°30'0"N
60°0'0"N
I243 Hegreneset
24B Bergen harbour area
I241 Nordnes, Bergen harbour
I242 Gravdalsneset
BERGEN
63A Ranaskjer, Ålvik
ØYSTESE
67B Strandebarm area
67F Strandebarm area
67D Strandebarm area
67E Strandebarm ar
65A Vikingneset, Mid Ha
29D Høyang
24G Vardøy
24A Vardøy
69A Terøya, Outer Hardangerfjord
23B Bømlo, Outer Selbjørnfjord
23F Kanhavet area
23A Austvik
LEIRVIK
21D Åkrafjord

MAP 7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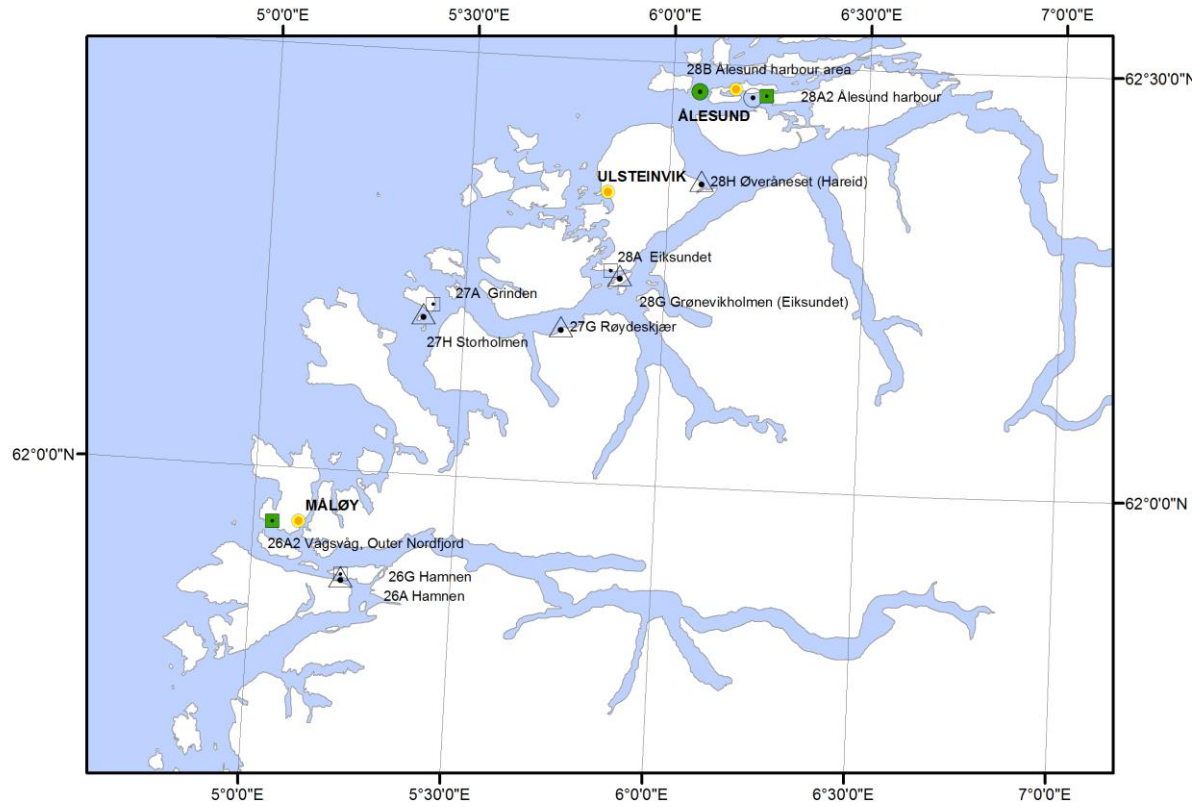
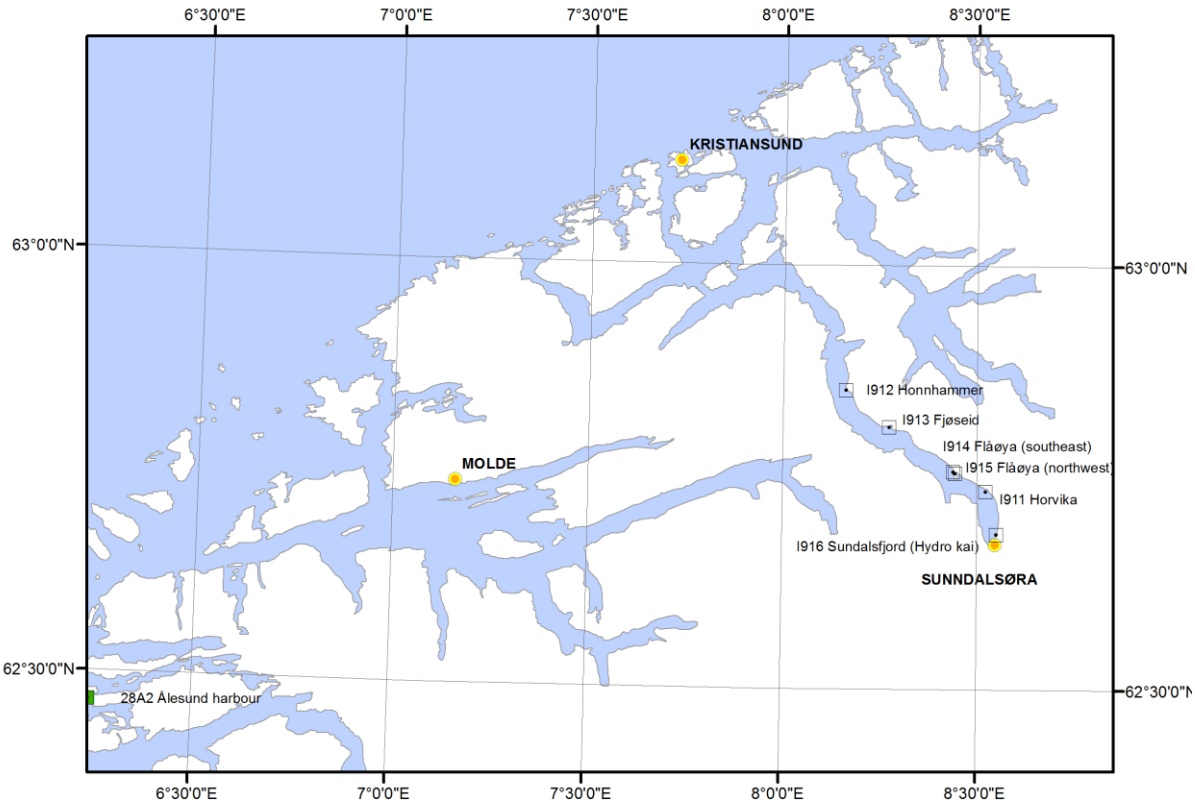
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
61°30'0"N
61°0'0"N
FLORØ
FØRDE
26G Hinnøy
25A Hinnøy

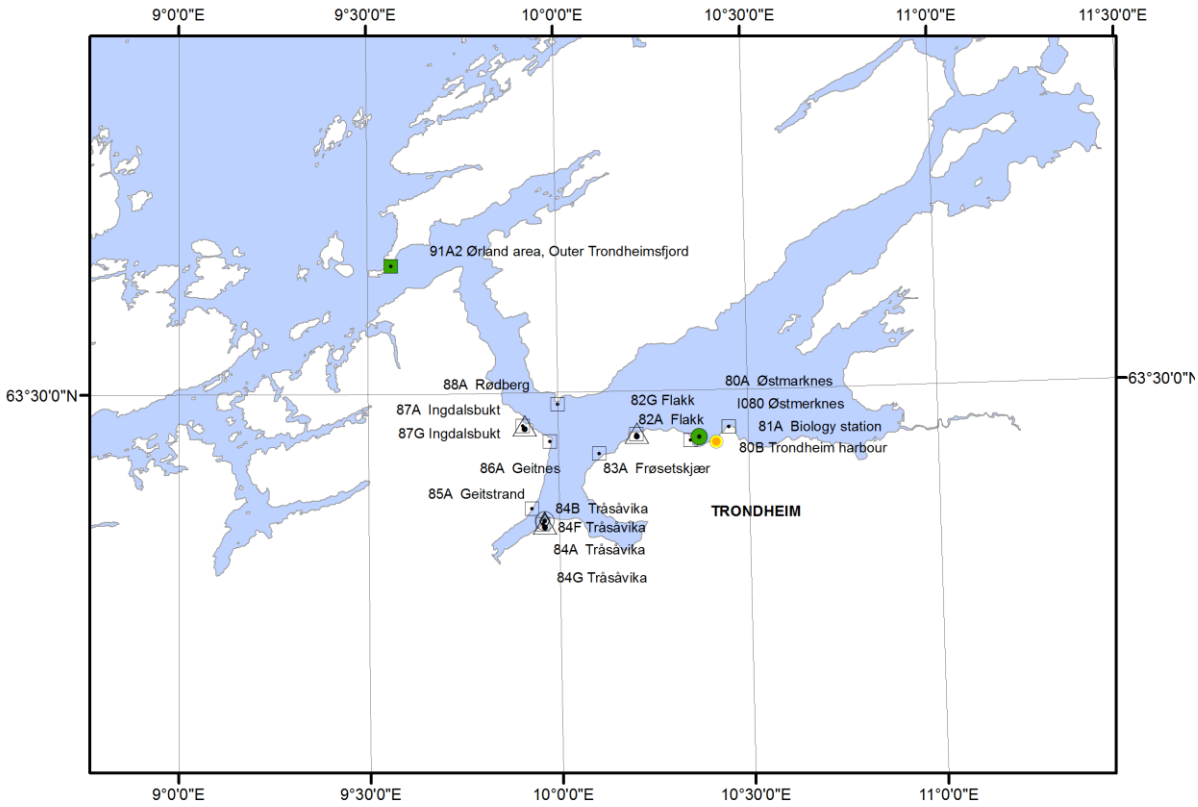
MAP 8


5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E
62°30'0"N
62°0'0"N
28B Ålesund harbour area
28A2 Ålesund harbour
ÅLESUND
ULSTEINVIK
28H Øveråneset (Hareid)
28A Eiksundet
27A Grinden
28G Grønevikholmen (Eiksundet)
27G Røydeskjær
27H Storholmen
MÅLØY
26A2 Vågsvåg, Outer Nordfjord
26G Hamnen
26A Hamnen

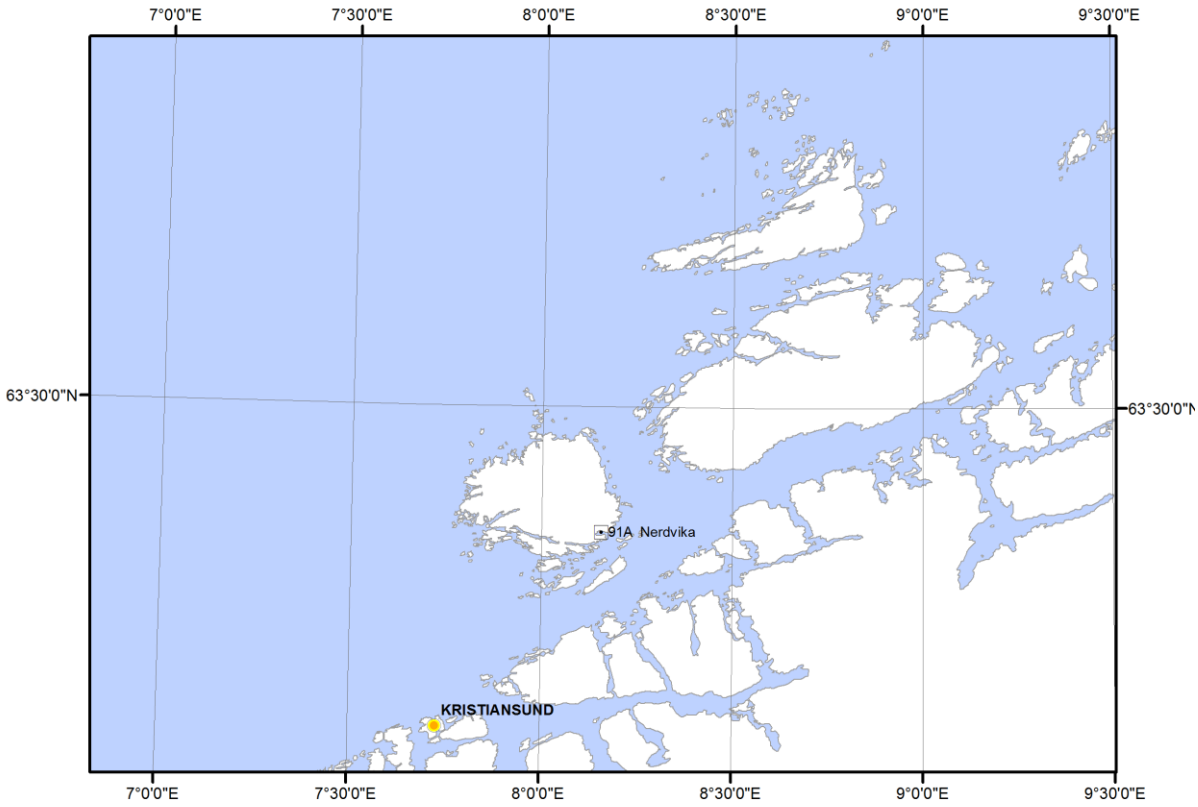
MAP 9


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
63°0'0"N
62°30'0"N
KRISTIANSUND
MOLDE
I912 Honnhammer
I913 Fjøseid
I914 Flåøya (southeast)
I915 Flåøya (northwest)
I911 Horvika
I916 Sundalsfjord (Hydro kai)
SUNNDALSØRA
28A2 Ålesund harbour

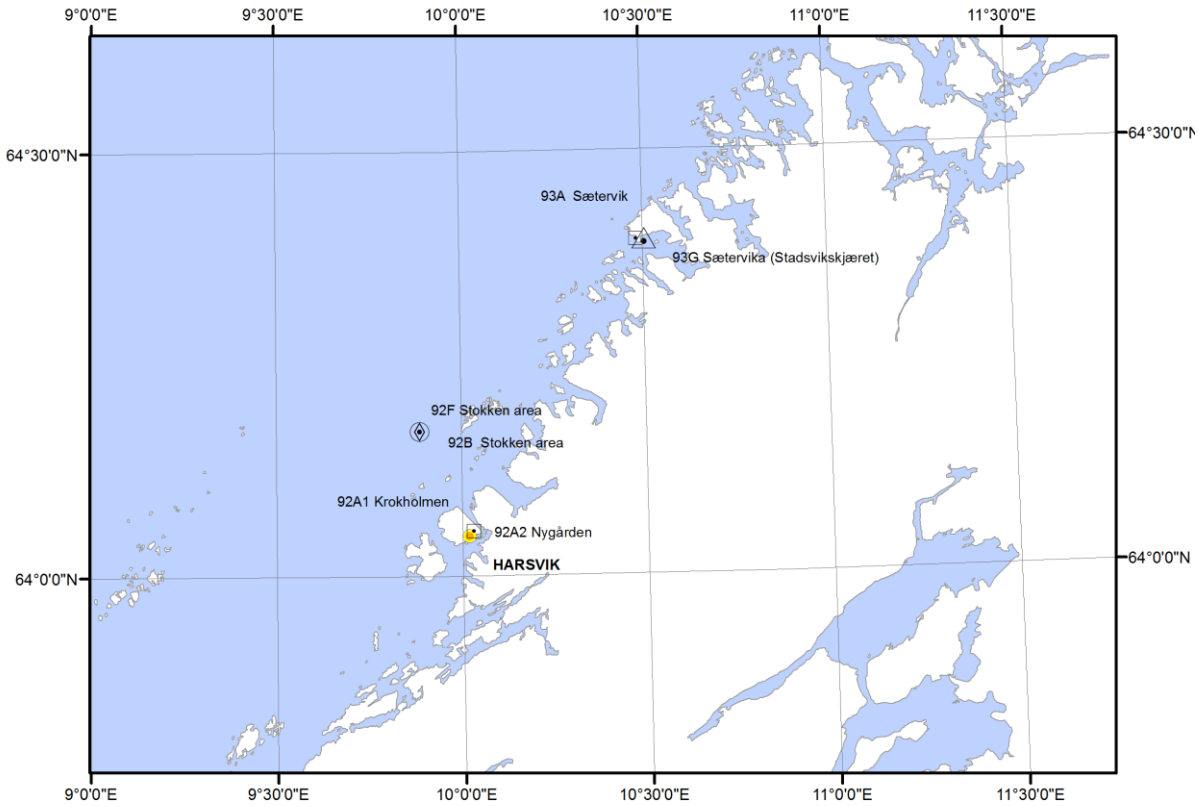
MAP 10


9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
63°30'0"N
91A2 Ørland area, Outer Trondheimsfjord
88A Rødberg
87A Ingdalsbukt
87G Ingdalsbukt
86A Geitnes
85A Geitstrand
84B Tråsåvika
84F Tråsåvika
84A Tråsåvika
84G Tråsåvika
82G Flakk
82A Flakk
80A Østmarknes
80Ø Østmerknes
81A Biology station
80B Trondheim harbour
83A Frøsetskjær
TRONDHEIM

MAP 11


7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
9°0'0"E
9°30'0"E
63°30'0"N
91A Nerdvika
KRISTIANSUND

MAP 12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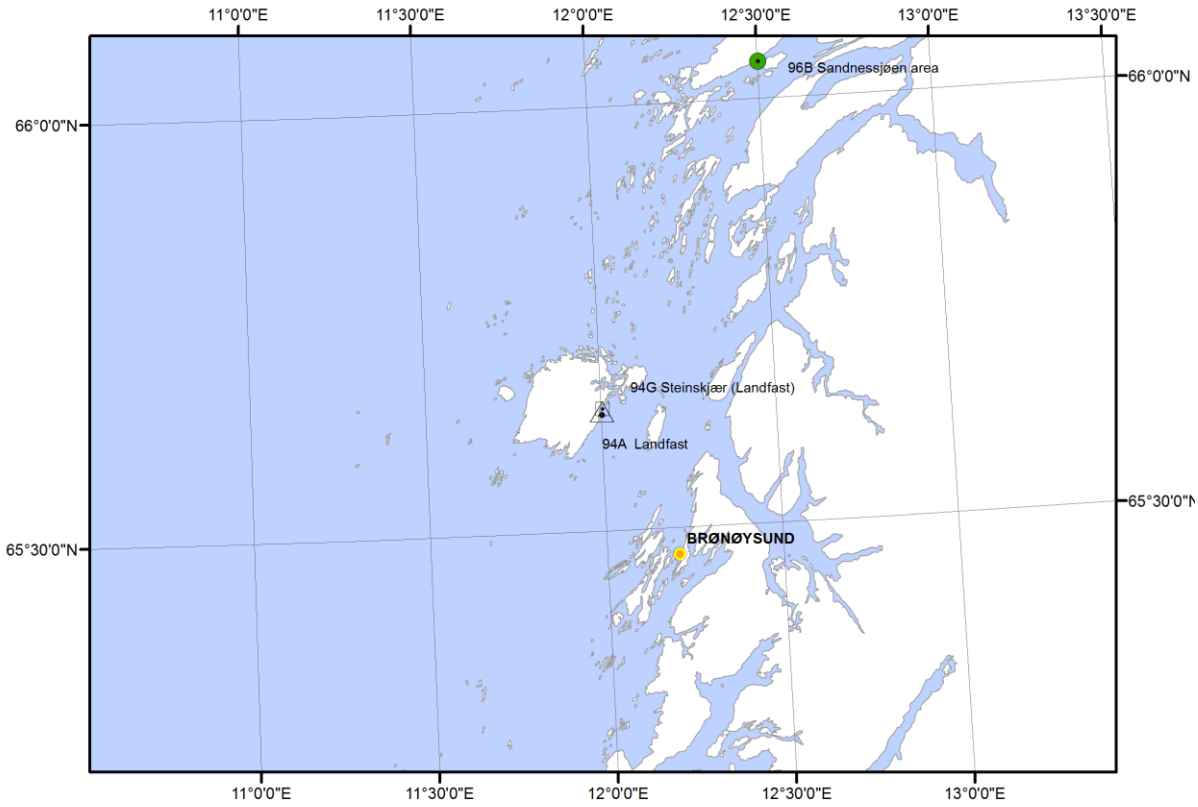
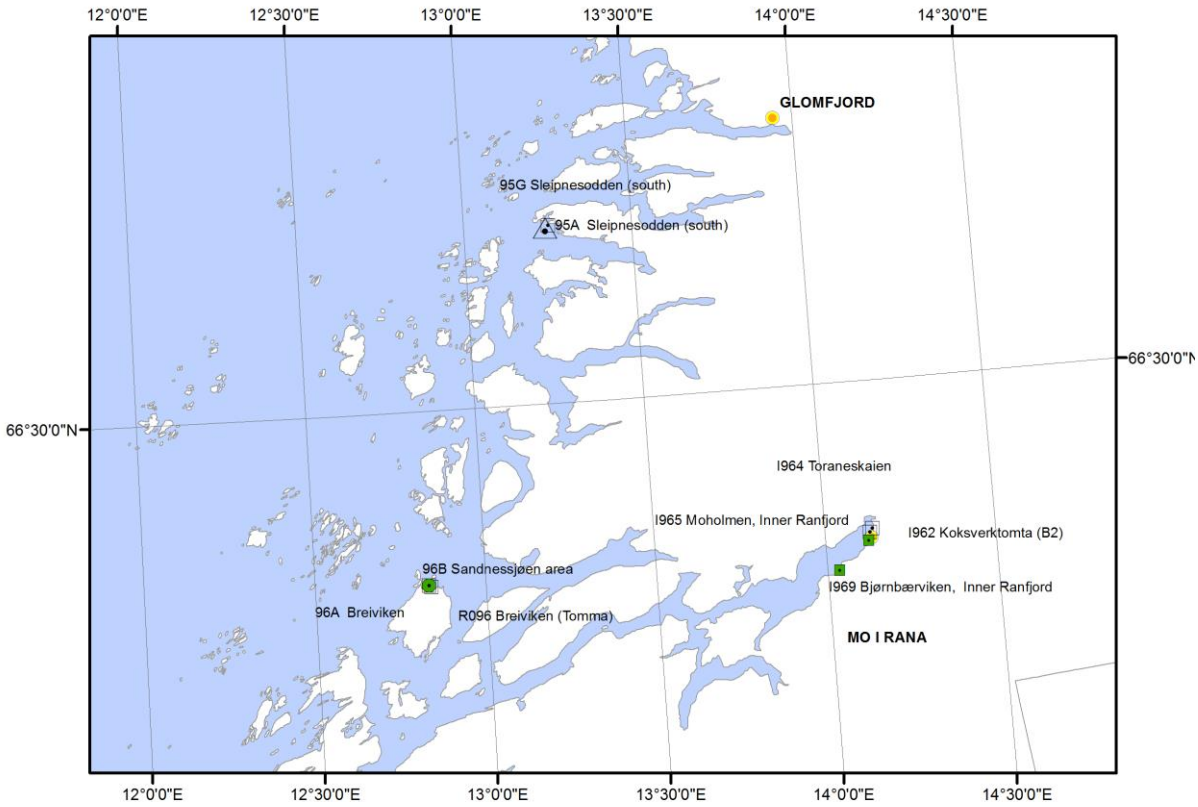
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
64°30'0"N
64°0'0"N
93A Sætervik
93G Sætervika (Stadsvikskjæret)
92F Stokken area
92B Stokken area
92A1 Krokholmen
92A2 Nygården
HARSVIK

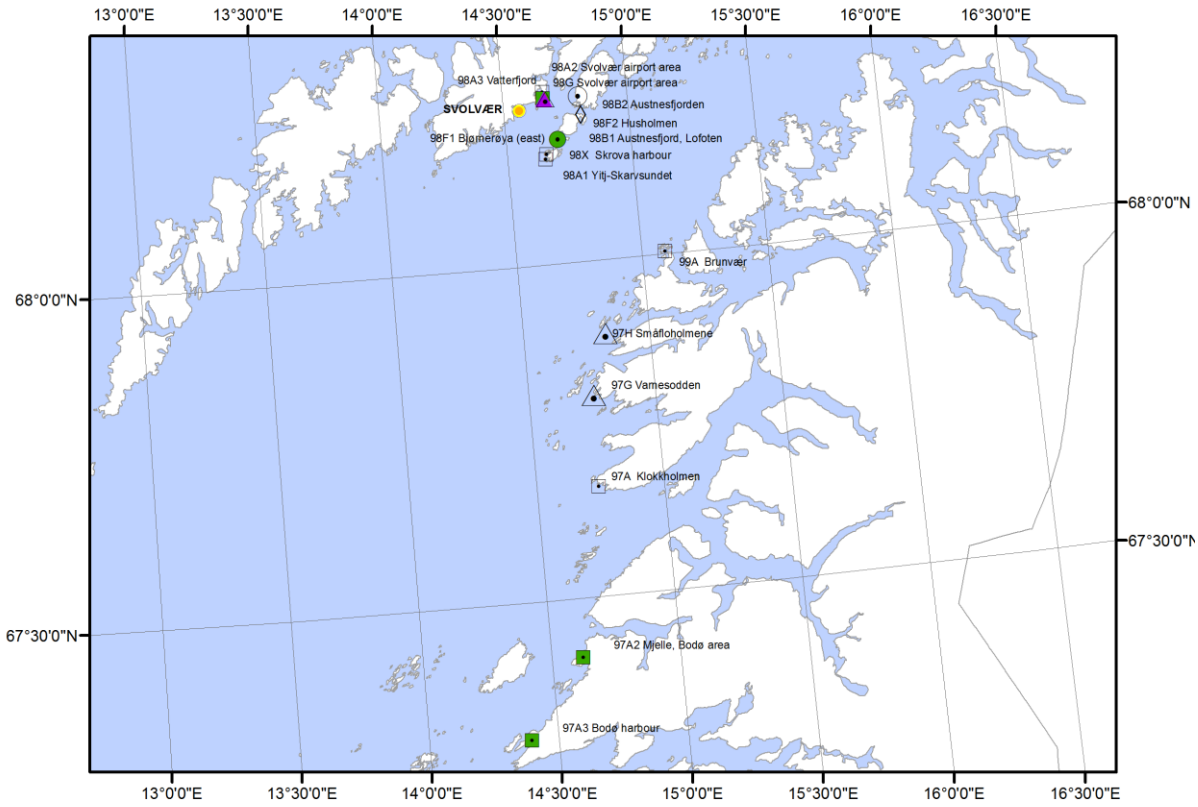
MAP 13


11°0'0"E
11°30'0"E
12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
66°0'0"N
65°30'0"N
96B Sandnessjøen area
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

MAP 14


12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
14°0'0"E
14°30'0"E
66°30'0"N
GLOMFJORD
95G Sleipnesodden (south)
95A Sleipnesodden (south)
I964 Toraneskaien
I965 Moholmen, Inner Ranfjord
I962 Koksverktomta (B2)
I969 Bjørnbærviken, Inner Ranfjord
96B Sandnessjøen area
96A Breiviken
R096 Breiviken (Tomma)
MO I RANA

MAP 15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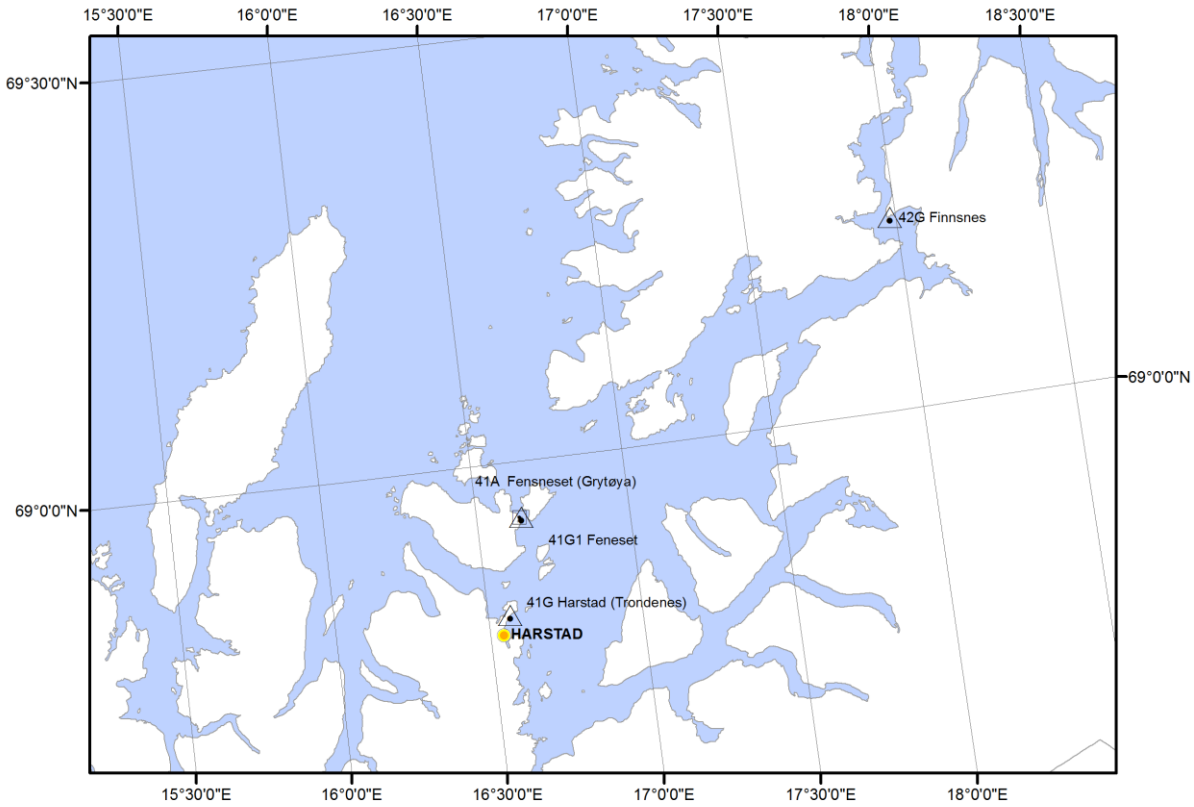
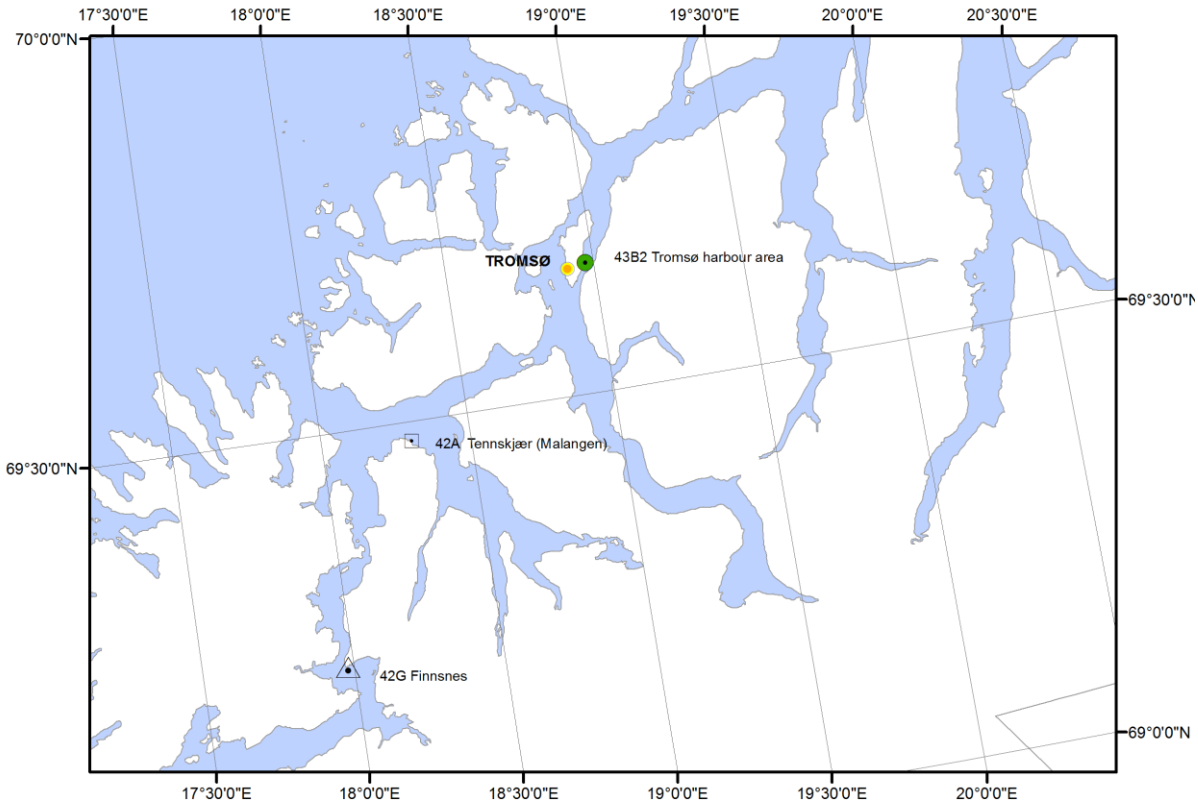
14°0'0"E
14°30'0"E
15°0'0"E
15°30'0"E
16°0'0"E
16°30'0"E
68°0'0"N
67°30'0"N
98A2 Svolvær airport area
98A3 Valterfjord
98G Svolvær airport area
98B2 Austnesfjorden
SVOLVÆR
98F2 Husholmen
98F1 Bjørnerøya (east)
98B1 Austnesfjord, Lofoten
98X Skrova harbour
98A1 Ytij-Skarvsundet
99A Brunvær
97H Småfloholmene
97G Vamesodden
97A Klokkholmen
97A2 Mjelle, Bodø area
97A3 Bodø harbour

MAP 16


15°30'0"E
16°0'0"E
16°30'0"E
17°0'0"E
17°30'0"E
18°0'0"E
18°30'0"E
69°30'0"N
69°0'0"N
42G Finnsnes
41A Fensneset (Grytøya)
41G1 Feneset
41G Harstad (Trondenes)
HARSTAD

MAP 17


17°30'0"E
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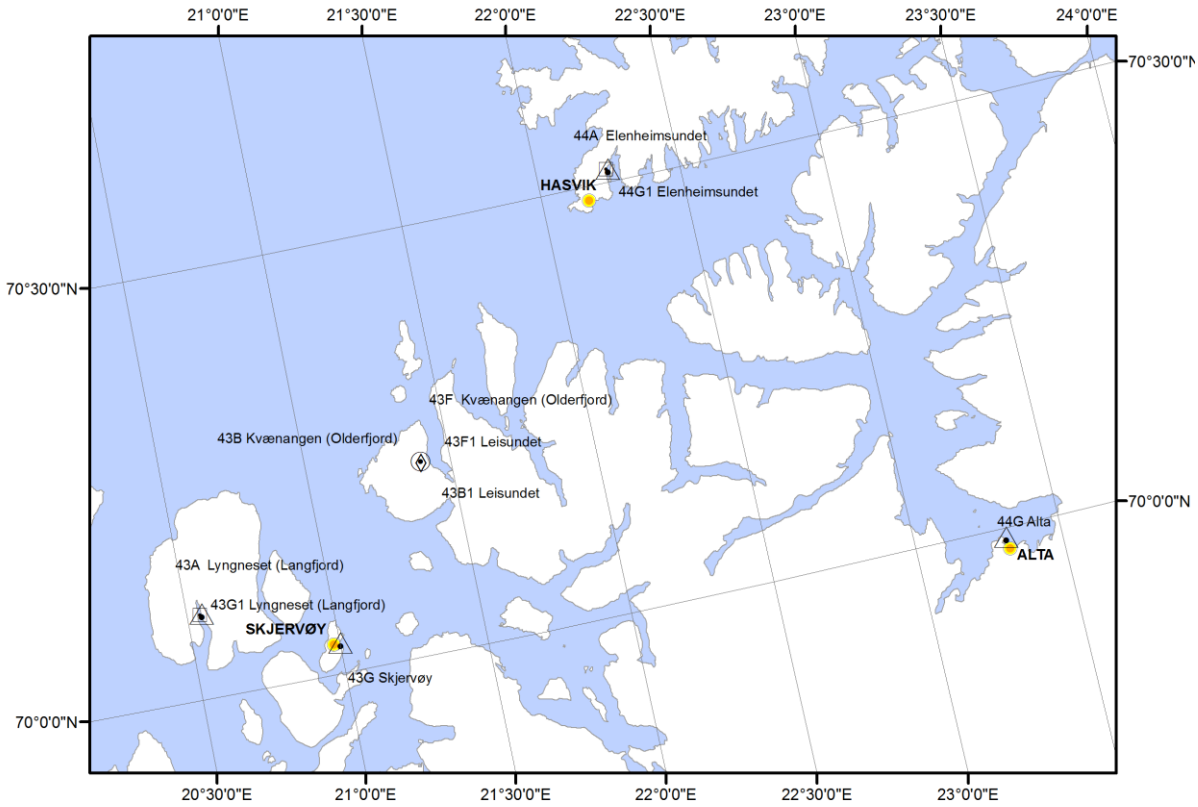
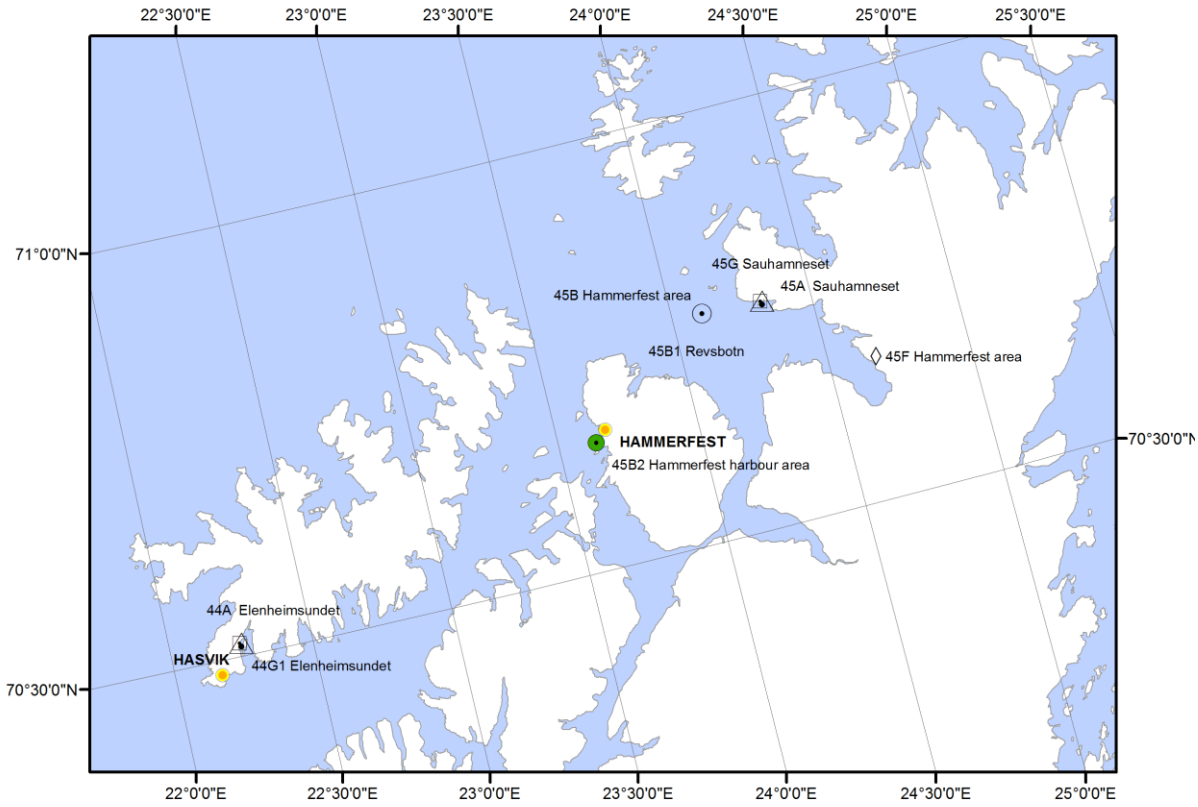
18°30'0"E
19°0'0"E
19°30'0"E
20°0'0"E
20°30'0"E
70°0'0"N
69°30'0"N
69°0'0"N
TROMSØ
43B2 Tromsø harbour area
42A Tennskjær (Malangen)
42G Finnsnes

MAP 18


21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
70°30'0"N
70°0'0"N
20°30'0"E
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet
43F Kvænangen (Olderfjord)
43B Kvænangen (Olderfjord)
43F1 Leisundet
43B1 Leisundet
44G Alta
ALTA
43A Lyngneset (Langfjord)
43G1 Lyngneset (Langfjord)
SKJERVØY
43G Skjervøy

MAP 19


22°30'0"E
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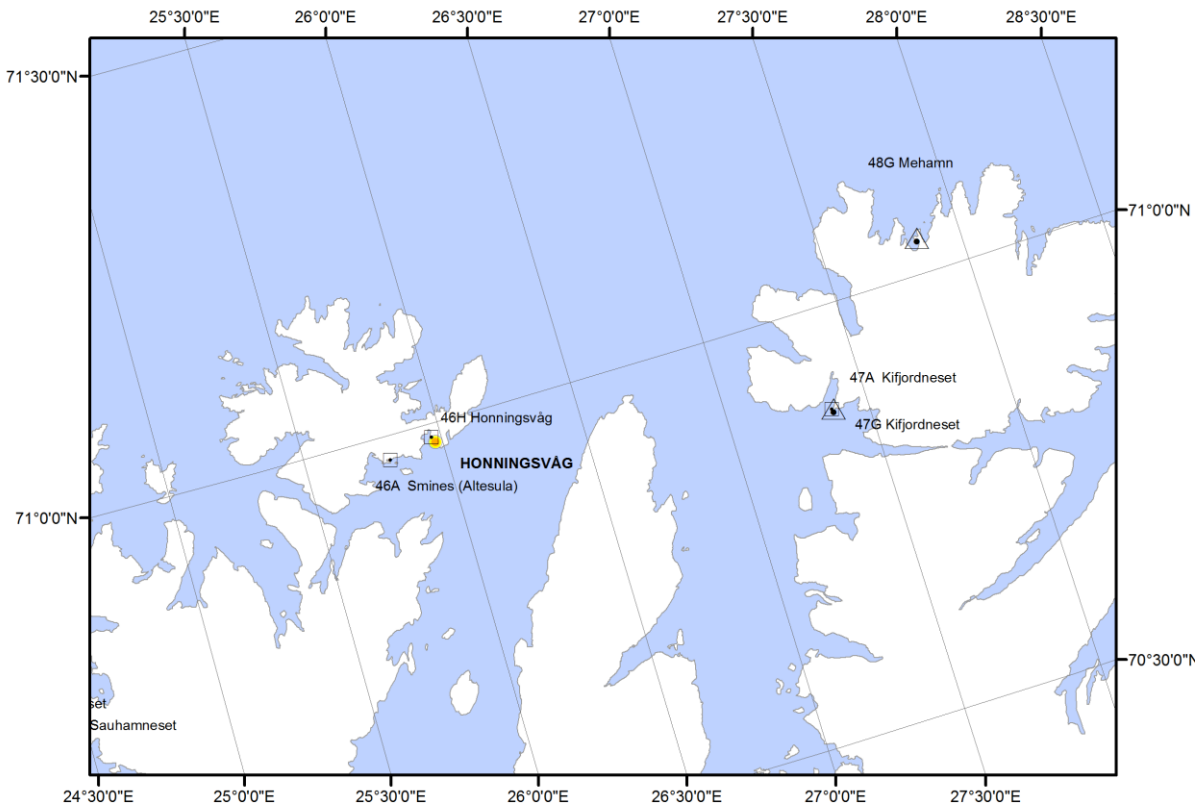
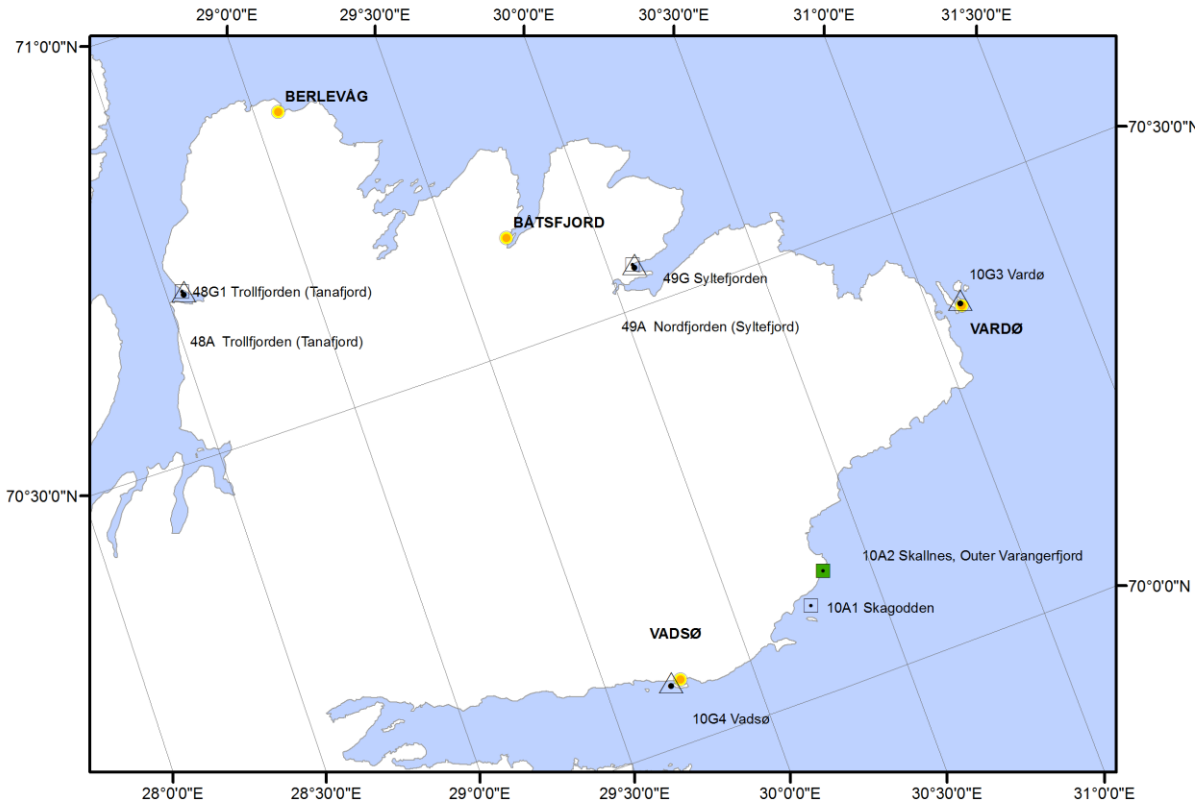
23°30'0"E
24°0'0"E
24°30'0"E
25°0'0"E
25°30'0"E
71°0'0"N
70°30'0"N
22°0'0"E
45G Sauhamneset
45A Sauhamneset
45B Hammerfest area
45B1 Revsbotn
45F Hammerfest area
HAMMERFEST
45B2 Hammerfest harbour area
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet

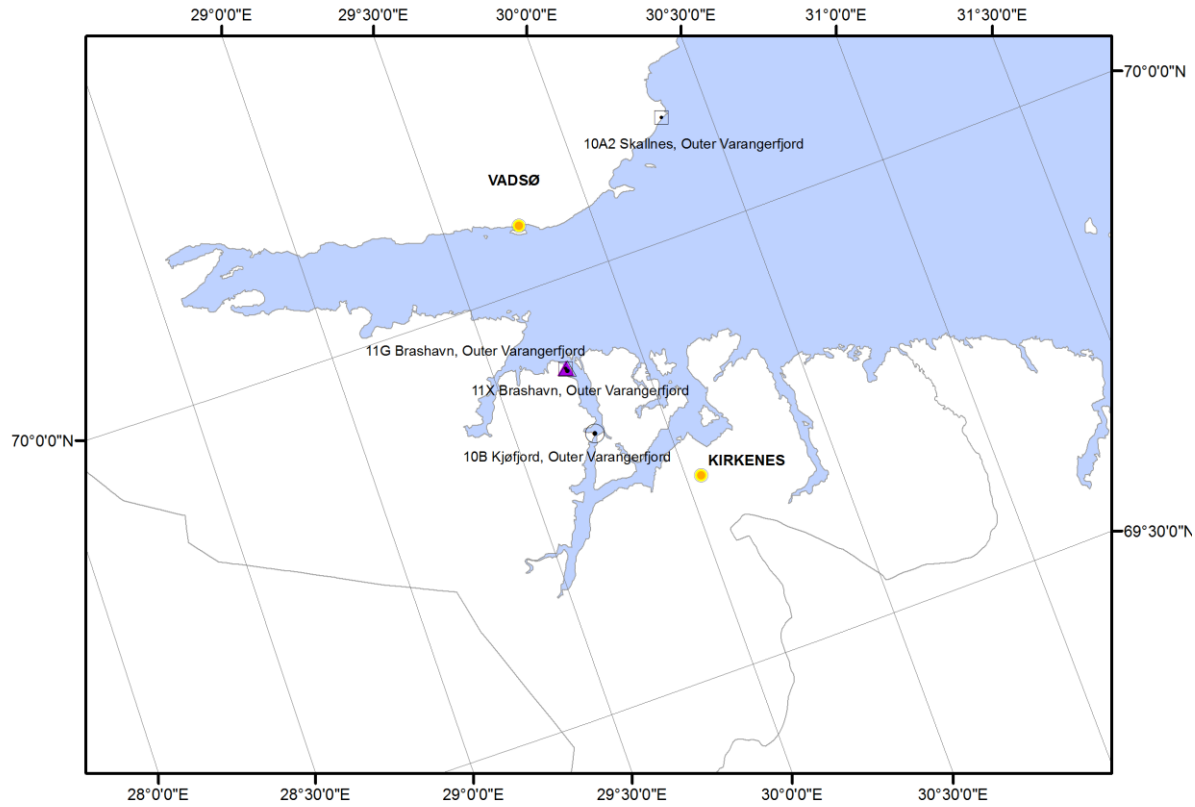
MAP 20


25°30'0"E
26°0'0"E
26°30'0"E
27°0'0"E
27°30'0"E
28°0'0"E
28°30'0"E
71°30'0"N
71°0'0"N
70°30'0"N
48G Mehamn
47A Kifjordneset
47G Kifjordneset
46H Honningsvåg
HONNINGSVÅG
46A Smines (Altesula)
Sauhamneset
24°30'0"E
25°0'0"E
25°30'0"E
26°0'0"E
26°30'0"E
27°0'0"E
27°30'0"E

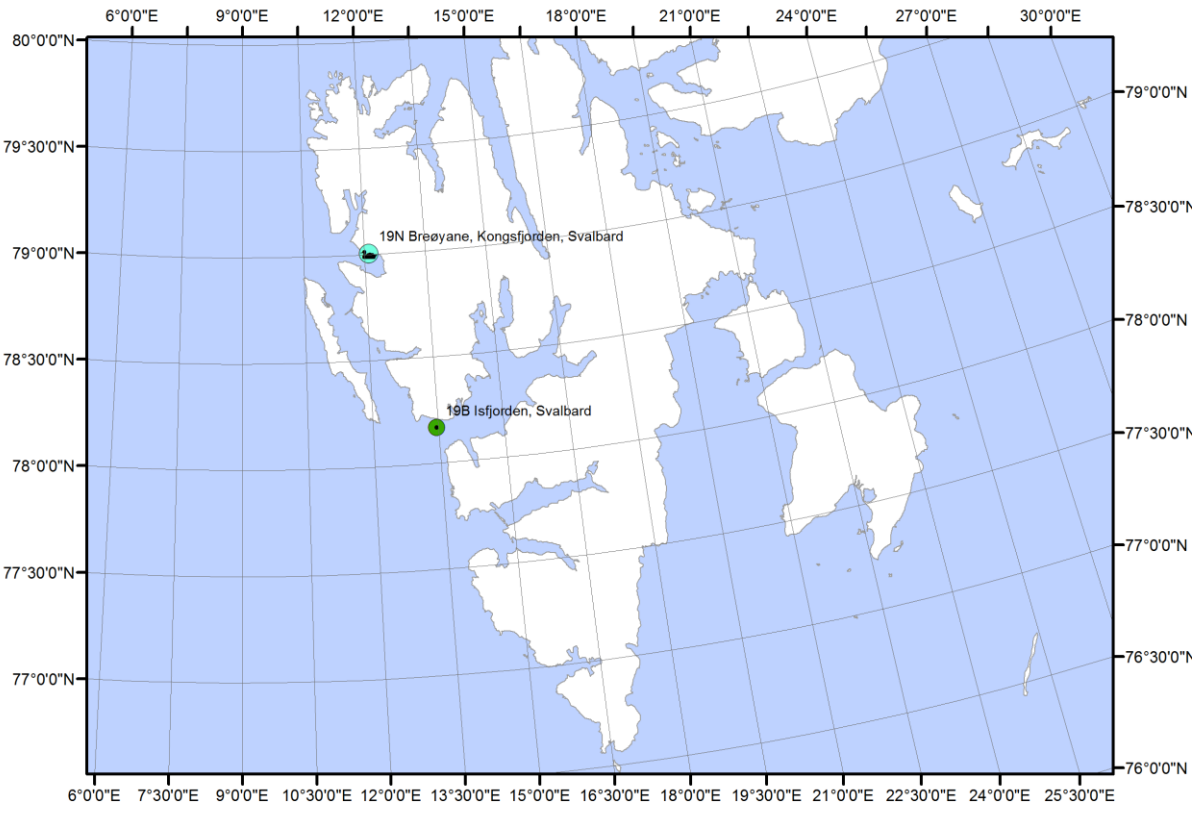
MAP 21


29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
71°0'0"N
70°30'0"N
70°0'0"N
BERLEVÅG
BÅTSFJORD
48G1 Trollfjorden (Tanafjord)
48A Trollfjorden (Tanafjord)
49G Syltefjorden
49A Nordfjorden (Syltefjord)
10G3 Vardø
VARDØ
10A2 Skallnes, Outer Varangerfjord
10A1 Skagodden
VADSØ
10G4 Vadsø
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E

MAP 22


29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
70°0'0"N
69°30'0"N
10A2 Skallnes, Outer Varangerfjord
VADSØ
11G Brashavn, Outer Varangerfjord
11X Brashavn, Outer Varangerfjord
10B Kjøfjord, Outer Varangerfjord
KIRKENES
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E

MAP 23


6°0'0"E
9°0'0"E
12°0'0"E
15°0'0"E
18°0'0"E
21°0'0"E
24°0'0"E
27°0'0"E
30°0'0"E
80°0'0"N
79°30'0"N
79°0'0"N
78°30'0"N
78°0'0"N
77°30'0"N
77°0'0"N
76°30'0"N
76°0'0"N
19N Breøyane, Kongsfjorden, Svalbard
19B Isfjorden, Svalbard
6°0'0"E
7°30'0"E
9°0'0"E
10°30'0"E
12°0'0"E
13°30'0"E
15°0'0"E
16°30'0"E
18°0'0"E
19°30'0"E
21°0'0"E
22°30'0"E
24°0'0"E
25°30'0"E

MAP 24

Appendix E
Overview of materials and analyses 2018-2019

Nominal station positions are shown on maps in Appendix D

Year:
2018t - samples taken in 2018
2019p – samples planned in 2019
2019t – samples taken in 2019

Species:
Blue Mussel (*Mytilus edulis***)**
Dogwhelk (*Nucella lapillus***)**
Common periwinkle (*Littorina littorea)*
Atlantic cod (*Gadus morhua***)**
European flounder (*Platichthus flesus***)**
Common eider duck (*Somateria mollissima*)

Tissue:
SB-Soft body tissue
LI-Liver tissue, in fish
MU-Muscle tissue, in fish
BL-Blood, in fish or eider
BI-Bile, in fish
EG-Eggs (homogenate of yolk and albumin), in eider

Overview follows on next page

Parameter-group codes (see **Appendix B** for descriptions of codes) 2018-2019:

code	Description	Me-SB	Nl/Ll-SB	Gm-Bl	Gm-BL	Gm/Pf-Ll	Gm/Pf-MU	Sm-BL	Sm-EG
I-MET	metals [1)]	X				X			
I-MET	Hg	X					X	X	X
ISOTO	$\delta^{15}N$ and $\delta^{13}C$	X					X	X	X
O-BR	PBDEs [2)]	X				X		X	X
OC-CB	PCBs [3)]	X				X			
OC-CL	HCB	X				X		X	X
OC-CP	SCCP, MCCP	X				X		X	X
OC-DD	DDT, DDE, DDD	X				X			
OC-HC	α-, γ-HCH	X				X			
OC-DC	Dechlorane plus [4)]					X			
O-FL	PFAS [5)]					X		X	X
O-PAH	PAHs [6)]	X				X			
O-MET	TBT [7)]	X	X						
O-FTA	Phthalates [8)]								
O-PHE	Phenols [9)]	X				X		X	X
PHC	PHCs [10)]	X	X			X		X	X
SLX	Siloxanes[11)]					X			
BEM	Biological effects met.[12)]		Imposex	OH-pyrene	ALA-D	EROD-activity, CYP1A [13)]			

[1)] Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn).

[2)] Polybrominated diphenyl ethers (PBDEs), including brominated flame retardants and includes a selection of: BDE28, BDE47, BDE49, BDE66, BDE71, BDE77, BDE85, BDE99, BDE100, BDE119, BDE138, BDE153, BDE154, BDE183, BDE205, HBCD.

[3)] Includes a selection of the congeners: PCB-28, -52,-101,-105,-118,-138,-153,-156,-180, 209, 5-CB, OCS and, when dioxins are analysed, the non-orto-PCBs, i.e. PCB-77, -81, -126, -169.

[4)] Includes: DBALD, DDC_ANT, DDC_BBF, DDC_CO, DDC_DBF, DDC_PA, DDC_PS, HCTBPH.

[5)] Includes: PFNA, PFOA, PFHpA, PFHxA, PFOS, PFBS, PFOSA.

[6)] Includes (with NPDs): ACNE, ACNLE, ANT, BAP, BBJF, BEP, BGHIP, BKF. BAA. CHR, DBA3A, DBT, DBTC1, DBTC2, DBTC3, FLE, FLU, ICDP, NAP, NAPC1, NAPC2, NAPC3, PA, PAC1, PAC2, PAC3, PER, PYR.

[7)] Includes: DBTIN, DPTIN, MBTIN, MPTIN, TBTIN, TPTIN.

[8)] O-FTA Phthalates, includes: BBP, DBPA, DEHA, DEHP, DEP, DEPA, DIBP, DIDP, DIHP, DINCH, DIPA, DMP, DNOP, DPF.

[9)] O-PHE phenols (octa non), includes: 4-n-NP, 4-n-OP, 4-t-NP, 4-t-OP.

[10)] PHC – phenols including BPA, TBBPA.

[11)] SLX – Siloxanes includes: D4, D5, D6.

[12)] Biological effects methods.

[13)] Cod only, CYP1A was not measured after 2016.

***Appendix E**. Sampling and analyses for 2018-2019 – biota.*

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2018t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3			3						
2019p	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3			3						
2019t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3			3						
2018t	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3		3	3	3		3	3		
2019p	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3		3	3				3		
2019t	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3		3	3				3		
2018t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	2	2		2	2		2	2			2				2		
2019p	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3			3				3		
2019t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	2	2		2	2		2	2			2				2		
2018t	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	0			0											0		
2019p	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	0			0											0		
2019t	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	0			0											0		
2018t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3									
2019p	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3									
2019t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3									
2018t	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	0			0											0		
2019p	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	0			0											0		
2019t	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	0			0											0		
2018t	**Mytilus edulis**	Whole soft body	**Tjøme, Outer Oslofjord (st. 36A1)**	59.07357	10.42522	3	3	3	3	3	3	3	3		3		3		3	3		
2019p	**Mytilus edulis**	Whole soft body	**Tjøme, Outer Oslofjord (st. 36A1)**	59.07357	10.42522	3	3	3	3	3	3	3	3		3					3		
2019t	**Mytilus edulis**	Whole soft body	**Tjøme, Outer Oslofjord (st. 36A1)**	59.07357	10.42522	3	3	3	3	3	3	3	3		3					3		
2018t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3					3	3		3	3		
2019p	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3					3				3		
2019t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3					3				3		
2018t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	3			3											3		
2019p	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	3			3											3		
2019t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	2			2											2		
2018t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	0		0		0	0	0	0			0	0		0	0		
2019p	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	3		3		3	3	3	3			3				3		
2019t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	0		0		0	0	0	0			0				0		
2018t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3			3	3		3	3		
2019p	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3			3				3		
2019t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	0		0		0	0	0	0			0				0		
2018t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3									
2019p	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3									
2019t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3									
2018t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3										3						
2019p	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3										3						
2019t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3										3						

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2018t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3							3		
2019t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3							3		
2018t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3											3		
2019p	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3											3		
2019t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3											3		
2018t	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	3			3	3		3	3		3					3		
2019p	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	0			0	0		0	0		0					0		
2019t	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	0			0	0		0	0		0					0		
2018t	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	0			0	0		0	0							0		
2019t	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	0			0	0		0	0							0		
2018t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3							3		
2019t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3							3		
2018t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3							3		
2019t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3							3		
2018t	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	0			3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	0			0	0		0	0							0		
2019t	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	0			0	0		0	0							0		
2018t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3										
2019p	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3										
2019t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3										
2018t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3									
2019p	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3									
2019t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3									
2018t	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	0			0											0		
2019p	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	0			0											0		
2019t	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	0			0											0		
2018t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3		3					3		
2019p	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3		3					3		
2019t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3		3					3		
2018t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3				3		3			3		
2019p	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3				3		3			3		
2019t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3				3		3			3		
2018t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3						3			3		
2019p	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3						3			3		
2019t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3						3			3		
2018t	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3				3		3			3		
2019p	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3				3		3			3		
2019t	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3				3		3			3		

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2018t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3						3			3		
2019p	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3						3			3		
2019t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3						3			3		
2018t	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3						3			3		
2019p	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3						3			3		
2019t	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3						3			3		
2018t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3						3			3		
2019p	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3						3			3		
2019t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3						3			3		
2018t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3				3	3	3			3		
2019p	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3				3	3	3			3		
2019t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3				3	3	3			3		
2018t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	3		3	3							3		
2019t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	0			0	0		0	0							0		
2018t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3							3		
2019p	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3							3		
2019t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	0			0	0		0	0							0		
2018t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1															1
2019p	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1															1
2019t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1															1
2018t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1															1
2019p	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1															1
2019t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1															1
2018t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1															1
2019p	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1															1
2019t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1															1
2018t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1															1
2019p	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1															1
2019t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1															1
2018t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1															1
2019p	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1															1
2019t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1															1
2018t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1															1

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2019p	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1															1
2019t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1															1
2018t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1															1
2019p	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1															1
2019t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1															1
2018t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1															1
2019p	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1															1
2019t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1															1
2018t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1															1
2019p	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1															1
2019t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1															1
2018t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	10		10	10	10	10	10	10	7	10		10		10		10	10
2019p	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15		15	15	15	15	15	15		15						15	15
2019t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	13		14	14	13	12	13	13		5						15	15
2018t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	10		15	15	15	15	15	15		15		15		15			
2019p	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15		15	15	15	15	15	15		15							
2019t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	5		5	6	5	5	5	5		6							
2018t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	4		4	4		4						4		4			
2019p	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15		15	15		15											
2019t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	11		11	11		11											
2018t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15		15			15						15		15			
2019p	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15		15			15											
2019t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	13		13			13											
2018t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15		9	9		9				9		9		5			
2019p	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15		15	15		15				15							
2019t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	9		9	10		10				10							
2018t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15									
2019p	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15									
2019t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15									
2018t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15		15		15		15			15
2019p	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15		15							15
2019t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15		15							15
2018t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		14	13	14	14	14	14		14		14		14			13
2019p	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		15	15	15	15	15	15		15							15
2019t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		15	15	15	15	15	15		15							15
2018t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		12	12		12			11	12		12		12		12	
2019p	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15				15						15	
2019t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	14		14	14		14				14						15	
2018t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15						15		15			
2019p	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15											

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2019t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	14		15	15		15											
2018t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15				14		15		15			
2019p	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15				15							
2019t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	11		11	11		11				11							
2018t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15													
2019p	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15													
2019t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15													
2018t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	11		12	12	12	12	12	12		12							
2019p	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	15	15	15	15		15							
2019t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	15	15	15	15		15							
2018t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			5	15		15		15		15	
2019p	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15				15						15	
2019t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15				15						15	
2018t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15			15													
2019p	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15			15													
2019t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15			15													
2018t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	8		8	8	8		8	15	2							8	
2019p	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15		15	15	15		15	15								15	
2019t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	0		0	0	0		0	0								0	
2018t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15			9	15		15		15		15	
2019p	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15				15						15	
2019t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15				15						15	
2018t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15														15		
2019p	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15														15		
2019t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15														15		
2018t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15														15		
2019p	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15														15		
2019t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	9														9		
2018t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	8														8		
2019p	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15														15		
2019t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15														15		
2018t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15														15		
2019p	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15														15		
2019t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15														15		
2018t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15														15		
2019p	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15														15		
2019t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	13														13		
2018t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15														15		
2019p	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15														15		
2019t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15														15		
2018t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15														15		
2019p	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15														15		

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2019t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15														15		
2018t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15														15		
2019p	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15														15		
2019t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15														15		
2018t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15														15		
2019p	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15														15		
2019t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15														14		
2018t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15														15		
2019p	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15														15		
2019t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15														15		
2018t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15														15		
2019p	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15														15		
2019t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	11														11		
2018t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15														15		
2019p	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15														15		
2019t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15														15		
2018t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15														15		
2019p	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15														15		
2019t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15														15		
2018t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15														15		
2019p	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15														15		
2019t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15														15		
2018t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15														15		
2019p	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15														15		
2019t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15														15		
2018t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15														15		
2019p	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15														15		
2019t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15														15		
2018t	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15														15		
2019p	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15														15		
2019t	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15														15		
2018t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2019p	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2019t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	13
2018t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690																	15
2019p	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690																	15
2019t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690																	15
2018t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2019p	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2019t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2018t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2019p	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	OC-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2019t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2018t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2019p	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2019t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2018t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2019p	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2019t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2018t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2019p	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2019t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2018t	**Platichthys flesus**	Liver	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3			3	3		3	3									
2019p	**Platichthys flesus**	Liver	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3			3	3		3	3									
2019t	**Platichthys flesus**	Liver	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3			3	3		3	3									
2018t	**Platichthys flesus**	Muscle	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3																
2019p	**Platichthys flesus**	Muscle	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3																
2019t	**Platichthys flesus**	Muscle	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3																
2018t	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15		15		15	15		
2019p	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15					15		
2019t	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15					15		
2018t	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15		15		15	15		
2019p	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15					15		
2019t	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15					15		

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2019

This Appendix is provided as an EXCEL file separate from this report but described below.

Only information for those time series that include data for either 2018 or 2019 is shown. The column headings are as follows:

Parameter Code: are described in **Appendix B**
IUPAC: International Union of Pure and Applied Chemistry (IUPAC) parameter name (if any).
CAS: Chemical Abstracts Services (CAS) parameter number (if any).
Parameter Name: Common name
Parameter Group: Parameters belong to one of 14 groups
Unit: µg/kg, mg/kg, ng/kg, etc.
Station Code
Station Name
Area: general area (if defined).
County
Water region: Water framework directive (WFD) water region
Water body ID: WFD water body identification
Water body name: WFD water body name

Species:

- **MYTI EDU**-Blue Mussel (*Mytilus edulis*)
- **LITT LIT**-Common periwinkle (*Littorina littorea*)
- **NUCE LAP**-Dogwhelk (*Nucella lapillus*)
- **GADU MOR**-Atlantic cod (*Gadus morhua*)
- **PLAT FLE** European flounder (*Platichthys flesus*)
- **SOMA MOL**-Common eider (*Somateria mollissima*)

Tissue:

- **SB**-Soft body tissue
- **LI**-Liver tissue
- **MU**-Muscle tissue
- **BL**-Blood
- **BI**-Bile
- **EG**-Eggs-homogenate of yolk and albumin

Basis: wet weight (**WW, WWa**), dry weight (**DW, DWa**) or lipid weight (**FB, FBa**), the "a" indicates concentration adjusted to length (concerns only cod).
PROREF: Norwegian provisional high reference contaminant concentration
V[Year columns]: median value for years 1981-2019. The gray-shade coding refers to relation to exceedances to Norwegian provisional high reference contaminant concentration (PROREF): below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 20
Q[Year columns]: symbol for years 1981-2019 that indicates the relation of the median to Environmental Quality Standards (2013/39/EU 2013) and other risk-based standards developed nationally (Norwegian_Environment_Agency 2016a), and these are referred to collectively in this report as Environmental Quality Standards (EQS). Green-filled circle indicates no exceedances and red-filled circle indicates exceedances of the quality standard.

N_string_[last/this] year: where "last year" is 2018 and "this year" is 2019. Number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample.
SD [last/this] year: standard deviation.
PROREF-class [last/this] year: exceedances to Norwegian provisional high reference contaminant concentration (PROREF): below PROREF (1) or exceeding PROREF by a factor of: 1-2 (2), 2-5 (3), 5-10 (4), 10-20 (5) or greater than 20 (6) (see ***Appendix C***).
EQS-class [last/this] year: below (1) or above (2) EU Environmental Quality Standard (EQS). Note: the EU EQRs are based on the whole organism whereas monitoring of fish in MILKYS is on a particular tissue. Hence, comparison is only relevant if it is assumed that the concentration found is the same for all tissues in the fish.
EQS threshold this year
Trend p(long) [last/this] year: The statistical significance (p)[year] of the trend for the entire time series.
Detectable % change(long) [last/this] year: the percent change that can be detected with 90 % confidence.
First Year(long) [last/this] year: first year in time series.
Last Year(long) [last/this] year: last year in time series.
No. of Years(long) [last/this] year: number of years with data.

Trend p(short) [last/this] year: The statistical significance (p)[year] of the trend for the last 10-year sampling period.
Detectable % change(short) [last/this] year: the percent change that can be detected with 90 % confidence.
First Year(short) [last/this] year: first year in time series for the last 10-year sampling period.
Last Year(short) [last/this] year: last year in time series for the last 10-year sampling period.
No. of Years(short) [last/this] year: number of years with data in time series for the last 10-year sampling period.

Trends [last/this] year: trends in concentrations of contaminants monitored. The analyses were done on time series with five or more years. An upward (🡅) or downward (🡇) arrow indicates statistically significant trends, whereas a zero (**O**) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed, but the results were insufficient to do a trend analysis. Results marked with a star (★) indicates that there is insufficient data above the quantification limit to perform a trend analysis. The result from the trend analysis for the entire time series (long-term) is shown before the slash "/", and the result for the last 10 years (short-term) is shown after the slash.

TREND_CHANGE last year-this year: indicates the difference (if any) between the year-before-last results and the last year's results.
PROREF_CHANGE last year-this year: indicates the difference (if any) between the year-before-last results and the last year's results.
EQS_CHANGE last year-this year: indicates the difference (if any) between the year-before-last results and the last year's results.

Note on quantification limit in trend analyses: half of the limit is used, however if a substance is included as part of a sum (e.g. PCB-7) then null is used. Note, that the number of such cases and position in a times series may affect whether or not a trend analyses can be applied (see **Chapter 2.8**).

Appendix G
Supplementary analyses of geographical coastal gradients for contaminants, trophic levels and PFAS

***Table 28**. Number of years of data (maximum) for MILKYS stations per station type (as defined by ICES), where IH = indicates stations impacted directly by discharges containing hazardous substances analysed for PFAS yearly, RH = representative of general conditions in terms of hazardous substances and B = baseline/reference station. The stations are designated one of these three types by expert judgment.*

Blue mussel	IH	RH	B	Cod	IH	RH	B
10A2	0	0	23	**02B**	0	8	0
15A	0	26	0	**10B**	0	0	25
22A	0	26	0	**13B**	11	0	0
26A2	0	8	0	**15B**	0	26	0
30A	26	0	0	**23B**	0	26	0
31A	0	26	0	**24B**	5	0	0
35A	0	24	0	**28B**	0	7	0
36A	0	19	0	**30B**	26	0	0
36A1	0	5	0	**36B**	0	26	0
51A	24	0	0	**43B2**	11	0	0
52A	24	0	0	**45B2**	7	0	0
56A	26	0	0	**53B**	26	0	0
57A	0	25	0	**71B**	8	0	0
63A	0	23	0	**80B**	0	11	0
64A	0	8	0	**96B**	0	7	0
65A	0	26	0	**98B1**	0	0	24
69A	0	23	0				
71A	0	24	0				
76A	0	17	0				
76A2	0	7	0				
91A2	0	8	0				
97A2	0	8	0				
98A2	0	0	22				
I023	0	25	0				
I024	0	23	0				
I131A	25	0	0				
I133	25	0	0				
I241	24	0	0				
I301	25	0	0				
I304	25	0	0				
I306	22	0	0				
I307	21	0	0				
I712	21	0	0				
I714	0	4	0				
I964	14	0	0				
I965	19	0	0				
I969	0	25	0				

***Table 29**. Coastal distance effect adjusted for years and year-effect adjusted for coast distance for blue mussel (whole soft body) and cod (fillet and liver) from non-impacted stations. The significance of the linear or non-linear trend (p) is estimated where a value less than 0.05 is considered statistically significant and is shown in red type. The variability of the non-linear component varies between one (a straight line) and seven (for these cases) indicating considerable variability. The estimated percent change in log10-transformed concentrations per 1000 km and the percent change in log10-transformed concentrations per 10 years is shown.*

			Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
Substance.Group	Parameter	Tissue	Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Percent per 10 years	Year Linear_p	Year Non_linear_df	Year Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
Metals and metalloids	AG	Liver	-30	< 0.001	5.51	< 0.001	41	0.06	2.14	< 0.001	1278	78	92
Metals and metalloids	AG	Whole soft body	23	0.04	2.22	< 0.001	53	0.02	2.94	< 0.001	607	65	86
Metals and metalloids	AS	Liver	-9	0.02	4.94	< 0.001	5	0.63	2.71	< 0.001	1270	90	97
Metals and metalloids	AS	Whole soft body	0	0.99	3.37	< 0.001	-15	0.1	1	0.003	660	66	95
Metals and metalloids	CD	Liver	101	< 0.001	4	< 0.001	-11	< 0.001	2.83	< 0.001	3148	88	97
Metals and metalloids	CD	Whole soft body	10	0.06	5.04	< 0.001	-33	< 0.001	2.79	< 0.001	1330	41	85
Metals and metalloids	CO	Liver	-22	< 0.001	6.51	< 0.001	-8	0.49	2.84	0.001	1270	77	93
Metals and metalloids	CO	Whole soft body	-12	< 0.001	1	< 0.001	4	0.43	1	0.45	639	71	99
Metals and metalloids	CR	Liver	-10	0.24	1.36	0.29	-51	< 0.001	2.53	< 0.001	1298	93	97
Metals and metalloids	CR	Whole soft body	-10	0.23	5.94	< 0.001	69	< 0.001	2.42	< 0.001	647	74	90
Metals and metalloids	CU	Liver	-14	< 0.001	6.53	< 0.001	-18	< 0.001	2.9	< 0.001	3148	88	99
Metals and metalloids	CU	Whole soft body	0	0.83	5.45	0.001	-7	< 0.001	1.8	< 0.001	1229	85	99
Metals and metalloids	HG	Muskel	67	0.05	6.817056	< 0.001	171	0.03	2.842037	< 0.001	3367	41	77
Metals and metalloids	HG	Whole soft body	-17	0.001	2.57	< 0.001	-8	0.13	1	0.07	1299	36	79
Metals and metalloids	NI	Liver	1	0.93	3.19	< 0.001	34	0.17	1	0.28	1278	96	97
Metals and metalloids	NI	Whole soft body	-3	0.67	2.75	0.003	57	< 0.001	2.57	< 0.001	647	66	91
Metals and metalloids	PB	Liver	4	0.05	1	0.11	-8	< 0.001	2.93	< 0.001	3148	97	99
Metals and metalloids	PB	Whole soft body	-8	0.25	6.38	< 0.001	-22	< 0.001	1	< 0.001	1330	49	80
Metals and metalloids	SN	Liver	3	0.68	1	0.4	-71	< 0.001	2.87	< 0.001	1270	96	97
Metals and metalloids	SN	Whole soft body	-11	0.07	1	0.06	-74	< 0.001	2.86	< 0.001	596	97	99
Metals and metalloids	ZN	Liver	-9	< 0.001	6.1	< 0.001	-4	0.001	2.97	< 0.001	3150	83	100
Metals and metalloids	ZN	Whole soft body	-3	0.05	2.42	0.04	-14	< 0.001	2.56	< 0.001	1244	50	99
Chlorobiphenyls	CB_S7	Liver	-27	< 0.001	6.83	< 0.001	-30	< 0.001	2.82	< 0.001	3232	90	97
Chlorobiphenyls	CB_S7	Muskel	-24	0.01	3.91	< 0.001	-4	0.78	1	0.14	617	NA	NA
Chlorobiphenyls	CB_S7	Whole soft body	-27	< 0.001	5.63	< 0.001	-7	0.18	2.87	< 0.001	1242	54	89
Chlorobiphenyls	CB101	Liver	-6	0.12	6.79	< 0.001	-42	< 0.001	1	< 0.001	3146	80	93
Chlorobiphenyls	CB101	Muskel	-1	0.96	3.74	< 0.001	-2	0.91	2.79	0.02	605	NA	NA

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
			Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Percent per 10 years	Year Linear_p	Year Non_linear_df	Year Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
Chlorobiphenyls	CB101	Whole soft body	-30	< 0.001	5.9	< 0.001	-18	0.001	2.8	< 0.001	1166	60	92
Chlorobiphenyls	CB105	Liver	-25	< 0.001	6.49	< 0.001	-41	< 0.001	2.77	< 0.001	2581	NA	NA
Chlorobiphenyls	CB105	Muskel	-24	0.02	3.91	< 0.001	-21	0.22	1.82	0.005	611	NA	NA
Chlorobiphenyls	CB105	Whole soft body	-21	< 0.001	5.72	< 0.001	-37	< 0.001	1	< 0.001	923	89	97
Chlorobiphenyls	CB114	Liver	-38	0.001	NA	NA	359	0.45	NA	NA	237	NA	NA
Chlorobiphenyls	CB114	Whole soft body	-17	0.3	NA	NA	10418	0.006	NA	NA	110	NA	NA
Chlorobiphenyls	CB118	Liver	-22	< 0.001	6.79	< 0.001	-40	< 0.001	2.82	< 0.001	3232	89	96
Chlorobiphenyls	CB118	Muskel	-24	0.05	3.93	< 0.001	-18	0.36	1	< 0.001	617	NA	NA
Chlorobiphenyls	CB118	Whole soft body	-30	< 0.001	6.32	< 0.001	-33	< 0.001	1.61	< 0.001	1240	23	56
Chlorobiphenyls	CB123	Liver	-32	0.02	NA	NA	554	0.42	NA	NA	237	NA	NA
Chlorobiphenyls	CB123	Whole soft body	-25	0.09	NA	NA	125930	< 0.001	NA	NA	110	NA	NA
Chlorobiphenyls	CB126	Liver	-27	0.005	NA	NA	49	0.12	NA	NA	259	NA	NA
Chlorobiphenyls	CB126	Whole soft body	-5	0.51	NA	NA	-38	< 0.001	NA	NA	159	0	0
Chlorobiphenyls	CB138	Liver	-26	< 0.001	6.82	< 0.001	-30	< 0.001	2.8	< 0.001	3232	91	97
Chlorobiphenyls	CB138	Muskel	-28	0.007	3.91	< 0.001	-13	0.5	1	0.01	617	NA	NA
Chlorobiphenyls	CB138	Whole soft body	-34	< 0.001	6.09	< 0.001	-20	< 0.001	2.69	< 0.001	1236	41	82
Chlorobiphenyls	CB153	Liver	-33	< 0.001	6.78	< 0.001	-24	< 0.001	2.82	< 0.001	3230	87	96
Chlorobiphenyls	CB153	Muskel	-35	< 0.001	3.91	< 0.001	0	0.97	1	0.23	617	NA	NA
Chlorobiphenyls	CB153	Whole soft body	-34	< 0.001	5.86	< 0.001	-21	< 0.001	2.77	< 0.001	1242	50	84
Chlorobiphenyls	CB156	Liver	-29	< 0.001	6.56	< 0.001	-42	< 0.001	2.62	< 0.001	2578	NA	NA
Chlorobiphenyls	CB156	Muskel	-8	0.12	3.82	< 0.001	2	0.85	1	0.39	613	NA	NA
Chlorobiphenyls	CB156	Whole soft body	-5	0.37	1	0.08	-50	< 0.001	2.84	< 0.001	925	98	100
Chlorobiphenyls	CB157	Liver	-38	< 0.001	NA	NA	-15	0.93	NA	NA	237	NA	NA
Chlorobiphenyls	CB157	Whole soft body	-27	0.03	NA	NA	68721	< 0.001	NA	NA	110	NA	NA
Chlorobiphenyls	CB167	Liver	-38	< 0.001	NA	NA	216	0.58	NA	NA	237	NA	NA
Chlorobiphenyls	CB167	Whole soft body	-20	0.06	NA	NA	30904	< 0.001	NA	NA	107	NA	NA
Chlorobiphenyls	CB169	Liver	-25	0.005	NA	NA	92	0.01	NA	NA	259	NA	NA
Chlorobiphenyls	CB169	Whole soft body	13	0.44	NA	NA	207	< 0.001	NA	NA	159	0	0
Chlorobiphenyls	CB180	Liver	-34	< 0.001	6.86	< 0.001	-24	< 0.001	2.85	< 0.001	3231	87	95
Chlorobiphenyls	CB180	Muskel	-28	< 0.001	3.93	< 0.001	-1	0.94	1	0.18	617	NA	NA
Chlorobiphenyls	CB180	Whole soft body	-8	0.14	1	0.05	22	< 0.001	2.99	< 0.001	1242	80	87
Chlorobiphenyls	CB189	Liver	-49	< 0.001	NA	NA	1071	0.3	NA	NA	237	NA	NA
Chlorobiphenyls	CB189	Whole soft body	-8	0.29	NA	NA	36771	< 0.001	NA	NA	110	NA	NA
Chlorobiphenyls	CB209	Liver	-11	< 0.001	1	< 0.001	-53	< 0.001	1.96	< 0.001	2337	NA	NA

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
			Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Percent per 10 years	Year Linear_p	Year Non_linear_df	Year Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
Chlorobiphenyls	CB209	Muskel	-2	0.38	1	0.53	17	0.005	2.56	< 0.001	606	NA	NA
Chlorobiphenyls	CB209	Whole soft body	-3	0.42	1	0.41	-12	0.03	2.95	< 0.001	812	NA	NA
Chlorobiphenyls	CB28	Liver	-17	< 0.001	6.78	< 0.001	-39	< 0.001	2.85	< 0.001	3222	92	96
Chlorobiphenyls	CB28	Muskel	-8	0.009	3.63	< 0.001	16	0.005	2.67	< 0.001	611	NA	NA
Chlorobiphenyls	CB28	Whole soft body	-15	0.01	2.7	0.001	25	< 0.001	2.95	< 0.001	1241	76	90
Chlorobiphenyls	CB52	Liver	-8	0.02	6.84	< 0.001	-41	< 0.001	1	< 0.001	3210	89	97
Chlorobiphenyls	CB52	Muskel	-5	0.37	3.85	< 0.001	-5	0.62	2.04	0.01	574	NA	NA
Chlorobiphenyls	CB52	Whole soft body	-25	< 0.001	3.96	< 0.001	9	0.21	2.82	< 0.001	1200	77	96
Chlorobiphenyls	CB77	Liver	-33	< 0.001	NA	NA	-36	0.12	NA	NA	259	NA	NA
Chlorobiphenyls	CB77	Whole soft body	-14	0.22	NA	NA	-28	< 0.001	NA	NA	156	51	95
Chlorobiphenyls	CB81	Liver	-38	0.003	NA	NA	-34	0.24	NA	NA	259	NA	NA
Chlorobiphenyls	CB81	Whole soft body	-5	0.63	NA	NA	0	0.8	NA	NA	159	0	0
Polycyclic aromatic hydrocarbons (PAHs)	ACNE	Whole soft body	24	0.11	1	0.34	44	0.12	2.02	0.005	160	79	90
Polycyclic aromatic hydrocarbons (PAHs)	ACNLE	Whole soft body	6	0.7	1	0.23	-17	0.26	2.01	0.003	160	91	98
Polycyclic aromatic hydrocarbons (PAHs)	ANT	Whole soft body	15	0.67	1	0.06	-41	0.2	2.26	0.006	160	61	70
Polycyclic aromatic hydrocarbons (PAHs)	BAP	Whole soft body	13	0.65	1	0.35	-18	0.61	1.71	0.27	160	65	78
Polycyclic aromatic hydrocarbons (PAHs)	BBJF	Whole soft body	-5	0.9	2.76	< 0.001	-13	0.92	1	0.83	128	79	91
Polycyclic aromatic hydrocarbons (PAHs)	BEP	Whole soft body	0	< 0.001	NA	NA	-9	< 0.001	NA	NA	61	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	BGHIP	Whole soft body	23	0.45	1	0.17	8	0.84	1.75	0.16	160	63	88
Polycyclic aromatic hydrocarbons (PAHs)	BKF	Whole soft body	-1	0.98	1	0.93	-40	0.56	1	0.16	128	77	84
Polycyclic aromatic hydrocarbons (PAHs)	BAA	Whole soft body	-15	0.68	3.79	< 0.001	-24	0.7	1	0.006	160	46	61
Polycyclic aromatic hydrocarbons (PAHs)	CHR	Whole soft body	-16	0.68	1	0.64	-20	0.72	1	0.67	129	17	26
Polycyclic aromatic hydrocarbons (PAHs)	DBA3A	Whole soft body	-8	0.66	1	0.45	-39	0.09	2.43	0.003	148	84	94
Polycyclic aromatic hydrocarbons (PAHs)	DBTC1	Whole soft body	-2	< 0.001	NA	NA	99	< 0.001	NA	NA	37	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	DBTC2	Whole soft body	-3	0.001	NA	NA	181	< 0.001	NA	NA	37	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	DBTC3	Whole soft body	490	< 0.001	NA	NA	1716	< 0.001	NA	NA	37	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	FLE	Whole soft body	42	0.02	1	0.02	1	0.94	2.66	0.002	160	84	100
Polycyclic aromatic hydrocarbons (PAHs)	FLU	Whole soft body	-10	0.84	1	0.57	-53	0.21	1.89	0.08	160	57	64
Polycyclic aromatic hydrocarbons (PAHs)	ICDP	Whole soft body	2	0.95	1	0.68	-7	0.93	1	0.99	159	81	92
Polycyclic aromatic hydrocarbons (PAHs)	KPAH	Whole soft body	-18	0.55	1	0.93	-30	0.43	2.14	0.03	158	0	3
Polycyclic aromatic hydrocarbons (PAHs)	NAP	Whole soft body	127	0.26	1	0.67	170	0.37	2.92	< 0.001	158	87	94
Polycyclic aromatic hydrocarbons (PAHs)	NAPC1	Whole soft body	-29	< 0.001	NA	NA	-95	< 0.001	NA	NA	36	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	NAPC2	Whole soft body	-64	< 0.001	NA	NA	-95	< 0.001	NA	NA	37	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	NAPC3	Whole soft body	201	< 0.001	NA	NA	81	0.01	NA	NA	37	NA	NA

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
			Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Percent per 10 years	Year Linear_p	Year Non_linear_df	Year Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
Polycyclic aromatic hydrocarbons (PAHs)	P_S	Whole soft body	5	0.85	1	0.55	-29	0.43	1.57	0.33	159	60	67
Polycyclic aromatic hydrocarbons (PAHs)	PA	Whole soft body	55	0.18	1	0.15	-2	0.96	2.64	0.2	160	41	52
Polycyclic aromatic hydrocarbons (PAHs)	PAC2	Whole soft body	-32	< 0.001	NA	NA	-19	< 0.001	NA	NA	37	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	PAH16	Whole soft body	53	0.21	1	0.24	60	0.37	2.67	0.08	159	45	57
Polycyclic aromatic hydrocarbons (PAHs)	PER	Whole soft body	41	0.43	NA	NA	102	0.02	NA	NA	61	NA	NA
Polycyclic aromatic hydrocarbons (PAHs)	PYR	Whole soft body	-8	0.86	1	0.54	-57	0.23	1.85	0.1	160	27	33
Organobromines	BDE100	Liver	-21	0.01	3.9	< 0.001	-16	0.15	1	0.005	948	80	94
Organobromines	BDE100	Whole soft body	25	0.18	1	0.61	-62	< 0.001	2.85	< 0.001	190	95	99
Organobromines	BDE119	Liver	13	0.14	1	0.15	-26	< 0.001	1	< 0.001	388	NA	NA
Organobromines	BDE119	Whole soft body	-7	0.46	1	0.47	-93	< 0.001	1	< 0.001	68	NA	NA
Organobromines	BDE126	Liver	-4	0.6	NA	NA	-62	< 0.001	NA	NA	493	91	97
Organobromines	BDE126	Whole soft body	-14	0.53	1	0.52	-41	0.35	2.92	< 0.001	173	100	100
Organobromines	BDE138	Liver	-26	0.1	1	0.72	-59	< 0.001	2.96	< 0.001	649	99	99
Organobromines	BDE138	Whole soft body	9	0.45	1	0.58	-69	< 0.001	2.95	< 0.001	72	NA	NA
Organobromines	BDE153	Liver	-14	0.03	1	0.11	-28	< 0.001	2.99	< 0.001	952	92	98
Organobromines	BDE153	Whole soft body	9	0.69	1	0.86	-49	0.05	2.84	0.002	190	98	99
Organobromines	BDE154	Liver	-13	0.09	3.7	< 0.001	41	< 0.001	2.82	< 0.001	948	93	99
Organobromines	BDE154	Whole soft body	6	0.78	1	0.68	-39	0.13	1	0.17	190	100	100
Organobromines	BDE156	Liver	-5	0.25	NA	NA	-22	0.41	NA	NA	196	NA	NA
Organobromines	BDE156	Whole soft body	-14	0.39	1	0.39	-72	0.02	2.93	< 0.001	57	NA	NA
Organobromines	BDE17	Liver	44	0.003	NA	NA	1029	0.001	NA	NA	196	NA	NA
Organobromines	BDE17	Whole soft body	-32	0.05	1	0.83	-88	0.002	2.95	< 0.001	57	NA	NA
Organobromines	BDE183	Liver	-9	0.49	1	0.54	-29	0.02	2.99	< 0.001	945	97	99
Organobromines	BDE183	Whole soft body	8	0.77	1	0.92	-60	0.15	2.72	0.02	184	100	100
Organobromines	BDE184	Liver	7	0.01	NA	NA	-3	0.54	NA	NA	196	NA	NA
Organobromines	BDE184	Whole soft body	-6	0.51	1	0.41	-38	0.35	2.94	< 0.001	57	NA	NA
Organobromines	BDE191	Liver	0	0.56	NA	NA	-5	0.1	NA	NA	196	NA	NA
Organobromines	BDE191	Whole soft body	-14	0.36	1	0.73	-31	0.43	2.97	< 0.001	57	NA	NA
Organobromines	BDE196	Liver	1	0.94	NA	NA	-45	< 0.001	NA	NA	825	97	98
Organobromines	BDE196	Whole soft body	-4	0.85	1	0.96	7	0.9	2.92	< 0.001	173	100	100
Organobromines	BDE197	Liver	-1	0.45	NA	NA	6	0.66	NA	NA	196	NA	NA
Organobromines	BDE197	Whole soft body	-3	0.41	1	0.3	27	0.66	2.97	< 0.001	57	NA	NA
Organobromines	BDE206	Liver	5	0.59	NA	NA	1700	< 0.001	NA	NA	196	NA	NA
Organobromines	BDE206	Whole soft body	-2	0.91	1	0.47	1584	< 0.001	1	< 0.001	57	NA	NA

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
			Percent per 1000 km	Dist Linear_p	Dist Non_linear_df	Dist Non_linear_p	Percent per 10 years	Year Linear_p	Year Non_linear_df	Year Non_linear_p	Number of samples	Percent below PROREF	Percent below 2xPROREFf
Organobromines	BDE207	Liver	4	0.5	NA	NA	77	0.009	NA	NA	196	NA	NA
Organobromines	BDE207	Whole soft body	-9	0.45	1	0.82	1064	< 0.001	1.07	< 0.001	57	NA	NA
Organobromines	BDE209	Liver	-11	0.32	NA	NA	-24	0.17	NA	NA	820	88	95
Organobromines	BDE209	Whole soft body	23	0.37	1	0.56	-18	0.76	2.73	0.06	173	98	99
Organobromines	BDE28	Liver	-1	0.89	3.73	0.005	-43	< 0.001	2.8	< 0.001	835	97	99
Organobromines	BDE28	Whole soft body	-13	0.57	1	0.42	-78	< 0.001	2.19	< 0.001	153	NA	NA
Organobromines	BDE47	Liver	-15	0.08	3.94	< 0.001	-38	< 0.001	1	< 0.001	952	88	96
Organobromines	BDE47	Whole soft body	-12	0.39	2.12	0.08	-65	< 0.001	1	< 0.001	190	98	99
Organobromines	BDE49	Liver	-2	0.87	1	0.83	-10	0.4	1	0.39	648	93	99
Organobromines	BDE49	Whole soft body	-13	0.49	3.17	< 0.001	-92	< 0.001	2.95	< 0.001	68	NA	NA
Organobromines	BDE66	Liver	-14	0.14	1	0.23	-44	< 0.001	2.94	< 0.001	648	95	99
Organobromines	BDE66	Whole soft body	-27	0.08	1	0.18	-92	< 0.001	2.8	< 0.001	68	NA	NA
Organobromines	BDE6S	Liver	-15	0.04	3.94	< 0.001	-31	< 0.001	1	< 0.001	948	86	95
Organobromines	BDE6S	Whole soft body	-2	0.88	1	0.52	-61	< 0.001	2.66	< 0.001	190	97	99
Organobromines	BDE71	Liver	-36	0.01	1	0.21	-65	< 0.001	2.99	< 0.001	641	99	100
Organobromines	BDE71	Whole soft body	-24	0.05	1	0.06	-93	< 0.001	1	< 0.001	63	NA	NA
Organobromines	BDE77	Liver	-34	0.02	1	0.98	-78	< 0.001	2.93	< 0.001	437	99	100
Organobromines	BDE77	Whole soft body	-24	0.02	1	0.03	-94	< 0.001	1	< 0.001	68	NA	NA
Organobromines	BDE85	Liver	-24	0.08	1	0.51	-52	< 0.001	2.98	< 0.001	648	100	100
Organobromines	BDE85	Whole soft body	-15	0.2	1	0.15	-91	< 0.001	2.6	< 0.001	68	NA	NA
Organobromines	BDE99	Liver	13	0.26	3.85	< 0.001	-29	0.008	2.55	< 0.001	952	92	98
Organobromines	BDE99	Whole soft body	-9	0.59	1	0.16	-59	< 0.001	2.86	< 0.001	190	93	98
Organobromines	BDESS	Liver	-11	0.11	3.91	< 0.001	-28	< 0.001	1	< 0.001	945	82	94
Organobromines	BDESS	Whole soft body	9	0.62	1	0.62	-32	0.32	1	0.33	184	26	51
Organobromines	HBCDA	Liver	30	0.05	NA	NA	-82	< 0.001	NA	NA	513	94	99
Organobromines	HBCDA	Whole soft body	-25	0.09	1.79	0.03	-62	< 0.001	1	< 0.001	161	98	100
Organobromines	HBCDB	Liver	-15	0.13	NA	NA	-93	< 0.001	NA	NA	513	92	94
Organobromines	HBCDB	Whole soft body	0	0.74	1	0.83	-81	< 0.001	2.74	< 0.001	161	94	97
Organobromines	HBCDD	Liver	22	0.09	NA	NA	-88	< 0.001	NA	NA	512	92	99
Organobromines	HBCDD	Whole soft body	-23	0.03	1.78	0.01	-69	< 0.001	1	< 0.001	160	95	98
Organobromines	HBCDG	Liver	-16	0.25	NA	NA	-89	< 0.001	NA	NA	512	93	95
Organobromines	HBCDG	Whole soft body	-22	0.06	1	0.07	-64	< 0.001	1.81	< 0.001	160	91	96
Organobromines	Sum HBCD	Liver	58	0.008	NA	NA	-97	< 0.001	NA	NA	355	NA	NA

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
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Organobromines	Sum HBCD	Whole soft body	-22	0.29	NA	NA	-72	0.09	NA	NA	90	NA	NA
Organobromines	TBBPA	Liver	-20	0.3	NA	NA	482	0.002	NA	NA	242	90	94
Organobromines	TBBPA	Whole soft body	3	0.85	1	0.55	53	0.25	2.75	0.001	109	92	99
Organochlorines (general)	HCB	Liver	25	< 0.001	2.97	< 0.001	-7	< 0.001	2.62	< 0.001	2834	87	99
Organochlorines (general)	HCB	Muskel	39	< 0.001	1	< 0.001	-2	0.67	2.68	0.1	613	NA	NA
Organochlorines (general)	HCB	Whole soft body	-12	0.06	1	0.03	39	< 0.001	2.91	< 0.001	998	81	88
Organochlorines (general)	OCS	Liver	3	0.07	3.51	< 0.001	-37	< 0.001	2.9	< 0.001	2771	NA	NA
Organochlorines (general)	OCS	Muskel	1	0.66	1	0.72	40	< 0.001	2.82	< 0.001	612	NA	NA
Organochlorines (general)	OCS	Whole soft body	0	0.82	1	0.89	-6	0.006	2.81	< 0.001	1004	NA	NA
Organochlorines (general)	QCB	Liver	12	< 0.001	1	< 0.001	-36	< 0.001	2.92	< 0.001	2768	NA	NA
Organochlorines (general)	QCB	Muskel	1	0.63	1	0.49	-3	0.2	1	0.24	613	NA	NA
Organochlorines (general)	QCB	Whole soft body	-4	0.58	1	0.27	44	< 0.001	2.98	< 0.001	1019	NA	NA
Organofluorines	PFBS	Liver	1	0.95	NA	NA	-95	< 0.001	NA	NA	738	98	100
Organofluorines	PFDcA	Liver	-4	0.18	NA	NA	-7	0.4	NA	NA	416	NA	NA
Organofluorines	PFDcA	Whole soft body	-23	0.42	NA	NA	-90	0.05	NA	NA	32	NA	NA
Organofluorines	PFHpA	Liver	14	0.38	NA	NA	-79	< 0.001	NA	NA	840	NA	NA
Organofluorines	PFHpA	Whole soft body	3	0.85	NA	NA	3	0.88	NA	NA	32	NA	NA
Organofluorines	PFHxA	Liver	16	0.54	NA	NA	-91	< 0.001	NA	NA	838	NA	NA
Organofluorines	PFHxA	Whole soft body	-5	0.29	NA	NA	18	0.54	NA	NA	32	NA	NA
Organofluorines	PFHxS	Liver	1	0.94	NA	NA	-71	< 0.001	NA	NA	416	NA	NA
Organofluorines	PFHxS	Whole soft body	-2	0.79	NA	NA	10	0.66	NA	NA	32	NA	NA
Organofluorines	PFNA	Liver	17	0.13	NA	NA	-83	< 0.001	NA	NA	841	93	99
Organofluorines	PFNA	Whole soft body	-3	0.14	NA	NA	-16	0.54	NA	NA	32	NA	NA
Organofluorines	PFOA	Liver	4	0.67	NA	NA	-86	< 0.001	NA	NA	815	98	100
Organofluorines	PFOA	Whole soft body	4	0.63	NA	NA	-26	0.5	NA	NA	32	NA	NA
Organofluorines	PFOS	Liver	-43	< 0.001	NA	NA	-85	< 0.001	NA	NA	839	80	89
Organofluorines	PFOS	Whole soft body	-6	0.45	NA	NA	-22	0.74	NA	NA	32	NA	NA
Organofluorines	PFOSA	Liver	-55	< 0.001	NA	NA	-70	< 0.001	NA	NA	769	83	96
Organofluorines	PFOSA	Whole soft body	-12	0.3	NA	NA	3183	0.004	NA	NA	32	NA	NA
Organofluorines	PFUdA	Liver	-5	0.31	NA	NA	5	0.71	NA	NA	416	NA	NA
Organofluorines	PFUdA	Whole soft body	-1	0.81	NA	NA	58	0.28	NA	NA	32	NA	NA
Phosphorus flame retardant (PFR)	EHDPP	Liver	6	0.56	NA	NA	-52	0.07	NA	NA	247	98	100
Phosphorus flame retardant (PFR)	EHDPP	Whole soft body	1	0.92	1	0.9	225	0.45	1	0.33	92	90	98

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
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Phosphorus flame retardant (PFR)	TBEP	Liver	17	0.42	NA	NA	-99	< 0.001	NA	NA	247	97	100
Phosphorus flame retardant (PFR)	TBEP	Whole soft body	-10	0.68	1	0.79	-96	0.01	1.95	0.01	92	90	99
Phosphorus flame retardant (PFR)	TBP	Liver	26	0.19	NA	NA	-86	0.001	NA	NA	256	99	100
Phosphorus flame retardant (PFR)	TBP	Whole soft body	-18	0.41	1	0.37	538	0.11	1	0.11	92	90	92
Phosphorus flame retardant (PFR)	TCEP	Liver	20	0.63	NA	NA	-100	< 0.001	NA	NA	247	98	100
Phosphorus flame retardant (PFR)	TCEP	Whole soft body	-1	0.91	1	0.69	-100	< 0.001	2.52	< 0.001	92	96	100
Phosphorus flame retardant (PFR)	TCPP	Liver	15	0.34	NA	NA	-33	0.53	NA	NA	244	99	100
Phosphorus flame retardant (PFR)	TCPP	Whole soft body	27	0.54	1	0.48	30	0.87	1.07	0.87	89	97	100
Phosphorus flame retardant (PFR)	TCrP	Liver	7	0.11	NA	NA	155	0.02	NA	NA	195	NA	NA
Phosphorus flame retardant (PFR)	TCrP	Whole soft body	-43	0.15	NA	NA	16742	0.005	NA	NA	62	NA	NA
Phosphorus flame retardant (PFR)	TCRP	Liver	0	0.5	NA	NA	917865	< 0.001	NA	NA	49	NA	NA
Phosphorus flame retardant (PFR)	TCRP	Whole soft body	16	0.72	NA	NA	3770	0.22	NA	NA	26	NA	NA
Phosphorus flame retardant (PFR)	TDCP	Liver	19	0.51	NA	NA	-100	< 0.001	NA	NA	247	98	100
Phosphorus flame retardant (PFR)	TDCP	Whole soft body	11	0.77	1	0.7	-100	< 0.001	1.57	< 0.001	92	95	98
Phosphorus flame retardant (PFR)	TEHP	Liver	21	0.49	NA	NA	-100	< 0.001	NA	NA	247	94	98
Phosphorus flame retardant (PFR)	TEHP	Whole soft body	-13	0.69	1	0.53	-100	< 0.001	2.09	< 0.001	92	96	100
Phosphorus flame retardant (PFR)	TIBP	Liver	14	0.19	NA	NA	-85	< 0.001	NA	NA	247	99	100
Phosphorus flame retardant (PFR)	TIBP	Whole soft body	-18	0.49	1	0.48	61	0.75	1	0.73	92	90	95
Phosphorus flame retardant (PFR)	ToCrP	Liver	15	0.74	NA	NA	-100	< 0.001	NA	NA	214	NA	NA
Phosphorus flame retardant (PFR)	ToCrP	Whole soft body	-11	0.77	NA	NA	-45	0.72	NA	NA	63	NA	NA
Phosphorus flame retardant (PFR)	TPhP	Liver	9	0.17	NA	NA	160	0.02	NA	NA	195	NA	NA
Phosphorus flame retardant (PFR)	TPhP	Whole soft body	-33	0.24	NA	NA	20331	0.009	NA	NA	62	NA	NA
Phosphorus flame retardant (PFR)	TPHP	Liver	7	0.65	NA	NA	240953	< 0.001	NA	NA	52	NA	NA
Phosphorus flame retardant (PFR)	TPHP	Whole soft body	-3	0.82	NA	NA	172028	< 0.001	NA	NA	30	NA	NA
Phenols/chlorophenols	4-N-NP	Liver	-39	0.21	NA	NA	-18	0.84	NA	NA	338	100	100
Phenols/chlorophenols	4-N-NP	Whole soft body	-4	0.86	1	0.07	185	0.06	2.99	< 0.001	131	NA	NA
Phenols/chlorophenols	4-N-OP	Liver	-10	0.79	NA	NA	-76	0.02	NA	NA	338	73	91
Phenols/chlorophenols	4-N-OP	Whole soft body	-7	0.7	1	0.02	142	0.18	2.98	< 0.001	132	NA	NA
Phenols/chlorophenols	4-T-NP	Liver	-15	0.38	NA	NA	-90	< 0.001	NA	NA	321	98	100
Phenols/chlorophenols	4-T-NP	Whole soft body	-24	0.32	1	0.21	2210	0.004	2.94	< 0.001	112	NA	NA
Phenols/chlorophenols	4-T-OP	Liver	-15	0.56	NA	NA	-70	0.02	NA	NA	338	74	91
Phenols/chlorophenols	4-T-OP	Whole soft body	-9	0.7	1	0.03	58	0.49	2.99	< 0.001	132	NA	NA
Phenols/chlorophenols	BPA	Liver	-11	0.28	NA	NA	-78	< 0.001	NA	NA	238	95	97
Phenols/chlorophenols	BPA	Whole soft body	17	0.09	1	0.21	-90	< 0.001	2.97	< 0.001	101	96	100

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
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Bisphenols	BPA	Liver	-11	0.28	NA	NA	-78	< 0.001	NA	NA	238	95	97
Bisphenols	BPA	Whole soft body	17	0.09	1	0.21	-90	< 0.001	2.97	< 0.001	101	96	100
Chlorinated paraffins	MCCP	Liver	4	0.8	NA	NA	137	< 0.001	NA	NA	527	92	97
Chlorinated paraffins	MCCP	Whole soft body	1	0.95	1	0.88	247	0.04	1.61	0.05	164	95	99
Chlorinated paraffins	SCCP	Liver	22	0.05	NA	NA	5	0.6	NA	NA	530	92	98
Chlorinated paraffins	SCCP	Whole soft body	4	0.87	1	0.68	-42	0.13	2.31	< 0.001	166	96	99
Dichloro-diphenyl-trichloroethane (DDTs)	DDEPP	Liver	2	0.39	3.62	< 0.001	-33	< 0.001	1	< 0.001	2834	95	99
Dichloro-diphenyl-trichloroethane (DDTs)	DDEPP	Muskel	1	0.9	2.96	< 0.001	-15	0.2	1	0.14	613	NA	NA
Dichloro-diphenyl-trichloroethane (DDTs)	DDEPP	Whole soft body	-34	0.02	6.74	< 0.001	-4	0.77	2.02	0.02	1046	42	61
Dichloro-diphenyl-trichloroethane (DDTs)	DDTEP	Liver	3	0.21	3.56	< 0.001	-26	< 0.001	1	< 0.001	2837	NA	NA
Dichloro-diphenyl-trichloroethane (DDTs)	DDTEP	Muskel	5	0.5	2.78	< 0.001	47	0.002	1	< 0.001	613	NA	NA
Dichloro-diphenyl-trichloroethane (DDTs)	DDTEP	Whole soft body	-26	0.09	6.59	< 0.001	23	0.17	1	0.12	1046	87	93
Dichloro-diphenyl-trichloroethane (DDTs)	DDTPP	Liver	-4	0.29	2.85	< 0.001	-56	< 0.001	2.64	< 0.001	1407	93	99
Dichloro-diphenyl-trichloroethane (DDTs)	DDTPP	Muskel	-4	0.24	1.46	0.44	-51	< 0.001	2.8	< 0.001	225	NA	NA
Dichloro-diphenyl-trichloroethane (DDTs)	DDTPP	Whole soft body	-9	0.65	6.28	< 0.001	17	0.39	2.69	0.01	838	74	85
Dichloro-diphenyl-trichloroethane (DDTs)	TDEPP	Liver	18	< 0.001	3.81	< 0.001	-39	< 0.001	2.82	< 0.001	2834	93	98
Dichloro-diphenyl-trichloroethane (DDTs)	TDEPP	Muskel	6	0.08	1.65	0.14	18	0.01	1	0.006	613	NA	NA
Dichloro-diphenyl-trichloroethane (DDTs)	TDEPP	Whole soft body	-15	0.17	6.58	< 0.001	-3	0.75	1.49	0.12	1042	41	71
Hexachlorocyclohexanes	HCHA	Liver	4	0.002	1	< 0.001	-64	< 0.001	2.77	< 0.001	2544	99	100
Hexachlorocyclohexanes	HCHA	Muskel	1	0.58	1	0.7	13	< 0.001	2.66	< 0.001	613	NA	NA
Hexachlorocyclohexanes	HCHA	Whole soft body	-5	0.31	1	0.09	3	0.54	2.99	< 0.001	890	NA	NA
Hexachlorocyclohexanes	HCHG	Liver	-14	< 0.001	1	< 0.001	-73	< 0.001	2.96	< 0.001	2546	96	100
Hexachlorocyclohexanes	HCHG	Muskel	-9	0.006	1	0.006	-30	< 0.001	1.32	< 0.001	608	NA	NA
Hexachlorocyclohexanes	HCHG	Whole soft body	-13	0.13	1	0.05	-28	< 0.001	2.97	< 0.001	889	NA	NA
Bio.effects method	EROD	Liver	17	0.13	NA	NA	-15	0.15	NA	NA	730	92	96
Isotopes	C/N	Whole soft body	1	0.6	1	0.58	31	< 0.001	2.61	< 0.001	305	83	100
Isotopes	Delta15N	Whole soft body	-6	0.38	3.63	< 0.001	-30	< 0.001	1	< 0.001	305	9	82
Organo-metallic compounds	DBT	Whole soft body	-36	0.07	NA	NA	-37	0.35	NA	NA	132	92	98
Organo-metallic compounds	DOT	Whole soft body	-13	0.2	NA	NA	20	0.23	NA	NA	95	99	100
Organo-metallic compounds	MBT	Whole soft body	-50	0.05	NA	NA	-11	0.71	NA	NA	83	88	96
Organo-metallic compounds	MOT	Whole soft body	-10	0.3	NA	NA	47	0.09	NA	NA	95	94	100
Organo-metallic compounds	TBT	Liver	4	0.81	NA	NA	6.45E+10	< 0.001	NA	NA	60	NA	NA
Organo-metallic compounds	TBT	Whole soft body	-45	0.004	NA	NA	-79	< 0.001	NA	NA	221	90	96
Organo-metallic compounds	TCHT	Whole soft body	-18	0.3	NA	NA	155	0.01	NA	NA	95	99	100

Substance.Group	Parameter	Tissue	Coastal distance effect adjusted for year				Year-effect adjusted for coastal distance				Value count and relation to PROREF		
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Organo-metallic compounds	TTBT	Whole soft body	-6	0.55	NA	NA	46	0.07	NA	NA	58	98	100
Others	% C	Whole soft body	-3	0.01	1	0.006	3	0.63	2.58	0.004	206	NA	NA
Others	% N	Whole soft body	-3	0.09	1	0.08	5	0.55	1.71	0.27	206	NA	NA
Others	C/N	Whole soft body	1	0.6	1	0.58	31	< 0.001	2.61	< 0.001	305	83	100
Others	Delta15N	Whole soft body	-6	0.38	3.63	< 0.001	-30	< 0.001	1	< 0.001	305	9	82
Others	DRYWT%	Liver	-2	0.09	1.99	0.01	-2	0.18	1	0.08	3189	NA	NA
Others	DRYWT%	Muskel	0	0.62	1	0.51	0	0.91	1	0.88	3381	NA	NA
Others	DRYWT%	Whole soft body	6	< 0.001	4.87	< 0.001	-7	< 0.001	1	< 0.001	1337	NA	NA
Others	Fett	Liver	1	0.04	3.54	< 0.001	3	< 0.001	1	< 0.001	3222	NA	NA
Others	Fett	Muskel	2	0.3	1.92	0.05	12	< 0.001	2.92	< 0.001	630	NA	NA
Others	Fett	Whole soft body	-14	0.39	1	0.38	-18	0.04	1	0.04	1269	NA	NA
Organo-metallic compounds	TPT	Whole soft body	-29	0.04	NA	NA	7	0.79	NA	NA	83	NA	NA

***Table 30**. Number of stations analysed for PFAS yearly. The cells for PFAS not analysed have grey background.*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PFAS	4	5	6	6	8	8	9	8	8	8	9	9	9	9	9
PFBS	4	5	6	6	8	8	9	8	8	8	9	9	9	0	0
PFDcA	0	0	0	0	0	0	0	8	8	8	9	9	9	9	9
PFHpA	4	5	6	6	8	8	9	8	8	8	9	9	9	9	9
PFHxA	4	5	6	6	8	8	9	8	8	8	9	9	9	9	9
PFHxS	0	0	0	0	0	0	0	8	8	8	9	9	9	9	9
PFNA	4	5	6	6	8	8	9	8	8	8	9	9	9	9	9
PFOA	4	5	6	6	8	8	9	8	8	8	9	9	9	9	9
PFOS	4	5	6	6	8	8	9	8	8	8	9	9	9	9	9
PFOSA	0	0	6	6	8	8	9	8	8	8	9	9	9	9	9
PFUdA	0	0	0	0	0	0	0	8	8	8	9	9	9	9	9

***Table 31**. Sample size for each station/year. The cells for sample size 0 have grey background.*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
10B	12	2	5	0	0	0	0	0	0	0	0	0	0	0	0
13B	0	0	0	0	25	19	21	6	10	14	14	15	12	9	10
15B	0	0	14	5	0	0	24	0	0	0	0	0	0	0	0
23B	18	20	23	21	21	20	22	11	15	14	15	15	13	14	15
24B	0	0	0	0	0	0	0	0	0	0	15	15	15	12	14
30B	17	22	21	23	20	25	25	13	16	15	12	15	12	10	5
36B	0	0	15	5	19	24	24	11	10	15	15	15	10	15	6
43B2	0	0	0	0	25	25	25	15	15	15	13	12	15	15	15
53B	10	21	22	5	17	21	24	14	6	9	14	15	15	15	15
80B	0	0	0	0	21	3	12	11	15	15	15	14	15	14	11
98B1	0	15	0	5	25	25	25	6	15	8	15	15	11	12	15

***Table 32**. Detection frequency for PFAS each year. NA: not analysed. Overall average is adjusted according to count for each year.*

PFAS	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Overall average
PFOS	75.4	76.2	56.2	95.3	86.7	98.8	87.6	78.2	97.1	100	100	99.2	100	99.1	99.1	**91.1**
PFOSA	NA	NA	27	73.4	30.6	38.9	49.5	74.7	100	100	95.3	98.5	91.5	87.9	93.4	**70.5**
PFUdA	NA	NA	NA	NA	NA	NA	NA	19.5	39.2	33.3	71.9	36.6	55.9	46.6	50	**45.1**
PFDcA	NA	NA	NA	NA	NA	NA	NA	13.8	19.6	1	16.4	5.3	7.6	15.5	27.4	**13.1**
PFHxA	0	2.5	0	0	3.5	0	0	1.1	0	0	0.8	5.3	3.4	4.3	0	**5.3**
PFHpA	0	0	0	3.1	0.6	0	0	0	0	0	0	0.8	1.7	15.5	0	**3.3**
PFOA	0	5.1	0	0	2.7	1.2	0.5	1.1	0	0	1.6	3.8	0.8	31	0	**1.8**
PFNA	0	2.5	0	0	1.2	21.6	6.4	19.5	3.9	0	4.7	3.8	0	6	0	**1.5**
PFHxS	NA	NA	NA	NA	NA	NA	NA	2.3	0	0	2.3	1.5	0	0	0	**1.4**
PFBS	0	0	0	3.1	1.2	0	0	0	8.8	0	0	0.8	11	NA	NA	**0.8**
Overall	**75.4**	**76.2**	**65.0**	**95.3**	**87.3**	**98.8**	**90.1**	**83.9**	**100**	**100**	**100**	**100**	**100**	**99.1**	**99.1**	**92.4**

***Table 33**. Overview of the distance (km) along the coast (from the starting point of the Norwegian coast at the border towards Sweden) to the stations are given. Also, distances between sampling station and nearest airport (Dist.1) and nearest upstream airport (Dist, 2, assuming that the Norwegian Coastal current are moving along the coast).*

Station_Name	Dist. along coast	Airport1	Dist.1	Airport2	Dist.2
30B Oslo City area	69	Kjeller flyplass	32	Kjeller flyplass	32
36B Færder area	105	Sandefjord lufthavn, Torp	19	Rygge lufthavn	43
13B Kristiansand harbour	287	Kristiansand lufthavn, Kjevik	9.8	Kristiansand lufthavn, Kjevik	9.8
15B Ullerø area	373	Kristiansand lufthavn, Kjevik	81	Kristiansand lufthavn, Kjevik	81
23B Karihavet area	634	Bergen lufthavn, Flesland	45	Haugesund lufthavn, Karmøy	62
53B Inner Sørfjord	654	Bergen lufthavn, Flesland	77	Haugesund lufthavn, Karmøy	112
24B Bergen harbour	692	Bergen lufthavn, Flesland	12	Bergen lufthavn, Flesland	12
80B Munkholmen	1206	Trondheim lufthavn, Værnes	28	Ørland lufthavn	48
98B1 Bjørnerøya (east)	1727	Svolvær lufthavn, Helle	6.7	Svolvær lufthavn, Helle	6.7
43B2 Tromsø harbour	2004	Tromsø lufthavn, Langnes	3.9	Tromsø lufthavn, Langnes	3.9
10B Varangerfjorden	2665	Kirkenes lufthavn, Høybuktmoen	11	Vadsø lufthavn	28

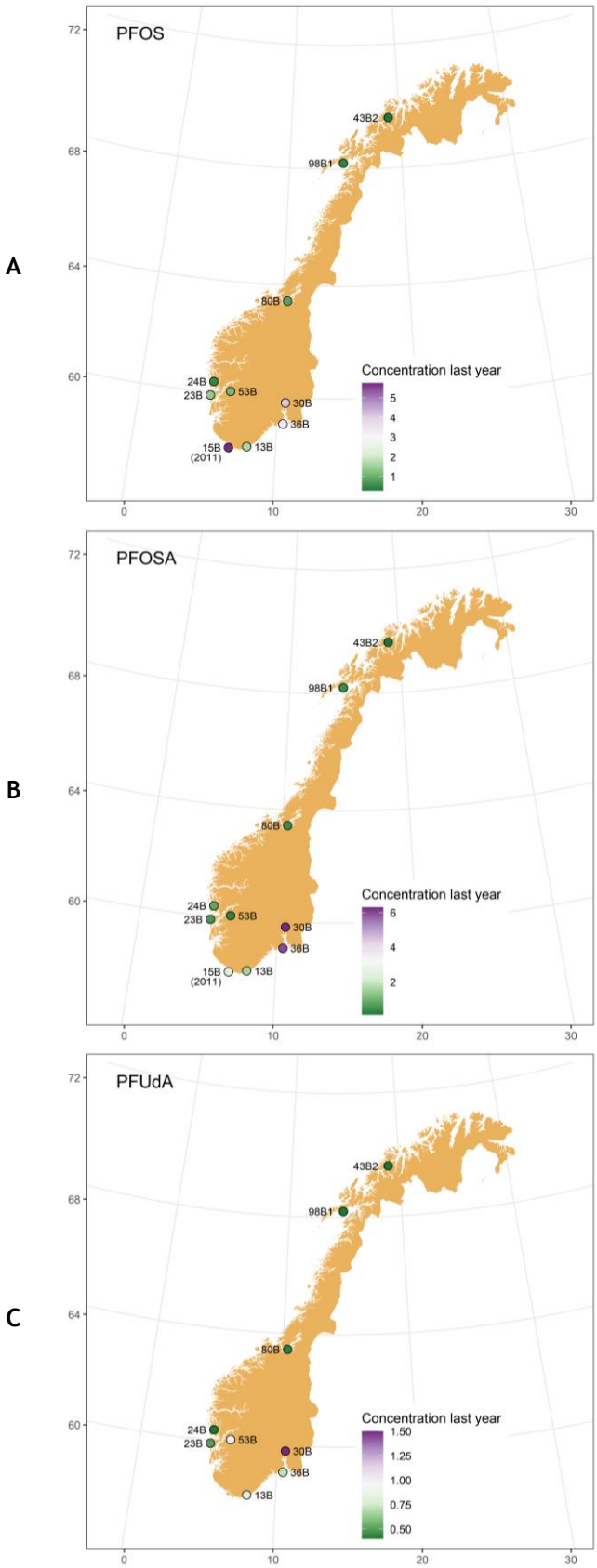

***Figure 89**. Maps with concentration gradients (2019) for PFOS (**A**), PFOSA (**B**) and PFuDA (**C**) where the concentration gradient is coloured according to a gradient from green to lilac.*

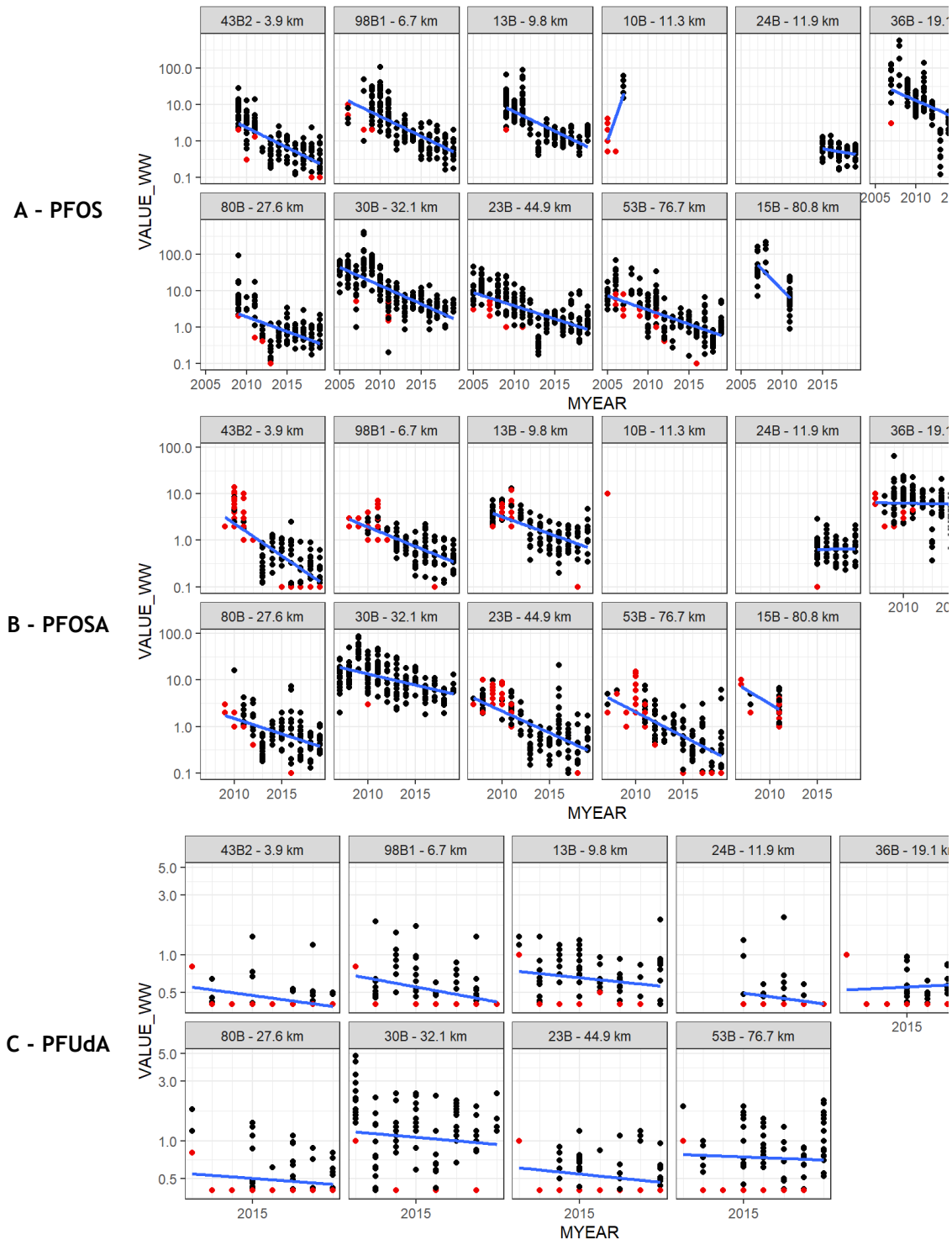

***Figure 90**. PFOS (**A**), PFOSA (**B**) and PFUdA (**C**) (µg/kg w.w.) in cod liver in MILKYS stations during 2005-2019. Concentrations below LOQ are indicated in red. The stations are ordered by the distance to the closest airport (increasing distance). it can be inferred that the LOQ has decreased during the years as the analytical method employed has been improved during the period. This is probably also the reason why the detection frequency of some PFAS (e.g. PFOS and PFOSA) has been increased (**Table 32**, **Appendix G**).*

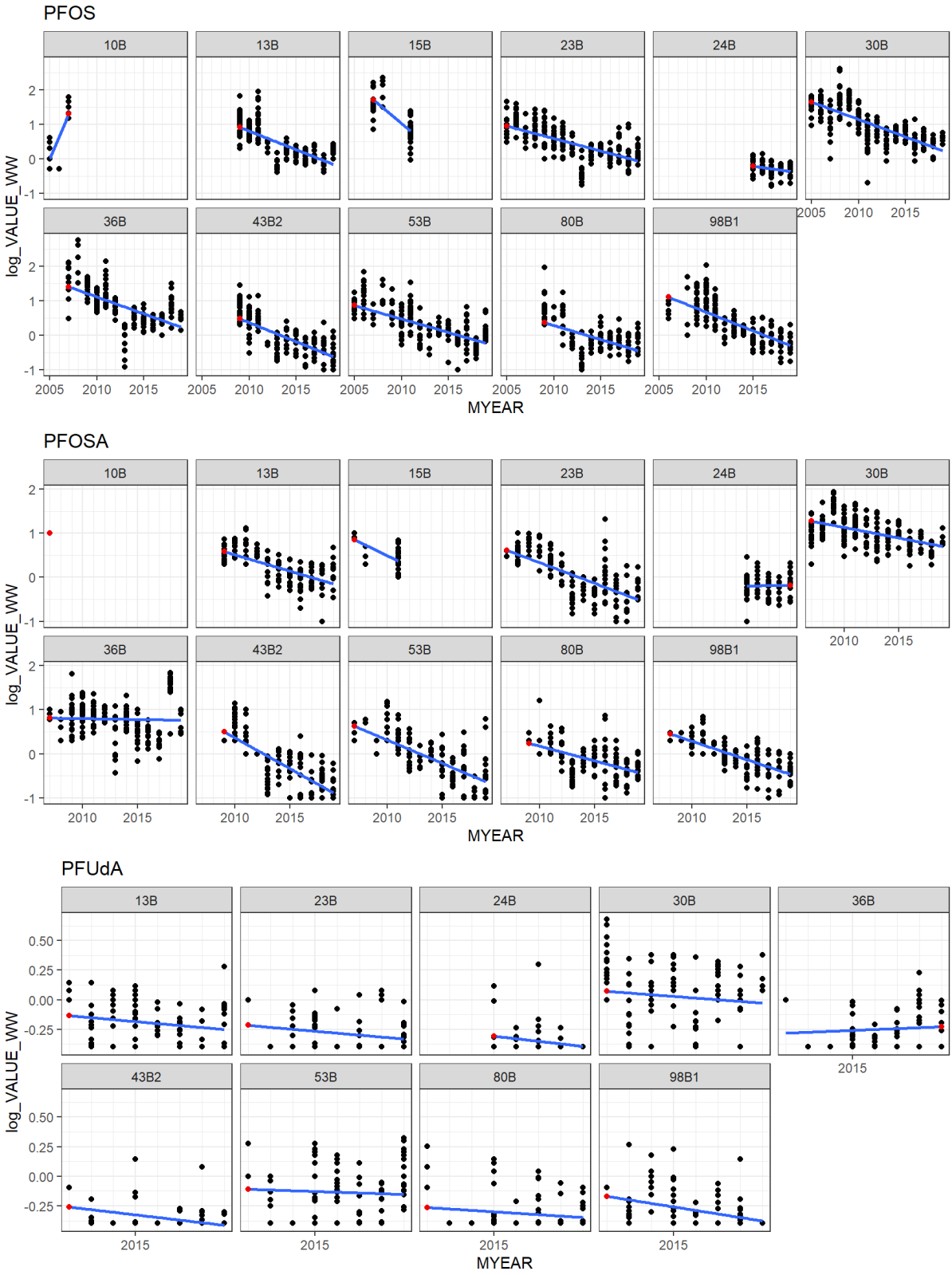

***Figure 91**. The red dot indicates the mean concentration estimated for the year with highest concentration. (See otherwise **Figure 90**).*

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