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Contaminants in coastal waters of Norway 2018.

Miljøgifter i norske kystområder 2018

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Summary
This programme examines the levels, trends and effects of contaminants in biota along the coast of Norway. The 2018-investigation included analyses of more than 133 different contaminants or biological effect parameters in five species (blue mussel, dogwhelk, common periwinkle, cod and the common eider). The contaminants include metals (Hg, Cd, Pb, Cu, Zn, Ag, As, Ni, Cr and Co), tributyltin (TBT), organochlorines (e.g. PCBs (PCB-7), DDT), PAHs, polybrominated diphenyl ethers (PBDEs), and perfluorinated alkylated substances (PFAS), as well as contaminants that have recently received much attention such as hexabromocyclododecane (HBCDs), chlorinated paraffins (SCCP, MCCP), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), alkyphenols, siloxanes (D4, D5 and D6) and dechlorane plus. Biological effects parameters included VDSI, OH-pyrene metabolites, ALA-D and EROD. In the report, 30 representative substances or parameters were chosen for analyses of 713 time series (last 10 years). Of these there were statistically significant trends in 102 cases: 79 were downwards and 23 upwards. The upward trends were also associated with metals (78.3 %), primarily Hg (17.4 %).The dominance of downward trends indicated that contamination is decreasing for the measured substances. The downwards trends for TBT-concentrations and effect parameter (VDSI) confirmed that the legislation banning the use of TBT has been effective. Of the 2018-medians (last year) for all 713 time series, there were 323 cases that could be classified against EQS, of which 203 (62.8 %) were below the EQS and 120 (37.2 %) were above the EQS. Of the 2018-medians for the 713 time series, 641 cases could be classified using Norwegian provisional high reference contaminant concentrations (PROREF). Of these, 463 were below PROREF and 173 exceeded PROREF: 117 by a factor of less than two, 45 by a factor between two and five, eight by a factor between five and 10, four by a factor between 10 and 20, and four 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. High concentrations of DDE in mussels from the Sørfjord were related to earlier use of DDT as pesticide in orchards along the fjord. Concentrations of an expanded list of PFAS in cod liver from the Inner Oslofjord sampled since 1990 are presented. Results of analyses of stable isotopes of carbon and nitrogen are presented to investigate the role of food origin and trophic levels for observed contaminant concentrations.

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Contaminants in coastal waters of Norway 2018
Miljøgifter i norske kystområder 2018

Preface

This report presents the results of the programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS), with investigations of contaminants in coastal waters of Norway in 2018, which 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 the concentration levels, trends and effects of hazardous substances. The results from Norway and other OSPAR countries provide a basis for a paramount evaluation of the state of the marine environment. OSPAR receives guidance from the International Council for the Exploration of the Sea (ICES).

The 2018 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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- Fieldwork and/or sample processing: Espen Lund, Bjørnar Beylich, Lise Tveiten, Marthe Torunn Solhaug Jenssen, Siri Moy, Marijana Stenrud Brkljacic, Janne Kim Gitmark, Jonny Beyer, Jarle Håvardstun, Maia Røst Kile, Eivind Ekholt Andersen, Henny Knudsen, Norman W. Green, Ingar Becsan and Kirk Meyer at NIVA, and Kjetil Sagerup and Guttorm Christensen at Akvaplan-niva.
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- Data programme management and operation: Dag Hjermann and Jan Karud at NIVA.
- Written assessment: Merete Schøyen, Sigurd Øxnevad, Norman W. Green, Anders Ruus (biological effects methods) and Dag Hjermann (statistical analyses) at NIVA.
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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, 5 November 2019.

Norman W. Green
Project Manager
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Summary

The 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 conclusion is that most trends of contaminant concentrations in marine organisms collected at stations in the Norwegian coastal water were downwards. The Inner Oslofjord is an area where more contaminants have relatively higher concentrations and hence this area warrants special concern. Furthermore, in this area the investigation found no trends for mercury (Hg) in cod fillet (*Gadus morhua*), but an upward short-term trend for short chain chlorinated paraffins (SCCP) in cod liver.

Monitoring contaminants and associated parameters along the Norwegian coast contributes to OSPAR’s Coordinated Environmental Monitoring Programme (CEMP). The 2018-investigation monitored blue mussel (*Mytilus edulis*) at 26 stations, dogwhelk (*Nucella lapillus*) at eight stations, common periwinkle (*Littorina littorea*) at one station, Atlantic cod (*Gadus morhua*) at 17 stations 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. The programme for 2018 included analyses of metals mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), nickel (Ni), chromium (Cr), cobalt (Co)), tributyltin (TBT), polychlorinated biphenyls (PCBs), pesticides (DDE, isomer of DDT), polycyclic aromatic hydrocarbons (PAHs), polybromated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS), hexabromocyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), alkylphenols, siloxanes (cVMS: D4, D5, D6), dechlorane plus, as well as biological effects parameters (VDSI, OH-pyrene, ALA-D, EROD).

The results from 2018 supplied data for a total of 3049 data sets (contaminant-station-species) on 133 different contaminants and in addition supplementary analyses of dechlorane plus compound and other PFAS. Thirty representative contaminants and biological effect parameters were chosen for presentation in this report. This selection had 713 time series of which there were statistically significant temporal trends (2009-2018) in 102 cases: 79 were downwards and 23 upwards. The downward trends were largely associated with concentrations of metals (27.8 %) and tributyltin (TBT) and effect of TBT (VDSI - *vas deferens sequence index*). The dominance of downward trends indicated that contamination was decreasing. The upward trends were also associated with metals (78.3 %), primarily Hg (17.4 %).

Of the 713 time series, 323 cases could be classified against Environmental Quality Standard (EQS) for EU priority substances and river basin specific pollutants, of which 203 (62.8 %) were below the EQS.

There were 641 time series that could be compared to a recently added NIVA-developed tool denoted Norwegian provisional high reference contaminant concentration (PROREF). PROREF is 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 consentrations 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 641 time series, 463 (72.2 %) were below PROREF, and 173 (27.8 %) exceeded PROREF: 117 (18.3 %) by a factor of less than two, 45 (7.0 %) by a factor between two and five, eight (1.2 %) by a factor between five and 10, four (0.6 %) by a factor between 10 and 20, and four (0.6 %) by a factor greater than 20. Even though most concentrations observed were below PROREF or did not exceed PROREF beyond a factor of two, the cases that exceeded PROREF should not be disregarded. For example, the blue mussel in the Mid Sørfjord exceeded PROREF for pesticides (DDE) by a factor greater than 20.

Levels and trends in fish

The concentrations of Hg in cod fillet at all stations exceeded the EQS in 2018, 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. No long-term (1984-2018) or short-term (2009-2018) trends for Hg in cod fillet from the Inner Oslofjord were found using the OSPAR method which targets specific length-groups or when adjusting to expected concentrations for 50 cm cod using the method taking into considerations fish-length. Cod fillet from the Outer Oslofjord exceeded the PROREF for Hg by a factor up to two, and no trends were found neither by using the OSPAR method nor after adjusting for fish length effects. There were significant upward long-term and short-term trends for Hg in cod fillet from Kristiansand harbor. The highest Hg concentration was found in cod fillet from Ålesund harbour and the exceedance of PROREF was by a factor between five and 10.

All concentrations of PCB-7 in cod liver exceeded the EQS in 2018. Cod liver from the Inner Oslofjord and Ålesund harbour exceeded the PROREF for PCB-7 by a factor between two and five. The highest concentrations of PCB-7 in Oslo 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 was below the EQS in 2018. 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 2018. The highest median concentrations of sum PBDEs were found in the Inner Oslofjord, Bergen harbour and Tjøme, respectively, and these stations exceeded PROREF of sum BDEs (28, 47, 99, 100, 153 and 154) 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 significantly higher in cod from Tjøme in the Outer Oslofjord than from all other stations in the present study, including the Inner Oslofjord. In 2017, there was no exceedance of PROREF for PFOSA in cod liver from Tjøme, compared to an exceedance of between five to 10 in 2018. Other studies have related PFAS concentrations in biota to earlier use of firefighting foam at Rygge airport. The reason behind the differences in concentrations between the stations are not fully understood, but it appears likely that as for PCB-7 and PBDEs a combination of urban sources and restricted water exchange provide high concentrations in the Inner Oslofjord. The lowest PFAS concentrations were found at Svalbard. Supplementary analysis of PFAS in cod liver from the Inner Oslofjord from 1990 to 2009 showed significant upward trends for PFDA, PFUnDA, PFDoA, PFTrDA and PFDS and significant downward trends for PFOS and PFOSA. PFOA has been below the EQS for the whole period, whereas PFOS has been below the EQS only since 2016.

All concentrations of hexabromocyclododecanes (HBCD) in cod liver were below the EQS in 2018, 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. The high concentrations of HBCD are probably related to urban activities, and especially for the Inner Oslofjord, reduced water exchange with the outer fjord. Decreasing levels of HBCD were found. There were both significant downward long- and short-term trends for HBCD in cod liver from Stathelle area in the Langesundfjord, in cod liver from Kirkøy, Hvaler and in cod liver from Bømlo. A significant downward short-term trend was also found for HBCD in cod liver from the Inner Oslofjord.

Short chain chlorinated paraffins (SCCP) were highest in cod liver from Ålesund harbour (and exceeded PROREF) whereas median concentration of medium chain chlorinated paraffins (MCCP) was highest in cod from Austnesfjord in Lofoten (but did not exceed PROREF). The source of the MCCP in Lofoten might be the local airport. There were both significant long- and short-term upward trends for SCCP in cod liver from the Austnesfjord in Lofoten. There was a significant upward short-term trend for SCCP in cod liver from the Inner Oslofjord when using data adjusted for fish length. A significant upward long-term trend was found for MCCP in cod liver from Bømlo in the Outer Selbjørnfjord. A significant downward long-term trend was found 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.

All concentrations of nonylphenol were below the EQS in 2018. When applying the EQS for octylphenol (0.004 µg/kg w.w.) in biota, several concentrations were above the EQS in 2018. Since the EQS for octylphenol is much lower than the quantification limit, it is not possible to classify this substance correctly.

Bisphenol A and tetrabrombisphenol A were not detected in cod liver, hence no conclusion can be drawn regarding possible differences between stations.

For siloxanes in cod liver, 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 D6.

The concentrations of dechloranes were low, and in many cases below the limit of quantification. The concentrations of dechloranes were slightly higher in cod from the Inner Oslofjord than in cod from Bergen harbour area.

Levels and trends in blue mussel

The concentration of Pb in blue mussel was highest at Odderøya in the Kristiansandfjord, and the PROREF was exceeded by a factor greater than 20. There were both significant upward long- and short-term trends for Pb at Gressholmen in the Oslofjord. There were significant upward long- and short-term trends for Cr at Gressholmen in the Inner Oslofjord and Brashavn in the Varangerfjord.

PCB-7 in blue mussel at all stations exceeded both the EQS and PROREF in 2018. The highest PCB-7 concentration was found at Gressholmen in the Inner Oslofjord.

For DDE, blue mussel from three stations in the Mid and Outer Sørfjord area exceeded PROREF by a factor of greater than 20. Two other stations in this area 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 in the area of Sørfjord.

Concentrations of PAHs in blue mussel were highest in the Oslo harbour area. All blue mussel stations had concentrations below PROREF for PAHs. Concentrations of KPAHs were highest at the station in Lastad at Søgne, which is located near a marina. Applying EQS for blue mussel, all stations had concentrations below this limit for anthracene, fluoranthene, benzo(a)pyrene, napthalene and benzo(a)anthracene. Blue mussel at all stations exceeded PROREF for KPAHs. Mussels at Akershuskaia exceeded PROREF for anthracene, fluoranthene and benzo(a)anthracene.

Concentrations of PBDEs (sum of six compounds – BDE6S) in blue mussel were higest in Bodø harbour area. All blue mussel stations were below PROREF for PBDEs.

All concentrations of HBCD were below the EQS in 2018, and the highest median concentrations of α-HBCD was found in Bodø harbour. Decreasing levels were found, and a significant downward long-term trend for HBCD in blue mussel from Gressholmen in the Inner Oslofjord.

Both SCCP and MCCP were highest in blue mussel from Bodø harbour. There were significant upward long- and short-term trends for SCCP in mussels from Svolvær airport area.
Bisphenol A and TBBPA were not detected in blue mussel

Levels in eider
Contaminants were analysed in the blood and eggs (homogenate of yolk and albumin) of the eider from Svalbard for the second 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 2018 was almost within the same range as in a comparable study in the Inner Oslofjord in 2017. The concentrations of PCB-7 was 10-14 times higher in eider blood and eggs, respectively, in the Inner Oslofjord in 2017 than at Svalbard in 2018. The concentrations of BDE 47 were 8 times higher in eider eggs in the Inner Oslofjord in 2017 than at Svalbard in 2018. The PFOS concentrations in eider blood and eggs are 10 times higher in a comparably study in the Inner Oslofjord than at Svalbard in 2018.

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, Farsund area, Inner Sørfjord), except at the reference station (Bømlo-Sotra area) in 2018 and indicates that the fish have been exposed to PAH. The median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord and the Inner Sørfjord were significantly lower in 2018, than in 2017, and the concentrations were highest in the Inner Oslofjord.

The ALA-D activity in the the Inner Sørfjord and Inner Oslofjord in 2018 were lower than at Bømlo. Reduced activities of ALA-D reflect higher exposure to lead. Higher concentrations of lead in cod liver have generally been observed in the Inner Oslofjord and Inner Sørfjord compared to Outer Selbjørnfjord at Bømlo.

In 2018, EROD activities in neither the Inner Oslofjord (st. 30B), nor the Inner Sørfjord (st. 53B) were higher than at the reference station (Outer Selbjørnfjord). 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. Although OH-pyrene (marker of PAH-exposure)

[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.

concentrations were higher in bile of cod from the Inner Oslofjord and the inner Sørfjord, than at the reference station, this pattern was not observed in the EROD activities. The EROD activities were below the ICES/OSPARs BAC. Concentrations over BAC would indicate possible impact by planar PCB-7, PCNs, PAHs or dioxins.

For the first time since 1991, there were no effects of TBT on dogwhelk (imposex parameter VDSI=0) at all eight stations in 2017. The 2018 surveys confirmed the results except for at Karmsundet (VDSI=0.129) due to one imposexed individual. There were significant downward long-term trends for TBT at six of eight stations. The synchronous decreases in both TBT concentrations and imposex parameters in dogwhelk coincides with the TBT bans. The results indicate that the legislation banning the use of TBT since 2008 has been effective.

Stable isotopes

The stabile isotope $\delta_{15}N$ is analysed as a measure of trophic position. Results showed very similar isotopic signatures among the stations in 2018 as in 2012-2017, indicating a geographical trend persistent in time. The isotopic signatures in mussels from the programme thus provide valuable information about the isotopic baselines along the Norwegian coast. The geographical differences in the baseline isotopic signatures must be taken into consideration when interpreting accumulation of contaminants in relation to trophic position. The $\delta_{15}N$ data in cod are assessed in relation to concentrations of selected contaminants. Generally, as fish grow through their lifetimes, they feed on larger prey organisms, thus a small increase in trophic level is likely to occur. At specific stations, particularly Hg increased with higher $\delta_{15}N$, i.e. higher concentrations in individuals with slightly higher trophic position.

Sammendrag

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Overvåkingsprogrammet «Miljøgifter i norske kystområder 2018 - MILKYS» omhandler nivåer, trender og effekter av miljøgifter langs norskekysten. Undersøkelsen gir grunnlag for bestemmelse av miljøtilstand langs norskekysten.

Resultatene viser at det hovedsakelig var nedadgående trender for konsentrasjon av de undersøkte miljøgiftene. Indre Oslofjord er et område med flere miljøgifter med relative høye konsentrasjoner som gir grunnlag for bekymring og behov for nærmere undersøkelser. I dette området ble det ikke observert trender for kvikksølv (Hg) i torskefilet, men en oppadgående korttidstrend for kortkjedete klorparafiner (SCCP) i torskelever.

Undersøkelsen inngår som en del av OSPARs koordinerte miljøovervåkingsprogram Coordinated Environmental Monitoring Programme (CEMP). I 2018 omfattet overvåkingen miljøgifter i blåskjell (Mytillus edulis) fra 26 stasjoner, purpursnegl (Nucella lapillus) fra 8 stasjoner, strandsnegl (Littorina littorea) fra én stasjon, torsk (Gadus morhua) fra 17 stasjoner 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 2018 omfattet analyser av 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), polysykliske aromatiske hydrokarboner (PAHer), polybromerte difenyletere (PBDEer), perfluorerte alkylforbindelser (PFAS), heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP), bisfenol A (BPA), tetrabrombisfenol A (TBBPA), alkyfenoler, siloksaner (cVMS: D4, D5, D6), dekloran plus, samt biologiske effekt-parametere (VDSI, OH-pyren, ALA-D, EROD).

2018-resultatene omfatter totalt 3049 datasett (miljøgifter-stasjoner-arter) for 133 forskjellige miljøgifter. Et utvalg på 30 representative miljøgifter og biologiske parametere presenteres i denne rapporten. Dette utvalget består av 713 tidsserier hvorav 102 viste statistisk signifikante trender for perioden 2009 til 2018: 79 var nedadgående og 23 var oppadgående. De nedadgående trendene omfattet metaller (27,8 %) og i noe mindre grad også tributyltinn (TBT) og effekt av TBT (VDSI – sædlederindeks). Dominansen av nedadgående trender indikerer avtagende nivåer av miljøgifter. De oppadgående trendene var i hovedsak også for metaller (78,3 %), og da primært kvikksølv (17,4 %).

Av de 713 tidsseriene kunne 323 av dem klassifiseres i forhold til miljøkvalitetsstandarder (EQS) or EUs prioriterte miljøgifter og vannregionspesifikke stoffer. I 2018 var 203 (62.8 %) lavere enn miljøkvalitetsstandardene.

Der var 641 tidsserier som 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 gir dermed en verdifull metode

for å vurdere nivåer av miljøgifter i tillegg til EQS. Av disse var 463 (72,2 %) lavere enn PROREF og 173 (27,8 %) overskred PROREF. For 117 tidsserier (18,3 %) var overskridelsen av PROREF på en faktor lavere enn to. For 45 tidsserier (7,0 %) var overskridelsen av PROREF på en faktor på mellom to og fem. For åtte tidsserier (1,2 %) var overskridelsen av PROREF på en faktor mellom fem og 10. For fire tidsserier (0,6 %) var overskridelsen av PROREF på en faktor mellom 10 og 20, og for fire tidsserier (0,6 %) var overskridelsen av PROREF på en faktor høyere enn 20.

Selv om de fleste konsentrasjonene var lavere eller oversteg PROREF med bare en faktor på under to, bør ikke tilfellene som overstiger PROREF ignoreres. Et eksempel på dette er blåskjell i midtre Sørfjorden som var hadde konsentrasjon av DDE som oversteg PROREF med en faktor på over 20.

Konsentrasjoner av miljøgifter i fisk

I 2018 var det overskridelse av miljøkvalitetsstandard (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, men det var ingen langtidstrend (1984-2018) eller kortidstrend (2009-2018) med OSPARs metode for spesifikke lengdegrupper. Det var heller ingen trender ved beregning med metode som tar hensyn til fiskelengde. Torsk fra Ytre Oslofjord hadde konsentrasjon av kvikksølv i filét som var opptil to ganger høyere enn PROREF, og det var ingen signifikante trender ved beregning med OSPAR-metoden og ved justering for fiskelengde. Det var signifikante oppadgående lang- og kortidstrender for kvikksølv i torskefilét fra Kristiansand havn. Den høyeste kvikksølvkonsentrasjonen ble funnet i torskefilét fra Ålesund havn, og overskridelsen var fem til ti ganger høyere enn PROREF.

Konsentrasjonene av PCB-7 i torskelever var høyere enn EQS. Det var forhøyede nivåer av PCB-7 i torskelever fra Indre Oslofjord og Ålesund havn, med overskridelse av PROREF for PCB-7 med en faktor på mellom to og fem. Den 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. I 2018 var de høyeste nivåene av PBDEer i torskelever fra henholdsvis Indre Oslofjord, Bergen havn og Tjøme, 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 signifikant høyere i torskelever fra Tjøme i Ytre Oslofjord enn fra alle andre stasjoner i denne undersøkelsen, også indre Oslofjord. I 2017 var det ingen overskridelse av PROREF for PFOSA i torskelever fra Tjøme, mens overskridelsen i 2018 var på mellom fem og 10 ganger. Flere andre studier har relatert PFAS konsentrasjoner i biota til bruken av brannskum på Rygge flystasjon. Nivåforskjellene mellom de ulike områdene 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, slik som resultatene var for PCB-7 og PBDEer. De laveste PFAS konsentrasjonene ble registrert på Svalbard. Supplerende PFAS-undersøkelser av torskelever fra indre Oslofjord fra 1990 til 2009 viste signifikante oppadgående trender for PFDA, PFUnDA, PFDoA,

PFTrDA og PFDS og signifikante nedadgående trender for PFOS og PFOSA. PFOA har vært under EQS i hele perioden, mens PFOS kun har vært under EQS siden 2016.

I 2018 var alle konsentrasjonene av heksabromsyklododekaner (HBCD) i torskelever lavere enn EQS. Av HBCDene var α-HBCD den mest dominerende diastereomeren. Torskelever fra Indre Oslofjord hadde signifikant høyere konsentrasjon av α-HBCD enn torsk fra de 12 andre stasjonene i denne undersøkelsen. De høye HBCD-konsentrasjonene er sannsynligvis relatert til urban påvirkning, og, særlig for Indre Oslofjord, lav vannutskifting med ytre fjord. Det ble funnet flere nedadgående nivåer for HBCD. Det var signifikant nedadgående langtidstrend og korttidstrend for HBCD i torskelever fra Stathelleområdet i Langesundsfjorden, fra Kirkøy på Hvaler og fra Bømlo.

Det var høyest konsentrasjon av kortkjedete klorerte parafiner (SCCP) i torskelever fra Ålesund havn (samt overskridelse av PROREF), og det var høyest mediankonsentrasjon av mellomkjedete klorparafiner (MCCP) i torskelever fra Austnesfjord i Lofoten. Kilden til MCCP i Lofoten kan være flyplassen i nærheten. Det var signifikante oppadgående langtidstrend og kortidstrend for SCCP i torskelever fra Austnesfjord i Lofoten (men ikke overskridelse av PROREF). Det var signifikat oppadgående korttidstrend for SCCP i torskelever fra Indre Oslofjord, når konsentrasjonene ble justert etter fiskelengde. Det var også signifikant oppadgående langtidstrend og korttidstrend for MCCP i torskelever fra Indre Oslofjord, og det var signifikat oppadgående langtidstrend for MCCP i torskelever fra Bømlo i Ytre Selbjørnfjord. Det var signifikant nedadgående langtidstrend for SCCP i torskelever fra Indre Sørfjorden.

Bisfenol A og TBBPA ble ikke påvist i torskelever, og det kan derfor ikke konkluderes noe angående forskjeller mellom ulike områder langs kysten.

Alle konsentrasjoner av nonylfenol var lavere enn EQS-verdien i 2018. Det ble påvist konsentrasjoner av oktylfenol i torskelever høyere enn EQS-verdien, men siden EQS-verdien er mye lavere enn kvantifiseringsgrensen er det ikke mulig å klassifisere dette stoffet på en god måte.

Det ble analysert for siloksaner i torskelever, og 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 siloksan D6.

Det var lave konsentrasjoner av dekloraner, og i mange tilfeller var nivået lavere enn kvantifiseringsgrensen. Det var noe høyere nivå av dekloraner i torsk fra Indre Oslofjord enn i torsk fra Bergen havn.

Konsentrasjoner av miljøgifter i blåskjell

Blåskjell fra Odderøya i Kristiansandsfjorden hadde høyest konsentrasjon av bly i denne undersøkelsen, og overskridelsen var mer enn 20 ganger høyere enn PROREF. Det var signifikant oppadgående langtidstrend og kortidstrend for bly i blåskjell fra Gressholmen i Indre Oslofjord. Det var signifikant oppadgående langtids- og korttidstrend for krom i blåskjell fra Gressholmen i Indre Oslofjord og fra Brashavn i Varangerfjorden.

Konsentrasjoner av PCB-7 i blåskjell overskred både EQS og PROREF ved alle stasjonene. Den høyeste PCB-7 konsentrasjonen var i blåskjell fra Gressholmen i indre Oslofjord.

Blåskjell fra tre stasjoner i midtre og ytre del av Sørfjorden hadde konsentrasjon av DDE som var mer enn 20 ganger høyrere enn PROREF. To andre stasjoner i dette området 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.

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 Lastad i Søgne, som ligger nær en småbåthavn. Ingen blåskjellstasjoner overskred EQS for antracen, fluoranten, benzo(a)pyren, naftalen eller benzo(a)antracen. Det var overkridelser av PROREF for KPAH ved alle stasjonene. Blåskjell ved Akershuskaia overskred PROREF for antracen, 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.

I 2018 var alle konsentrasjonene av HBCD i blåskjell lavere enn miljøkvalitetsstandarden (EQS). Det var høyest konsentrasjon av α-HBCD i blåskell fra Bodø havn. Det ble funnet nedadgående nivåer for HBCD i blåskjell, bl.a. var det signifikant nedadgående langtidstrend for HBCD i blåskjell fra Gressholmen i Indre Oslofjord.

Det var høyest konsentrasjoner av kortkjedete klorparafiner (SCCP) og mellomkjedete klorparafiner (MCCP) i blåskjell fra Bodø havn. Det ble påvist signifikant oppadgående langtids- og korttidstrend for SCCP i blåskjell fra Svolvær.

Bisfenol A og tetrabrombisfenol A ble ikke påvist i blåskjell i denne undersøkelsen.

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

Konsentrasjonene av kvikksølv (Hg) i blod og egg hos ærfugl på Svalbard i 2018 var omtrent på samme nivå som i en sammenliknbar studie fra indre Oslofjord i 2017. Konsentrasjonene av PCB-7 er 10-14 ganger høyere i henholdsvis blod og egg i indre Oslofjord i 2017 enn på Svalbard i 2018. Konsentrasjonene av BDE 47 var åtte ganger høyere i ærfugl egg fra indre Oslofjord i 2017 enn på Svalbard i 2018. PFOS konsentrasjonene i ærfugl blod og egg er 10 ganger høyere i indre Oslofjord enn på Svalbard i 2018.

Biologiske effekter
ICES/OSPARs vurderingskriterium for bakgrunnsnivå[2] («background assessment criteria», BAC) for OH-pyren i torskegalle ble overskredet på alle undersøkte stasjoner (Indre Oslofjord, Farsund-området og Indre Sørfjorden), inkludert referansestasjonen (Bømlo-Sotra området) i 2018, og dette viser at fisken har vært eksponert for PAH. Median-konsentrasjonen av OH-pyren metabolitter i galle i torsk fra Indre Oslofjord og Indre Sørfjorden var signifikant lavere i 2018 enn i 2017, med høyest konsentrasjon i torsk fra Oslofjorden.

I 2018 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 Ytre Selbjørnfjord på Bømlo.

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

I 2018 var median EROD-aktivitet i lever fra Indre Oslofjord og Indre Sørfjorden lavere enn referanse stasjonen (ytre Selbjørnfjord på Bømlo). Høy aktivitet av hepatic cytochrome P4501A (EROD-aktivitet) skjer normalt som en respons på plane organiske molekyler som PCB'er, PAH-forbindelser og dioksiner. Selv om det var høyere konsentrasjoner av OH-pyren (indikator på PAH-eksponering) i galle av torsk fra indre Oslofjord og indre Sørfjorden enn på referansestasjonen, så var det ikke tilsvarende høyt nivå for EROD-aktivitet. EROD-aktiviteten var lavere enn ICES/OSPARs bakgrunnsvurderingsnivå (BAC). Konsentrasjoner over dette nivået ville indikere mulig påvirkning fra plane PCBer, PCNer, PAHer eller dioksiner.

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 2018 bekreftet disse resultatene, bortsett fra at det ble funnet ett individ med imposex i Karmsundet (VDSI=0.129). Det var signifikante langtidstrender for TBT ved seks av åtte stasjoner. Den synkrone nedgangen i både TBT-konsentrasjoner og imposex-parametere i purpursnegl startet da bruk av TBT ble forbudt siden 2008. Resultatene indikerer at forbudet mot bruk av TBT har vært effektivt.

Stabile isotoper

Stabile isotoper av nitrogen (uttrykt som $\delta_{15}N$) er analysert for å tolke en organismes posisjon i næringskjeden. Resultatene viste veldig like isotop-signaturer i 2018 som i årene 2012-2017. Dette tyder på at den romlige trenden er stabil over tid og at isotopsignaturer i muslinger gir verdifull informasjon om bakgrunnsnivået for isotopsignaturer langs norskekysten. Det må tas hensyn til geografiske forskjeller i bakgrunnsnivå for isotopsignaturer når en skal tolke akkumulering av miljøgifter i forhold til trofisk nivå. Data for stabile isotoper ($\delta_{15}N$) i torsk er vurdert i sammenheng med konsentrasjoner av utvalgte miljøgifter. I hovedsak spiser fisk større byttedyr etterhvert som de vokser, og dette medfører ofte overgang til høyere trofisk nivå. Det ble funnet økende konsentrasjon av kvikksølv (miljøgifter med kjente biomagnifiserende egenskaper) med økende nivå av $\delta_{15}N$, dvs. høyere konsentrasjoner i individer på noe høyere trofisk nivå.

Contents

1. Introduction

1.1 Background

The programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) is administered by the Norwegian Environment Agency (*Miljødirektoratet*). The programme focuses on the levels, trends and effects of hazardous substances in fjords and coastal waters, which also represents the Norwegian contribution to the Coordinated Environmental Monitoring Programme (CEMP). CEMP is a common 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.

The objective for the performed monitoring 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.

Concentrations of hazardous substances in sediment, pore water, mussels and fish constitute time-integrating indicators for the quality of coastal water. Many of these substances tend to accumulate in tissues (bioaccumulation) in organisms and show higher concentrations relative to their surroundings (water and in some cases sediment). Hence, it follows that substances may be detected, which would otherwise be difficult to detect when analysing water or sediment only. Using concentrations in biota as indicators, as opposed to using water or sediment, are of direct ecological importance as well as being important for human health considerations and quality assurance related to commercial interests involved in harvesting marine resources. 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).

MILKYS applies the OSPAR CEMP methods. 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 included monitoring in sediment (Green et al. 2010a) and to a larger degree biota, the main emphasis being:

- Oslofjord-area, including the Hvaler area, Singlefjord and Grenlandfjord area, since 1981.
- Sørfjord/Hardangerfjord since 1987.
- Orkdalsfjord area and other areas in outer Trondheimfjord, 1984-1996 and 2004-2005.
- Arendal and Lista areas since 1990.
- Lofoten area since 1992.
- Coastal areas of Norway's northern most counties Troms and Finnmark since 1994.
- Bergen since 2015
- Svalbard since 2017

The previous investigations have shown that the Inner Oslofjord area has elevated levels of polychlorinated biphenyls (PCB-7) in cod liver, mercury, lead and zinc in sediments and elevated concentrations of mercury 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, mercury and lead. Investigations in Orkdalsfjord focused on three blue mussel stations. The results from these investigations have been reported earlier Green *et al.* (2007; 2008).

It can be noted that environmental status has in previously 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 (NorwegianEnvironmentAgency 2016), 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 the monitoring of Oslofjord area and Sørfjord/Hardangerfjord, MILKYS also includes the annual monitoring of contaminants at selected stations in Lista and Bømlo areas on the south and west coast of Norway, 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. The sampling also includes fish 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 reference areas, areas that are considered to be little affected by contaminants, and to assess possible temporal trends.

Biological effects methods (BEM) or biomarkers were introduced in the Norwegian MILKYS in 1997. The purpose of these markers is, by investigations on molecular/cell/individual level, to give warning signals if biota is affected by toxic compounds and to assist in establishing an understanding of the specific mechanisms involved. The reason to use biological effects methods within monitoring programmes is to evaluate whether marine organisms are affected by contaminant inputs. Such knowledge cannot be derived from 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 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 divided into three issues of concern: levels, trends and effects. Different monitoring strategies are used, especially with regards to the selection of indicator media (blue mussel, snail, cod liver etc.) and selection of contaminants to be monitored. Sample frequency is annual for biota. 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. 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.

Choice of contaminants for each station has changed considerably after 2011. Pesticides and dioxin analyses have since been discontinued except for DDTs at some stations in the Sørfjord/Hardangerfjord. However, many new contaminant analyses 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. The Norwegian Pollution and Reference Indices (Green, Heldal, et al. 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 not included in the 2018 investigations, however, in 2018 siloxane was also investigated at the cod station in Varangerfjord in addition to those investigated previously.

Due to the change in the programme, many time series have been discontinued since 2012. However, independent funding from the Norwegian Ministry of Climate and Environment ensured that some of these time series have been maintained after 2012. This involved extra analyses (mostly pesticides) of MILKYS-samples, as well as collection and analyses at additional stations. These stations included blue mussel (eight stations) and flatfish (three stations). However, in 2017 one blue mussel station and two flatfish stations were discontinued, and from 2018 six more blue mussel stations, all seven are exclusive to Ministry, will be discontinued.

All the results are publicly available. The results for flatfish are not included in this report, but they are included in the submission to ICES and the national database *Vannmiljø*[3] (including results for the eider duck). This additional funding from the Ministry also ensured that investigation of biological effect in cod from the Inner Sørfjord and from Bømlo on the West Coast could be continued. The results for blue mussel and cod from these investigations are included in this report.

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, 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 of Coastal Waters (*Økosystemovervåking i kystvann* (ØKOKYST)), Environmental Contaminants in an Urban Fjord (*Miljøgifter i en urban fjord*) as well as MAREANO[4] and Arctic Monitoring and Assessment Programme (AMAP)[5]. The first three programmes are operated by NIVA on behalf of Norwegian Environment Agency.

1.2 Purpose

An aim of the Norwegian Environment Agency is to obtain an overview of the status and trends of the environment as well as to assess the importance of various sources of pollution. The Norwegian Environment Agency seeks to develop a knowledgebase for the public and for the management of the environment.

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

[4] 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.

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

MILKYS is used as a tool to promote "cessation of discharges, emissions and losses of hazardous substances by the year" (OSPAR[6]) This will be accomplished through:

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 and is designed to address issues relevant to OSPAR (2014) including OSPAR priority substances (OSPAR 2007). The programme will also contribute to the demands on Norway by the EU 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. 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).

[6] See https://www.ospar.org/work-areas/hasec/chemicals

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. In addition, microplastics were investigated in blue mussel from 17 stations.

Samples were collected during 2018 and analysed according to OSPAR guidelines (OSPAR 2003, 2012)[7] 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 2018-programme also included investigation of contaminants in the common eider (*Somateria mollissima*).

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 2***).

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

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

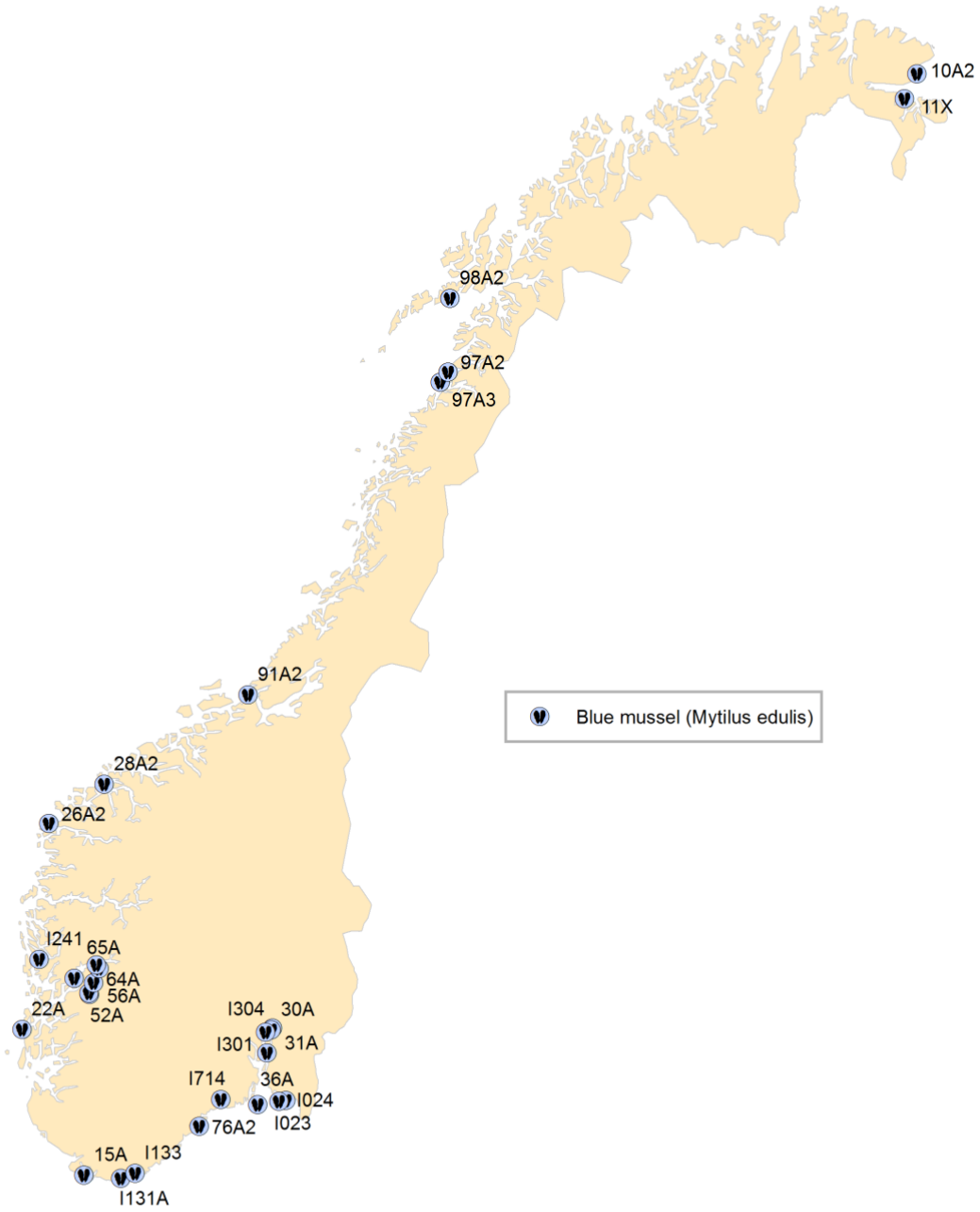


***Figure 1**. Stations where blue mussel were sampled in 2018. See also station information in detailed maps in **Appendix D**.*

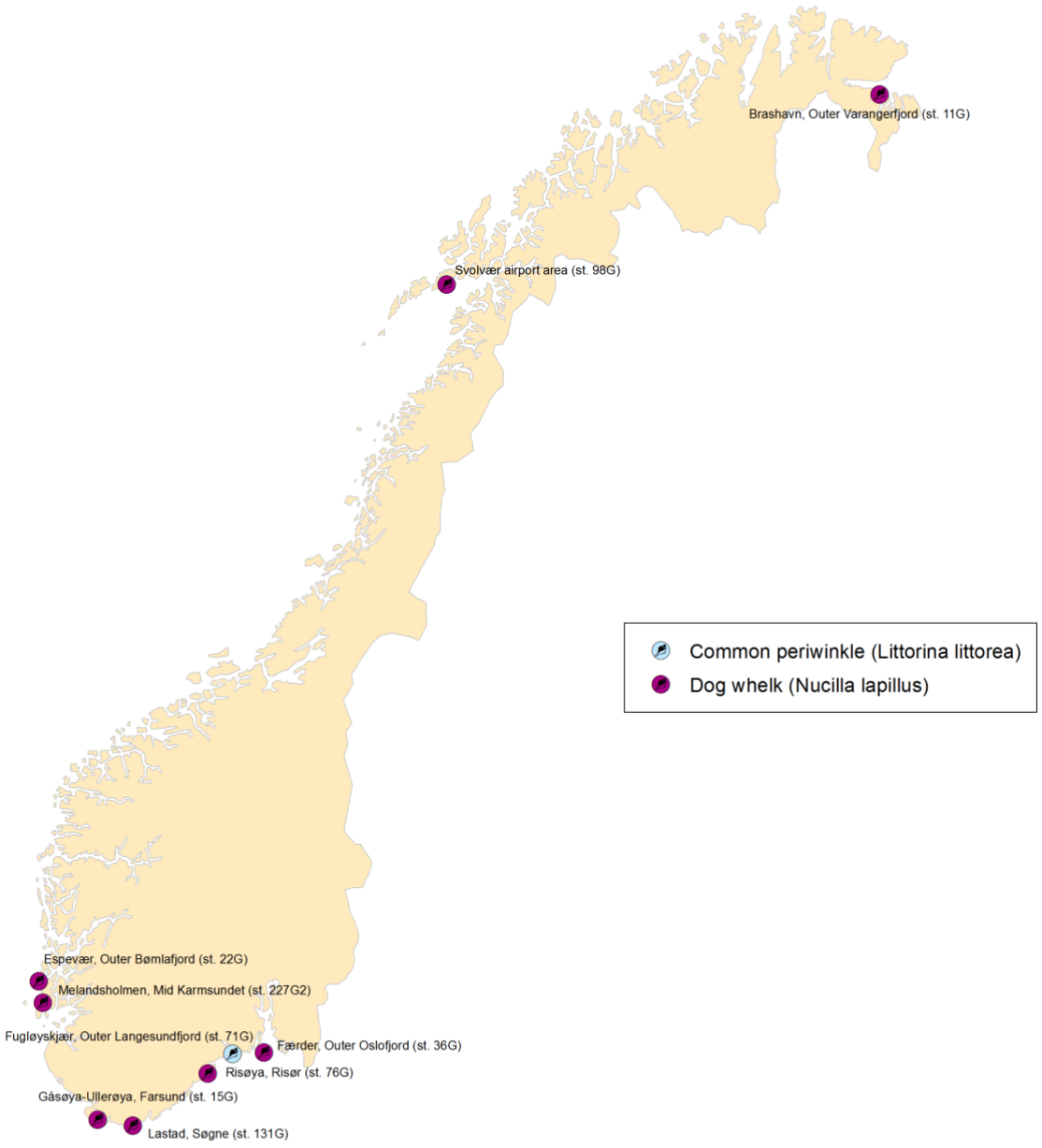


***Figure 2**. Stations where dogwhelk and common periwinkle were sampled in 2018. See also station information in detailed maps in **Appendix D**.*

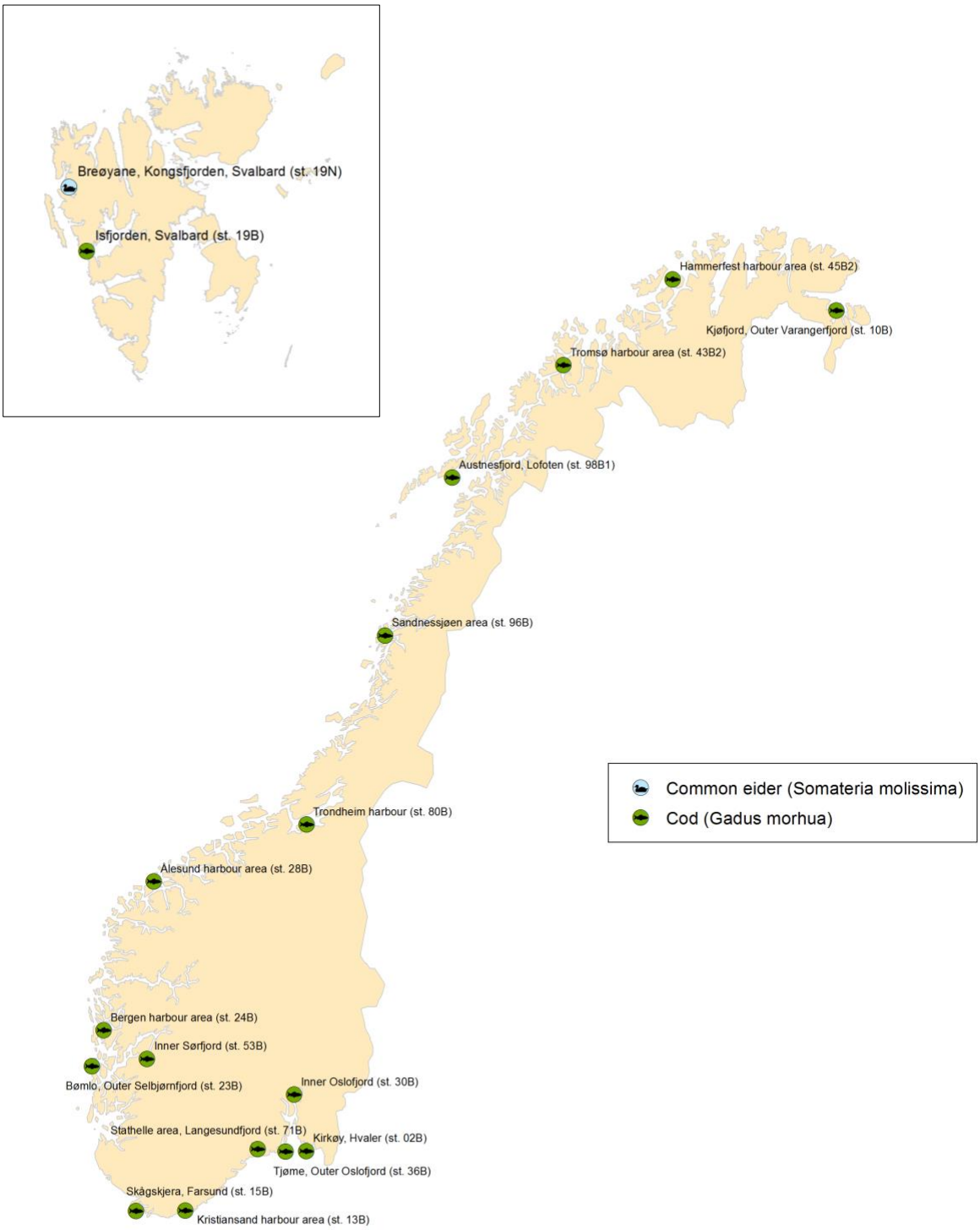


***Figure 3**. Stations where cod and the common eider were sampled in 2018. Note insert map of Svalbard and see also station information in detailed maps in **Appendix D**.*

2.1.2 Blue mussel

A sufficient number of individuals for three pooled samples of blue mussel were found at nearly all of the 28 stations, including the seven stations funded directly by the Ministry of Climate and Environment[8]. The exceptions being one station with no samples (Bjørkøya st. 71A). 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 3rd September to 20th November 2018. 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.

For certain stations prior to the 2012-investigations the intestinal canal was cleared for contents (depuration) in mussels following OSPAR guidelines (OSPAR 2012), cf. (Green, Schøyen, 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)). This practice 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 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 31st August to 9th November 2018.

[8] 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.

2.1.4 Atlantic cod

At least 15 individuals of Atlantic cod were sampled at most of the 17 stations, the exception being Kirkøy at Hvaler (st. 02B) where only 8 individuals were caught (***Figure 3***).

The cod were sampled from 16th August 2017 to 9th November 2018. 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 fisherman 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 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 1***), 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 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**). Ålesund harbour area (st. 28B), Trondheim harbour (st. 80B), Sandnessjøen area (st. 96B), Tromsø harbour (st. 43B2), Hammerfest harbour area (st. 45B2) and the reference station Isfjorden, Svalbard (st. 19B) were the six 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. 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.

2.1.5 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 during the period 16th to 23rd June 2018 (***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 2017-samples is shown in ***Table 2***. Note that the table also includes an overview of some supplementary investigations funded by the Ministry of Climate and Environment that are relevant to this report.

Table 2*. Analyses and target organisms of 2018. The value indicates the total number of stations investigated of which those funded by the Ministry of Climate and Environment as a supplement are indicated in parentheses*. (See also* ***Appendix B*** *for complete list of chemical codes.)*

Parameter	Blue mussel	Dogwhelk	Common periwinkle	Cod liver	Cod 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)	33 (8)			17		1	1
Mercury (total Hg)	33 (8)				17	1	1
Organotin (MBT, DBT, TBT, TPT)	7 (7)	8	1				
PCB-7 (PCB28, -52, -101, -118, -138, -153, and -180**)**	31 (8)			15		1	1
HCB, OCS, 5CS**	8 (8)			8 (7)			
∑DDT (p-p`-DDT, p-p`-DDE, p-p`-DDD**)**	19 (8)			7 (6)			
PAH-16******							
ACNE, ACNLE, ANT, BAA, BAP, BBJF, BGHIP, BKF, DBA3A, FLE, FLU, ICDP, NAP, PA, PYR	10						
Polybrominated diphenyl ethers (PBDEs)							
BDE28, 47, 99, 100, 126, 153, 154, 183, 196 and 209	10			10		1	1
Hexabromocyclododecane (HBCDs: α-, ß-, γ-HBCD**)**	9			12		1	1
Perfluorinated alkylated substances (PFAS)							
PFNA, PFOA, PFHpA, PFHxA, PFHxS, PFOS, PFBS, PFOSA				9		1	1
Supplementary analyses of 80 stored samples 1990-2009				1			
PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoA, PFTrDA, PFTeDA, PFPeDA, PFBS, PFPS, PFHxS, PFHpS, PFOS, 8Cl-PFOS, PFNS, PFDS, PFDoS, PFOSA, meFOSA, etFOSA, meFOSE, etFOSE, 4:2 FTS, 6:2 FTS, 8:2 FTS, 10:2 FTS, 12:2 FTS, FOSAA, meFOSAA, etFOSAA,							
Chlorinated paraffins (SCCP (C10-C13) and MCCP (C14-C17)**)**	10			12		1	1
Alkylphenoln (Octylphenol, nonylphenol**)**	8			11		1	1
Tetrabrombisphenol A (TBBPA)	10			11		1	1
Bisphenol A (BPA)	10			11		1	1
Siloxanes (D4, D5, and D6)				4		1	1
Dechlorane plus				5			
DBALD, DDC_ANT, DDC_BBF, DDC_CO, DDC_DBF, DDC_PA, DDC_PS, HCTBPH,							

*) Supplementary investigations previously funded by the Ministry of Climate and Environment involved additional analyses on samples from blue mussel stations 30A, I301, I304, 31A, 36A1, 71A, I712, 51A, 56A, 65A, 22A, 10A2 and 11X; cod stations 30B, 36B, 15B, 53B, 23B, 98B1 and 10B; as well as all analyses (except for microplastics) for blue mussel stations: 35A, 52A, 57A, 63A, 69A, I133, I306, I307. This support by the Ministry has been discontinued and in part taken up by the Norwegian Environment Agency.

**) Analyses exclusive for investigations funded by the Ministry of Climate and Environment and are not assessed in this report.

***) Homogenate of yolk and albumin.

****) Chrysene (CHR) has been discontinued.

An overview of the applied analytic methods is presented in ***Table 3***. 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 13)***. Mercury was analysed on a fillet sample from each cod. Furthermore, Biological Effects Methods (BEM) were performed on individual cod.

***Table 3**. 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 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	**NIVA/EFM**	0.001 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
cadmium (Cd)	7440-43-9	**NILU**	0.002 mg/kg	20 %	Standard method	ISO 17025, accredited
copper (Cu)	7440-50-8	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
copper (Cu)	7440-50-8	**NILU**	0.06 mg/kg	20 %	Standard method	ISO 17025, accredited
lead (Pb)	7439-92-1	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
lead (Pb)	7439-92-1	**NILU**	0.01 mg/kg	20 %	Standard method	ISO 17025, accredited
zinc (Zn)	7440-66-6	**NIVA/EFM**	0.5 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
zinc (Zn)	7440-66-6	**NILU**	0.5 mg/kg	20 %	Standard method	ISO 17025, accredited
silver (Ag)	7440-22-4	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
silver (Ag)	7440-22-4	**NILU**	0.02 mg/kg	20 %	Standard method	ISO 17025, accredited
arsenic (As)	7440-38-2	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
arsenic (As)	7440-38-2	**NILU**	0.03 mg/kg	20 %	Standard method	ISO 17025, accredited
chrome (Cr).	7440-47-3	**NIVA/EFM**	0.02 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
chrome (Cr).	7440-47-3	**NILU**	0.03 mg/kg	20 %	Standard method	ISO 17025, accredited
nickel (Ni)	7440-02-0	**NIVA/EFM**	0.04 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
nickel (Ni)	7440-02-0	**NILU**	0.03 mg/kg	20 %	Standard method	ISO 17025, accredited
cobalt (Co)	7440-48-4	**NIVA/EFM**	0.005 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
cobalt (Co)	7440-48-4	**NILU**	0.002 mg/kg	20 %	Standard method	ISO 17025, accredited
tin (Sn)	7440-31-5	**NIVA/EFM**	0.1 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
tin (Sn)	7440-31-5	**NILU**	0.5 mg/kg	30 %	Standard method	ISO 17025, accredited
Total-Hg	7439-9-76	**NIVA/EFM**	0.005 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	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB28	7012-37-5	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025
PCB52	35693-99-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB52	35693-99-3	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB101	37680-73-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB101	37680-73-2	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB118	31508-00-6	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB118	31508-00-6	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB138	35065-28-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB138	35065-28-2	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB153	35065-27-1	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB153	35065-27-1	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
PCB180	35065-29-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB180	35065-29-3	**NILU**	0.02-0.2 µg/kg	25 %	Standard method	ISO 17025, accredited
p-p`DDT	50-29-3	**NIVA/EFM**	0.2 µg/kg low fat. 4 µg/kg high fat	60 %	Internal method	ISO 17025
p-p`DDE	82413-20-5	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
p-p`DDD	72-54-8	**NIVA/EFM**	0.1 µg/kg low fat. 2 µg/kg high fat	50 %	Internal method	ISO 17025
PBDEs						
BDE47	5436-43-1	**NIVA/EFM**	0.005 µg/kg mussels. 0.1 µg/kg high fat	30 %	Internal method	ISO 17025
BDE47	5436-43-1	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE99	60348-60-9	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE99	60348-60-9	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE100	189084-64- 8	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE100	189084-64- 8	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
BDE126*	366791-32-4	**NIVA/EFM**	0.01 µg/kg mussels	50 %	Internal method	ISO 17025
BDE126*	366791-32-4	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE153	68631-49-2	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE153	68631-49-2	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE154	207122-15-4	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE154	207122-15-4	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE183	207122-16-5	**NIVA/EFM**	0.03 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025
BDE183	207122-16-5	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE196	32536-52-0	**NIVA/EFM**	0.05 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025
BDE196	32536-52-0	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE209	1163-19-5	**NIVA/EFM**	0.5 µg/kg mussels. 0.5 µg/kg high fat	50 %	Internal method	ISO 17025
BDE209	1163-19-5	**NILU**	1.0 µg/kg	30-45 %	Internal method	ISO 17025
α, ß, γ-HBCD	134237-50-6 (α isomer), 134237-51-7 (ß isomer), 134237-52-8 (γ isomer)	**EF-GFA**	0.006 ng/g	40 %	Internal method, validated	ISO 17025
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	ISO 17025
Tetrabrombisphenol A (TBBPA)	79-94-7	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
		NILU	3-15 µg/kg	30-40 %	Internal method	ISO 17025
Bisphenol A (BPA)	80-05-7	**EF-GFA**	1-5 ng/g	40 %	Internal method, validated	ISO 17025
		NILU	3-15 µg/kg	30-40 %	Internal method	ISO 17025
PFAS						
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	**EF-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**	0.3-30 µg/kg	>50 %	Internal method	ISO 17025
MCCP (C14-C17)	85535-85-9	**EF-GFA**	5-10 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
MCCP (C14-C17)	85535-85-9	**NILU**	0.3-30 µg/kg	>50 %	Internal method	ISO 17025

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
Acrylphenols						
Octylphenol	27193-28-8 (1806-26-4, 67632-66-0, 140-66-9,)	**EF-GFA**	10-50 ng/g	40 %	Internal method, validated	ISO 17025
Octylphenol	27193-28-8 (1806-26-4, 67632-66-0, 140-66-9,)	**NILU**	0.5-1 µg/kg	30-40 %	Internal method	ISO 17025
4-nonylphenol	104-40-5 (25154-52-3, 84852-15-3)	**EF-GFA**	10-50 ng/g	40 %	Internal method, validated	ISO 17025
4-nonylphenol	104-40-5 (25154-52-3, 84852-15-3)	**NILU**	0.5-1 µg/kg	30-40 %	Internal method	ISO 17025
Tin compounds						
Monobutyltin (MBT)	2406-65-7 (78763-54-9)	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Dibutyltin (DBT)	1002-53-5	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Tributyltin (TBT)	688-73-3	**EF-GFA**	0.5 ng/g	30 %	Internal method, validated	ISO 17025
Triphenyltin (TPT)	668-34-8	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Siloxane						
Octamethylcyclo-tetrasiloxane (D4)	556-67-2	**NILU**	2.7 µg/kg	20 %	Internal method	ISO 17025
Decamethylcyclo-pentasiloxane (D5)	541-02-6	**NILU**	1.5 µg/kg	20 %	Internal method	ISO 17025
Dodecamethylcyclo-hexasiloxane (D6)	540-97-6	**NILU**	1.5-2.0 µg/kg	20 %	Internal method	ISO 17025
Dichlorane plus						
Dibromoaldrin		**NILU**	Ca. 0.076 µg/kg	20 %	Internal method	ISO 17025
Dechlorane 601		**NILU**	Ca. 0.012 µg/kg	20 %	Internal method	ISO 17025
Dechlorane 602		**NILU**	Ca. 0.006 µg/kg	20 %	Internal method	ISO 17025
Dechlorane 603		**NILU**	Ca. 0.291 µg/kg	20 %	Internal method	ISO 17025
Dechlorane 604		**NILU**	Ca. 0.020 µg/kg	20 %	Internal method	ISO 17025
Dechlorane plus syn		**NILU**	Ca. 0.080 µg/kg	20 %	Internal method	ISO 17025
Dechlorane plus anti		**NILU**	Ca. 0.122 µg/kg	20 %	Internal method	ISO 17025
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

2.2.2 Laboratories and brief method descriptions

The 2018-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 3***). 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 chromium, 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 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 NILU analyses of PCB-7 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[9] (***Table 4***).

Table 4*. The seven suggested PCB-congeners (the sum is denoted as PCB-7), which according to OSPAR (2018) 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 EFM 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 3***).

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**).

[9] Several marine conventions (e.g. OSPAR and HELCOM[9]) use ΣPCB-7 to provide a common basis for PCB assessment.

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 2017/2018. Results are given based on the total extractable fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

Samples for NILU analyses of PBDE and chlorinated paraffins (SCCP/MCCP) 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 2018 (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. Determination of bisphenol A (BPA) and tetrabromobisphenol A (TBBPA) were done at Eurofins GFA by GC-MS while hexabromocyclododecane (α, ß, γ-HBCD) were determined by LC-MS-MS also by Eurofins GFA.

Samples for NILU analyses of chlorinated paraffins (SCCP/MCCP) 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. Samples of alkylphenols and bisphenols were extracted with organic solvents, cleaned up with SPE before determination on LC-QTOF-MS or LC-TOF-MS.

Siloxanes, i.e. octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed by NILU – Norwegian Institute for Air Research. 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.

Dechlorane plus was analyzed by NILU, with the same extraction methods as described for their analyses of PCB-7, brominated flame retardants and SCCP/MCCP. Antioxidant MB1 was analyzed using GC-MS.

For fish, the target tissues for quantification of hazardous substances were liver and fillet (***Table 2***), whereas for the biological effects methods (BEM) liver, blood, and bile were used (cf. ***Table 5***). 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 was measured. These measurements were stored in the database and published periodically.

The dogwhelk were analysed for organotin compounds (see ***Table 3***).

2.3 Biological effects analysis

Four biological effects methods (BEM) are assessed using methods described by ICES (see ***Table 3***) 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 5***. 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 5*. 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.

Imposex (on dogwhelk) and intersex analysis (on the common periwinkle) are a measure of effects of TBT, and are usually performed on fresh samples, but can be performed after that 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 3***). 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 2018 included four biological effects methods (BEM) (cf. ***Table 5***). 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 on dogwhelks and common periwinkles. This impact is assessed when dogwhelks and the common periwinkles are analysed for imposex and intersex[10], respectively see ***Table 3***).

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 2018-samples. The results are acceptable. These QUASIMEME exercises

[10] 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 2017 samples (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.

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. 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 ratio s were expressed in δ notation as the deviation from standard (Ruus et al. 2015).

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) 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 half value is shown. It should be noted that the LOQ can vary within and among sets of samples 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 10***, ***Table 11***). 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 (NorwegianEnvironmentAgency 2016).

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 background dossiers for the EQS (2013/39/EU 2013) as well as the national environmental quality standards (NorwegianEnvironmentAgency 2016) applied foodstuff limits if these are lower than the limits found by assessing risk of secondary poisoning or 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 implemented.

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. 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 2018-investigations addresses the principle cases primarily where median concentrations exceeded EQS and secondarily where median concentrations exceeded PROREF (***Table 10***, ***Table 11***). 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 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 data for 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 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.
    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
    i. All the raw data from the reference stations for the unique combination of contaminant, species, tissue and basis for the period 1991-2016 were used.
    j. 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 6***. PROREF values have been adjusted slightly since 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 6***, **Appendix C**).

In this report assessment of the change in PROREF from 2017 to 2018 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, ALAD in cod. PROREF could not be calculated for three PCBs (PCB81, PCB126 and PCB169), PFAS and acrylphenols 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 0.622 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 third 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 6**. 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*] (NorwegianEnvironmentAgency 2016) (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 wt. Basis	PROREF-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
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
CB_S7	Mytilus edulis	**Soft body**	10A2,41A,11X,98A2,64A,97A2	**6**	194	µg/kg	1.157	0.4891	0.4228	0.600	0.5187
DDEPP	Mytilus edulis	**Soft body**	43A,41A,10A2,11X	**4**	147	µg/kg	0.224	0.2240	1.0000	610.000	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	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
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	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
FLU	Mytilus edulis	**Soft body**	98A2,I023	**2**	32	µg/kg	5.350	5.3500	1.0000	30.000	5.6075
NAP	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
CB_S7	Gadus morhua	**Liver**	98B1,10B,92B,43B	**4**	1229	µg/kg	614.000	614.0000	1.0000	0.600	0.0010
DDEPP	Gadus morhua	**Liver**	23B,10B,98B1	**3**	1498	µg/kg	160.750	160.7500	1.0000	610.000	3.7947
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
HBCDA	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	7.000	7.0000	1.0000	167.000	23.8571
BDE6S	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	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

Parameter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
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	**Muscle**	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 (NorwegianEnvironmentAgency 2016). 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 (2016) 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 p,p DDE.
6*) Apply 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*) Not official EQS for BDE47, but this PBDE is often the most dominant BDE.
8*) Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa).

Proposed background assessment criteria (BAC) for EROD, OH-pyrene, and VDSI (OSPAR 2013) were used to assess the results (***Table 7***).

Table 7*. 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	0.7*	-	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 0.7 ng/ml or by a factor of about 30.

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 E**. 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 mercury in cod filet from the Inner Oslofjord was examined more closely (Green et al. 2015).

The model approach uses a Loess[11] 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_+

[11] Derived from the term “locally weighted scatter plot smooth”, e.g. used in linear regression.

is ≥7, one tests whether there is a significant difference in the smoothed annual concentration at 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. A case in point is shown for SCCP; *with no adjustment for cod length (**Figure 60 A**) the p-value for the trend analysis is 0.0592, whereas when adjusted for cod length (**Figure 60 B**) the p-values is 0.0379, and hence significant*.

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.

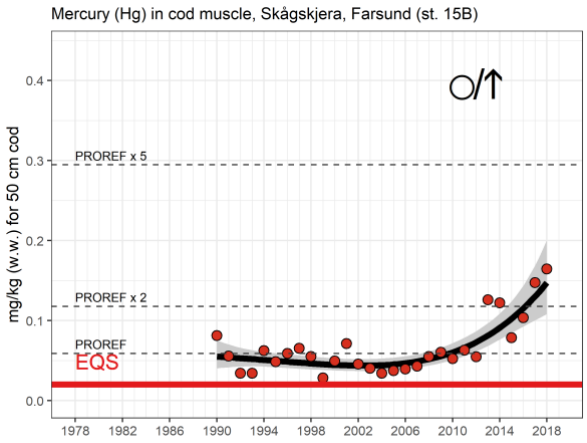


***Figure 4**. Example of time series (Hg in cod fillet from Skågskjera, Farsund, normalized for length) that show the median concentration (dots), running mean of median values (Loess smoother – thick black line) and 95 % confidence intervals surrounding the running mean (grey zone). A horizontal thick 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, and a grey dot indicates that EQS can not be applied. The horizontal dashed grey lines indicate the lower boundaries relative to PROREF[12]; where exceedances are indicated, by a factor of: <2, 2-5, 5-10, 10-20 and greater than 20 (the latter three categories are not shown in the figure, cf. **Table 26**). A light blue triangle (see for example **Figure 17 A**) 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 2009-2018 (short-term or recent trend) and the result is shown after the slash. A small filled square (▪) 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 (★) 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 Other statistical analyses

Trend analyses on supplementary investigations of PFAS were performed on log-normal-transformed concentrations using the statistical package JMP Statistical Discovery™ from SAS. Values below the LOQ were treated in the same way as described above (see **Chapter 2.6**).

Specific analyses to test the differences between stations or years was done on the JMP statistical package 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.

[12] 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.

2.10 Note on presentation of contaminant tables

Summaries of the results for some organic contaminants are presented in ***Table 13*** to ***Table 19***. These tables provide some extensive details and warrant explanation. Some of the analyses, especially of the "new" contaminants (e.g. HBCD, SCCP/MCCP, BPA, TBBPA, alkyphenols), 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 13*** is shown below in ***Table 8*** 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 10 samples whereof all 7 were pooled with a maximum of four fish livers in each pool. This means that analyses were done on three individual cod (10-7=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 blue mussel from Gressholmen is blank and indicates that none of the three values were above LOQ, whereas for the eider duck egg, the D.d.i. indicates that only three of the 15 samples of eggs had concentrations of BDE28 above LOQ and these ranged from 0.0084 to 0.0691 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**). Also note that when there are only three samples the median can be the minimum or maximum of this range shown by the "D.d.i.".

Table 8*. Example table – extract from* ***Table 13****. 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 one half of 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	2018	Med.	S.d.	D.d.i
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.002	0.000	
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.002	0.000	
Cod, liver				
Inner Oslofjord (st. 30B)	10 (7-4)	0.579	0.658	10 (0.386-2.33)
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	0.408	0.203	15 (0.227-0.94)
Eider, blood				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.016	0.002	
Eider, egg				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.008	0.016	3 (0.0084-0.0691)

3. Results and discussion

3.1 General information on measurements

A summary of the levels and trends of selected set of contaminants or their effects in Atlantic cod, blue mussel, dogwhelk and common periwinkle along the coast of Norway in 2018 is shown in ***Table 10*** and ***Table 11***. More details on trend analyses for the entire monitored period that include results from either 2017 or 2018 are shown in **Appendix F**. The results from 2018 present data for a total of 3049 data sets (contaminant[13]-station-species-tissue) on 133 different contaminants excluding supplementary analyses of dechlorane plus compounds and other PFAS. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period[14], whereas a short-term trend refers to the analysis on data for the last 10 years, i.e. 2009-2018 and can also be referred to as recent trend.

Assessment of levels and time trend analyses were performed on a selection of 30 representative contaminants (only levels were reported for the common eider[15]) or their effect (VDSI), and totalled 713 data series[16] for the 2018 data (***Table 9***). Of the 713 cases, 323 cases could be classified against EQS, of which 203 (62.8 %) were below the EQS and 120 (37.2 %) were above the EQS (***Figure 5 A***). Of the 713 cases, 641 could be compared to PROREF, and of these 463 (72.2 %) were below PROREF. Of the 641 cases, 173 of these (27.8 %) exceeded PROREF: 117 (18.3 %) by a factor of less than two, 45 (7.0 %) by a factor between two and five, eight (1.2 %) by a factor between five and 10, four (0.6 %) by a factor between 10 and 20, and four (0.6 %) by a factor greater than 20 (***Figure 5 B***). Of the 713 data series recent and significant trends were registered in 102 cases: 79 (11.1 %) were downwards trends and 23 (3.2 %) were upwards (***Figure 5 C***). The downward trends were primarily associated with metals (27.8 %), tributyltin (TBT, 7.6 %) and VDSI (the effect of TBT) (5.1 %), but also PFOS (8.9 %) and PFOSA (7.6 %) (***Figure 6 C***). The upward trends were also mainly associated with metals (78.3 %), primarily Hg (17.4 %).

Primary focus was on those cases where median concentrations in 2018 were over EQS and, secondarily, on those cases where provisional high reference concentration (PROREF) were exceeded, and where significant upward trends were found, and to a lesser degree where no significant trends or significant downward trends were found. The evaluation also focused to a lesser degree on cases where median concentrations in 2018 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 (2016).

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

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

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

[15] 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.

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

***Table 9**. Selection of representative contaminants and number of time series assessed for each target species-tissue. Counts include supplementary investigations funded by the Ministry of Climate and Environment and are marked with an asterisk " * " 1*. The specific results are shown in **Table 11**.*

1*) Eggs homogenate of yolk and albumin.

Contaminant /BEM	Description	Blue mussel	Dog whelk, periwinkle	Cod, liver	Cod fillet	Eider, blood	Eider, egg*	TOTAL
Ag	Silver	26		17		1	1	45
Cd	Cadmium	26		17		1	1	45
Co	Cobalt	26		17		1	1	45
Cr	Chromium	26		17		1	1	45
Hg	Mercury	28			17	1	1	47
Ni	Nickel	26		17		1	1	45
Pb	Lead	26		17		1	1	45
PCB-7	sum of PCB congeners 28+52+101+118+138+153+180	26		16		1	1	44
DDEPP	p,p'-DDE (a DDT metabolite)	17		7				24
HBCDA	α—hexabromocyclododecane	11		13		1	1	26
BDE6S	sum of PBDE congeners 28+47+99+100+153+154	11		11		1	1	24
BDE47	p,p'-DDE (a DDT metabolite)	11		11		1	1	24
BDE100	α—hexabromocyclododecane	11		11		1	1	24
BDE209		11		11		1	1	24
SCCP		11		13		1	1	26
MCCP		11		13		1	1	26
PAHs (P_S)	sum nondicyclic PAHs	7						7
KPAHs (PK_S)	sum carcinogen PAHs	7						7
ANT	anthracene	7						7
BAA	benzo[a]anthracene	7						7
B[a]P	benzo[a]pyrene	7						7
FLU	fluoranthene	7						7
NAP	naphthalene	7						7
PFOA	perfluorooctanoic acid	7		10		1	1	19
PFOS	perfluorooctanesulfonic acid	7		10		1	1	19
PFOSA	perfluorooctanesulfonamide	7		10		1	1	19
TBT	tributyltin (formulation basis)	7	9					16
TPTIN	triphenyltin	7	9					16
VDSI	Vas Deferens Sequence Index		9					9
D5	decamethylcyclopentasiloxane			5		1	1	7
TOTAL		**388**	**27**	**243**	**17**	**19**	**19**	**713**

*) Egg homogenate of yolk and albumin

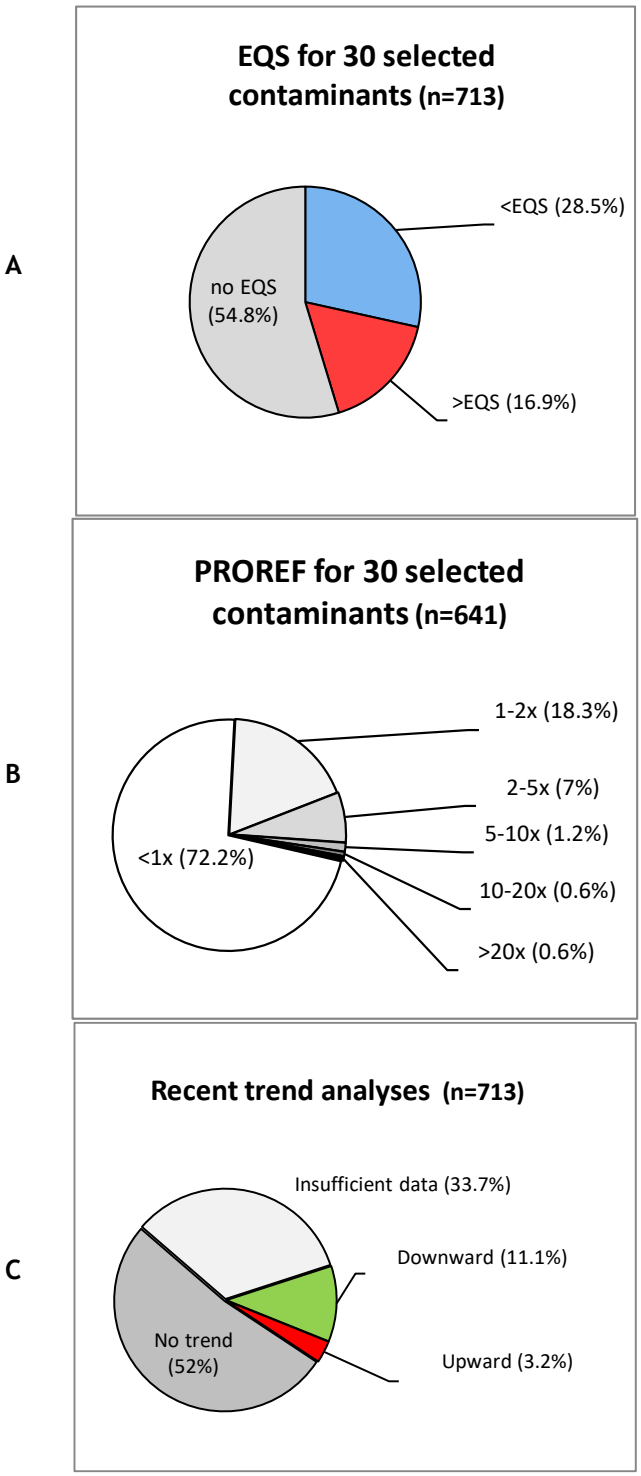


Figure 5. *Summary of frequency of exceedance to EQS (**A**), Norwegian provisional high reference contaminant concentration (PROREF) (**B**) and the results from short-term trend analyses (**C**) and for 30 selected contaminants (excluding results from the common eider, cf.* ***Table 9****).*

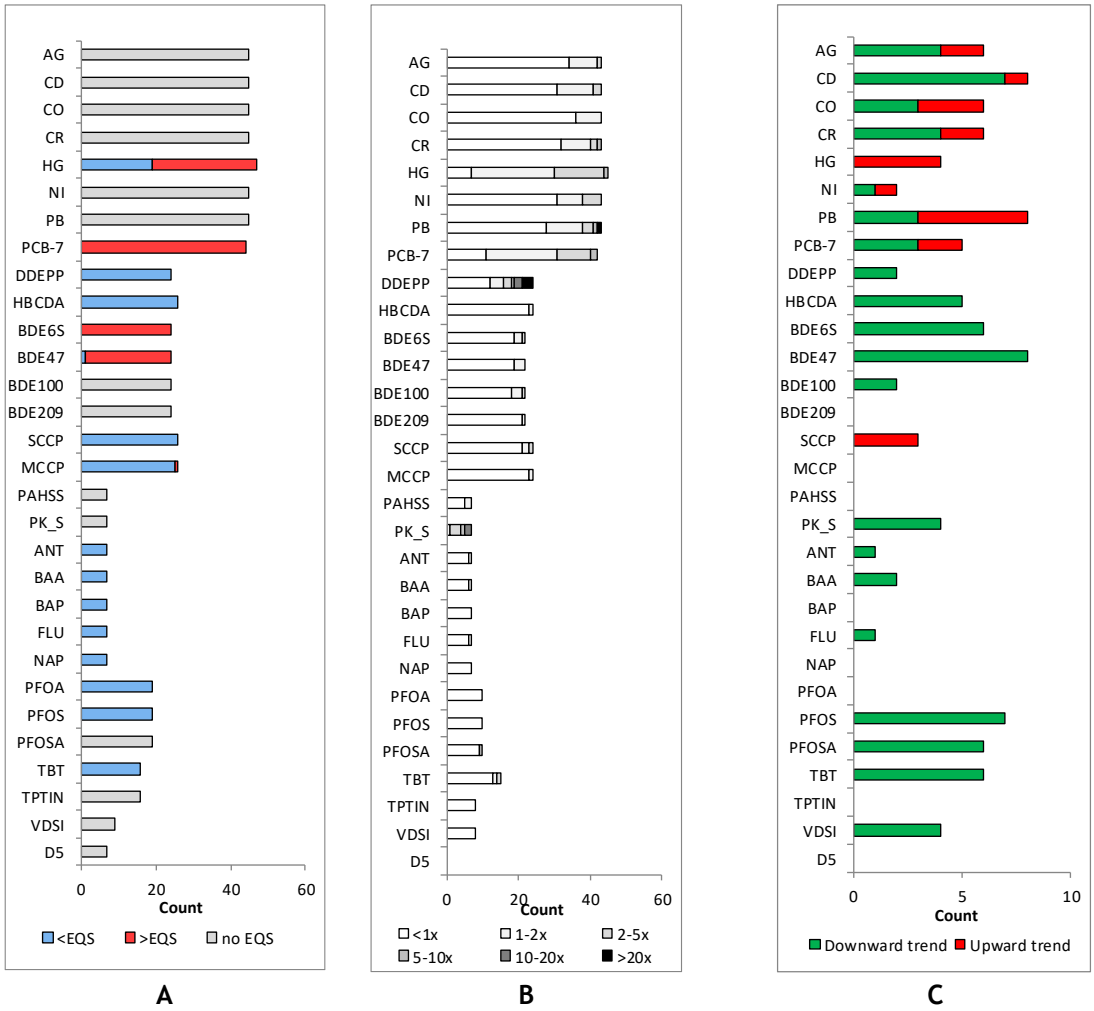


Figure 6. *Summary of frequency of exceedance to EQS (**A**), Norwegian provisional high reference contaminant concentration (PROREF) (**B**) and short-term trends (**C**) and for each of the 30 selected contaminants (excluding results from the common eider, cf.* ***Table 9****, (see* ***Appendix B*** *for description of chemical codes).*

Table 10. *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 2018 in five species: blue mussel, cod, 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 no exceedances and red-filled circles indicate exceedances of EQS with respect to Environmental Quality Standards from the Water Framework Directive (WFD), cf. Environmental Quality Standard Directive-(2013/39/EU 2013) or national quality standards (*) by Norwegian Environment Agency (2016) for hazardous substances in "biota" 1. Abbreviations for contaminants can be seen in* ***Appendix B****.*

Station name	Species	Tissue***	HG***	PCB-7**	DDEPP*	4-N-NP*	4-N-OP*	HBCDA*	BDE6S*	BDE47	SCCP*	MCCP*'	ANT*	BAA**	BAP*	FLU*	NAP*	PFOA*'	PFOS*	TBT*	TPTIN*	D5*
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	●	●																		
Sylterøya, Langesundfjord (st. I714)	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	●	●																		
Byrkjenes, Inner Sørfjord (st. 51A)	Blue mussel	Soft body	●	●	●													●	●			
Eitrheimsneset, Inner Sørfjord (st. 52A)	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	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●			
Skallnes, Outer Varangerfjord (st. 10A2)	Blue mussel	Soft body	●	●	●																	
Brashavn, Outer Varangerfjord (st. 11X)	Blue mussel	Soft body	●	●	●																	

Station name	Species	Tissue***	HG* ***	PCB-7**	DDEPP*	4-N-NP*	4-N-OP*	HBCDA*	BDE6S*	BDE47	SCCP*	MCCP*'	ANT*	BAA**	BAP*	FLU*	NAP*	PFOA*'	PFOS*	TBT*	TPTIN*	D5*
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	●	●		●	●	●	●	●	●	●										
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	●	●																		
Kjøfjord, Outer Varangerfjord (st. 10B)	Cod	Liver	●	●	●																	●
Svalbard (st. 19B)	Cod	Liver	●	●		●	●	●	●	●	●	●						●	●			●
Breøyane (st. 19N)	Eider duck	Blood	●	●				●	●	●	●	●						●	●			●
Breøyane (st. 19N)	Eider duck	Egg	●	●				●	●	●	●	●						●	●			●
Fugløyskjær, Outer Langesundfjord (st. 71G)	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 i measured in fillet

***Table 11**. Assessment of levels and trends of median concentrations of contaminants with respect to PROREF in samples collected in 2018 in five species: blue mussel, cod, eider duck, common periwinkle and dogwhelk.* Tissues: soft body (for blue mussel, dogwhelk and common periwinkle), liver (cod except for Hg) and fillet (cod, mercury). *The grey-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 *(see **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 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. (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**.*

Station name	Species	Tissue	AG	CO	CD	CR	HG	NI	PB	PCB-7	DDEPP	HBCDA	SCCP	MCCP	BDE47	BDE100	BDE209	BDE65	PAH-16	BKF	BGHIP	ICDP	BAP	FLU	NAP	PFOS	PFOA	PFOSA	TBT	TPTIN	VDSI	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/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	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	★/★	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	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪	🡇/★	▪/▪		
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	O/O	★/★	★/★	★/★	★/★	O/O	★/★							
Kirkøy, Hvaler (st. I024)	Blue mussel	Soft body	★/★	O/O	O/🡇	O/O	🡇/O	O/O	O/O	🡇/O																						
Bjørkøya, Langesundfjord (st. 71A)	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/O	O/O	★/★	★/★	O/O	★/★							
Sylterøya, Langesundfjord (st. I714)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪							
Risøy (st. 76A2)	Blue mussel	Soft body	★/★	O/O	O/O	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/★	★/★	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								▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪				🡇/🡇	★/★		
Gåsøya-Ullerøya, Farsund (st. 15A)	Blue mussel	Soft body	🡇/🡇	🡇/🡇	O/O	O/O	O/O	O/O	O/O	O/O																						
Byrkjenes, Inner Sørfjord (st. 51A)	Blue mussel	Soft body					🡇/O			🡇/O	O/O															▪/▪	▪/▪	▪/▪				
Eitrheimsneset, Inner Sørfjord (st. 52A)	Blue mussel	Soft body	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	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																					
Espevær, Outer Bømlafjord (st. 22A)	Blue mussel	Soft body	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	★/★	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	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	★/★	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	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	★/★	▪/▪	▪/▪	▪/▪				
Skallnes, Outer Varangerfjord (st. 10A2)	Blue mussel	Soft body	🡇/🡇	O/O	O/O	O/O	🡇/O	O/O	🡇/🡇	O/O	🡇/O																					
Brashavn, Outer Varangerfjord (st. 11X)	Blue mussel	Soft body	🡇/🡇	O/O	O/O	🡅/🡅	O/O	O/O	🡇/O	O/O	🡇/O																					

Station name	Species	Tissue	AG	CO	CD	CR	HG	NI	PB	PCB-7	DDEPP	HBCDA	SCCP	MCCP	BDE47	BDE100	BDE209	BDE65	PAH-16	BKF	BGHIP	ICDP	BAP	FLU	NAP	PFOS	PFOA	PFOSA	TBT	TPTIN	VDSI	D5
Inner Oslofjord (st. 30B)	Cod	Liver	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				
Kirkøy, Hvaler (st. 02B)	Cod	Liver	O/O	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	★/★	↓/↓								↓/↓	★/★	↓/↓				
Skågskjera, Farsund (st. 15B)	Cod	Liver	↑/↑	↑/↑	O/O	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/↓								↓/↓	★/★	↓/↓				
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/↓	★/★	↓/↓				
Bergen harbour area (st. 24B)	Cod	Liver	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪				▪/▪
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/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								↓/↓	★/★	↓/↓				
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/O	↓/↓	↓/↓	★/★	↓/↓								↓/↓	★/★	↓/↓				▪/▪
Hammerfest harbour area (st. 45B2)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	★/★	↓/↓																						
Kjøfjord, Outer Varangerfjord (st. 10B)	Cod	Liver	O/O	O/O	O/O	↓/↓	↓/O	O/O	O/↑	↓/O	↓/O																					▪/▪
Svalbard (st. 19B)	Cod	Liver	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪				▪/▪
Breøyane (st. 19N)	Eider duck	Blood	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪				▪/▪
Breøyane (st. 19N)	Eider duck	Egg	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪				▪/▪
Fugløyskjær, Outer Langesundfjord (st. 71G)	Periwinkle	Soft body																									↓/★		▪/▪		↓/▪	
Færder, Outer Oslofjord (st. 36G)	Dog whelk	Soft body																									↓/↓		★/★		↓/↓	
Risøya, Risør (st. 76G)	Dog whelk	Soft body																									↓/O		★/★		↓/O	
Lastad, Søgne (st. 131G)	Dog whelk	Soft body																									↓/★		★/★		↓/O	
Gåsøya-Ullerøya, Farsund (st. 15G)	Dog whelk	Soft body																									↓/★		★/★		↓/O	
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																									↓/O		★/★		↓/↓	
Brashavn, Outer Varangerfjord (st. 11G)	Dog whelk	Soft body																									★/★		★/★		O/O	

3.2 Levels and trends in contaminants

3.2.1 Overview of metals

In 2018, metals were analysed in blue mussels from 28 stations, in cod from 17 stations and in eider from one station (***Table 12***). They are discussed in more detail in **Chapters 3.2.2 - 3.2.11**, and only a brief summary is provided here.

EQS was only applicable for Hg, and it was exceeded at 28 (60 %) of these 47 stations (***Figure 6*** **A**). Applying PROREF to the 303 cases for metals, 65.7 % were below PROREF and the rest were above it, and only one (Pb) exceeded PROREF by a factor of more than 10 (***Figure 7 A***). Analyses showed that 66.6 % of the data series for metals indicated no short-term trends, but for 12.6 % of the series a significant trend was found; 6.9 % downward and 5.7 % upward (***Figure 7 B***).

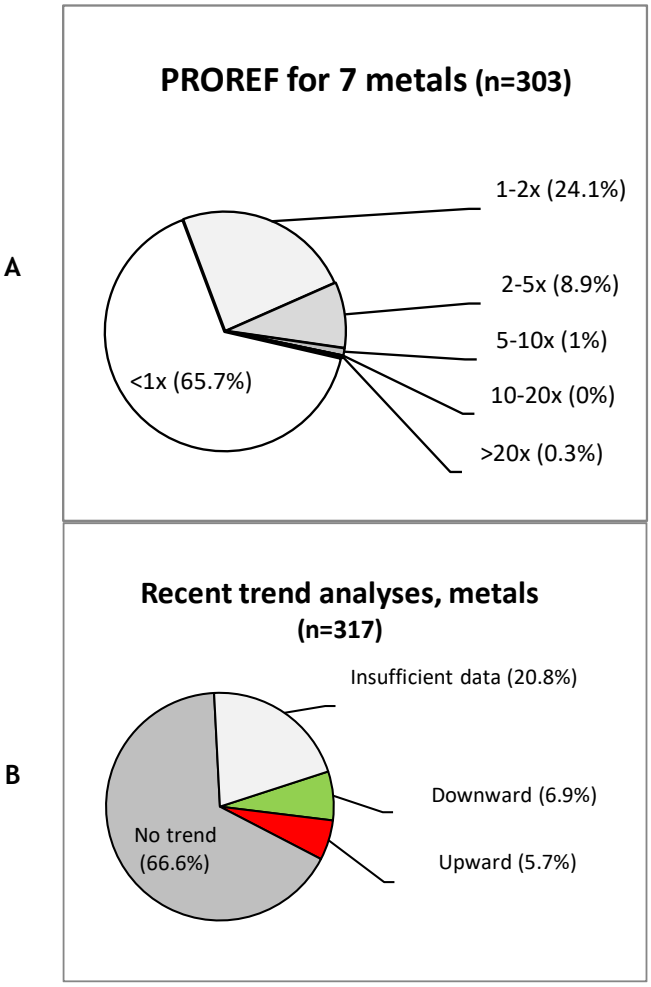


Figure 7. *Summary of frequency of exceedance to the Norwegian provisional high reference contaminant concentration (PROREF) (A) and the results from short-term trend analyses (**B**) and for 30 selected contaminants (excluding results from the common eider, cf.* ***Table 9****). Grey-shade coding in figure B refers to relation to PROREF[17] (cf.* ***Table 26***).

[17] 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 – 1467/1997) in previous reports.

***Table 12**. Median concentrations (µg/kg w.w.) and standard deviations for metals in blue mussel, cod liver, and eider blood and eggs in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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 also **Chapter 2.10** for more details and **Appendix B** for description of chemical codes.)*

Component	Count	AG			AS			CD			CO			CR			CU			HG			NI			PB			ZN		
Species and sampling locality	2018	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	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)	0.005	0.000	3 (0.0048-0.00	1.700	0.058	3 (1.7-1.8)	0.290	0.015	3 (0.27-0.3)	0.069	0.004	3 (0.069-0.076	0.540	0.084	3 (0.4-0.55)	0.740	0.026	3 (0.73-0.78)	0.019	0.001	3 (0.018-0.02)	0.330	0.042	3 (0.27-0.35)	0.340	0.045	3 (0.3-0.39)	24.000	1.155	
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.010	0.001	3 (0.0084-0.01	1.600	0.058	3 (1.6-1.7)	0.200	0.000	3 (0.2-0.2)	0.140	0.006	3 (0.14-0.15)	1.100	0.361	3 (0.9-1.6)	0.690	0.072	3 (0.65-0.79)	0.020	0.001	3 (0.02-0.021)	0.700	0.195	3 (0.62-0.99)	0.960	0.067	3 (0.87-1)	16.000	5.508	15 (9.2-41)
Gåsøya, Inner Oslofjord (st. I304)	3 (3-50)	0.004	0.002	2 (0.0041-0.00	1.900	0.173	3 (1.9-2.2)	0.260	0.021	3 (0.23-0.27)	0.084	0.001	3 (0.084-0.085	0.520	0.096	3 (0.49-0.67)	0.650	0.166	3 (0.6-0.91)	0.016	0.001	3 (0.016-0.017	0.420	0.067	3 (0.38-0.51)	0.330	0.123	3 (0.29-0.52)	29.000	3.055	
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	0.014	0.005	3 (0.0054-0.01	2.200	0.404	3 (1.9-2.7)	0.120	0.025	3 (0.1-0.15)	0.059	0.012	3 (0.059-0.079	0.200	0.653	3 (0.14-1.3)	0.770	0.093	3 (0.72-0.9)	0.015	0.001	3 (0.014-0.015	0.180	0.361	3 (0.17-0.8)	0.170	0.035	3 (0.13-0.2)	22.000	2.517	3 (1173.913-1380.952
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.004	0.001	1 (0.0052)	1.800	0.100	3 (1.7-1.9)	0.110	0.006	3 (0.11-0.12)	0.067	0.004	3 (0.062-0.069	0.300	0.072	3 (0.18-0.31)	0.620	0.012	3 (0.6-0.62)	0.013	0.001	3 (0.012-0.014	0.270	0.057	3 (0.19-0.3)	0.096	0.015	3 (0.093-0.12)	18.000	2.082	
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.004	0.000		2.000	0.153	3 (1.8-2.1)	0.190	0.015	3 (0.17-0.2)	0.088	0.007	3 (0.087-0.1)	2.000	1.015	3 (1.3-3.3)	0.890	0.040	3 (0.82-0.89)	0.021	0.002	3 (0.019-0.022	1.300	0.638	3 (0.84-2.1)	0.098	0.002	3 (0.096-0.1)	17.000	5.033	
Kirkøy, Hvaler (st. I024)	3 (3-50)	0.004	0.000		1.300	0.058	3 (1.3-1.4)	0.150	0.006	3 (0.15-0.16)	0.140	0.006	3 (0.14-0.15)	0.690	0.047	3 (0.67-0.76)	1.300	0.058	3 (1.3-1.4)	0.017	0.000	3 (0.017-0.017	0.610	0.012	3 (0.61-0.63)	0.190	0.010	3 (0.18-0.2)	20.000	1.528	3 (1769.2308-2900)
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.004	0.000		2.000	0.252	3 (1.7-2.2)	0.310	0.010	3 (0.3-0.32)	0.068	0.004	3 (0.062-0.07)	0.520	0.061	3 (0.42-0.53)	0.680	0.155	3 (0.63-0.92)	0.042	0.002	3 (0.04-0.044)	0.280	0.050	3 (0.23-0.33)	0.230	0.023	3 (0.19-0.23)	23.000	4.583	
Risøya, Risør (st. 76A2)	3 (3-50)	0.006	0.003	3 (0.0059-0.01	3.200	0.115	3 (3-3.2)	0.130	0.015	3 (0.11-0.14)	0.061	0.019	3 (0.06-0.094)	0.990	0.599	3 (0.074-1.2)	0.580	0.078	3 (0.54-0.69)	0.017	0.002	3 (0.013-0.017	0.700	0.386	3 (0.12-0.85)	0.160	0.050	3 (0.11-0.21)	14.000	3.055	
Lastad, Søgne (st. I131A)	3 (3-50)	0.008	0.005	2 (0.0075-0.01	2.400	0.361	3 (1.9-2.6)	0.170	0.040	3 (0.13-0.21)	0.062	0.008	3 (0.053-0.068	0.084	0.082	3 (0.072-0.22)	0.790	0.425	3 (0.74-1.5)	0.018	0.002	3 (0.016-0.02)	0.091	0.079	3 (0.076-0.22)	0.240	0.075	3 (0.18-0.33)	17.000	10.786	
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	0.004	0.000		1.700	0.058	3 (1.6-1.7)	0.200	0.000	3 (0.2-0.2)	0.110	0.006	3 (0.11-0.12)	0.600	0.078	3 (0.49-0.64)	0.910	0.023	3 (0.87-0.91)	0.025	0.002	3 (0.024-0.027	0.720	0.049	3 (0.64-0.73)	4.900	1.644	3 (2.4-5.5)	25.000	2.309	
Gåsøya-Ullerøya, Farsund (st. 15A)	3 (3-50)	0.006	0.002	3 (0.0046-0.00	2.300	0.058	3 (2.3-2.4)	0.140	0.015	3 (0.12-0.15)	0.062	0.006	3 (0.052-0.063	0.440	0.101	3 (0.43-0.61)	0.640	0.967	3 (0.61-2.3)	0.014	0.001	3 (0.014-0.015	0.410	0.159	3 (0.32-0.63)	0.310	0.029	3 (0.26-0.31)	25.000	2.082	3 (125-208.3333)
Byrkjenes, Inner Sørfjord (st. 51A)	3 (3-50)																			0.044	0.003	3 (0.041-0.047									
Eitrheimsneset, Inner Sørfjord (st. 52A)	3 (3-50)	0.010	0.001	3 (0.0082-0.01	1.900	0.000	3 (1.9-1.9)	0.370	0.032	3 (0.36-0.42)	0.081	0.005	3 (0.077-0.086	0.098	0.007	3 (0.097-0.11)	0.960	0.055	3 (0.87-0.97)	0.041	0.003	3 (0.038-0.043	0.110	0.006	3 (0.11-0.12)	1.500	0.400	3 (1.1-1.9)	27.000	1.528	
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)																			0.044	0.015	3 (0.04-0.067)									
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	0.006	0.001	3 (0.0057-0.00	1.600	0.321	3 (1.5-2.1)	0.180	0.052	3 (0.18-0.27)	0.065	0.002	3 (0.061-0.065	0.440	0.191	3 (0.17-0.54)	0.600	0.208	3 (0.53-0.92)	0.030	0.009	3 (0.023-0.041	0.320	0.131	3 (0.11-0.35)	0.520	0.165	3 (0.35-0.68)	11.000	1.155	15 (10-117.6471)
Utne, Outer Sørfjord (st. 64A)	3 (3-50)	0.007	0.001	3 (0.0056-0.00	1.800	0.100	3 (1.7-1.9)	0.170	0.021	3 (0.14-0.18)	0.068	0.005	3 (0.061-0.07)	0.700	0.114	3 (0.67-0.88)	0.810	0.083	3 (0.69-0.85)	0.020	0.002	3 (0.018-0.022	0.470	0.092	3 (0.47-0.63)	0.220	0.010	3 (0.21-0.23)	13.000	1.528	15 (10-57)
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	0.013	0.002	3 (0.013-0.016	2.400	0.569	3 (1.6-2.7)	0.150	0.015	3 (0.13-0.16)	0.050	0.006	3 (0.048-0.06)	0.150	0.123	3 (0.08-0.32)	0.860	0.156	3 (0.59-0.86)	0.020	0.004	3 (0.018-0.026	0.140	0.088	3 (0.064-0.24)	0.230	0.068	3 (0.13-0.26)	15.000	7.371	3 (1076.9231-1969.69
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.005	0.001	2 (0.0049-0.00	1.600	0.115	3 (1.6-1.8)	0.074	0.002	3 (0.073-0.077	0.043	0.008	3 (0.041-0.056	0.130	0.084	3 (0.12-0.27)	0.780	0.232	3 (0.65-1.1)	0.016	0.001	3 (0.015-0.017	0.160	0.062	3 (0.13-0.25)	0.140	0.026	3 (0.13-0.18)	12.000	1.000	
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.004	0.000	1 (0.004)	1.800	0.153	3 (1.7-2)	0.120	0.010	3 (0.11-0.13)	0.062	0.009	3 (0.049-0.065	0.270	0.282	3 (0.2-0.72)	1.100	0.100	3 (1-1.2)	0.020	0.003	3 (0.018-0.023	0.230	0.208	3 (0.16-0.55)	0.410	0.091	3 (0.38-0.55)	30.000	1.528	
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.004	0.000		1.900	0.058	3 (1.9-2)	0.110	0.008	3 (0.096-0.11)	0.041	0.005	3 (0.04-0.049)	0.079	0.065	3 (0.076-0.19)	0.900	0.065	3 (0.83-0.96)	0.018	0.001	3 (0.017-0.019	0.078	0.062	3 (0.069-0.18)	0.150	0.017	3 (0.12-0.15)	23.000	2.082	15 (11-33)
Ålesund harbour (st. 28A2)	3 (3-50)	0.004	0.000	2 (0.0044-0.00	2.900	0.252	3 (2.7-3.2)	0.120	0.015	3 (0.11-0.14)	0.058	0.006	3 (0.052-0.064	0.230	0.093	3 (0.18-0.36)	1.200	0.169	3 (0.97-1.3)	0.024	0.001	3 (0.023-0.024	0.310	0.059	3 (0.22-0.33)	0.240	0.020	3 (0.22-0.26)	26.000	2.309	
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	0.005	0.000	3 (0.0042-0.00	3.000	0.100	3 (2.9-3.1)	0.120	0.000	3 (0.12-0.12)	0.077	0.014	3 (0.074-0.1)	0.360	0.084	3 (0.35-0.5)	1.100	0.081	3 (0.96-1.1)	0.012	0.001	3 (0.012-0.013	0.240	0.067	3 (0.2-0.33)	0.130	0.006	3 (0.12-0.13)	14.000	1.528	
Bodø harbour (st. 97A3)	3 (3-50)	0.004	0.001	1 (0.0057)	1.900	0.058	3 (1.9-2)	0.120	0.006	3 (0.11-0.12)	0.059	0.017	3 (0.049-0.082	0.230	0.684	3 (0.2-1.4)	0.930	0.384	3 (0.77-1.5)	0.014	0.002	3 (0.012-0.015	0.250	0.377	3 (0.17-0.86)	0.230	0.060	3 (0.18-0.3)	24.000	4.041	3 (1818.1818-2100)
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.004	0.000		1.800	0.265	3 (1.7-2.2)	0.110	0.006	3 (0.11-0.12)	0.044	0.009	3 (0.035-0.053	0.240	0.029	3 (0.19-0.24)	0.750	0.031	3 (0.73-0.79)	0.016	0.001	3 (0.015-0.016	0.140	0.031	3 (0.12-0.18)	0.190	0.021	3 (0.16-0.2)	13.000	0.577	3 (1083.3333-1352.94
Svolvær airport area (st. 98A2)	3 (3-50)	0.005	0.001	3 (0.0048-0.00	2.000	0.058	3 (2-2.1)	0.210	0.006	3 (0.2-0.21)	0.041	0.002	3 (0.04-0.043)	0.220	0.035	3 (0.19-0.26)	0.820	0.026	3 (0.78-0.83)	0.015	0.001	3 (0.014-0.016	0.180	0.031	3 (0.16-0.22)	0.110	0.010	3 (0.1-0.12)	14.000	2.646	3 (1307.6923-3090.90
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.004	0.000		1.800	0.265	3 (1.7-2.2)	0.110	0.006	3 (0.11-0.12)	0.044	0.009	3 (0.035-0.053	0.240	0.029	3 (0.19-0.24)	0.750	0.031	3 (0.73-0.79)	0.016	0.001	3 (0.015-0.016	0.140	0.031	3 (0.12-0.18)	0.190	0.021	3 (0.16-0.2)	13.000	0.577	3 (1083.3333-1352.94
Brashavn, Outer Varangerfjord (st. 11X)	3 (3-50)	0.010	0.001	3 (0.0098-0.01	1.600	0.058	3 (1.5-1.6)	0.220	0.006	3 (0.22-0.23)	0.046	0.002	3 (0.044-0.047	0.210	0.046	3 (0.15-0.24)	0.660	0.031	3 (0.64-0.7)	0.010	0.000	3 (0.01-0.01)	0.270	0.032	3 (0.22-0.28)	0.052	0.005	3 (0.051-0.06)	12.000	0.577	3 (117.6471-135.2941
Skallnes, Outer Varangerfjord (st. 10A2)	3 (3-50)	0.011	0.001	3 (0.0087-0.01	1.500	0.058	3 (1.5-1.6)	0.430	0.006	3 (0.42-0.43)	0.053	0.002	3 (0.052-0.055	0.330	0.031	3 (0.31-0.37)	0.660	0.031	3 (0.64-0.7)	0.008	0.001	3 (0.007-0.009	0.320	0.025	3 (0.3-0.35)	0.110	0.010	3 (0.1-0.12)	15.000	8.386	14 (16-131.9149)

Table 12. *(cont.)*

Component	Count	AG			AS			CD			CO			CR			CU			HG			NI			PB			ZN		
Species and sampling locality	2018	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	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Cod, liver (all metals except Hg), filet (Hg)																															
Inner Oslofjord (st. 30B)	15	2.850	2.272	10 (1.6-7.7)	17.500	9.580	10 (3.7-33)	0.105	0.062	10 (0.035-0.2)	0.050	0.011	10 (0.029-0.062)	0.040	0.019	8 (0.034-0.093)	4.250	3.324	10 (0.96-13)	0.204	0.123	15 (0.064-0.475)	0.105	0.051	10 (0.048-0.21)	0.066	0.039	10 (0.039-0.14)	26.500	6.900	15 (16.3272-171.0729)
Tjøme, Outer Oslofjord (st. 36B)	15	1.200	2.098	15 (0.072-8.7)	6.000	3.016	15 (2.9-12)	0.043	0.075	15 (0.0099-0.31)	0.036	0.018	15 (0.012-0.075)	0.037	0.062	10 (0.03-0.26)	3.200	2.370	15 (1.2-9.1)	0.112	0.207	15 (0.063-0.845)	0.049	0.020	10 (0.042-0.11)	0.030	0.004	7 (0.031-0.044)	21.000	8.119	
Kirkøy, Hvaler (st. 02B)	8	0.350	0.233	4 (0.11-0.65)	4.850	4.424	4 (3.2-13)	0.053	0.032	4 (0.027-0.096)	0.053	0.016	4 (0.027-0.066)	0.083	0.032	4 (0.054-0.13)	2.750	3.122	4 (1.7-8.5)	0.143	0.034	8 (0.094-0.181)	0.071	0.035	3 (0.056-0.12)	0.030	0.000		30.500	16.269	3 (84.6154-92.8571)
Stathelle area, Langesundfjord (st. 71B)	15	0.320	0.239	15 (0.071-0.83)	3.500	1.965	15 (1.7-9.5)	0.039	0.019	15 (0.0066-0.07)	0.033	0.018	15 (0.013-0.072)	0.120	0.084	15 (0.047-0.35)	6.400	4.925	15 (2.1-21)	0.238	0.151	15 (0.132-0.626)	0.096	0.055	15 (0.051-0.26)	0.042	0.007	14 (0.034-0.056)	37.000	9.716	12 (13.1725-4577.3762
Kristiansand harbour area (st. 13B)	15	0.730	0.552	9 (0.073-1.9)	4.200	3.105	9 (1.8-12)	0.044	0.038	9 (0.0044-0.12)	0.030	0.030	9 (0.016-0.11)	0.031	0.030	5 (0.031-0.12)	7.400	4.226	9 (2.2-16)	0.140	0.069	15 (0.031-0.278)	0.085	0.033	8 (0.048-0.13)	0.034	0.006	7 (0.031-0.047)	40.000	10.876	3 (26-30)
Skågskjera, Farsund (st. 15B)	15	1.100	0.681	15 (0.51-3.2)	8.000	3.367	15 (3.9-16)	0.038	0.010	15 (0.022-0.055)	0.069	0.031	15 (0.025-0.13)	0.099	0.202	15 (0.049-0.86)	9.900	5.620	15 (7.4-25)	0.216	0.167	15 (0.084-0.781)	0.083	0.144	14 (0.048-0.62)	0.030	0.000		48.000	9.363	10 (25.8621-113.3333)
Inner Sørfjord (st. 53B)	15	0.170	0.151	15 (0.062-0.62)	2.800	0.787	15 (1.9-4.9)	0.042	0.029	15 (0.013-0.1)	0.022	0.011	15 (0.0079-0.037)	0.056	0.026	12 (0.036-0.11)	10.000	5.266	15 (5.6-23)	0.115	0.109	15 (0.083-0.428)	0.040	0.046	7 (0.048-0.19)	0.046	0.023	10 (0.031-0.1)	31.000	7.926	15 (12-46)
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.590	0.544	14 (0.049-2.2)	5.500	5.612	14 (1.8-22)	0.037	0.056	14 (0.01-0.18)	0.032	0.023	14 (0.0035-0.075)	0.062	0.025	13 (0.041-0.13)	7.650	5.173	14 (1.7-20)	0.153	0.084	15 (0.096-0.366)	0.041	0.018	7 (0.042-0.094)	0.030	0.006	6 (0.037-0.05)	37.000	14.675	3 (107.1429-135.7143)
Bergen harbour area (st. 24B)	15	0.120	1.739	12 (0.0075-6.2)	2.200	0.903	12 (0.72-4.4)	0.011	0.016	12 (0.0036-0.06)	0.019	0.011	12 (0.0038-0.039)	0.047	0.028	9 (0.034-0.11)	4.500	6.054	12 (0.52-19)	0.123	0.116	15 (0.019-0.473)	0.075	0.047	12 (0.053-0.23)	0.030	0.001	1 (0.035)	22.000	7.171	15 (16.2213-101.685)
Ålesund harbour area (st. 28B)	15	0.290	0.399	15 (0.094-1.3)	5.600	3.618	15 (2.5-13)	0.022	0.277	15 (0.0071-1.1)	0.024	0.022	15 (0.0059-0.095)	0.061	0.237	9 (0.051-0.97)	3.100	3.764	15 (0.65-15)	0.354	0.226	15 (0.113-0.867)	0.054	0.172	11 (0.041-0.72)	0.030	0.003	2 (0.033-0.042)	22.000	12.670	15 (15.7281-157.6256)
Trondheim harbour (st. 80B)	15	0.046	0.135	15 (0.0088-0.5)	4.500	4.416	15 (3-21)	0.011	0.026	15 (0.0039-0.077)	0.011	0.016	15 (0.0039-0.058)	0.030	0.015	7 (0.031-0.085)	2.200	1.581	15 (0.28-6.5)	0.098	0.061	15 (0.057-0.249)	0.061	0.066	10 (0.048-0.27)	0.030	0.000		14.000	9.535	
Sandnessjøen area (st. 96B)	15	0.410	1.297	15 (0.088-4.4)	7.900	9.248	15 (2.8-29)	0.069	0.125	15 (0.012-0.53)	0.023	0.017	15 (0.0039-0.059)	0.039	0.049	8 (0.039-0.19)	2.800	5.248	15 (0.86-21)	0.102	0.078	15 (0.061-0.351)	0.040	0.051	7 (0.054-0.2)	0.030	0.000		32.000	13.923	
Austnesfjord, Lofoten (st. 98B1)	15	0.083	1.207	12 (0.034-4.3)	3.150	3.674	12 (1.3-15)	0.042	1.084	12 (0.016-3.8)	0.014	0.079	11 (0.0044-0.28)	0.031	0.004	6 (0.031-0.04)	2.050	8.729	12 (0.23-32)	0.070	0.055	15 (0.038-0.215)	0.040	0.251	3 (0.043-0.91)	0.030	0.000		25.500	14.276	
Tromsø harbour area (st. 43B2)	15	0.350	0.928	15 (0.046-3.1)	4.100	1.508	15 (1.4-6.3)	0.150	0.420	15 (0.033-1.6)	0.016	0.038	15 (0.0041-0.16)	0.042	0.179	12 (0.03-0.73)	4.600	3.685	15 (1.4-14)	0.034	0.067	15 (0.017-0.285)	0.070	0.140	15 (0.042-0.6)	0.048	0.010	15 (0.037-0.07)	12.000	9.295	3 (440-700)
Hammerfest harbour area (st. 45B2)	15	0.180	0.172	15 (0.025-0.61)	4.200	2.109	15 (2.6-8.7)	0.110	0.037	15 (0.031-0.18)	0.018	0.009	15 (0.0083-0.042)	0.069	0.030	15 (0.038-0.12)	4.000	3.233	15 (1.5-14)	0.042	0.053	15 (0.018-0.236)	0.086	0.088	10 (0.044-0.27)	0.030	0.010	1 (0.067)	19.000	9.149	
Kjøfjord, Outer Varangerfjord (st. 10B)	15	0.380	0.152	8 (0.17-0.63)	5.200	3.436	8 (3.1-14)	0.190	0.058	8 (0.096-0.26)	0.021	0.006	8 (0.017-0.037)	0.084	0.030	8 (0.055-0.15)	2.650	1.520	8 (1.8-5.9)	0.033	0.014	15 (0.02-0.065)	0.079	0.042	8 (0.052-0.18)	0.038	0.003	7 (0.035-0.041)	17.500	6.042	14 (12.1035-63.5271)
Isfjorden, Svalbard (st. 19B)	15	0.150	0.170	15 (0.058-0.7)	3.700	1.424	15 (2.1-7.9)	0.110	0.042	15 (0.041-0.19)	0.016	0.014	15 (0.01-0.065)	0.064	0.290	13 (0.031-1)	1.900	1.821	15 (1.1-6.6)	0.032	0.027	15 (0.021-0.132)	0.064	0.203	14 (0.048-0.78)	0.039	0.006	15 (0.035-0.06)	11.000	6.574	3 (146.6667-208.3333)
Eider, blood																															
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.001	0.001	15 (4e-04-0.0027)	0.037	0.018	15 (0.0304-0.0854)	0.003	0.002	15 (0.001-0.0074)	0.002	0.002	15 (0.0011-0.008)	0.028	0.002	1 (0.0375)	0.454	0.068	15 (0.3859-0.601)	0.139	0.045	15 (0.0837-0.257)	0.016	0.000		0.044	0.045	15 (0.0236-0.206)	5.247	0.636	3 (20-25)
Eider, egg																															
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.006	0.005	15 (0.0016-0.017)	0.127	0.041	15 (0.0856-0.2035)	0.000	0.000		0.007	0.001	15 (0.0039-0.009)	0.026	0.034	3 (0.0294-0.1568)	0.894	0.138	15 (0.7008-1.154)	0.129	0.053	15 (0.0916-0.298)	0.015	0.005	4 (0.0178-0.0307)	0.005	0.003	15 (0.0013-0.011)	12.639	2.023	3 (245.8333-357.1429)

3.2.2 Mercury (Hg)

Mercury (Hg) is found naturally in the earth's crust. Mercury can be organic, inorganic or elemental, and has toxic effects on i*nter 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 is released. In the present study, Hg was analysed in blue mussel at 28 stations, in cod fillet at 17 stations and in eider blood and eggs at one station (***Table 2***).

Environmental Quality Standards (EQS) for priority substances

EU has provided EQS of 0.02 mg/kg w.w. in biota (cf. ***Table 6***). Applying this EQS for blue mussel, concentrations of Hg were above or at the EQS at Gressholmen (st. 30A, 0.020 mg/kg w.w.) in the Inner Oslofjord, at Singlekalven (st. I023) at Hvaler, at Sylterøya (st. I714, 0.042 mg/kg w.w.) in the Langesundfjord and at Odderøya (st. I133, 0.025 mg/kg w.w.) in the Kristiansandfjord (***Table 10***). This was also the case at Byrkjenes (st. 51A, 0.044 mg/kg w.w.), Eitrheimsneset (st. 52A, 0.041 mg/kg w.w.), Kvalnes (st. 56A, 0.044 mg/kg w.w.), Krossanes (st. 57A, 0.030 mg/kg w.w.) and Utne (st. 64A, 0.020 mg/kg w.w.) in the Sørfjord, and at Vikingneset (st. 65A, 0.020 mg/kg w.w.) in the Mid Hardangerfjord. Concentrations of Hg above or at the EQS were also observed at Nordnes (st. I241, 0.020 mg/kg w.w.) on the west coast and at Ålesund (st. 28A2, 0.024 mg/kg w.w.).

The EQS for biota (0.020 mg/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 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 (0.020 mg/kg w.w.) at all stations in 2018, also at the reference station (st. 19B) at Svalbard (***Table 10***).

Applying this EQS for eider blood and eggs, the Hg concentrations would have exceeded the EQS (***Table 10***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Hg by a factor between two and five times at Sylterøya (st. I714) in the Langesundfjord and at Odderøya (st. I133) in the Kristiansandfjord (***Table 11***). This was also the case at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A) in the Sørfjord. For blue mussel, the exceedances were a factor of up to two in the Oslofjord at Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Solbergstrand (st. 31A). This was also the result at Singlekalven (st. I023), Kirkøy (st. I024) and at Tjøme (st. 36A1) in the Outer Oslofjord. This was also the case at Risøy (st. 76A2) at Risør, Lastad (st. I131A) at Søgne and Gåsøya-Ullerøya (st. 15A) in Farsund. 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 at Vågsvåg (st. 26A2) in the Outer Nordfjord, 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 by a factor between five and 10 in Ålesund harbour (st. 28B). The exceedances were a factor between two and five in the Inner Oslofjord (st. 30B) and at Kirkøy (st. 02B) at Hvaler. This was also the case at Stathelle area in the Grenlandfjord (st. 71B),

Kristiansand harbour area (st. 13B), Skågskjera in Farsund (st. 15B), in the inner Sørfjord (st. 53B), Bømlo (st. 23B) and Bergen harbour (st. 24B). The exceedances were a factor up to two at Tjøme (st. 36B) in the Outer Oslofjord, Trondheim harbour (st. 80B), Sandnessjøen (st. 96B) and Austnesfjord in Lofoten (st. 98B1).

Increase in PROREF factor since 2017

Blue mussel at Gåsøya-Ullerøya in Farsund (st. 15A), Bodø harbour (st. 97A3) and Akershuskaia (st. I301) did not exceed the PROREF in 2017, while the exceedance was up to two times PROREF in 2018.

Cod fillet from Kirkøy at Hvaler (st. 02B) exceeded the PROREF by a factor up to two in 2017, while the exceedance was between two and five times in 2018. In 2017, the median concentration of cod fillet from Sandnessjøen (st. 80B) was below PROREF, while the exceedance was up to two times in 2018.

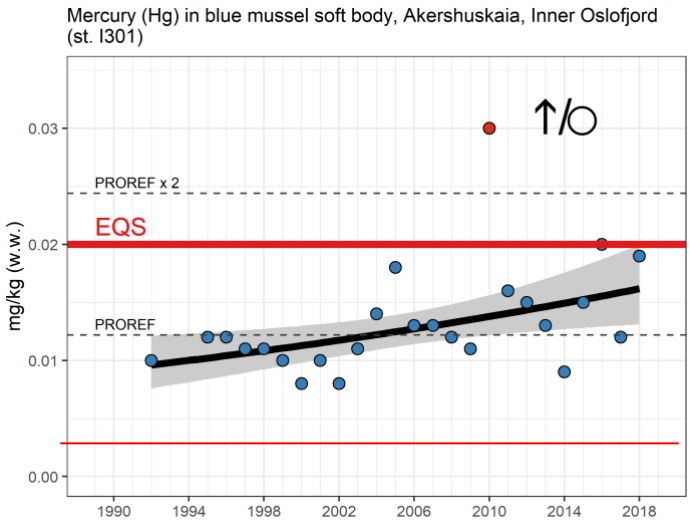
Upward trends

In blue mussel, a significant upward long-term trend was found at Akershuskaia (st. I301) in the Inner Oslofjord (***Figure 8 A***). A significant upward short-term trend was found at Eitrheimsneset (st. 52A) in the Inner Sørfjord (***Figure 8 B***).

In cod fillet, both significant upward long- and short-term trends were found in Kristiansand harbour (st. 13B) (***Figure 9 A***). Significant upward short-term trends were found at Skågskjera in Farsund (st. 15B) and at Bømlo (st. 23B) in the Outer Selbjørnfjord.

When fish-length was taken into account, cod fillet at Kristiansand harbour (st. 13B) also showed both significant upward long- and short-term trends (***Figure 9 B***) whereas significant upward short-time trends were found at Skågskjera (st. 15B) in Farsund (***Figure 10 A***), at Bømlo (st. 23B) (***Figure 10 B***) in the Outer Selbjørnfjord and at Kjøfjord (st. 10B) in the Outer Varangerfjord (***Figure 10 C***).

A



B

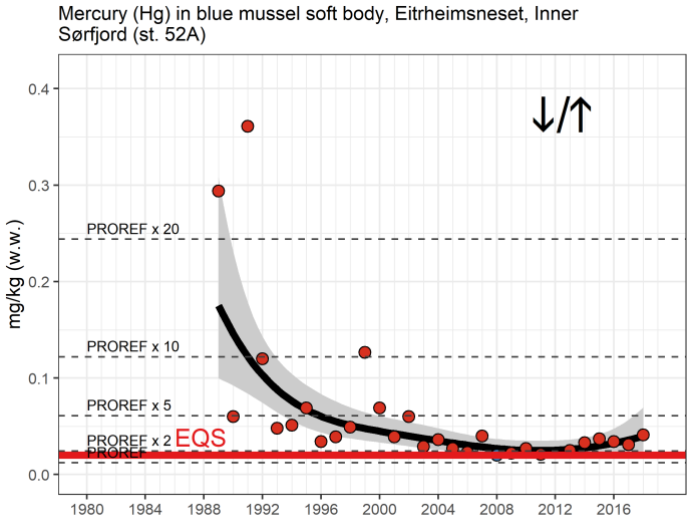
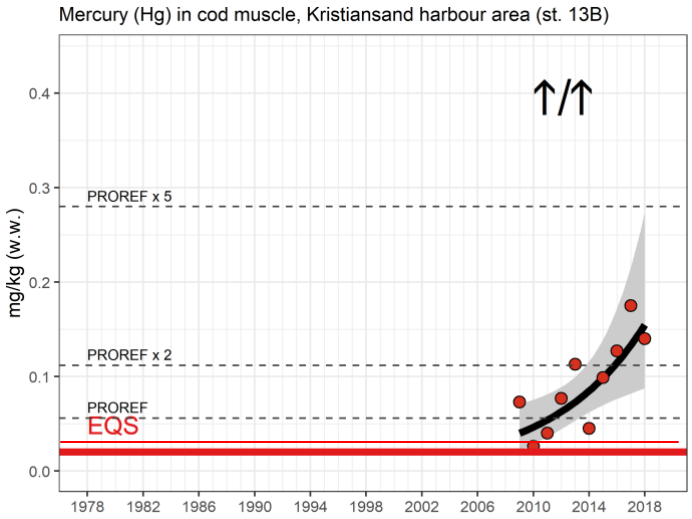


Figure 8. *Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from Akershuskaia (st. I301) in the Inner Oslofjord (***A***) and Eitrehimsneset (st. 52A) (***B***). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

A



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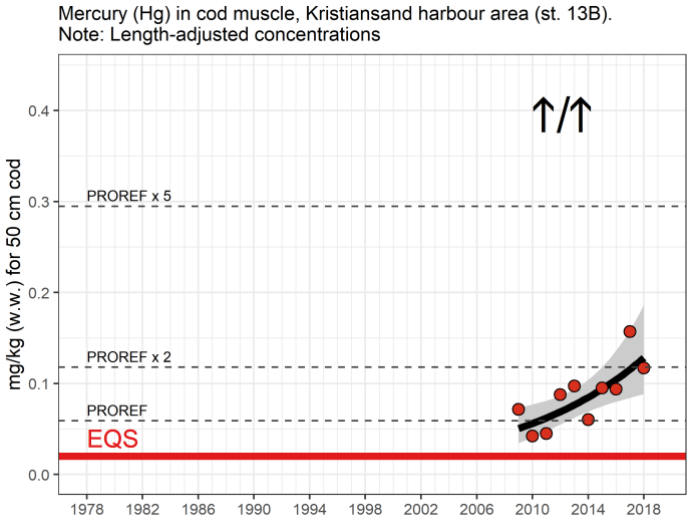
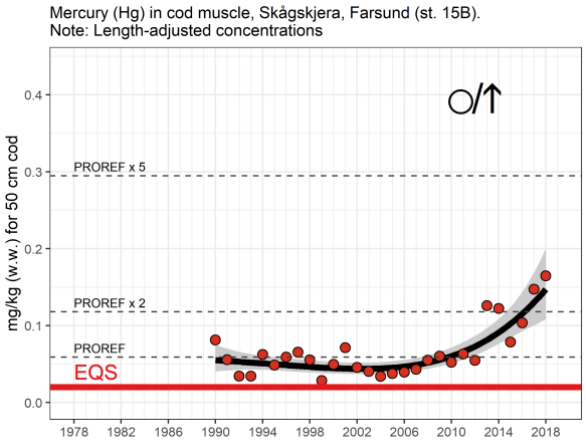
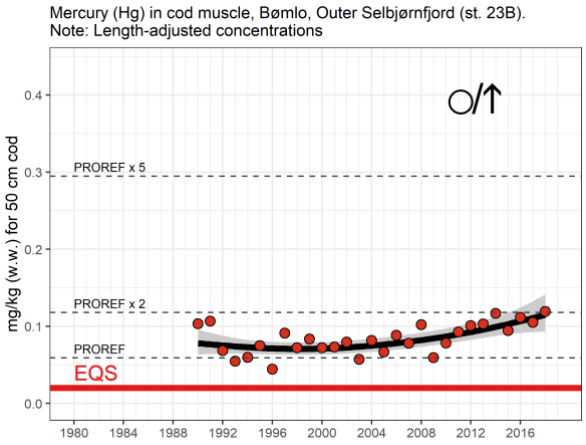


Figure 9. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Kristiansand harbour (st. 13B); no adjustment for length (***A***) and adjusted for length (***B***). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** *C).*

A



B



C

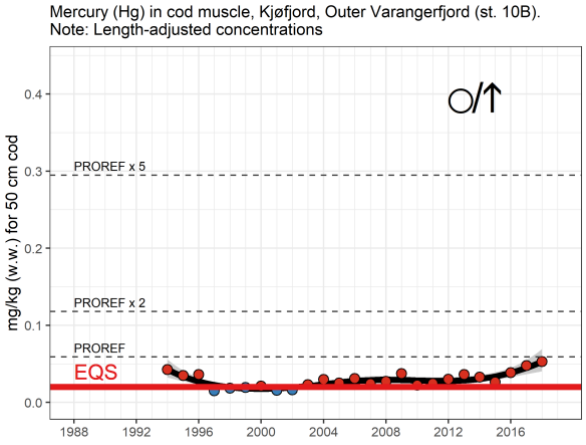


Figure 10. *Median concentrations (mg/kg w.w.) of mercury (Hg) adjusted for length in cod fillet from Skågskjera (st. 15B) in Farsund (**A**), Bømlo (st. 23B) in the Outer Selbjørnfjord (**B**) and Kjøfjord (st. 10B) in the Outer Varangerfjord (**C**). The EQS is indicated with a horizontal red line, and 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*).*

Decrease in PROREF factor since 2017

Blue mussel exceeded PROREF by a factor between two to five in 2017, and up to two times in 2018 at Kirkøy (st. I024) at Hvaler and Ålesund harbour (st. 28A2). The mussel at Ørland area (st. 91A2) in the Outer Trondheimfjord exceeded the PROREF by a factor up to two times in 2017, while there was no exceedance in 2018.

Cod fillet from the Inner Sørfjord (st. 53B) exceeded PROREF by a factor between five and 10 in 2017, and between two and five in 2018. Cod fillet from Trondheim harbour (st. 80B) exceeded PROREF by a factor between two and five in 2017, and below two in 2018.

Downward trends

In blue mussel, a significant downward long-term trend was found at Solbergstrand (st. 31A) in the Mid Oslofjord and at Kirkøy (st. I024) at Hvaler. This was also observed in the Sørfjord at Byrkjenes (st. 51A) (***Figure 11***), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A). The same result was seen at Skallnes (st. 10A2) in the Varangerfjord.

In cod fillet, a significant downward long-term trend was found at Kjøfjord (st. 10B) in the Outer Varangerfjord.

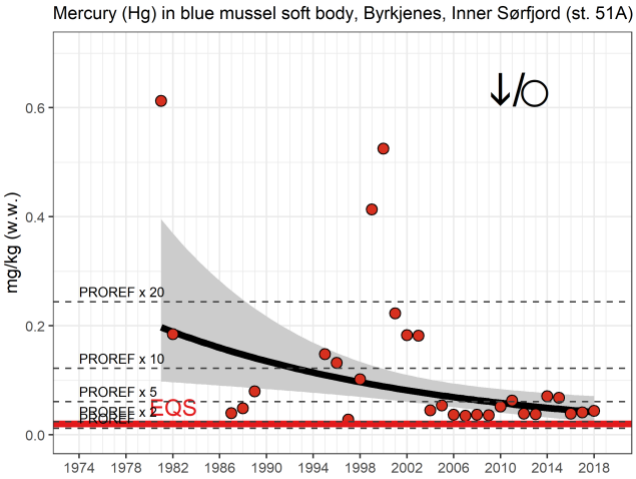
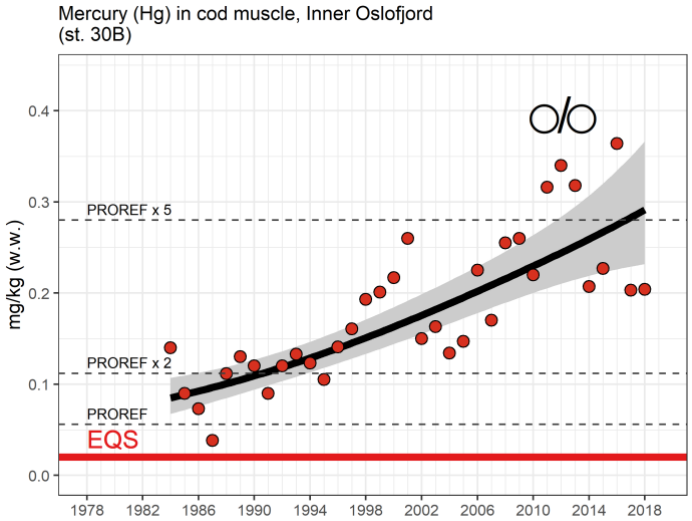


Figure 11. *Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from Byrkjenes (st. 51A). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix C***).*

No trends

In recent years, there has been focus on trends for Hg in cod fillet from the Inner Oslofjord (st. 30B). In 2018, no significant trends were found, neither when using the OSPAR method which targets specific length-groups nor when using the metods adjusted for fish-length (***Figure 12***).

A



B

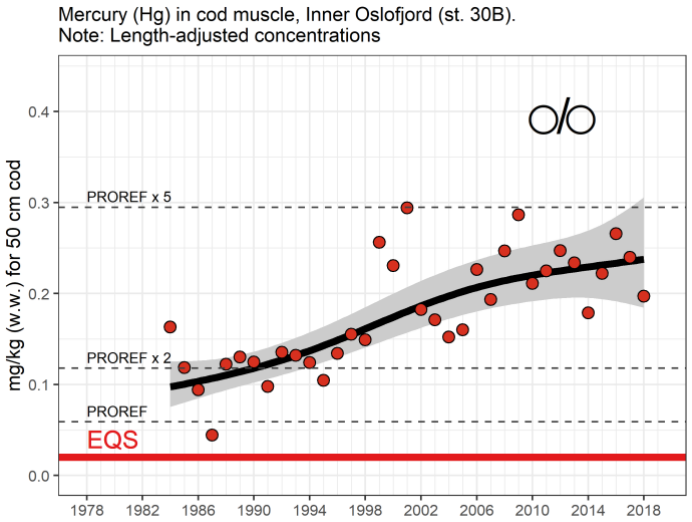


Figure 12. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from 1984 to 2018 in the Inner Oslofjord (st. 30B); no adjustment for length (**A**) and adjusted for length (**B**). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Hg concentration was 0.139 mg/kg w.w. in blood, and 0.129 mg/kg w.w. in eggs.

Comparison with other studies

In the present study, blue mussel at Byrkjenes in the Inner Sørfjord had lower concentration (median 0.044 mg/kg w.w.) than a comparable study at the same station in 2018 (mean 0.051 mg/kg w.w.) (Ruus, Borgersen, et al. 2019). Hg concentrations exceeded EQS at all three blue

mussel stations in the Sørfjord (Ruus, Borgersen, et al. 2019). The collection of blue mussel in both studies took place during the autumn.

In the present study, cod fillet from the Inner Oslofjord had lower concentration (median 0.204 mg/kg Hg w.w.) than a comparable study from the Inner Oslofjord in 2018 (mean 0.327 mg/kg Hg w.w.) (Ruus, Bæk, et al. 2019). The collection of cod in both studies took place during the autumn.

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Hg concentrations below EQS (Øxnevad et al. 2019).

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 et al. 2003).

Most of the Hg-pollution in Norwegian lakes is now due to atmospherically deposited Hg originating from other parts of the world (Jartun et al. 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 et al. 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 and Rognerud 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 et al. 2017).

In the present study, Hg concentration (median 0.129 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 0.139 mg Hg/kg w.w. in blood and 0.129 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 et al. 2018). The Hg concentrations in eider blood and eggs at Svalbard in 2018 was almost within the same range as in the Inner Oslofjord in 2017.

General, large scale trends

In 2017, 0.5 tons of mercury was released in Norway, and there has been an 80 % reduction in emissions of mercury and mercury compounds since 1995 (https://miljostatus.miljodirektoratet.no/kvikksolv).

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 et al. 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 et al. 2018). The exception is river Alna close to the stations in the Inner 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 is some evidence of downward trends. Seven downward long-term trends and one upward long-term trend were found in blue mussel. However, both upward long- and short-term trend were found in cod fillet from Kristiansand harbour. One downward long-term trend was found in cod fillet from Kjøfjord in the Outer Varangerfjord, while three upward short-term trends were found in cod fillet from Farsund and Bømlo.

When considering the total of 46 possible recent short-term (2009-2018) trends for both cod and blue mussel, significant trends are limited to upwards at four stations (***Table 11***, ***Figure 13***).

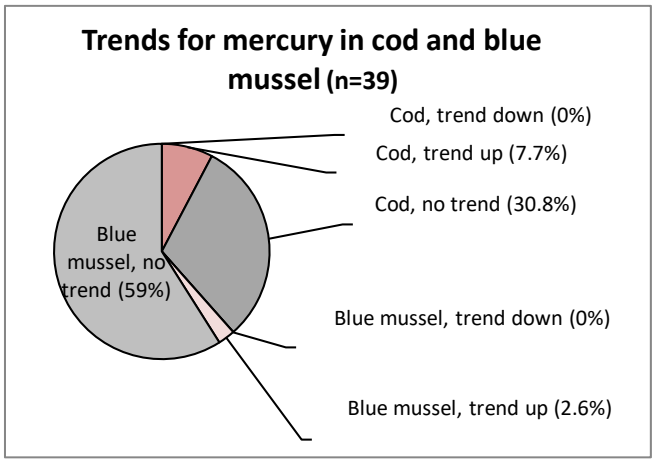


Figure 13. *Frequency of short-term (recent) trends (2009-2018) for Hg in blue mussel and cod fillet.*

In the present study, there were upward long-term trends in blue mussel at Akershuskaia and cod fillet from the Kristiansand harbour. Furthermore, upward short-term trends in blue mussel at Eitrheimsneset and cod fillet from Skågskjera in Farsund and Bømlo in the Outer Selbjørnfjord were registered. Possible explanations of increasing trends could be related to factors such as; climate change, more favourable conditions for methyl mercury 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 et al. 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 et al. 2013b). 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 et al. 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 mercury at Lista/Birkenes (Bohlin-Nizzetto, Aas, and Warner 2018). The riverine input to the Inner Oslofjord from Alna river was 0.07 kg Hg in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 0.33 kg Hg in 2018 to the Inner Oslofjord (VEAS 2019).

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 89 kg Hg/year in 2018 (***Figure 14***). The emissions to air varied between 216 kg Hg/year in 2008 to 89 kg Hg/year in 2018 for the period 2008-2018.

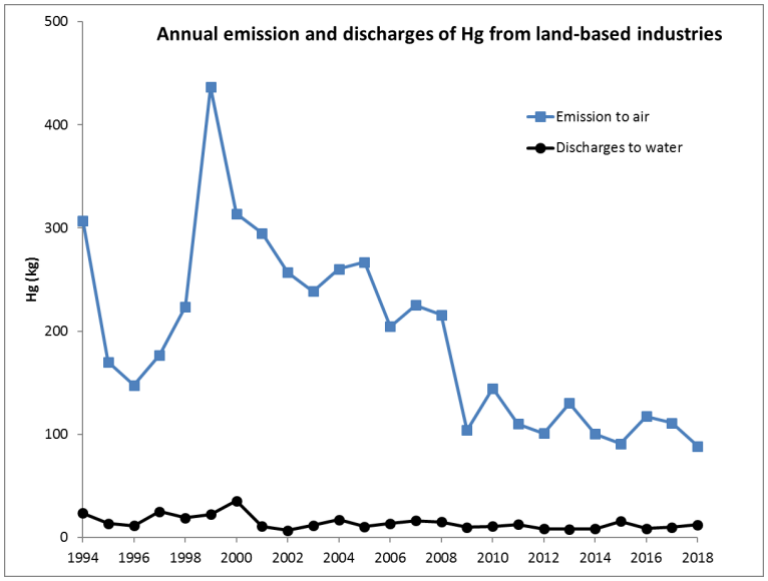


Figure 14. *Annual emissions of Hg to air and discharges to water from land-based industries for the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 cadmium naturally found in small quantities in the earth's crust. In the present study, cadmium was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord and Skallneset (st. 10A2) in the Outer Varangerfjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Cd by a factor between two and five (***Table 11***). Blue mussel at eight other stations exceeded the PROREF by a factor of up to two. These blue mussel stations were in the Oslofjord at Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304). A similar exceedance was also observed at Singlekalven (st. I023) at Hvaler, Sylterøya (st. I714) in the Langesundfjord, and at Odderøya (st. I133) in the Kristiansandfjord. This was also the result at Krossanes (st. 57A) in the Outer Sørfjord, at Svolvær airport area (st. 98A2) in Lofoten, and in the Varangerfjord at Brashavn (st. 11X).

Cod liver at Tromsø harbour (st. 43B2) and Kjøfjord (st. 10B) in the Outer Varangerfjord exceeded the PROREF by a factor up to two.

Increase in PROREF factor since 2017

Blue mussel exceeded PROREF by a factor up to two in 2017, and between two and five times in 2018 at Skallnes (st. 10A2) in the Outer Varangerfjord. The mussel did not exceed PROREF at Gressholmen (st. 30A) in 2017, while in 2018 PROREF was exceeded by a factor up to two.

Cod liver from Tromsø harbour (st. 43B2) had concentration below PROREF in 2017, while the exceedance was by a factor of up to two in 2018.

Upward trends

There was a significant upward short-term trend in blue mussel at Gåsøya (st. I304) in the Inner Oslofjord (***Figure 15***).

Decrease in PROREF factor since 2017

Blue mussel at Solbergstrand (st. 31A) in the Mid Oslofjord, Kirkøy (st. I024) at Hvaler, and Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord, had Cd concentrations that exceeded PROREF by a factor up to two in 2017, while the concentrations were below PROREF in 2018.

The Cd concentration in cod liver from Hammerfest harbour (st. 45B2) exceeded PROREF by a factor between two and five in 2017 and was below PROREF in 2018. The Cd concentration in cod liver from Svalbard (st. 19B) exceeded PROREF by a factor up to two in 2017 and was below PROREF in 2018.

A

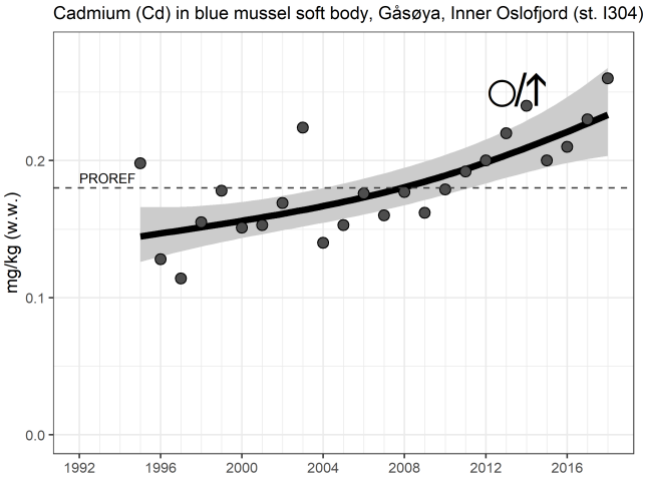


Figure 15. *Median concentrations (mg/kg w.w.) of cadmium (Cd) in blue mussel from the Inner Oslofjord from 1995 to 2018* at *Gåsøya (st. I304). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

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. This was also the case at Espevær (st. 22A) in the Outer Bømlafjord and at Nordnes (st. st. I241) in Bergen harbour. There were significant downward long-term trends at Solbergstrand (st. 31A) in the Mid Oslofjord and at Eitrheimsneset (st. 52A) in the Inner Sørfjord. There were significant downward short-term trends at Gressholmen (st. 30A) in the Inner Oslofjord and Kirkøy (st. I024) at Hvaler.

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

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cd concentration was 0.003 mg/kg w.w. in blood and <0,000 mg/kg w.w. in eggs.

Comparison with other studies

In the present study, cod liver from the Inner Oslofjord had lower concentration (median 0.105 mg/kg Cd w.w.) than a comparable study from the Inner Oslofjord in 2018 (mean 0.198 mg/kg Cd w.w.) (Ruus, Bæk, et al. 2019). 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 Cd-concentrations in blue mussel from Karmsundet in 2018 were below PROREF at two stations (Schøyen, Håvardstud, et al. 2019). The highest Cd concentration was 0.14 mg/kg w.w. (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Cd concentrations below PROREF (Øxnevad et al. 2019).

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 (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/kadmium-og-kadmiumforbindelser/).

Discharges of Cd to water from land-based industries showed a decrease from 2000 (1734 kg Cd/year) to 2018 (80 kg Cd/year) (***Figure 16***). The emission of Cd to air showed a gradually decrease from 1999 (560 kg Cd/year) to 2014 (53 kg Cd/year).

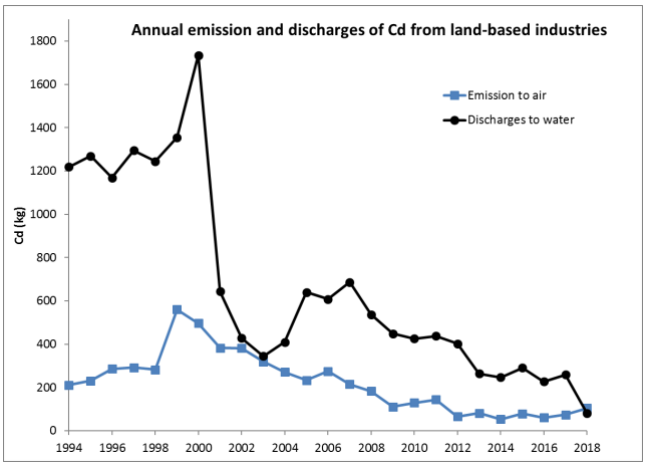


Figure 16. *Annual emissions of Cd to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 21.66 kg/year in 2018 (www.norskeutslipp.no). This might influence the Cd concentration in blue mussel at Eitrheimsneset which exceeded the PROREF by a factor between two and five since 2015.

Total riverine input of Cd in Norway has been estimated to be 2 tonnes in 2017 (Kaste et al. 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 0.01 tonnes Cd in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 4.5 kg Cd to the Inner Oslofjord in 2018 (VEAS 2019) .

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 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel at Odderøya (st. I133) in the Kristiansandfjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Pb by a factor greater than 20. The exceedance was by a factor between five and 10 at Eitrheimsneset (st. 52A) in the Inner Sørfjord. The exceedance was by a factor between two and five at Gressholmen (st. 30A) in the Inner Oslofjord, Krossanes (st. 57A) in the Outer Sørfjord and Nordnes (st. I241) in the Bergen harbour area. Blue mussel exceeded PROREF by a factor of up to two at nine stations (***Table 11***). These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, and at Sylterøya (st. I714) in the Langesundfjord. This was also the result at Lastad at Søgne (st. I131A) and Gåsøya-Ullerøya in Farsund (st. 15A). This was also observed 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 Bodø harbour (st. 97A3).

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Pb by a factor up to two (***Table 11***).

Increase in PROREF factor since 2017

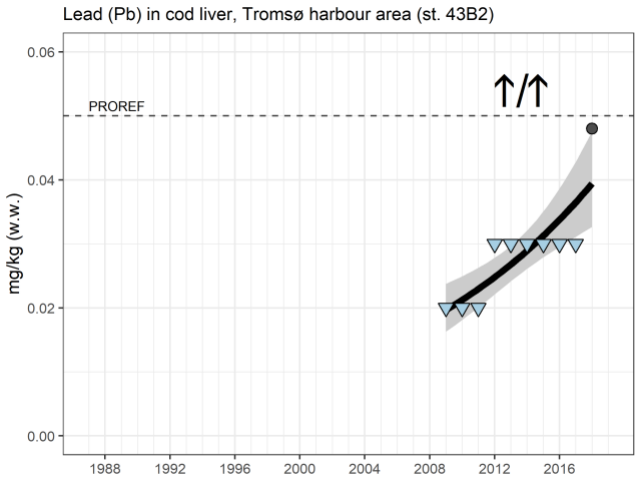
Blue mussel at Odderøya (st. I133) exceeded PROREF of Pb by a factor between 10 and 20 in 2017, while the exceedance was greater than 20 times in 2018. At Sylterøya (st. I714) in the Langesundfjord and at Ålesund (st. 28A2), the concentrations of Pb were below PROREF in 2017, while the exceedance was up to two times in 2018.

Upward trends

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

There were both significant upward long- and short-term trends in cod liver at Tromsø harbour (st. 43B2) (***Figure 17 A***). There were significant upward short-term trends in cod liver from Tjøme (st. 36B) in the Outer Oslofjord, Bømlo (st. 23B) (***Figure 17 B***) in the Outer Selbjørnfjord and Kjøfjord (st. 10B) in the Outer Varangerfjord (***Figure 18***). As is apparent from these figures, the trends were largely influenced by changes in LOQ, and caution is advised when interpreting these results.

A



B

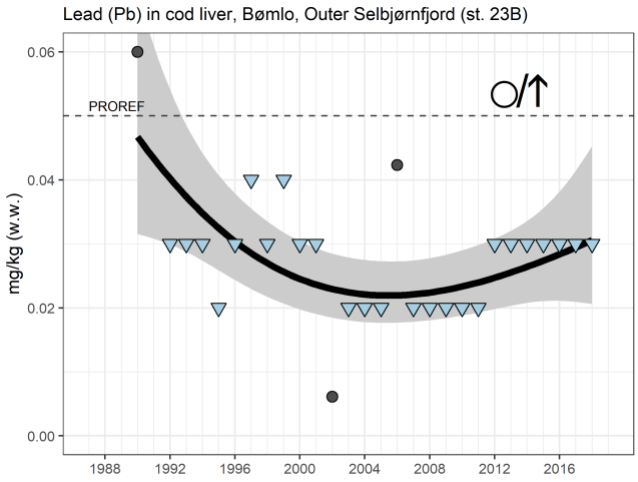


Figure 17. *Median concentrations (mg/kg w.w.) of lead (Pb) in cod liver from 1990 or 2009 to 2018 at Tromsø harbour (st. 43B2) (**A**) and in* the *Outer Selbjørnfjord at* Bømlo *(st. 23B) (**B**). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

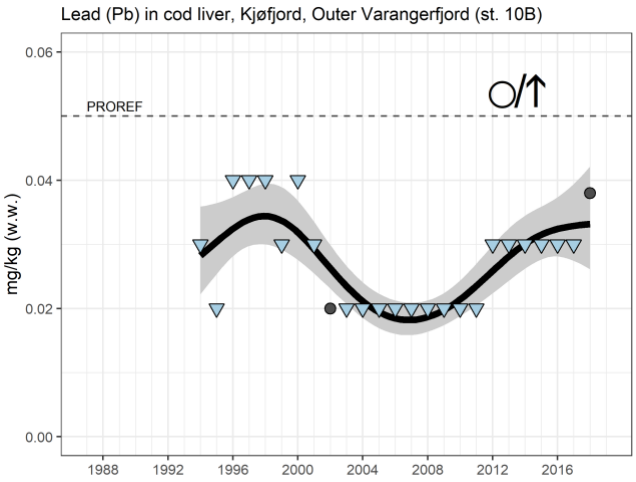


Figure 18. *Median concentrations (mg/kg w.w.) of lead (Pb) in cod liver from Kjøfjord (st. 10B) in the Outer Varangerfjord. The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Decrease in PROREF factor since 2017

Blue mussel exceeded PROREF of Pb by a factor between five and 10 in 2017, while it was no exceedance at Mjelle (st. 97A2) in Bodø in 2018. Blue mussel at Kirkøy (st. I024) at Hvaler, Risøy (st. 76A2) in Risør and Vågsvåg (st. 26A2) in the Outer Nordfjord exceeded PROREF by a factor up to two in 2017, while the concentrations were below PROREF in 2018.

Cod liver exceeded PROREF of Pb by a factor between two and five in 2017, while it was up to two times in the Inner Oslofjord (st. 30B) in 2018. In the Inner Sørfjord (st. 53B), the exceedance of PROREF in cod liver was up to two times in 2017, while it was no exceedance in 2018.

Downward trends

Of the trend analysis performed for blue mussel, 12 revealed significant downward long-term trends (***Table 11***). Both significant downward long- and short-term trends were observed at Nordnes (st. I241) in Bergen harbour, at Espevær (st. 22A) on the west coast and at Skallnes (st. 10A2) in the Varangerfjord. Significant downward long-term trends were found at Akershuskaia (st. I301) in the Oslofjord, Singlekalven (st. I023) at Hvaler, Eitrheimsneset (st. 52A) and Krossanes (st. 57A) in the Sørfjord, and Vikingneset (st. 65A) in the Mid Hardangerfjord. This was also observed in blue mussel at Svolvær airport (st. 98A2), and Brashavn (st. 11X) in the Varangerfjord.

In cod liver, 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).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Pb concentrations were 0.044 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 showed lower concentration (median 0.066 mg/kg Pb w.w.) than observed in a comparable study (mean 0.104 mg/kg Pb w.w.) in the Inner Oslofjord in 2018 (Ruus, Bæk, et al. 2019). 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 4.9 mg/kg w.w. and exceeded the PROREF by a factor greater than 20. Another recent survey in compliance with the EU Water Framework Directive, showed that Pb concentrations in blue mussel from the Kristiansandfjord in 2018 exceeded PROREF at four of five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest Pb concentration (1.3 mg/kg w.w.) was found at Kolsdalsbukta (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Pb concentrations that exceeded PROREF (Øxnevad et al. 2019).

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

General, large scale trends

In 2017, 71 tons of lead was released in Norway and there has been a 90 % decline since 1995 (https://miljostatus.miljodirektoratet.no/bly). 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 tonne to the Lofoten/Barents Sea (Kaste et al. 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 0.16 tonnes Pb in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 39 kg Pb in 2018 (VEAS 2019).

Discharges of Pb to water from land-based industries in Norway showed a decrease from 2010 (6841 kg Pb/year) to 2018 (1989 kg Pb/year) (***Figure 19***).

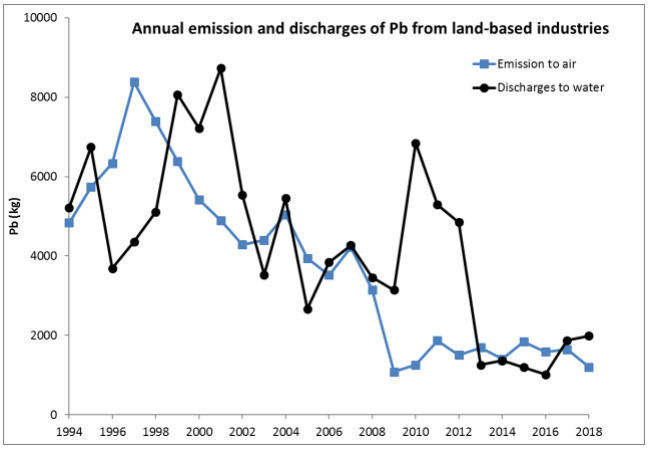


Figure 19. *Annual emissions of Pb to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 present study, Cu was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

In 2018, the Cu concentrations were below PROREF in both blue mussel and cod liver (***Table 11***).

Upward trends

A significant upward short-term trend was found at Skågskjera in Farsund (st. 15B) (***Figure 20***).

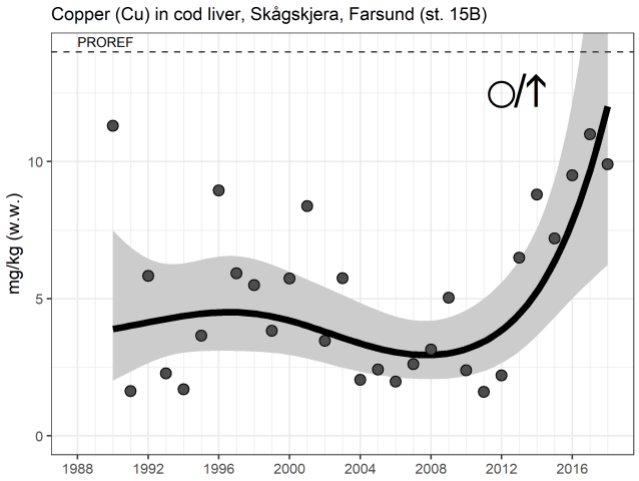


Figure 20. *Median concentrations (mg/kg w.w.) of copper (Cu) in cod liver from Skågskjera in Farsund (st. 15B).The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Decrease in PROREF factor since 2017

Blue mussel at Bodø harbour (st. 97A3) exceeded PROREF by a factor up to two in 2017, while the Cu concentration was below PROREF in 2018.

Cod liver from the Bømlo (st. 23B) in the Outer Selbjørnfjord exceeded PROREF by a factor up to two in 2017, while the Cu concentration was below PROREF in 2018.

Downward trends

There were both significant downward long- and short-term trends in mussel from Gåsøya (st. I304) in the Inner Oslofjord, Gåsøya-Ullerøya (st. 15A) in Farsund, Krossanes (st. 57A) in the Outer Sørfjord and at Vikingneset (st. 65A) in the Mid Hardangerfjord. This was also the case at Ørland area (st. 91A2) in the Outer Trondheimfjord and at Mjelle in the Bodø area (97A2). Significant downward long-term trends were observed at Kirkøy (st. I023) at Hvaler, Eitrheimsneset (st. 52A) in the Inner Sørfjord and at Skallnes (st. 10A2) in the Outer Varangerfjord. Significant downward short-term trends were found at Lastad (st. I131A) at Søgne and at Brashavn (st. 11X) in the Outer Varangerfjord.

There were both significant downward long- and short-term trends in cod liver from the Inner Oslofjord (st. 30B). Cod liver from Tjøme (st. 36B) in the Outer Oslofjord and Kjøfjord (st. 10B) in the Outer Varangerfjord had significant downward long-term trends.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cu concentrations were 0.454 mg/kg w.w. in blood and 0.894 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 2017 (mean 6.05 mg/kg Cu w.w.) (Ruus, Bæk, et al. 2019). 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 0.91 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 2018 exceeded PROREF at one of five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest Cu concentration (3.3 mg/kg w.w.) was found at Glencore harbour (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had Cu concentrations below PROREF (Øxnevad et al. 2019).

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.

Discharges of Cu to water from land-based industries showed a gradually decrease from 2005 (90 186 kg Cu/year) to 2018 (11 419 kg Cu/year) (***Figure 21***).

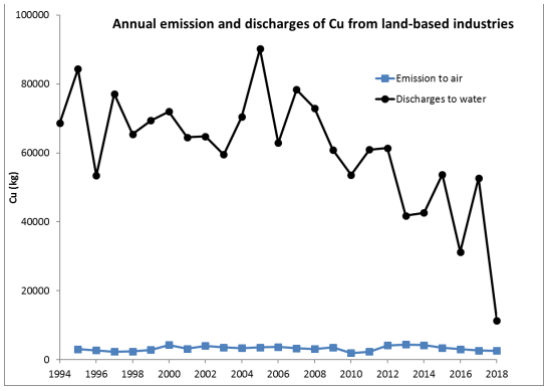


Figure 21. *Annual emissions of Cu to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 Cu in Norway has been 165 tonnes in 2017 (Kaste et al. 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. 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 et al. 2018), or about 87 % of the total (1264 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.43 tonnes Cu in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 434 kg Cu in 2018 (VEAS 2019).

3.2.6 Zinc (Zn)

Zink (Zn) is an element. In the present study, Zn was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel from 13 stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Zn, but by less than a factor of two (***Table 11***).

These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord, Kirkøy (st. I024) at Hvaler and Tjøme (st. 36A1) in the Outer Oslofjord. This was also the result at Sylterøya (st. I714) in the Langesundfjord, Odderøya (st. I133) in the Kristiansandfjord, and Gåsøy-Ullerøya (st. 15A) in Farsund. This was also the case at Eitrheimsneset (st. 52A) in the Inner Sørfjord, Nordnes (st. I241) in Bergen harbour area, Vågsvåg (st. 26A2) in the Outer Nordfjord and Ålesund harbour (st. 28A2). This was also observed at Bodø harbour (st. 97A3).

Cod liver exceeded PROREF for Zn by a factor up to two at Stathelle area (st. 71B) in the Langesundfjord, Kristiansand harbour (st. 13B), Bømlo (st. 23B) in the Outer Selbjørnfjord and at Skågskjera (st. 15B) in Farsund.

Increase in PROREF factor since 2017

In 2017, no exceedances in PROREF were found in blue mussel at Sylterøya (st. I714) in the Langesundfjord and at Eitrheimsneset (st. 52A) in the Inner Sørfjord, while the Zn concentrations exceeded PROREF by a factor of up to two in 2018.

In 2017, no exceedances in PROREF were found in cod liver from Stathelle (st. 71B) in the Langesundfjord and at Bømlo (st. 23B) in the Outer Selbjørnfjord, while the Zn concentrations exceeded PROREF by a factor of up to two in 2018.

Upward trends

A significant upward short-term trend was found in blue mussel from Eitrheimsneset (st. 52A) in the Inner Sørfjord.

Both significant upward long- and short-term trends were found in cod liver from Sandnessjøen (st. 96B). A significant upward short-term trend was found at Skågskjera in Farsund (st. 15B).

Decrease in PROREF factor since 2017

In 2017, the exceedance of PROREF was less than two times at Svolvær (st. 98A2), while it was no exceedance in 2018.

Downward trends

In blue mussel, both significant downward long- and short-term trends were found at Gressholmen (st. 30A) in the Inner Oslofjord, at Vikingneset (st. 65A) in the Mid Hardangerfjord and at Espevær (st. 22A) in the Outer Bømlafjord. Downward long-term trends were found at Lastad (st. I131A) at

Søgne, at Eitrheimsneset (st. 52A) in the Inner Sørfjord, Krossanes (st. 57A) in the Outer Sørfjord and Brashavn (st. 11X) in the Outer Varangerfjord.

In cod liver, a significant downward long-term trend was found in the Inner Sørfjord (st. 53B).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Zn concentrations were 5.247 mg/kg w.w. in blood and 12.639 mg/kg w.w. in eggs.

Comparison with other studies

In the present study, cod liver from the Inner Oslofjord (median 26.5 mg/kg Zn w.w.) was about the same level as a comparable study from the Inner Oslofjord in 2018 (mean 23.9 mg/kg Zn w.w.) (Ruus, Bæk, et al. 2019). 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 25.0 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 2018 exceeded PROREF at four of five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest Zn concentration (23 mg/kg w.w.) was found in Hanneviksbukta (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS station Bjørnbærviken (st. I969) had Zn concentration below PROREF, while the levels at Toraneskaien (st. I964) and Moholmen (st. I965) exceeded PROREF (Øxnevad et al. 2019).

General, large scale

Discharges of Zn to water from land-based industries showed a gradually decrease from 2005 (200 785 kg Zn/year) to 2018 (18 656 kg Zn/year) (***Figure 22***).

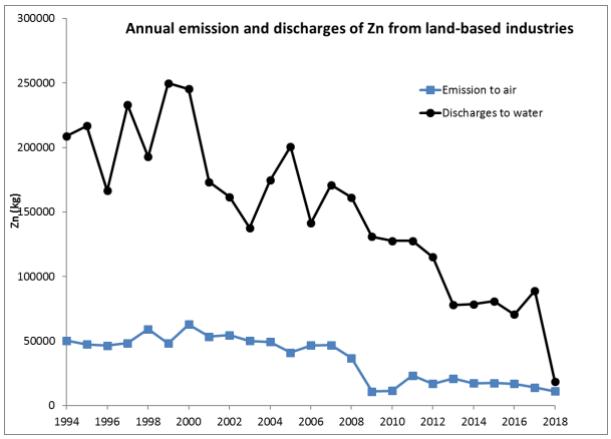


Figure 22. *Annual emissions of Zn to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 Zn in Norway has been 407 tonnes in 2017 (Kaste et al. 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 et al. 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 1.85 tonnes Zn in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 1857 kg Zn in 2018 (VEAS 2019).

3.2.7 Silver (Ag)

Silver (Ag) is an element. In the present study, Ag was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel at six stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) of Ag by a factor up to two (***Table 11***). These stations were located at Gressholmen (st. 30A) in the Inner Oslofjord and at Solbergstrand in the Mid Oslofjord. This was also the result at Eitrheimsneset (st. 52A) in the Inner Sørfjord, at Vikingneset (st. 65A) in the Mid Hardangerfjord, and in the Outer Varangerfjord at Skallnes (st. 10A2) and Brashavn (st. 11X).

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Ag by a factor between two and five. Cod liver from Tjøme (st. 36B) in the Outer Oslofjord and Skågskjera (st. 15B) at Farsund exceeded PROREF by a factor up to two.

Increase in PROREF factor since 2017

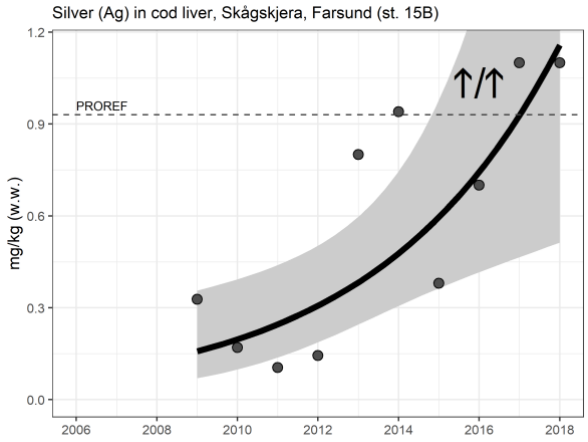
In 2017, it was no exceedance of PROREF for Ag in blue mussel at Vikingneset (st. 65A) in the Mid Hardangerfjord and Brashavn (st. 11X) in the Outer Hardangerfjord, while the exceedance was by a factor up to two in 2018.

In 2017, the Ag concentration in cod liver at Tjøme was below PROREF for Ag, but the exceedance was up to two in 2018.

Upward trends

There were both significant upward long-and short-term trends in cod liver from Skågskjera (st. 15B) in Farsund (***Figure 23 A***) and from Sandnessjøen area (st. 96B), also when adjusted for length (***Figure 23 B*** for Skågskjera in Farsund).

A



B

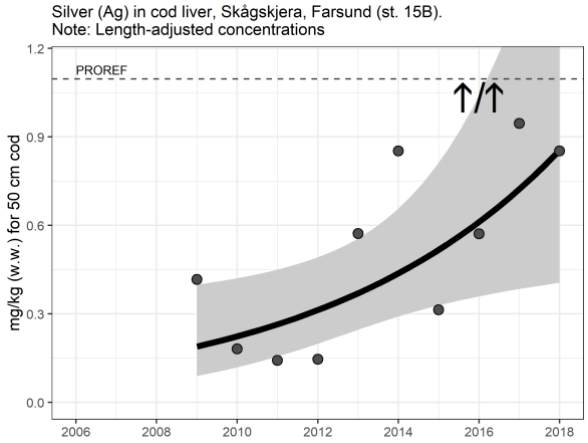


Figure 23. *Median concentrations (mg/kg w.w.) of silver (Ag) in cod liver from Skågskjera (st. 15B) in Farsund; no adjustment for length (***A***) and adjusted for length (***B***). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Decrease in PROREF factor since 2017

The Ag concentrations in blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord had decreased from exceeding the PROREF by a factor of two to five in 2017, to up to two in 2018. Furthermore, exceedences in PROREF decreased by a factor of up to two in 2017, to no exceedances in 2018 at Utne (st. 64A) in the Outer Sørfjord and Svolvær airport (st. 98A2) in Lofoten.

The Ag concentration in cod liver in the Inner Oslofjord (st. 30B) had decreased to exceeding the PROREF by a factor between two and five in 2018, from between five and 10 times in 2017. In 2017, the exceedance of PROREF was up to two times at Bømlo (st. 23B) in the Outer Selbjørnfjord to no exceedance in 2018.

Downward trends
There were both significant downward long- and short-term trends in blue mussel from Gåsøya-Ullerøya (st. 15A) in Farsund, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord.

A significant downward short-term trend was found in cod liver from the Inner Oslofjord (st. 30B).

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 0.006 mg/kg w.w. in eggs.

Comparison with other studies
In 2018, the highest Ag concentration in the present study was found in cod liver from the Inner Oslofjord (2.85), as in 2017 (5.350 mg/kg w.w.), 2016 (2.4 mg/kg w.w.) and 2015 (6.85 mg/kg w.w.). 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 2018 revealed a median concentration of 2.85 mg/kg Ag (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2018 showed higher mean concentration (6.7 mg/kg Ag w.w.) (Ruus, Bæk, et al. 2019). The collection of cod in both studies took place during the autumn.

In the present study, the Ag concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord was <0.004 mg/kg w.w. Another recent survey in compliance with the EU Water Framework Directive, showed that Ag concentrations in blue mussel from the Kristiansandfjord in 2018 exceeded PROREF at two of five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest Ag concentration (0.022 mg/kg w.w.) was found at Glencore harbour (Schøyen, Kringstad, and Håvardstun 2019).

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 silver 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 et al. 2011).

General, large scale
Discharges of Ag to water from land-based industries showed a decrease from 1994 (9.74 kg Ag/year) to 2009 (0.1 kg Ag/year) (***Figure 24***). The discharges to water in 2018 were 1.19 kg Ag).

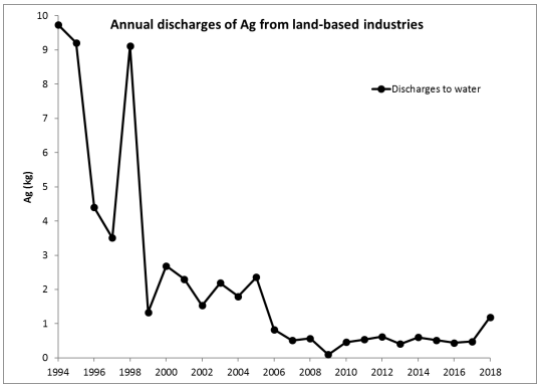


Figure 24. *Annual discharges of Ag to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New 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 arsenic. Today such use is prohibited, and the use has been significantly reduced (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/arsen-og-arsenforbindelser/). In the present study, As was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for As by a factor of up to two at Risøy (st. 76A2) at Risør, Ålesund (st. 28A2) and at Ørland (st. 91A2) in the Outer Trondheimfjord (***Table 11***).

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

Increase in PROREF factor since 2017

In 2017, the As concentrations in blue mussel were below PROREF at Risøy (st. 76A2) at Risør, while the exceedances were less than a factor of two in 2018.

In 2017, the cod liver had concentrations below PROREF for As, while the exceedance was less than two in 2018 in the Inner Oslofjord (st. 30B).

Decrease in PROREF factor since 2017

In 2017, the As concentrations in blue mussel exceeded PROREF by a factor of up to two at Solbergstrand (st. 31A) in the Mid Oslofjord, Utne (st. 64A) in the Outer Sørfjord, Vågsvåg (st. 26A2) in the Ourter Nordfjord and Svolvær airport area (st.98A2) were up to a PROREF factor of two, while in 2018 concentrations were below PROREF.

Downward trends

In blue mussel, both significant downward long- and short-term trends were observed at Gåsøya-Ullerøya in Farsund (st.15A), at Vikingneset (st. 65A) in the Mid Hardangerfjord, at Vågsvåg

(st. 26A2) in the Outer Nordfjord, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

In cod liver, both significant downward long- and short-term trends were observed at Bømlo (st. 23B) in the Outer Selbjørnfjord.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the As concentrations were 0.037 mg/kg w.w. in blood and 0.127 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord, revealed median concentration of 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 2018 had higher mean concentration (38.3 mg/kg As w.w.) (Ruus, Bæk, et al. 2019). 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 1.7 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 2018 were below PROREF at all five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest As concentration (1.8 mg/kg w.w.) was found at Kolsdalsbukta and Myrodden (Schøyen, Kringstad, and Håvardstun 2019).

Concentrations of As in blue mussel from Karmsundet in 2018 exceeded PROREF at two stations (Schøyen, Håvardstud, et al. 2019). The highest As concentration was 3.7 mg/kg w.w. (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had As concentrations below PROREF (Øxnevad et al. 2019).

In the present study, As concentration (median 0.127 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 (517 kg As/year) to 2010 (2587 kg As/year) and from 2013 (1511 kg As/year) to 2016 (2195 kg As/year) (***Figure 25***). Discharges to water was 1955 kg As/year in 2017.

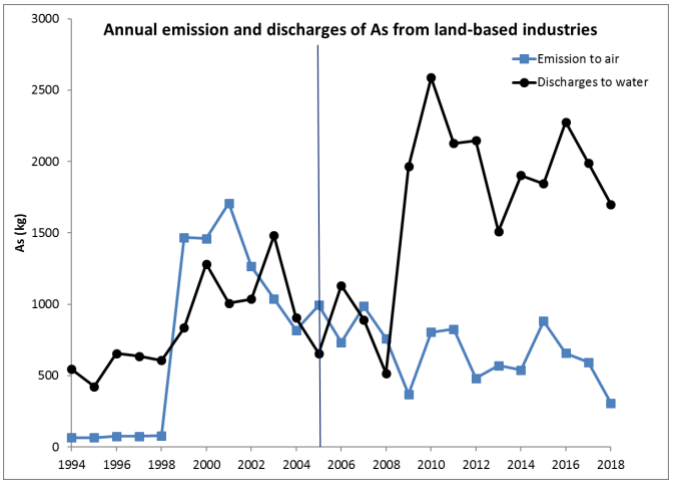


Figure 25. *Annual emissions of As to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). The vertical line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, 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 et al. 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 et al. 2018), indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from industrial (2 tonnes) effluents amounting to 2 tonnes or about 8 % of the total (26 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.03 tonnes As in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 46 kg As in 2018 (VEAS 2019).

3.2.9 Nickel (Ni)

Nickel (Ni) is an element. In the present study, Ni was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord, Singlekalven (st. I023) and Kirkøy (st. I024) at Hvaler, Risøy (st. 76A2) at Risør and Odderøya (st. I133) in the Kristiansandfjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Ni by a factor between two and five (***Table 11***). Blue mussel at seven other stations exceeded this level by a factor up to two. These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord. This was also the case at Gåsøya-Ullerøya (st. 15A) in Farsund, and in the Outer Sørfjord at Krossanes (st. 57A) and Utne (st. 64A). This was also the result in Ålesund harbour (st. 28A2) and at Skallnes (st. 10A2) in the Outer Varangerfjord.

Increase in PROREF factor since 2017

In 2017, blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and Odderøya (st. I133) in the Kristiansandfjord exceeded the PROREF of Ni by a factor less than two, while the exceedance was between two and five times in 2018. In 2017, the Ni concentration in mussel at Singlekalven (st. I023) at Hvaler, and Risøy (st. 76A2) at Risør was below PROREF, while the exceedance was between two and five times in 2018. Levels were below PROREF at Gåsøya (st. I304) in the Inner

Oslofjord, Gåsøy-Ullerøya (st. 15A) at Farsund, and in the Outer Sørfjord at Krossanes (st. 57A) and Utne (st. 64A) in 2017, while the exceedance was less than two times in 2018.

Upward trends

Both significant upward long- and short-term trends were found in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord (***Figure 26***).

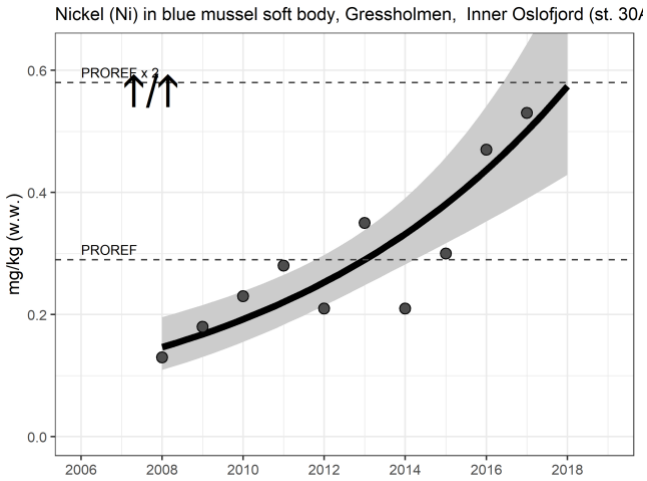


Figure 26. *Median concentrations (mg/kg w.w.) of nickel (Ni) in blue mussel from 2008 or 2009 to 2018 in Gressholmen (st. 30A) in the Inner Oslofjord. The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Decrease in PROREF factor since 2017

In 2017, the Ni concentrations in blue mussel were below PROREF at Solbergstrand (st. 31A) in the Mid Oslofjord, while it exceeded PROREF by a factor between two and five in 2018. The concentrations in blue mussel were also below PROREF in 2017, but the exceedance was less than two at Lastad (st. I131A) at Søgne, Bodø harbour (st. 97A2) and at Brashavn (st. 11X) in the Outer Varangerfjord in 2018.

The Ni concentrations in cod liver were below the PROREF in 2018, as in 2017.

Downward trends

In cod liver, both significant downward long- and short-term trends were found in the Kristiansand harbour (st. 13B).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Ni concentrations were <0.016 mg/kg w.w. in blood and <0.016 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 0.105 mg/kg Ni (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2018 showed

a concentration of 0.156 mg/kg Ni w.w. (Ruus, Bæk, et al. 2019). 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 0.720 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 2018 exceeded PROREF at all five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest Ni concentration (11 mg/kg w.w.) was found at Glencore harbour (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Moholmen (st. I965) and Bjørnbærviken (st. I969) had Ni concentrations below PROREF, while the level exceeded PROREF at Toraneskaien (st. I964) (Øxnevad et al. 2019).

General, large scale

Discharges of Ni to water from land-based industries had decreased gradually from 2001 (22 590 kg Ni/year) to 2018 (5 139 kg Ni/year) (***Figure 27***).

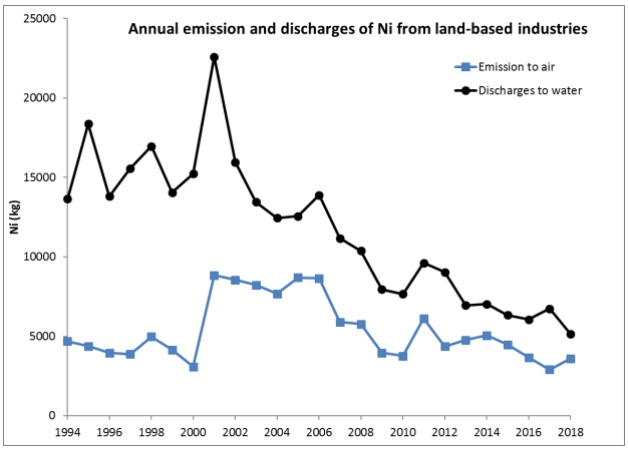


Figure 27. *Annual emissions of Ni to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 et al. 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 0.11 tonnes Ni in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 247 kg Ni in 2018 (VEAS 2019).

3.2.10 Chromium (Cr)

Chromium (Cr) is an element found in several forms that have different toxicities. In the present study, Cr was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

In blue mussel, the exceedances of the Norwegian provisional high reference contaminant concentration (PROREF) of Cr were by a factor between five and 10 at Singlekalven (st. I023) at Hvaler (***Table 11***). The exceedances of PROREF were by a factor between two and five at Gressholmen (st. 30A) in the Inner Oslofjord and at Risøy (st. 76A2) at Risør. Blue mussel at eight other stations exceeded this level by a factor of up to two. These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, Kirkøy (st. I024) at Hvaler, Sylterøya (st. 71A) in the Langesundfjord and Odderøya (st. I133) in the Kristiansandfjord. This was also the case at Gåsøya-Ullerøya (st. 15A) at Farsund, and at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord.

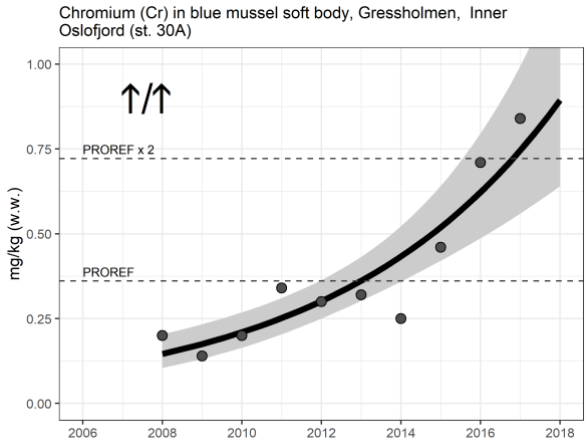
Increase in PROREF factor since 2017

In 2017, blue mussel at Singlekalven (st. I023) at Hvaler exceeded PROREF by a factor less than two, compared to between five and 10 in 2018. There was no exceedance of PROREF of Cr in blue mussel in 2017, while the exceedance was between two and five times in 2018 at Risøy (st. 76A2) at Risør. There were no exceedances of PROREF of Cr in blue mussel in 2017, while the exceedances were less than two in 2018 at Gåsøya (st. I304) in the Inner Oslofjord, Odderøya (I133) in the Kristiansandfjord, Gåsøya-Ullerøya (st. 15A) in Farsund, and in the Outer Sørfjord at Krossanes (st. 57A) and Utne (st. 64A).

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 Brashavn (st. 11X) in the Outer Varangerfjord (***Figure 28 A*** *and* ***B****, respectively*).

A



B

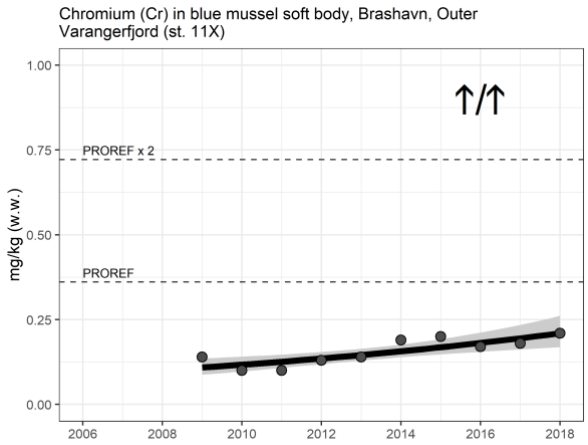


Figure 28. *Median concentrations (mg/kg w.w.) of chromium (Cr) in blue mussel from 2008 or 2009 to 2018 in Gressholmen in the Inner Oslofjord (st. 30A) (**A**) and Brashavn (st. 11X) in the Outer Varangerfjord (**B**). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Decrease in PROREF factor since 2017

Blue mussel at Solbergstrand (st. 31A) in the Inner Oslofjord had Cr concentration that exceeded PROREF by a factor between five to 10 in 2017, while the level was below PROREF in 2018. In 2017, the Cr concentration exceeded PROREF by a factor between two and five, while the levels were below PROREF in 2018 at Ørland area (st. 91A2) in the Outer Trondheimfjord. In 2017, the Cr concentration exceeded PROREF by a factor up to two, while the levels were below PROREF in 2018 at Lastad (st. I131A) at Søgne, Ålesund (st. 28A2) and Skallnes (st. 10 A2) in the Outer Varangerfjord.

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 Kjøfjord in the Outer Varangerfjord (st. 10B).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cr concentrations were <0.028 mg/kg w.w. in blood and 0.026 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 0.040 mg/kg Cr (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2018 had lower mean concentration (0.029 mg/kg Cr w.w.) (Ruus, Bæk, et al. 2019). 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 Karmsundet in 2018 were below PROREF at two stations (Schøyen, Håvardstud, et al. 2019). The highest Cr concentration was 0.26 mg/kg w.w. (Schøyen, Kringstad, and Håvardstun 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Moholmen (st. I965) and Bjørnbærviken (st. I969) had Cr concentrations below PROREF, while the level exceeded PROREF at Toraneskaien (st. I964) (Øxnevad et al. 2019).

General, large scale trends

In 2017, 39 tons of Cr and Cr compounds was released in Norway and there has been a 60 % decline since 1995 (https://miljostatus.miljodirektoratet.no/krom). Each year, 22 tons of chromium 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 29***. The discharges to water in 2018 was 1817 kg Cr/years.

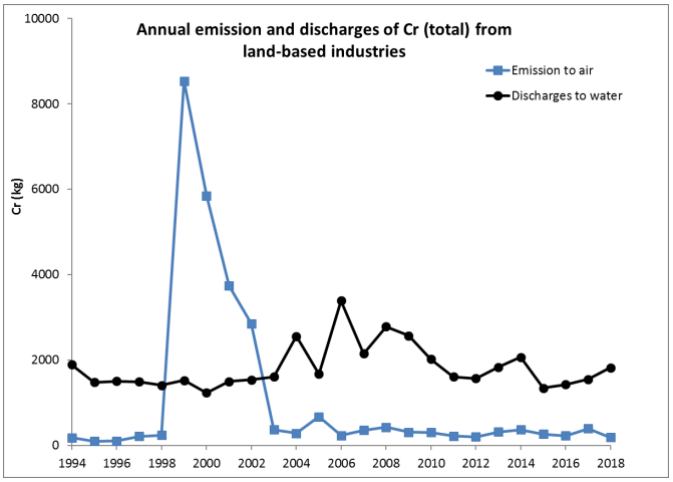


Figure 29. *Annual emissions of Cr to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 et al. 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 et al. 2018), or about 9 % of the total (34 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.10 tonnes Cr in 2017 (Kaste et al. 2018). VEAS sewage treatment plant reported a discharge of 48 kg Cr in 2018 (VEAS 2019) .

3.2.11 Cobalt (Co)

In the present study, cobalt (Co) was analysed in blue mussel at 26 stations, in cod liver at 17 stations and in eider blood and eggs at one station (***Table 2***).

Levels exceeding PROREF

Blue mussel at six stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Co by a factor of up to two (***Table 11***). These stations were Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, Singlekalven (st. I023) and Kirkøy (st. I024) at Hvaler, Odderøya (st. I133) in the Kristiansandfjord and Eitrheimsneset (st. 52A) in the Inner Sørfjord.

Co in cod liver at Skågskjera (st. 15B) in Farsund also exceeded PROREF by a factor of less than two.

Increase in PROREF factor since 2017

In 2017, the Co concentration in blue mussel at Singlekalven (st. I023) at Hvaler and Eitrheimsneset (st. 52A) in the Inner Sørfjord was below PROREF, while the exceedance was by a factor up to two in 2018.

In 2017, the Co concentration in cod liver from Skågskjera (st. 15B) in Farsund was below PROREF, while the exceedance in 2018 was by a factor up to two.

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 2017
Blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord and Ørland (st. 91A2) in the Outer Trondheimfjord exceeded the PROREF of Co by a factor up to two in 2017, while there were no exceedances in 2018.

Downward trends
Both significant downward long- and short-term trends were observed in blue mussel at Odderøya (st. I133) in the Kristiansandfjord, Gåsøya-Ullerøya (st. 15A) at Farsund and Vikingneset (st. 65A) in the Mid Hardangerfjord.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Co concentrations were 0.002 mg/kg w.w. in blood and 0.007 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 0.110 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 2018 exceeded PROREF at four of five stations (Schøyen, Kringstad, and Håvardstun 2019). The highest Co concentration (40 mg/kg w.w.) was found at Hanneviksbukta (Schøyen, Kringstad, and Håvardstun 2019).

General, large scale trends
Discharges of Co to water from land-based industries showed decreasing values from 2017 (733 kg Co/year) to 2018 (552 kg Co/year) (***Figure 30***).

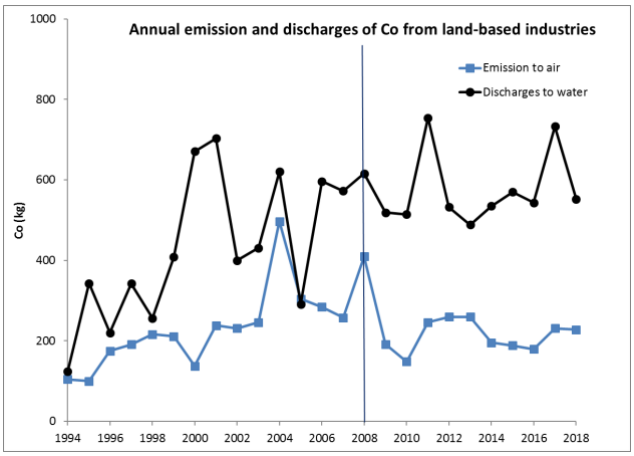


Figure 30. *Annual emissions of Co to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). The vertical grey line at 2008 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal*

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. 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 superimposition of male sex characters onto females, such as imposex in dogwhelk and intersex in common periwinkle. 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) at one station (***Table 2***).

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 (< 16.0 µg/kg w.w.), dogwhelk (< 4.5 µg/kg w.w.) and common periwinkle (< 1.7 µg/kg w.w.), all TBT-concentrations were below EQS in 2018 (***Table 10***), as in 2017.

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 2018, as in 2017 (***Table 10***).

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 of between two and five at Akershuskaia (st. I301) and by a factor up to two at Gressholmen (st. 30A) (***Table 11***).

Increase in PROREF factor since 2017

Blue mussel at Akershuskaia (st. I301) exceeded PROREF for TBT by a factor up to two in 2017, but exceeded this limit by a factor between two and five in 2018.

Downward trends

For blue mussel, there were both significant downward long- and short-term trends for TBT at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner 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 (<1.2 µg/kg w.w.) at seven stations, except for at Melandsholmen (st. 227G2) in the Mid Karmsundet where the concentration was <4.5 µg/kg w.w.

Downward trends of TBT

There were both significant downward long- and short-term trends for TBT at Færder (st. 36G) in the Outer Oslofjord and at Espevær (st. 22G) in the Outer Bømlafjord. There were significant downward trends at Risøya (st. 76G) at Risør, at Lastad (st. 131G) at Søgne, at Gåsøya-Ullerøya (st. 15G) in Farsund and at Svolvær airport area (st. 98G) in Lofoten.

Biological effects of TBT (imposex/VDSI) in dogwhelk
The effects of TBT, the imposex parameter VDSI, were zero at seven stations. The VDSI was 0.129 at Melandsholmen (st. 227G2) in the Mid Karmsundet, due to one imposexed individual. 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 2018, as in 2017.

Increase in VDSI since 2017
The effect of TBT in dogwhelk was higher at Melandsholmen (st. 227G2) in the Mid Karmsundet in 2018 (VDSI=0.129) than in 2017 (VDSI=0).

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

Common periwinkle
Levels of TBT
The TBT concentration in common periwinkle at Fugløyskjær (st. 71G) in the Outer Langesundfjord was 1.7 µg/kg (w.w.).

Downward trend of TBT
A significant downward long-term trend for TBT was observed.

Biological effects of TBT (intersex/ISI) in common periwinkle
The effect of TBT in common periwinkle, the intersex parameter ISI, was zero in 2018, as in 2017.

Downward trend of ISI
A significant downward long-term trend for ISI was observed.

Comparison with other studies
In another comparable study in a former TBT-polluted fjord arm, Vikkilen, close to Grimstad in 2018, no intersex could be seen in common periwinkle two years after sediment remediation actions (Øxnevad and Tveiten 2018). Higher levels of TBT and intersex/imposex were measured close to the shipyard prior to the total ban in 2008 and sediment remediation in 2016. There were reductions of TBT concentrations in common periwinkle and blue mussel, and positive effects were also seen for the mud snail *Nassarius reticulatus* and the common whelk *Buccinum undatum*.

General, large scale trends
In the present study 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 and longer than 25 meters in 2003/2008, 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 Karmsund. In populations close to much ship traffic, the recovery took longer time than at remote stations. In the Karmsund 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 31***, ***Figure 32***). In the post-ban period since 2008, the VDSI levels have been below PROREF (3.68) at all stations, and the levels has been close to zero at many of the stations. A typical example of decreasing trends is shown for Færder in ***Figure 33***.

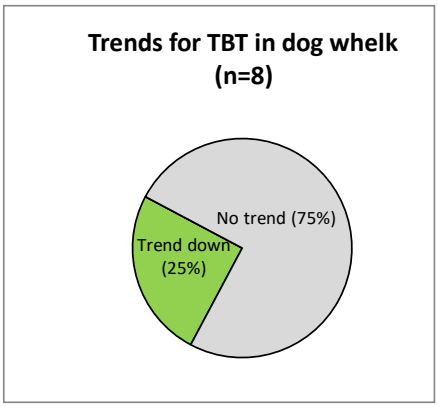


Figure 31. *Frequency of recent trends for the concentration of TBT in dogwhelk (n=8) (2009-2018). No upward trends were detected. Concerns about LOQ prevented some trend analyses.*

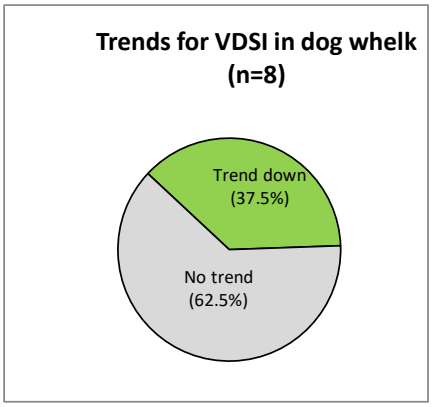


Figure 32. *Frequency of recent trends for VDSI in dogwhelk (n=8) (2009-2018). No upward trends were detected.*

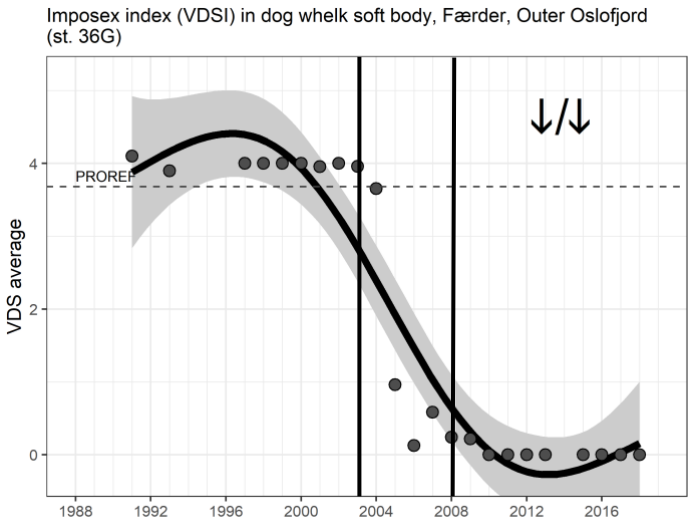


Figure 33. *Changes in VDSI for dogwhelk from Færder (st. 36G) (1991-2018). The vertical black lines indicate the initial ban of TBT in 2003 and total ban in 2008. The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

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 2018 is shown in ***Figure 34***, 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 increased from 1.93 g TBT and TPTIN/year in 2016 to 6.66 g TBT and TPTIN in 2018.

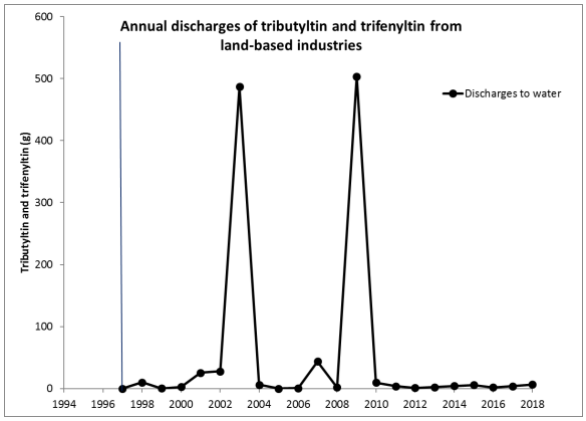


Figure 34. *Annual discharges of TBT and TPTIN to water from land-based industries in the period 1997-2018 (data from www.norskeutslipp.no, 25 June 2019). No data are reported for 1994-1996. The vertical grey line at 1997 marks when the MILKYS-measurements of TBT started. The MILKYS-measurements of VDSI 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 4***) are a group of chlorinated organic compounds that previously had a broad industrial and commercial application. In the present study, PCB-7 was analysed in blue mussel at 26 stations, in cod liver at 16 stations and in eider blood and eggs at one station (***Table 2***).

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 6***), the concentrations at all stations exceeded the limit (***Table 10***).

When applying the EQS for PCB-7 (0.6 µg/kg w.w.) on cod liver (see ***Table 6***), all stations exceed this value (***Table 10***).

Applying this EQS for eider blood and eggs, the concentrations of PCB-7 would have exceeded the EQS (***Table 10***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for PCB-7 at all stations (***Table 11***). The mussels exceeded the limit by a factor between five to 10 at Gressholmen (st. 30A) in the Inner Oslofjord and at Ålesund harbour (st. 28A2). The exceedance was between a factor of two and five at Akershuskaia (st. I301), Gåsøya (st. I304) and Solbergstrand (st. 31A) in the Oslofjord. This was also the case at Nordnes in Bergen harbour (st. I241) and at Vågsvåg (st. 26A2) in the Outer Nordfjord. This was also the result at Ørland area (st. 91A2) in the Outer Trondheimfjord and at Skallnes (st. 10A2) in the Outer Varangerfjord. The exceedance was by a factor up to two at the remaining 17 blue mussel stations.

The PROREF in cod liver was exceeded by a factor between five and 10 in the Inner Oslofjord (st. 30B) and Ålesund harbour (st. 28B). The PROREF in cod liver was exceeded by a factor between two and five at Tjøme (st. 36B) in the Outer Oslofjord, in the Kristiansand harbour (st. 13B) and in Bergen harbour (st. 24B).

Increase in PROREF factor since 2017

Blue mussel at five stations had increased PROREF factors since 2017. The PROREF was exceeded by a factor between two and five in 2017, while the exceedance was between five and 10 in 2018 in Ålesund (st. 28A2). The exceedance was by a factor less than two in 2017, while it was between two and five in 2018 at Gåsøya (st. I304) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord, Vågsvåg (st. 26A2) in the Outer Nordfjord and at Skallnes (st. 10A2) in the Outer Varangerfjord.

The PROREF in cod liver was exceeded by a factor less than two in 2017 in Ålesund harbour (st. 28B), while it exceeded this limit by a factor between two and five in 2018. In 2017, PCB-7 in cod liver was below PROREF at Tjøme (st. 36B) in the Outer Oslofjord, while it exceeded PROREF by a factor less than two in 2018.

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

Decrease in PROREF factor since 2017
The PROREF was exceeded by a factor between five and 10 in 2017, while the exceedance was between two and five times in 2018 at Akershuskaia (st. I301) in the Inner Oslofjord. The PROREF was exceeded by a factor between two and five in 2017, while the exceedance was less than two times in 2018 at Bodø (st. 97A3).

In cod liver, the PROREF for PCB-7 was exceeded by a factor between five and 10 at Bergen harbour (st. 24B) in 2017, while the exceedance was by a factor less than two in 2018. In 2017, the PROREF for PCB-7 was exceeded by a factor between two and five in the Inner Sørfjord (st. 53B), while there was no exceedance in 2018.

Downward trends
For blue mussel, there were significant downward long-term trends at 14 of the 26 stations (***Table 11***). These stations were Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. 65A) and Solbergstrand (st. 31A) in the Oslofjord, Singlekalven (st. I023) and Kirkøy (st. I024) at Hvaler, and Odderøya (st. I133) in the Kristiansandfjord. This was also the case at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A) in the Sørfjord, and at Vikingneset (st. 65A) in the Mid Hardangerfjord. This was also the result at Espevær (st. 22A) in the Outer Bømlafjord and Nordnes (st. I241) in Bergen harbour.

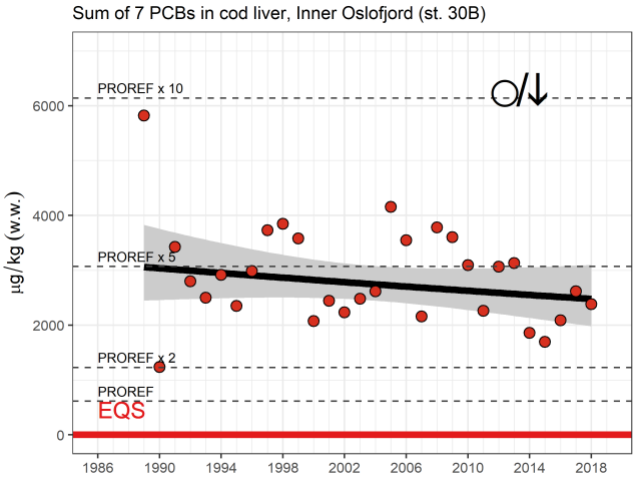
For cod liver, there were significant downward long-term trends at six of the 16 stations. There were both significant downward long- and short-term trends in cod liver from Trondheim harbour (st. 80B) and Hammerfest harbour (st. 45B2). There were significant downward long-term trends at Tjøme (st. 36B) in the Outer Oslofjord, Skågskjera in Farsund (st. 15B), Bømlo (st. 23B) and Kjøfjord in the Varangerfjord (st. 10B). A significant downward short-term trend was found in the Inner Oslofjord (st. 30B).

The Inner Oslofjord
Blue mussel at Gressholmen (st. 30A) exceeded PROREF by a factor between five to 10 in 2018. Mussels at Akershuskaia (st. I301) and Gåsøya (st. I304) exceeded PROREF by a factor between two and five in 2018.

Cod liver caught at 100 m depth in the Inner Oslofjord (st. 30B) exceeded PROREF by a factor between two to five in 2018. A significant downward short-term trend was detected in 2018 (***Figure 35 A***). When adjusting for length, a significant downward short-term trend was also registered (***Figure 35 B***).

In cod liver from the Inner Oslofjord (st. 30B), the congener CB28 (<251.0 µg/kg w.w.) exceeded PROREF by a factor of more than 20. The exceedance of PROREF for CB52 (<251.0 µg/kg w.w.) was between 10 and 20 times.

A



B

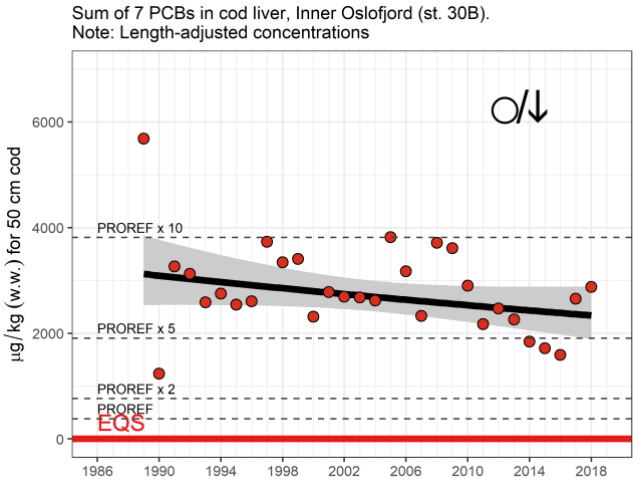


Figure 35. *Median concentrations (mg/kg w.w.) of PCB-7 in cod liver from 1990 to 2018 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PCB-7 were 1.118 µg/kg w.w. in blood and 9.307 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 2 384.7 µg PCB-7/kg (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2018 had almost the same mean concentration (2378.5 µg PCB-7/kg w.w.) (Ruus, Bæk, et al. 2019). 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 et al. 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 2018, blue mussel at the former MILKYS station Bjørnbærviken (st. I969) had PCB-7 concentrations below EQS, while the levels exceeded EQS at Toraneskaia (st. I964) and Moholmen (st. I965) (Øxnevad et al. 2019).

In the present study, the concentration of PCB-153 (median <0.255 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 et al. 2018).

In the present study, the median concentrations were 1.118 µg PCB-7/kg w.w. in blood and 9.307 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 et al. 2018), which was 10-14 times higher concentrations in the Inner Oslofjord compared to results from Svalbard.

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 36***. High emission to air was reported in 2008 (140 g PCBs/year), while the emission was 4,71 g PCBs/year in 2018. Investigations by Schuster *et al.* (2010) indicate that emissions in the northern Europe have declined during the period 1994-2008 by about 50 %.

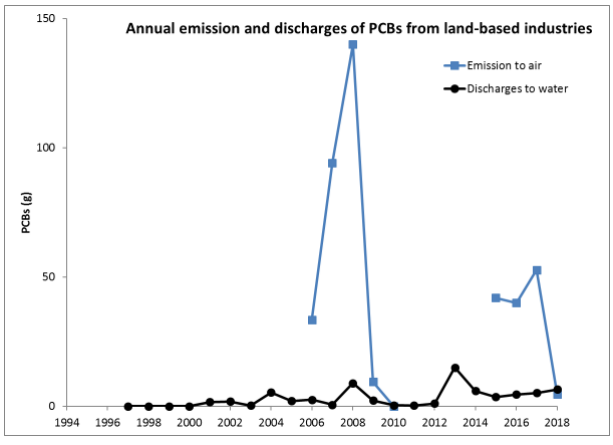


Figure 36. *Annual emissions of PCBs to air and discharges to water from land-based industries in the period 1997-2018 (data from www.norskeutslipp.no, 25 June 2019). No data for emissions to air are reported for 1994-2005 and 2011-2014. No data for discharges to water are reported for 1994-1996. Note 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 (ppDDE)

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 ppDDE) was analysed in blue mussel at 17 stations and in cod liver at seven stations (***Table 2***).

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 ppDDE in biota (see ***Table 6***). Applying this EQS for blue mussel and cod liver, all concentrations were below EQS. In the present study ppDDE has been used as a proxy for the priority substance DDT.

Levels exceeding PROREF

Concentrations of ppDDE exceeded the Norwegian provisional high reference contaminant concentration (PROREF) at nine blue mussel stations (***Table 11***). 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 Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord. Mussels exceeded PROREF by a factor between 10 and 20 at Byrkjenes (st. 51A) and Eitrheimsneset (st. 52A) in the Inner Sørfjord. Mussel exceeded PROREF by a factor between five and 10 at Vikingneset (st. 65A) in the Mid Hardangerfjord. Mussels at Solbergstrand (st. 31A) in the Mid Oslofjord exceeded PROREF by a factor between two and five. At Gressholmen (st. 30A) in the Inner Oslofjord and at Espevær (st. 22A), the exceedance was by a factor of up to two.

Concentrations of ppDDE exceeded PROREF by a factor between two and five in the Inner Sørfjord (st. 53B). The exceedance was up to two times in the Inner Oslofjord (st. 30B) and at Tjøme (st. 36B).

Increase in PROREF factor since 2017

Blue mussel exceeded the PROREF of ppDDE by a factor between 10 and 20 in 2017, compared to greater than 20 times in 2018 at Krossanes (st. 57A) in the Outer Sørfjord. Mussels exceeded the PROREF by a factor between five and 10 in 2017, while the exceedance was between 10 and 20 times in 2018 at Eitrheimsneset (st. 52A) in the Inner Sørfjord. Blue mussel exceeded the PROREF of ppDDE by a factor between two and five in 2017, while the exceedance was between five and 10 times at Vikingneset (st. 65A) in the Mid Hardangerfjord in 2018. In 2017, mussels exceeded PROREF by a factor less than two at Solbergstrand (st. 31A) in the Mid Oslofjord, while the exceedance was between two and five times in 2018. Blue mussel had concentrations below PROREF in 2017, but they exceeded this limit by a factor of up to two in 2018 at Espevær (st. 22A) in the Outer Bømlafjord.

In 2017, the ppDDE concentrations were lower than PROREF, but they exceeded PROREF by a factor up to two at the Inner Oslofjord (st. 30B) and at Tjøme (st. 36B) in the Outer Oslofjord.

Upward trends

There was a significant upward long-term trend in blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord (***Figure 37***).

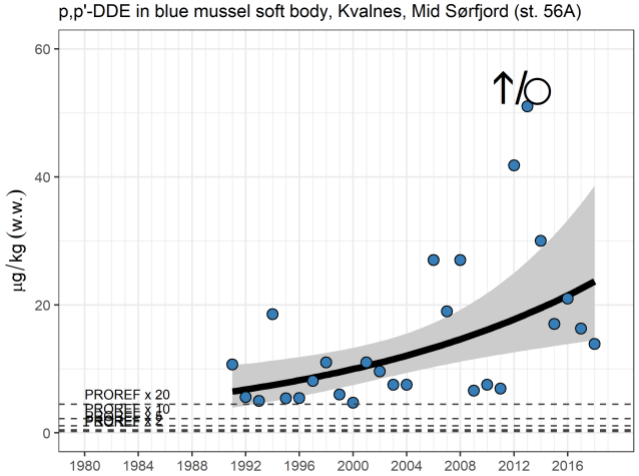


Figure 37. *Median concentrations (mg/kg w.w.) of ppDDE in blue mussel from 1992 to 2018 in the Mid Sørfjord at Kvalnes (st. 56A). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Decrease in PROREF factor since 2017

In 2017, there was an exceedance of PROREF of ppDDE by a factor between two and five in blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord, compared to no exceedance in 2018. In 2017, the exceedance of PROREF was less than two times at Risøy (st. 76A2) at Risør and Odderøya (st. I133) in the Kristiansandfjord, compared to no exceedance in 2018.

Downward trends

Both significant downward long-term and short-term trends for ppDDE in blue mussel were found at Gåsøya (st. I301) in the Inner Oslofjord. Significant downward long-term trends were found in blue mussel at five stations. These stations were Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, Odderøya (st. I133) in the Kristiansand harbour, and Skallnes (st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord.

Both significant downward long-term and short-term trends for ppDDE 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, at Bømlo (st. 23B) in the Outer Selbjørnfjord, and Kjøfjord in the Outer Varangerfjord (st. 10B).

Comparison with other studies, Sørfjord

In the present study, blue mussel from Krossanes had concentration of 4.7 µg/kg ppDDE (w.w.) and mussels from Utne, on the opposite side of the fjord, had concentration of 13.1 µg/kg ppDDE (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 at 26.7 µg DDT/kg w.w. at Grimo, on the opposite side (Ruus, Borgersen, et al. 2016).

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 ppDDE 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 ppDDE 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, Hylland, and Walday 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 et al. 2004). The variations in concentrations of ΣDDT and the ratio between ppDDT/ppDDE (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, Ruus, and Måge 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 et al. 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 ppDDE in sediment were observed in Mid Sørfjord (Green et al. 2010b).

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 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 the present study, PAHs[18] were analysed in blue mussel at seven stations (***Table 2***).

PROREF
Blue mussel at all stations were below the Norwegian provisional high reference contaminant concentration (PROREF) for PAH-16 (***Table 11***).

[18] 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).

Decrease in PROREF factor since 2017

Mussels at Akershuskaia (st. I301) exceeded PROREF of PAH-16 by a factor of up to two in 2017, compared to no exceedance in 2018. Mussel at Singlekalven (st. I203) exceeded PROREF by a factor less than two in 2017, compared no no exceedances in 2018.

Downward trends

Significant downward long-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 Gressholmen.

Comparison with other studies

In the Inner Ranfjord in 2018, significant downward trends were found for PAH compounds in blue mussels at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) (Øxnevad et al. 2019).

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries can be seen in ***Figure 38***. In 2018, the emission to air was 50 754 kg PAHs. In 2018, 32 892 kg PAHs originated from Vest-Agder, according to www.norskeutslipp. The discharges to water were 5 467 kg PAHs in 2018. In 2018, 1 645 kg PAHs was from Vest-Agder, according to www.norskeutslipp.

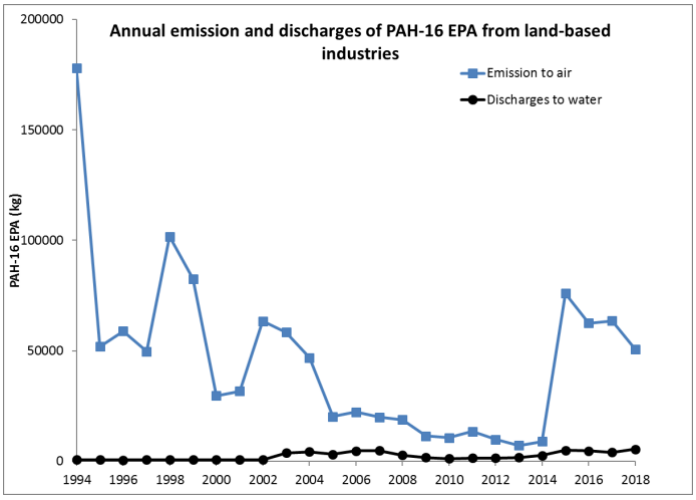


Figure 38. *Annual emissions of PAHs (PAH-16 EPA) to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are 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.*

3.2.16 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 seven stations (***Table 2***).

Levels exceeding PROREF

Blue mussel at all seven stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for KPAHs (***Table 11***). The exceedances were by a factor between 10 and 20 at Akershuskaia (st. I301) in the Inner Oslofjord and at Lastad at Søgne (st. I131A). The

concentrations of KPAHs were highest at Lastad (9.0 µg/kg). The exceedances were by a factor between five and 10 at Sylterøya (st. I714) in the Langesundfjord, and between two and five at Gressholmen (st. I3044) and Gåsøya (st. I304) in the Inner Oslofjord, and at Svolvær airport area (st. 98A2). The exceedance was by a factor less than two at Singlekalven (st. I023) at Hvaler.

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

Comparison with other studies
In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) exceeded PROREF for KPAH by a factor greater than 20 (Øxnevad et al. 2019).

3.2.17 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 seven stations (***Table 2***).

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 2018 (***Table 10***), as in previous years.

Levels exceeding PROREF
Except for blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord, mussels at all stations had concentrations below the Norwegian provisional high reference contaminant concentration (PROREF) for anthracene. Mussel at Akershuskaia exceeded PROREF by a factor less than two.

Downward trends
Both significant downward long- and short-term trends were found at Lastad (st. I131A) at Søgne. A significant downward long-term trend was found at Gressholmen (st. 30A) in the Inner Oslofjord.

Comparison with other studies
In the Kristiansandfjord in 2018, blue mussel had anthracene concentrations below EQS at all five stations (Næs 2019).

In the Sørfjord in 2018, blue mussel had anthracene concentrations below EQS at all three stations (Ruus, Borgersen, et al. 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had anthracene concentrations below EQS (Øxnevad et al. 2019).

General, large scale trends
Emissions of anthracene to air and discharges to water from land-based industries can be seen in ***Figure 39***. In 2018, the emission to air was 1 598 kg anthracene. The discharges to water were 15 kg anthracene in 2018.

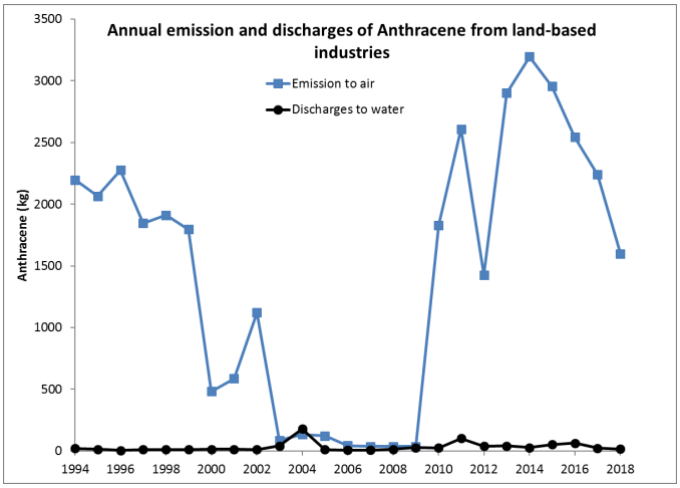


Figure 39. *Annual emissions of anthracene to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.18 Fluoranthene (FLU)

Fluoranthene is a PAH-compound. In the present study, fluoranthene was analysed in blue mussel at seven stations (***Table 2***).

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 10***).

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 11***).

Decrease in PROREF factor since 2017

In 2017, blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord had fluoranthene concentration that exceeded PROREF by a factor between two and five, compared to less than two times in 2018.

Downward trends

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

Comparison with other studies

In the Kristiansandfjord in 2018, blue mussel had fluoranthene concentrations below EQS at all five stations (Næs 2019).

In the Sørfjord in 2018, blue mussel had fluoranthene concentrations below EQS at all three stations (Ruus, Borgersen, et al. 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had fluoranthene concentrations below EQS (Øxnevad et al. 2019).

General, large scale trends

Emissions of fluoranthene to air and discharges to water from land-based industries can be seen in ***Figure 40***. In 2018, the emission to air was 2 912 kg fluoranthene. The discharges to water were 641 kg fluoranthene in 2018.

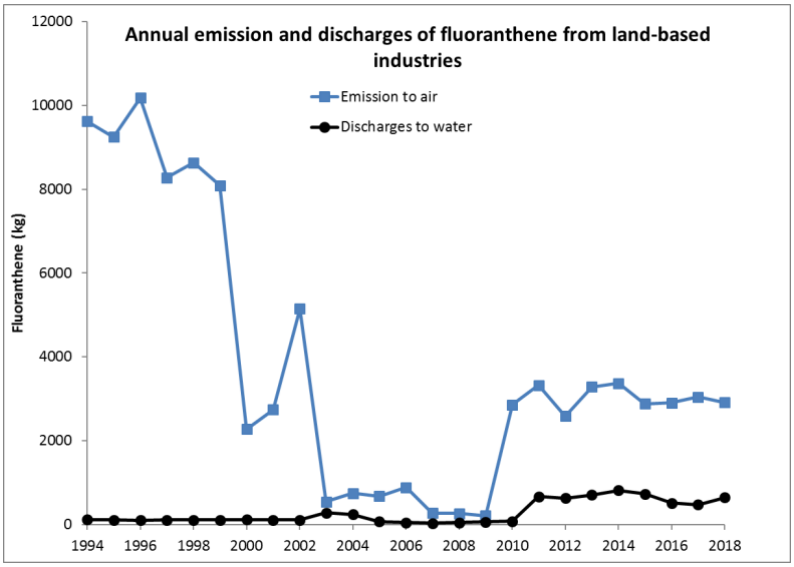


Figure 40. *Annual emissions of fluoranthene to air and discharges to water from land-based industries in the period 1994-2019 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not 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 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 seven stations (***Table 2***).

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 10***).

Levels exceeding PROREF

Blue mussel Akershuskaia (st. I301) in the Inner Oslofjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for benzo(a)anthracene by a factor of up to two (***Table 11***).

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 also seen at Lastad at Søgne (st. I131A).

Comparison with other studies

In the Kristiansandfjord in 2018, blue mussel had benzo(a)anthracene concentrations below EQS at all five stations (Næs 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had concentrations of benzo(a)anthracene below EQS (Øxnevad et al. 2019).

3.2.20 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 seven stations (***Table 2***).

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 10***).

Comparison with other studies

In the Kristiansandfjord in 2018, blue mussel had B[a]P concentrations below EQS at four stations and exceeded PROREF at one station (Næs 2019).

In the Sørfjord in 2018, blue mussel had B[a]P concentrations below EQS at all three stations (Ruus, Borgersen, et al. 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had B[a]P concentrations below EQS (Øxnevad et al. 2019).

General, large scale trends

Emissions of B[a]P to air and discharges to water from land-based industries can be seen in ***Figure 41***. In 2018, the emission to air was 623 552 kg B[a]P. The discharges to water were 69 445 kg B[a]P in 2018.

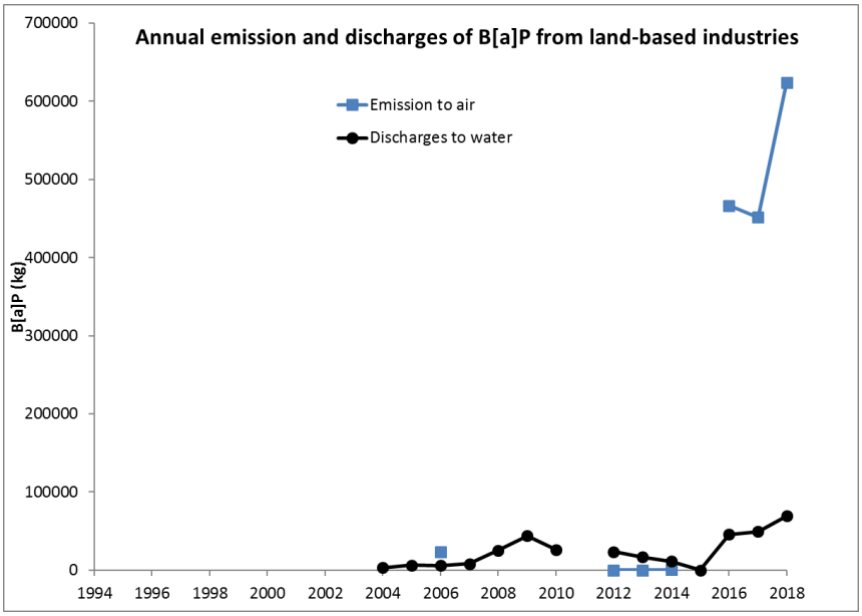


Figure 41. *Annual emissions of B[a]P to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.21 Naphthalene (NAP)

Naphthalene is a PAH-compound. Naphthalene was analysed in blue mussel at seven stations (***Table 2***).

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 10***).

Decrease in PROREF factor since 2017

The concentrations at all blue mussel stations were below PROREF for naphthalene in 2018. Changes in PROREF from 2017 to 2018 are due to changes in detection limits.

Except for blue mussel at Gressholmen (st. 30A), there was a decrease in PROREF at all stations. In 2017, there was an exceedance of PROREF by a factor between two and five in blue mussel at Gåsøya (st. I304), compared to concentration below PROREF in 2018. In 2017, the exceedances of PROREF were by a factor up to two, compared to no exceedances at Akershuskaia (st. I301) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler, Sylterøya (st. I714) in the Langesundfjord, Lastad (st. I131A) at Søgne and Svolvær (st. 98A2) in Lofoten.

Comparison with other studies

In the Kristiansandfjord in 2018, blue mussel had naphthalene concentrations below EQS at all five stations (Næs 2019).

In the Sørfjord in 2018, blue mussel had naphthalene concentrations below EQS at all three stations (Ruus, Borgersen, et al. 2019).

In the Inner Ranfjord in 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had naphthalene concentrations below EQS (Øxnevad et al. 2019).

General, large scale trends

Emissions of naphthalene to air and discharges to water from land-based industries can be seen in ***Figure 42***. In 2018, the emission to air was 12 134 kg naphthalene. The discharges to water were 1 495 kg naphthalene in 2018.

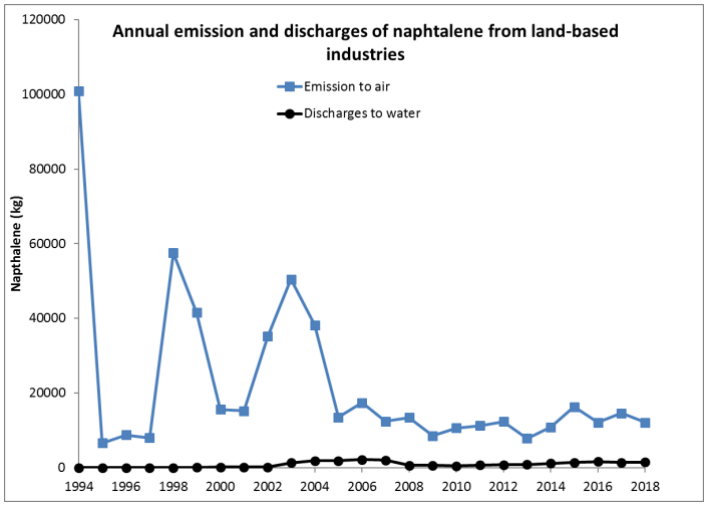


Figure 42. *Annual emissions of naphthalene to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 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 the present study, BDEs were analysed in blue mussel at 11 stations, cod liver at 11 stations and in eider blood and eggs at one station (***Table 2***).

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 10***).

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 10***). These results 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 BDE47 has been used as a proxy for the priority substance PBDE.

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) exceeded PROREF of sum BDEs (28, 47, 99, 100, 153 and 154) by a factor of between two to five. Cod liver from Tjøme (st. 36B) in the Outer Oslofjord (st. 30B) and Bergen harbour (st. 24B) exceeded PROREF by a factor less than two (***Table 11***, ***Table 13***, ***Figure 45***).

3.2.23 BDE47

The most dominant congener in 2018 was BDE47, which was also the case in 2017. BDE47 was detected at all blue mussel and cod stations sampled in 2018, as in 2017. The highest median concentrations of BDE47 were found in mussels from Bodø harbour (st. 97A3) (0.194 µg BDE47/kg w.w.) and in cod liver from the Inner Oslofjord (29.5 µg/kg w.w.).

Increase in PROREF factor for sum BDEs since 2017

In 2017, cod liver exceeded PROREF by a factor up to two for sum BDEs (28, 47, 99, 100, 153 and 154) in the Inner Oslofjord (st. 30B), compared to two to five times in 2018. In 2017, cod liver was below PROREF for sum BDEs at Tjøme (st. 36B) in the Outer Oslofjord, while the exceedance was up to two times in 2018.

Decrease in PROREF factor for sum BDEs since 2017

In 2017, cod liver exceeded PROREF by a factor between two and five for sum BDEs (28, 47, 99, 100, 153 and 154) in Bergen harbour (st. 24B), while the exceedances were less than two in 2018.

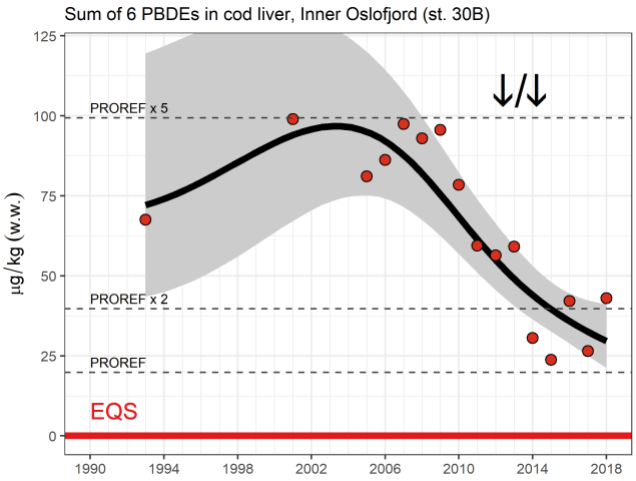
Downward trends for sum BDEs

A significant downward long-term trend was found for sum BDEs in blue mussel from Gressholmen (st. 30A) in the Inner Oslofjord.

Both significant downward long- and short-term trends were found for sum BDEs in cod liver from the Inner Oslofjord (s. 30B), Kristiansand harbour (st. 13B), Bømlo (st. 23B) in the Outer Selbjørnfjord, Trondheim harbour (st. 80B) and Tromsø harbour (st. 43B2).

Both significant downward long- and short-term trends were found in cod liver for sum BDEs (28, 47, 99, 100, 153 and 154) from the Inner Oslofjord (st. 30B) (***Figure 43 A***), Kristiansand harbour (st. 13B) (***Figure 44 A***), Bømlo (st. 23B) (***Figure 43 B***), Trondheim harbour (st. 80B) and Tromsø harbour (st. 43B2) (***Figure 44 B***).

A



B

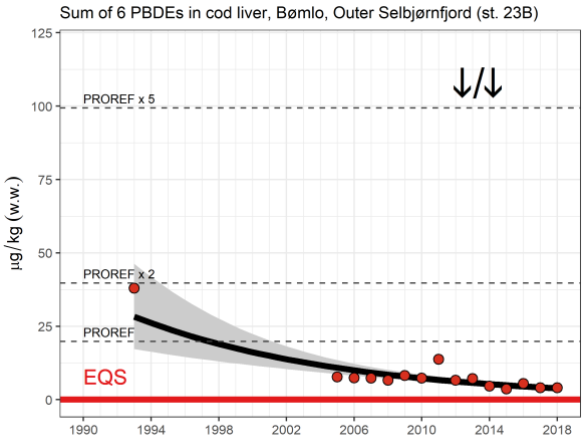
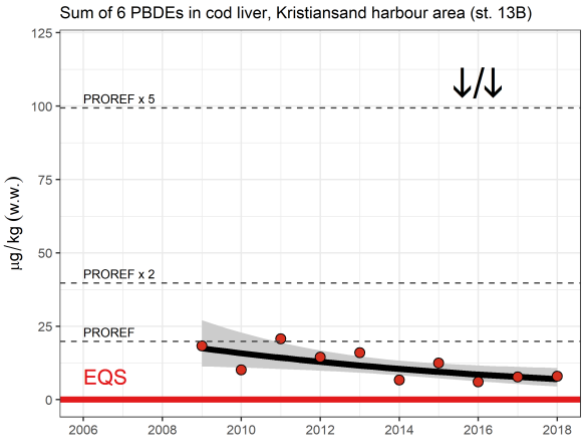


Figure 43. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 1993 or 2009 to 2018 in Inner Oslofjord (st. 30B) (**A**) and Bømlo (st. 23B) (**B**). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

A



B

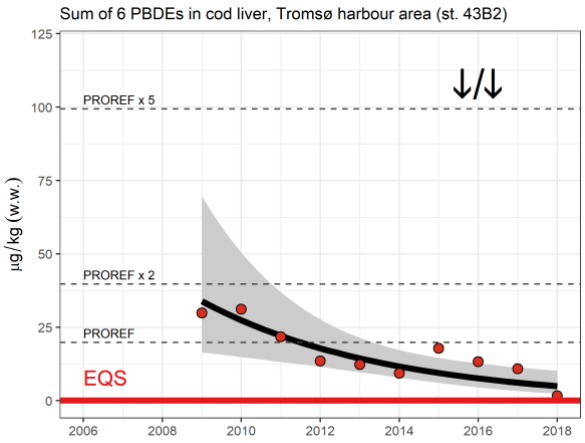


Figure 44. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 1984 to 2018 at Kristiansand harbour (st. 13B) (**A**) and Tromsø harbour (st. 43B2) (**B**). The EQS is indicated with a horizontal red line, and the Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Statistical considerations for cod liver

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 13***) in 2017. It seems like the deviations were 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 congener BDE47 was significantly higher in these two harbours than in at Færder and Bømlo, and another dominant congener BDE100 was significantly higher in the Oslo harbour than in 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 46***). 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 2018, PBDEs were analysed in cod from 11 stations (***Table 13***). 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.

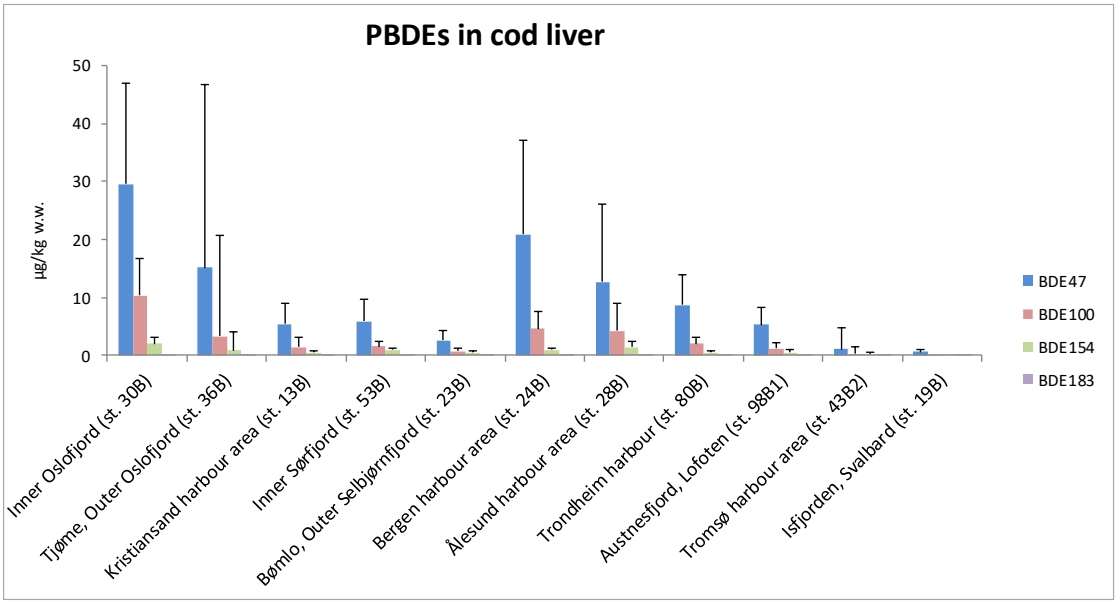


Figure 45*. Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2018. Only the results are shown where concentrations were above the limit of quantification for half or more of the samples. The error bar indicates one standard deviation above the median.*

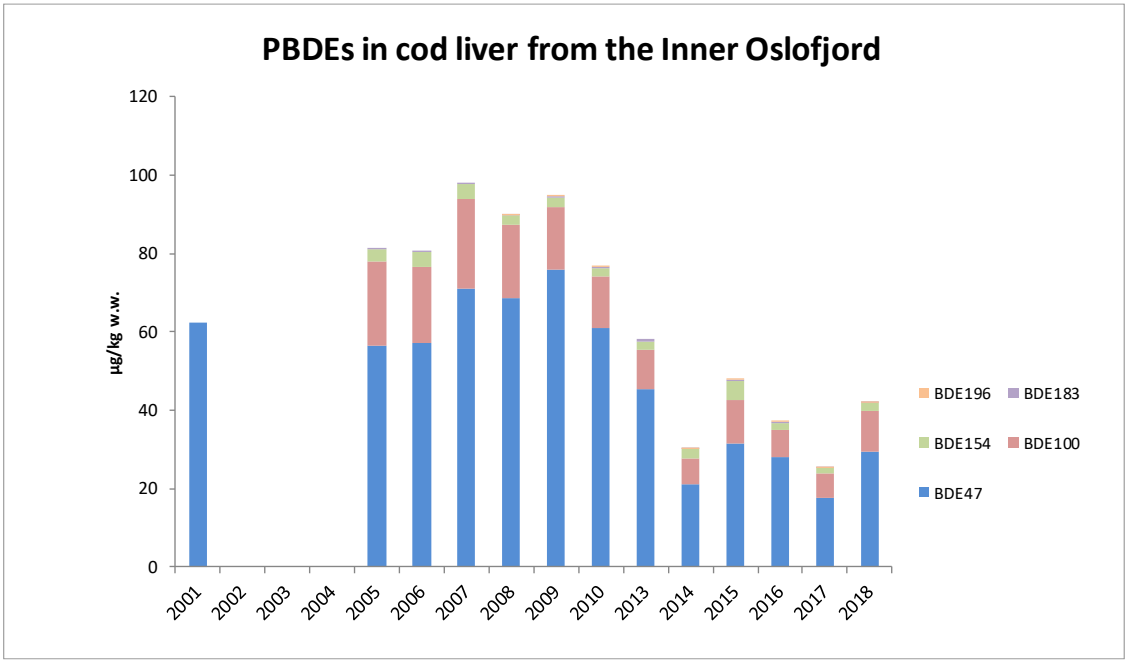


Figure 46*. Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2018 in the Inner Oslofjord (st. 30B).*

***Table 13**. Median concentrations (µg/kg w.w.) and standard deviations for PBDE congeners in blue mussel, cod liver, and eider blood and eggs in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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. 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 6**, see also **Chapter 2.10** for more details and **Appendix B** for description of chemical codes).*

Component	Count	BDE28			BDE47			BDE99			BDE100			BDE126			BDE153		
Species and sampling locality	2018	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)	0.002	0.000		0.011	0.003	3 (0.009-0.0142)	0.004	0.000	3 (0.004-0.0043)	0.004	0.000		0.004	0.000		0.006	0.000	
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.002	0.000		0.010	0.003	3 (0.0101-0.0155)	0.005	0.001	2 (0.0046-0.0061)	0.004	0.000	1 (0.0042)	0.004	0.000		0.006	0.000	
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.002	0.000		0.024	0.006	3 (0.0203-0.0316)	0.013	0.005	3 (0.012-0.0203)	0.004	0.000		0.004	0.000		0.006	0.000	
Sylteroya, Langesundfjord (st. I714)	3 (3-50)	0.002	0.000		0.034	0.006	3 (0.0291-0.041)	0.018	0.004	3 (0.014-0.0226)	0.006	0.002	2 (0.0063-0.0081)	0.004	0.000		0.006	0.000	
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.003	0.000	2 (0.003-0.003)	0.095	0.020	3 (0.0929-0.129)	0.062	0.013	3 (0.058-0.0816)	0.024	0.010	3 (0.0226-0.0403)	0.004	0.000		0.008	0.001	
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.002	0.000	1 (0.002)	0.078	0.008	3 (0.0735-0.0891)	0.068	0.013	3 (0.0545-0.0802)	0.024	0.004	3 (0.0214-0.0296)	0.004	0.000		0.007	0.001	
Ålesund harbour (st. 28A2)	3 (3-50)	0.002	0.000		0.030	0.005	3 (0.0289-0.0382)	0.024	0.004	3 (0.0169-0.0254)	0.010	0.002	3 (0.0078-0.0115)	0.004	0.000		0.006	0.000	
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	0.002	0.000		0.017	0.003	3 (0.0155-0.0222)	0.005	0.001	2 (0.0051-0.0053)	0.005	0.001	2 (0.0046-0.0057)	0.004	0.001		0.006	0.000	
Bodø harbour (st. 97A3)	3 (3-50)	0.006	0.009	3 (0.0044-0.0212)	0.194	0.051	3 (0.138-0.24)	0.113	0.036	3 (0.0723-0.144)	0.049	0.009	3 (0.0365-0.0541)	0.004	0.000		0.010	0.004	1 (0.0112)
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.002	0.000		0.036	0.010	3 (0.0293-0.0481)	0.023	0.006	3 (0.0166-0.028)	0.015	0.004	3 (0.0095-0.0183)	0.004	0.000		0.006	0.000	
Svolvær airport area (st. 98A2)	3 (3-50)	0.002	0.000		0.008	0.001	3 (0.0079-0.0089)	0.004	0.000		0.004	0.000		0.004	0.000		0.006	0.000	
Cod, liver																			
Inner Oslofjord (st. 30B)	10 (7-4)	0.579	0.658	10 (0.386-2.33)	29.500	17.305	10 (18.8-72.4)	0.355	0.331	10 (0.0977-1.26)	10.330	6.416	10 (4.74-22.4)	0.242	0.091	10 (0.109-0.402)	0.065	0.040	5 (0.0663-0.167)
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	0.408	0.203	15 (0.227-0.94)	15.100	31.493	15 (7.77-131)	0.519	0.397	15 (0.0642-1.69)	3.370	17.374	15 (1.05-67.6)	0.143	0.156	14 (0.0617-0.644)	0.094	0.062	12 (0.0364-0.287)
Kristiansand harbour area (st. 13B)	9 (5-4)	0.168	0.075	9 (0.0683-0.267)	5.420	3.603	9 (1.63-11.6)	0.083	0.106	8 (0.0357-0.361)	1.480	1.666	9 (0.335-5.76)	0.084	0.034	9 (0.03-0.133)	0.029	0.016	4 (0.032-0.0679)
Inner Sørfjord (st. 53B)	15 (1-4)	0.196	0.113	15 (0.102-0.496)	5.920	3.754	15 (3.93-17.5)	0.260	0.169	15 (0.146-0.787)	1.620	0.782	15 (1.19-3.78)	0.075	0.034	15 (0.0361-0.18)	0.040	0.042	10 (0.0396-0.164)
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	0.144	0.101	13 (0.0494-0.407)	2.655	1.714	14 (0.556-7.24)	0.026	0.067	7 (0.026-0.272)	0.781	0.554	14 (0.123-2.19)	0.019	0.010	3 (0.02-0.0545)	0.030	0.021	6 (0.0313-0.102)
Bergen harbour area (st. 24B)	12 (2-3)	0.493	0.251	12 (0.164-0.966)	20.900	16.070	12 (7.01-51)	0.548	1.706	12 (0.183-6.2)	4.620	3.069	12 (1.64-10.8)	0.033	0.016	11 (0.0198-0.0645)	0.120	0.108	12 (0.0522-0.441)
Ålesund harbour area (st. 28B)	15	0.274	0.449	15 (0.0617-1.57)	12.700	13.356	15 (1.39-52.5)	0.174	0.145	15 (0.0124-0.497)	4.300	4.663	15 (0.487-15.2)	0.060	0.057	11 (0.0272-0.188)	0.031	0.091	11 (0.0208-0.372)
Trondheim harbour (st. 80B)	15	0.294	0.110	15 (0.147-0.487)	8.700	5.123	15 (4.12-24.7)	0.336	0.155	15 (0.118-0.638)	1.990	1.184	15 (0.575-5.32)	0.051	0.025	10 (0.0307-0.105)	0.029	0.012	1 (0.0631)
Austnesfjord, Lofoten (st. 98B1)	12 (3-3)	0.254	0.192	11 (0.0671-0.52)	5.325	2.941	12 (0.293-8.85)	0.029	0.077	7 (0.0206-0.234)	1.230	0.878	12 (0.0737-2.53)	0.056	0.048	8 (0.0256-0.162)	0.028	0.004	1 (0.0396)
Tromsø harbour area (st. 43B2)	15	0.073	0.115	15 (0.0254-0.372)	1.150	3.591	15 (0.303-11.8)	0.025	0.083	8 (0.0253-0.291)	0.229	1.195	15 (0.0577-4.03)	0.018	0.007	4 (0.0228-0.0369)	0.027	0.003	2 (0.0341-0.0356)
Isfjorden, Svalbard (st. 19B)	15	0.056	0.023	15 (0.0197-0.111)	0.646	0.500	15 (0.263-2.46)	0.018	0.002	4 (0.0193-0.0237)	0.122	0.097	15 (0.0457-0.458)	0.018	0.001		0.027	0.001	
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.016	0.002		0.088	0.011		0.028	0.004		0.014	0.002		0.002	0.001	1 (0.0038)	0.011	0.002	1 (0.0113)
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.008	0.016	3 (0.0084-0.0691)	0.048	0.012	9 (0.047-0.0825)	0.023	0.008	12 (0.0141-0.0379)	0.028	0.010	14 (0.0093-0.0428)	0.004	0.007	2 (0.0052-0.029)	0.019	0.015	13 (0.0109-0.0602)

Table 13. *(cont.)*

Component	Count	BDE154			BDE183			BDE196			BDE209			BDE6S			BDESS		
Species and sampling locality	2018	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)	0.006	0.000		0.010	0.000		0.020	0.000		0.196	0.003		0.033	0.003	3 (0.0304-0.0365)	0.410	0.009	3 (0.4011-0.4186)
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.006	0.000		0.010	0.000		0.020	0.000		0.198	0.003		0.032	0.004	3 (0.0321-0.0398)	0.417	0.005	3 (0.4123-0.4223)
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.006	0.000		0.010	0.000		0.020	0.000		0.198	0.001		0.055	0.010	3 (0.0502-0.0697)	0.434	0.010	3 (0.4309-0.45)
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.006	0.000		0.010	0.000		0.019	0.000		0.194	0.003		0.071	0.012	3 (0.0608-0.0852)	0.444	0.012	3 (0.4436-0.4655)
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.008	0.002		0.010	0.000		0.020	0.000		0.196	0.040		0.198	0.046	3 (0.1912-0.2743)	0.584	0.092	3 (0.5829-0.7424)
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.007	0.002		0.010	0.000		0.019	0.000		0.192	0.005		0.186	0.027	3 (0.1645-0.2185)	0.593	0.038	3 (0.5382-0.6113)
Ålesund harbour (st. 28A2)	3 (3-50)	0.008	0.001		0.010	0.000		0.020	0.000		0.765	0.584	3 (0.751-1.77)	0.077	0.011	3 (0.069-0.0911)	1.028	0.579	3 (1.0193-2.026)
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	0.006	0.000		0.010	0.000		0.020	0.000		0.196	0.004		0.042	0.005	3 (0.0387-0.0478)	0.422	0.015	3 (0.4055-0.4362)
Bodø harbour (st. 97A3)	3 (3-50)	0.008	0.003	1 (0.0117)	0.010	0.003		0.020	0.016	1 (0.0473)	1.840	18.428	3 (0.374-33)	0.399	0.104	3 (0.2632-0.467)	2.615	22.038	3 (0.8344-39.8643)
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.006	0.000		0.010	0.000		0.020	0.000		0.199	0.002		0.088	0.020	3 (0.0694-0.1084)	0.465	0.026	3 (0.454-0.5032)
Svolvær airport area (st. 98A2)	3 (3-50)	0.006	0.000		0.010	0.000		0.020	0.001		0.199	0.005		0.030	0.001	3 (0.0293-0.0309)	0.412	0.010	3 (0.395-0.413)
Cod, liver																			
Inner Oslofjord (st. 30B)	10 (7-4)	1.980	1.100	10 (0.901-4.34)	0.049	0.022		0.097	0.003		0.971	0.033		42.988	24.569	10 (27.248-98.407)	49.469	29.079	10 (33.8404-121.927)
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	0.835	3.139	15 (0.327-9.69)	0.047	0.003		0.094	0.004		0.935	0.042		21.096	51.908	15 (11.0053-209.8	26.659	53.456	15 (14.0084-219.6109
Kristiansand harbour area (st. 13B)	9 (5-4)	0.469	0.224	9 (0.191-0.839)	0.049	0.002		0.098	0.004		0.980	0.036		8.014	5.434	9 (2.4568-18.8949)	10.383	5.694	9 (4.7979-22.3613)
Inner Sørfjord (st. 53B)	15 (1-4)	0.945	0.219	15 (0.403-1.3)	0.046	0.006		0.091	0.010		0.909	0.101		9.270	4.812	15 (5.9248-23.712)	12.825	5.438	15 (8.8394-29.6564)
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	0.511	0.286	14 (0.129-1.15)	0.046	0.003		0.093	0.005		0.926	0.887	3 (1.11-4.27)	4.071	2.640	14 (0.8745-11.033	6.899	2.847	14 (2.684-13.7096)
Bergen harbour area (st. 24B)	12 (2-3)	0.970	0.423	12 (0.34-1.88)	0.048	0.021	1 (0.119)	0.094	0.009		0.939	0.089		27.536	20.271	12 (10.121-64.57)	31.607	22.057	12 (12.6335-68.3803)
Ålesund harbour area (st. 28B)	15	1.510	0.866	15 (0.182-2.69)	0.010	0.046	2 (0.0183-0.0443)	0.020	0.000		0.195	0.016	3 (0.198-0.254)	19.099	18.807	15 (2.1633-71.828	22.391	19.720	15 (2.9285-74.848)
Trondheim harbour (st. 80B)	15	0.488	0.230	15 (0.26-1.18)	0.047	0.013		0.093	0.005		0.952	0.374		12.204	6.436	15 (5.4661-31.536	18.860	7.579	15 (7.9035-37.905)
Austnesfjord, Lofoten (st. 98B1)	12 (3-3)	0.561	0.406	11 (0.119-1.21)	0.047	0.004		0.094	0.007		0.957	0.523		7.701	4.410	12 (0.4501-13.218	11.237	5.591	12 (2.2612-17.8817)
Tromsø harbour area (st. 43B2)	15	0.171	0.387	15 (0.0405-1.32)	0.046	0.003		0.092	0.005		0.917	0.149	2 (0.908-1.1)	1.671	5.276	15 (0.4704-17.574	4.327	5.830	15 (2.2782-20.8545)
Isfjorden, Svalbard (st. 19B)	15	0.090	0.044	15 (0.033-0.218)	0.046	0.002		0.091	0.004		0.935	0.046	2 (0.997-1.02)	0.977	0.657	15 (0.4069-3.2993)	2.884	0.768	15 (2.1983-5.6353)
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.006	0.003	5 (0.0072-0.0146)	0.008	0.012	2 (0.0093-0.0546)	0.016	0.007		0.312	1.189	7 (1.3-3.98)	0.164	0.022	5 (0.1647-0.1765)	0.000	0.000	
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.037	0.019	15 (0.013-0.0824)	0.004	0.017	2 (0.0146-0.0694)	0.008	0.022	1 (0.0918)	0.998	0.594	14 (0.73-2.1)	0.176	0.054	15 (0.0994-0.2716)	0.000	0.000	

Levels in blue mussel

The congeners BDE47, 99 and 100 showed concentrations above the LOQ for half or more of the samples at all stations (***Table 11***, ***Table 13***, ***Figure 47***).

The highest median concentration was found in mussels from Bodø harbour (st. 97A3) (1.840 µg BDE209/kg w.w.) (***Figure 47 B***). The median value was based on three replicates where one was unusually high (33 µg BDE209/kg w.w.). However, even without this value the median of was 1.11 µg BDE209/kg w.w. and still the highest. This station also had the highest median concentration of BDE209 in 2017[19]. The second most dominant congener in 2018 was BDE47, which was also the case in 2017. BDE47 was detected at all stations in 2018, as in 2017. The highest median concentration was found in mussels from Bodø harbour (st. 97A3) (0.194 µg BDE47/kg w.w.).

Statistical considerations of blue mussel

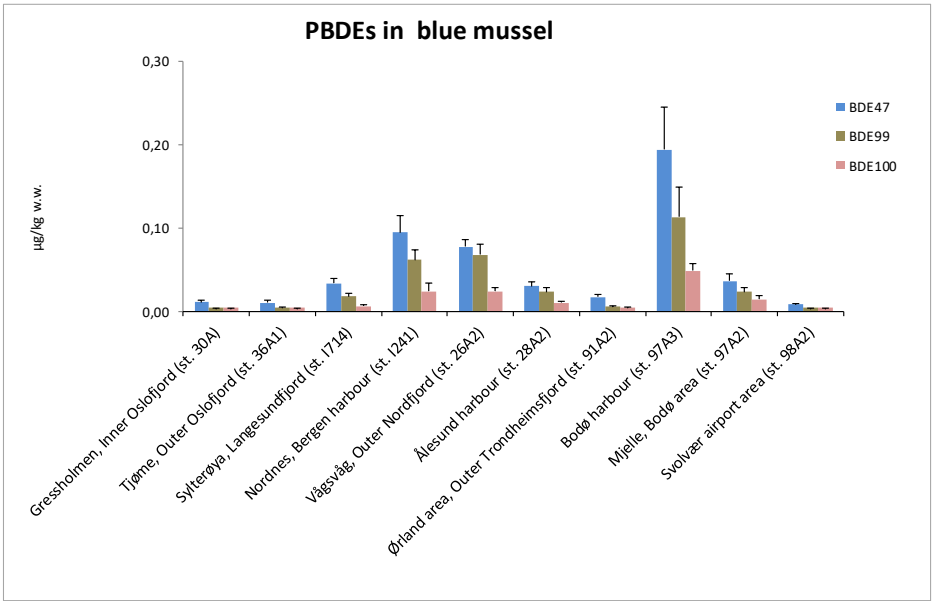
Blue mussel from Nordnes (st. I241) in Bergen harbour and Bodø harbour (st. 97A3) showed significantly higher concentrations of BDE47 than mussels from all the other stations (Tukey-Kramer HSD test, see also ***Figure 47***).

[19] It should be noted that while finalizing this report, a printing error was discovered in the report for the 2017 results (Green et al. 2018). This concerned the presentation of BDE209, BDE6S and BDESS in the table corresponding to ***Table 13*** in this present study. The corrected portion of the table is shown below.

Corrected portion of Table 14 in Green et al. (2018).

Component	Count	BDE209			BDE6S			BDESS		
Species and sampling locality	2017	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)	0.099	0.000		0.066	0.006	3[0.0574-0.0692]	0.258	0.006	3[0.2503-0.2621]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.099	0.001		0.039	0.003	3[0.0345-0.0392]	0.154	0.002	3[0.1505-0.1547]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.093	0.015		0.036	0.003	3[0.0356-0.0419]	0.148	0.012	3[0.1448-0.1679]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.125	0.000	1[0.12]	0.049	0.000	1[0.049]	0.269	0.000	1[0.268]
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.095	0.001		0.061	0.005	3[0.0575-0.0669]	0.246	0.007	3[0.2442-0.2568]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.099	0.006	1[0.10]	0.339	0.002	3[0.3356-0.3404]	0.556	0.002	3[0.5544-0.5591]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.097	0.002		0.135	0.019	3[0.1199-0.1575]	0.338	0.030	3[0.3157-0.3755]
Ålesund harbour (st. 28A2)	3 (3-50)	0.182	0.057	2[0.159-0.182]	0.088	0.019	3[0.0714-0.1087]	0.370	0.038	3[0.3665-0.4339]
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	0.091	0.005		0.033	0.003	3[0.0309-0.0362]	0.139	0.003	3[0.136-0.1428]
Bodø harbour (st. 97A3)	3 (3-50)	0.434	0.068	3[0.371-0.507]	0.379	0.035	3[0.3384-0.408]	0.799	0.087	3[0.7749-0.9365]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.097	0.002		0.055	0.022	3[0.04-0.0843]	0.242	0.028	3[0.2307-0.283]
Svolvær airport area (st. 98A2)	3 (3-50)	0.104	0.006		0.026	0.002	3[0.0227-0.0272]	0.227	0.013	3[0.2119-0.2384]
Cod, liver										
Inner Oslofjord (st. 30B)	12 (8-3)	0.953	0.113		26.471	38.926	12[18.1258-152.775]	30.218	42.405	12[21.4923-168.8753]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	0.949	0.085		2.253	0.521	10[1.7053-3.6038]	4.281	0.644	10[3.5156-5.8447]
Kristiansand harbour area (st. 13B)	12 (5-2)	0.971	0.061		7.728	4.330	12[3.7823-15.6427]	10.235	5.037	12[5.4788-20.3648]
Inner Sørfjord (st. 53B)	15 (3-2)	0.939	0.050		19.200	10.175	15[11.3836-44.0784]	23.886	10.791	15[14.8402-49.1676]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	0.962	2.995	6[1.28-10.8]	4.077	1.521	13[2.3998-8.2615]	7.329	3.650	13[4.6375-18.145]
Bergen harbour area (st. 24B)	15 (4-2)	0.962	0.035		41.336	67.211	15[9.7946-282.491]	47.577	71.661	15[13.3218-304.7123]
Ålesund harbour area (st. 28B)	15 (3-2)	0.957	0.892	1[4.4]	15.143	8.745	15[0.9118-31.003]	18.332	10.456	15[2.6398-37.143]
Trondheim harbour (st. 80B)	15	0.962	0.104		8.842	8.426	15[0.1766-29.6379]	12.314	9.472	15[2.135-36.5033]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)	0.971	0.371		3.844	4.748	11[0.4664-16.8913]	5.940	5.372	11[2.3472-21.2678]
Tromsø harbour area (st. 43B2)	15	0.971	0.037		10.897	4.559	15[4.0494-19.6017]	14.442	5.007	15[6.5983-23.2852]
Isfjorden, Svalbard (st. 19B)	15	0.971	0.051		1.170	0.891	15[0.7449-4.119]	3.327	1.094	15[2.5221-6.8778]
Eider, blood										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.134	0.079	3[0.169-0.414]	0.070	0.000	2[0.0701-0.071]	0.313	0.089	6[0.3169-0.6242]
Eider, egg										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.187	0.326	9[0.134-1.21]	0.208	0.101	15[0.0884-0.4351]	0.550	0.496	15[0.3838-2.0896]

A



B

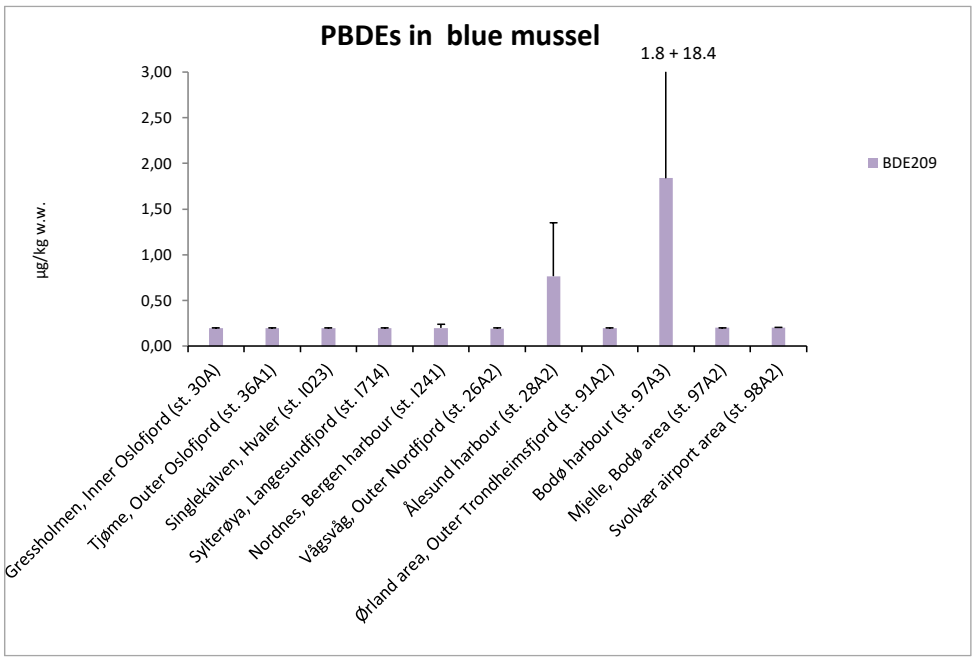


***Figure 47**. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2018; BDE47, BDE99 and BDE100 (**A**) and BDE209 (**B**). Only the results where concentrations were above the limit of quantification for half or more of the samples are shown. The error bar indicates one standard deviation above the median.*

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 29.5 µg BDE47/kg (w.w.), and the mean concentration in a comparable study in 2018 (Ruus, Bæk, et

al. 2019) was 29.9 µg BDE47/kg (w.w.). The median concentration of BDE100 was 10.3 µg /kg (w.w.) in the present study, while the mean concentration was 9.6 µg/kg (w.w.) in the study performed by Ruus *et al*. (2019). The median concentration of BDE154 was 2.0 µg/kg (w.w.) in the present study, while the mean concentration was 1.9 µg/kg (w.w.) in the comparable study (Ruus, Bæk, et al. 2019). 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 <0.164 µg/kg w.w. in blood and 0.176 µg/kg w.w. in eggs. The concentrations of BDE47 in eider were <0.088 µg/kg w.w. in blood and 0.048 µg/kg w.w. in eggs.

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 et al. 2005). This is lower than the sum BDEs (28, 47, 99, 100, 153 and 154) (42.99 µg/kg w.w.) found at MILKYS cod stations in the Inner Oslofjord (st. 30B) in 2018 (cf. ***Figure 45***).

The congeners BDE47 and 100 were the most dominant in 2018, 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 et al. 2012). In recent years, there has been a clear reduction of PBDE concentrations in freshwater fish from Mjøsa (Jartun et al. 2019).

In the present study, the median concentration of PBDE47 (0.048 µg/kg w.w.) in eider eggs from Svalbard was almost within the same range as 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, Herzke, and Kaasa 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 et al. 2018), which was eight times higher than at Svalbard.

General, large scale trends

No significant upward long-term trends were found. The only significant upward short-term trend was found for BDE154 in cod liver from the Austnesfjord in Lofoten (st. 98B1).

There was a total of 32 significant downward long-term trends (sum BDE not included), six were found in blue mussel and 26 in cod liver. Of 22 significant downward short-term trends, four were found in blue mussel and 18 in cod liver.

These results of dominating downward trends are more in line with the general decreasing trends for penta-mix PBDEs (that includes BDE100) (Law et al. 2014)), PBDEs in European emissions (Schuster et al. 2010) and 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 has been globally regulated through the Stockholm convention since 2009.

Emissions of brominated diphenyl ethers to air and discharges to water from land-based industries can be seen in ***Figure 48***. 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.

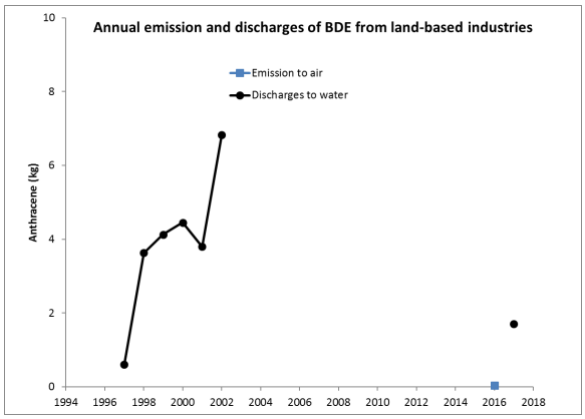


Figure 48. *Annual emissions* of *brominated diphenyl ethers* to *air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore 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 products. There are approximately 5000 PFASs on the marked globally (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/perfluorerte-stoffer-pfos-pfoa-og-andre-pfas-er/). In the present study, PFAS were analysed in blue mussel at seven stations, cod liver at 10 stations, and in eider blood and eggs at one station (***Table 2***, ***Table 11***, ***Figure 50***). 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 (2013/39/EU). Applying this for blue mussel, all stations were below the EQS. 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 7.4 µg/kg w.w. at Tjøme (st. 36B) in the Outer Oslofjord).

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, all stations were below the EQS. Applying this EQS for cod liver, all concentrations were below EQS (***Table 10***).

Levels exceeding PROREF
Cod liver from Tjøme (st. 36B) in the Outer Oslofjord exceeded the Norwegian provisional high reference contaminant concentrations (PROREF) for both PFAS and perfluorooctanesulfonamide (PFOSA) in 2018.

Increase in PROREF factor since 2017
In 2017, cod liver from Tjøme (st. 36B) in the Outer Oslofjord had levels of PFAS and PFOSA below PROREF, while the exceedances were by a factor of five to 10 for PFOSA and two to five times for PFAS in 2018.

Decrease in PROREF factor since 2017
In 2017, cod liver from the Inner Oslofjord exceeded PROREF for both PFAS and PFOSA by a factor of up to two, while there were no exceedances in 2018.

Downward trends
For both PFOS and PFOSA, both significant downward long- and short-term trends were found in cod liver from Kristiansand harbour (st. 13B), Inner Sørfjord (st. 53B), 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) and Tjøme (36B) in the Outer Oslofjord regarding PFOS, and at Bømlo (st. 23B) in the Outer Selbjørnfjord for PFOSA.

A significant downward long-term trend was found for perfluorononanoic acid (PFNA) in cod liver from the Inner Sørfjord.

Significant downward short-term trends were found in the Inner Oslofjord (st. 30B) for PFOSA, at Bømlo (st. 23B) for PFOS, and at Tjøme (st. 36B) in the Outer Oslofjord and in the Austnesfjord (st. 98B1) in Lofoten for PFAS.

Levels in blue mussel
Data for PFAS in blue mussel are not sufficient to analyse trends or PROREF. At Gressholmen (st. 30A), the concentration of PFOSA was 0.2 µg/kg w.w. At Tjøme (st. 36A1), the concentrations of PFOS and PFDcA (perfluorodecanoic acid) were 0.13 and 1.10 µg/kg w.w., respectively. All other PFAS concentrations were below LOQ.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PFOS were 1.0 µg/kg w.w. in blood and 2.4 µg/kg w.w. in eggs. The concentrations of PFOA were 1.1 µg/kg w.w. in blood and <0.5 µg/kg w.w. in eggs.

PFOS
In blue mussel, the concentration of PFOS was 0.130 µg/kg w.w. at Tjøme (st. 36A1) in the Outer Oslofjord. The levels at all other blue mussel stations were below LOQ (<0.100-0.500 µg/kg w.w.).

In cod liver, the highest median concentration of PFOS was also found at Tjøme (st. 36B) in the Outer Oslofjord (7.4 µg/kg w.w.) and the lowest level was observed at Svalbard (st. 19B, 0.230 µg/kg w.w.) (***Figure 50***, ***Figure 51***, ***Table 14***). At Tjøme (st. 36B) the PFOS concentrations had increased from 2.9 µg/kg (w.w.) in 2017 to 7.4 µg/kg (w.w.) in 2018.

Significant downward trends for PFOS were dominating in 2018, as in the previous years. Both significant downward long- and short-term trends were found for PFOS from the Inner Oslofjord (st. 30B), Tjøme (st. 36B), Kristiansand harbour (st. 13B), Inner Sørfjord (st. 53B), Austnesfjord (st. 98B1) in Lofoten and Tromsø harbour (st. 43B2).

PFOSA

In blue mussel, the concentration of PFOSA was 0.200 µg/kg w.w. at Gressholmen (st. 30A) in the Inner Oslofjord. The levels at all other blue mussel stations were below LOQ (<0.100-0.500 µg/kg w.w.).

Maximum median concentration of PFOSA was 44.0 µg/kg (w.w.) in cod liver at Tjøme (st. 36B) from the Outer Oslofjord, and a minimum level was found in the Inner Sørfjord (st. 53B) and at Svalbard (st. 19B) (<0.1 µg/kg w.w.). The concentration of PFOSA was 3,65 µg/kg (w.w.) in the Inner Oslofjord (***Figure 50***, ***Figure 51***). In 2018, 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 Tjøme (st. 36B) in the Outer Oslofjord than any other station (Tukey-Kramer HSD test).

Both significant downward long- and short-term trends were also found for PFOSA in cod liver from Kristiansand harbour (st. 13B), Bømlo (st. 23B) in the Outer Selbjørnfjord, the Inner Sørfjord (st. 53B), Austnesfjord (st. 98B1) in the Lofoten and Tromsø harbour (st. 43B2). A significant downward short-term trend was found in cod liver from the inner Oslofjord (st. 30B).

The median concentrations of the remaining PFASs were mostly below LOQ (***Table 14***).

PFNA

Both in blue mussel and cod liver, all concentrations of PFNA **(**perfluorononanoic acid) were below LOQ (<0.500 µg/kg w.w.).

A significant downward long-term trend was found for PFNA in cod liver from the Inner Sørfjord (st. 53B).

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 3.3 µg PFOS/kg (w.w.) and 3,7 µg PFOSA/kg (w.w.) in 2018. Cod liver from a comparable study from the Inner Oslofjord in 2018 had higher mean concentrations of both PFOS (6.2 µg/kg w.w.) (median 5.6 µg/kg w.w.) and PFOSA (12.1 µg/kg w.w.) (median 8.6 µg/kg w.w.) (Ruus, Bæk, et al. 2019). 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. 2010b). 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 et al. 2014) as opposed to what was observed in the present study.

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 2017 (2.9 µg PFOS/kg w.w. and 1.95 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 et al. 2017). Another study has also related PFAS concentrations in blue mussel to earlier use of firefighting foam in the area (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 2018, blue mussel at the former MILKYS stations Toraneskaien (st. I964), Moholmen (st. I965) and Bjørnbærviken (st. I969) had concentrations of PFOS and PFOA below EQS (Øxnevad et al. 2019).

In the present study, the median concentrations of PFOS (2.4 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, Herzke, and Kaasa 2013).

In the present study, the median concentrations were 1.0 µg PFOS/kg w.w. in blood and 2.4 µg PFOS/kg w.w. in eider eggs from Svalbard. A comparable study of eider duck from the Inner Oslofjord in 2018, found mean values of 9.97 µg PFOS/kg w.w. in blood and 23.21 µg PFOS/kg w.w. in eggs (Ruus, Bæk, et al. 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 et al. 2007). All concentrations observed in this present study were lower (maximum 7.4 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, Heldal, et al. 2011) and from three stations in the Norwegian Sea was 0.75, 0.82 and 11 µg/kg w.w. (Green, Heldal, et al. 2012).

PFAS compounds in freshwater fish were investigated in 2016 (Fjeld et al. 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.* (2019) showed decreasing annual mean concentrations for PFOS for all fish in Lake Mjøsa from 2013 to 2018.

PFOA has been strictly regulated nationally in consumer products from June 2014[20]. 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 short-term trends in PFOS (for the period 2009-2018). 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[21]) to water from land-based industries are shown in ***Figure 49***. The discharges to water had increased from 330 g PFAS in 2013 to 4171 g PFAS in 2017, end then decreased to 1332 g PFAS in 2018.

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

[21] 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.)

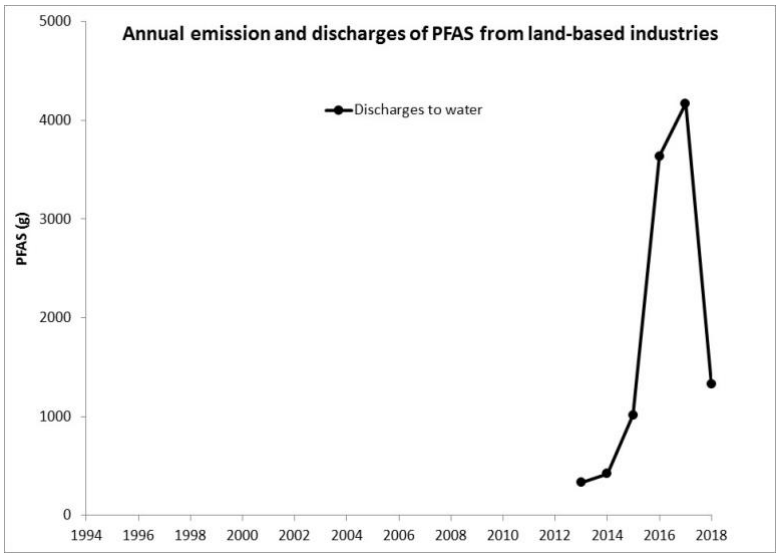


Figure 49. *Annual discharges of PFAS to water from land-based industries for 2013 to 2018 (data from www.norskeutslipp.no, 25. June 2019). No data for emissions to air are reported, and no data for discharges to water are reported for 1994-2012. Note that emissions and discharges from municipal treatment 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.*

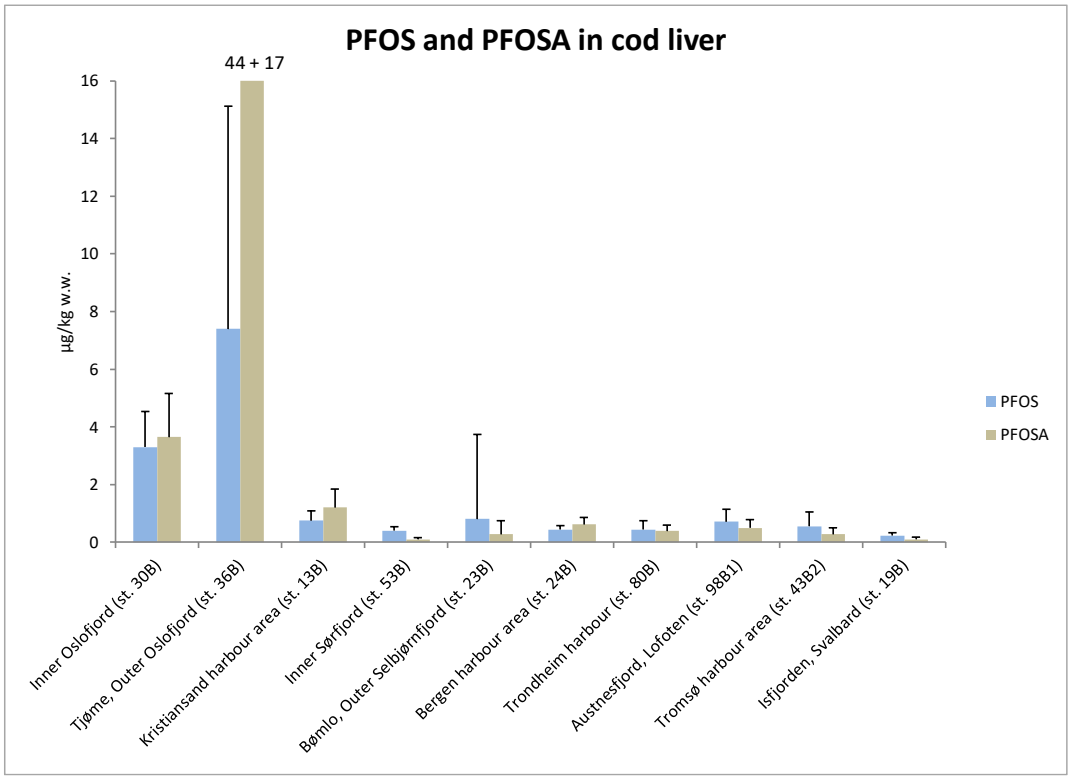


***Figure 50**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver in 2018. The error bar indicates one standard deviation above the median. (See also **Table 14**).*

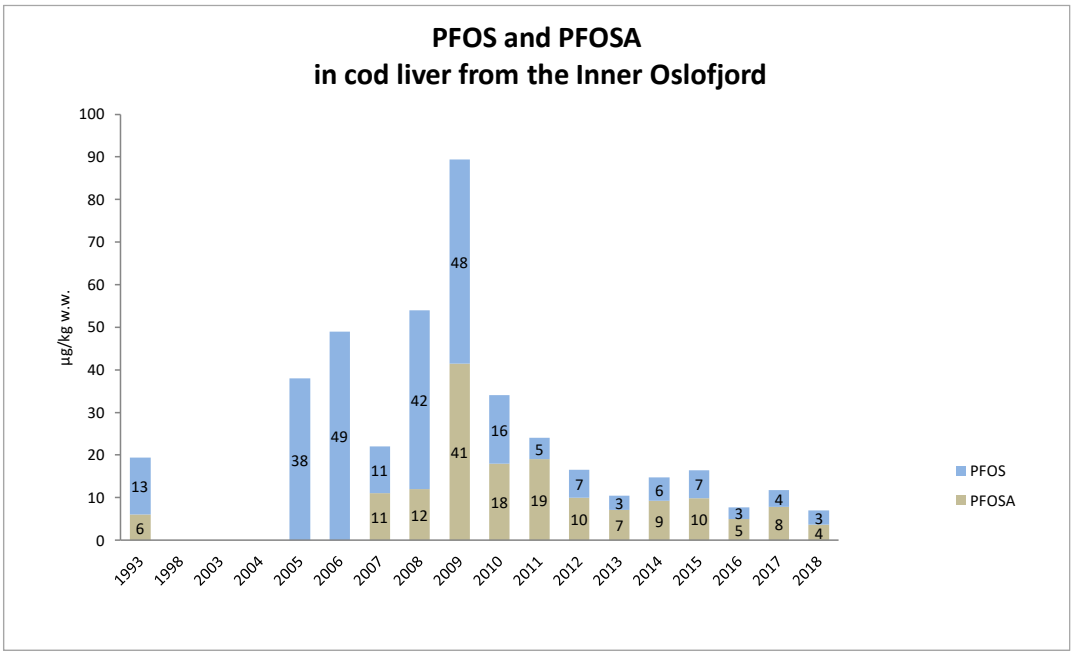


***Figure 51**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2018 in the Inner Oslofjord (st. 30B).*

***Table 14**. Median concentrations (µg/kg w.w.) and standard deviations of the PFAS-compounds analysed in blue mussel, cod liver, and eider blood and eggs in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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 **Chapter 2.10** for more details and **Appendix B** for description of chemical codes.)*

Component	Count	PFNA			PFOA			PFOS			PFOSA			PFUdA		
Species and sampling locality	2018	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		0.5	0		0.1	0		0.2	0.029	3 (0.2-0.25)	0.4	0	
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.5	0		0.5	0		0.13	0.01	3 (0.12-0.14)	0.1	0.006	1 (0.11)	0.4	0	
Byrkjenes, Inner Sørfjord (st. 51A)	3 (3-50)	0.5	0		0.5	0		0.1	0		0.1	0		0.4	0	
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.5	0		0.5	0		0.1	0		0.1	0		0.4	0	
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.5	0		0.5	0		0.1	0		0.1	0		0.4	0	
Ålesund harbour (st. 28A2)	3 (3-50)	0.5	0		0.5	0		0.1	0		0.1	0		0.4	0	
Svolvær airport area (st. 98A2)	3 (3-50)	0.5	0		0.5	0		0.1	0		0.1	0		0.4	0	
Cod, liver																
Inner Oslofjord (st. 30B)	10 (7-4)	0.5	0.003	1 (0.51)	0.925	1.116	7 (0.62-3.9)	3.3	1.225	10 (0.96-4.9)	3.65	1.5	10 (1.9-6.5)	1.05	0.473	8 (0.82-1.9)
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	0.5	0.057	2 (0.59-0.71)	1.7	1.172	11 (0.97-3.6)	7.4	7.722	15 (1.6-31)	44	17	15 (2.8-69)	0.87	0.381	11 (0.63-1.7)
Kristiansand harbour area (st. 13B)	9 (5-4)	0.5	0		0.64	0.269	6 (0.62-1.3)	0.75	0.33	9 (0.4-1.3)	1.2	0.645	8 (0.39-1.9)	0.4	0.153	4 (0.46-0.83)
Inner Sørfjord (st. 53B)	15 (1-4)	0.5	0		0.5	0		0.4	0.145	15 (0.21-0.83)	0.1	0.055	6 (0.11-0.31)	0.51	0.18	11 (0.41-0.89)
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	0.5	0		0.9	0.619	9 (0.54-2.1)	0.81	2.933	14 (0.38-9.7)	0.275	0.468	12 (0.16-1.8)	0.4	0.301	3 (1-1.2)
Bergen harbour area (st. 24B)	12 (2-3)	0.5	0		0.5	0		0.435	0.135	12 (0.2-0.71)	0.62	0.233	12 (0.23-1)	0.4	0.054	2 (0.47-0.58)
Trondheim harbour (st. 80B)	14	0.5	0		0.5	0		0.435	0.303	14 (0.17-1.1)	0.385	0.209	14 (0.13-0.73)	0.4	0.147	3 (0.42-0.88)
Austnesfjord, Lofoten (st. 98B1)	12 (3-3)	0.5	0.012	1 (0.54)	0.5	0.107	1 (0.87)	0.71	0.43	12 (0.16-1.5)	0.49	0.3	12 (0.12-1.1)	0.445	0.281	7 (0.43-1.4)
Tromsø harbour area (st. 43B2)	15	0.5	0.098	3 (0.57-0.85)	0.5	0.473	2 (1-2.3)	0.55	0.504	14 (0.14-2.3)	0.28	0.218	13 (0.15-0.91)	0.4	0.205	5 (0.43-1.2)
Isfjorden, Svalbard (st. 19B)	15	0.5	0		1.4	0.899	14 (0.57-3.4)	0.23	0.094	15 (0.14-0.43)	0.1	0.08	6 (0.14-0.36)	0.4	0.008	1 (0.43)
Eider, blood																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.79	0.306	14 (0.66-1.7)	1.1	2.433	10 (0.61-7.9)	1	1.105	15 (0.53-4.9)	0.1	0		0.4	0.387	1 (1.9)
Eider, egg																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.5	0.342	7 (0.68-1.6)	0.5	0.561	3 (0.84-2.1)	2.4	1.1	15 (1.1-4.9)	0.1	0		0.5	0.177	11 (0.42-1)

3.2.25 Supplementary perfluorinated alkylated substances (PFAS)

Supplementary, PFAS have been analysed in cod liver from 80 cod from 1990 to 2009. In addition, detailed results could be acquired by reviewing archived full-scan-mass spectrometry results from analyses of 2015-2018 samples. In total, 129 samples were analysed for 32 PFAS compounds (***Table 15***, **Appendix G**).

Generally, the PFAS acids PFDA, PFUnDA, PFDoA, PFTrDA and PFPeDA as well as the PFAS sulfonate acids PFOS, PFDS and PFOSA were found in samples collected since the early 1990s. The results for PFDA, PFUnDA (***Figure 52 B***), PFDoA (***Figure 52 C***), PFTrDA (***Figure 52 D***), and PFDS (***Figure 53*** B) showed a significant upward trend, whereas PFOS (***Figure 53 A***) and PFOSA (***Figure 53 C***) showed a significant downward trend.

EQS are established for PFOA and PFOS. PFOA has been below the EQS for the whole period (***Figure 52 A***), whereas PFOS has been below the EQS only since 2016.

MILKYS currently includes 13 of the 32 PFAS compounds registered in this supplementary investigation. PFUnDA and PFTrDA are not routinely monitored in MILKYS. Because these two have upward trends, they should be included as routine in MILKYS.

Comparison with other studies

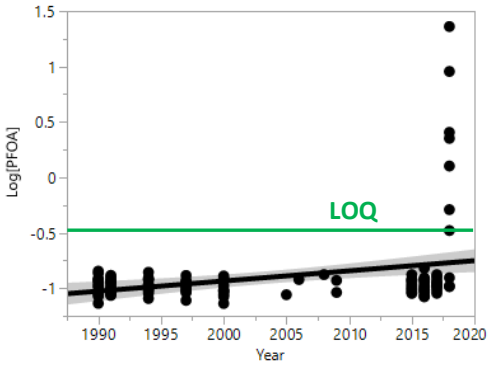
Jartun *et al.* (2019) showed decreasing annual mean concentrations for PFOS for all fish in Lake Mjøsa from 2013 to 2018. The total detectable PFAS (PFDA, PFUDA, PFDoDA, PFTrDA, PFTeDA and PFOS) seem to have downward trends for vendace (*Coregonus albula*), European smelt (*Osmerus eperlanus*) and brown trout (*Salmo trutta*) in Lake Mjøsa. Knowledge of the most important local sources for PFAS in Lake Mjøsa is limited. In Lake Femunden, PFTrDA was dominating in brown trout liver from 2014 to 2018, and downward trends were found for this substance, PFUDA and PFDoDA.

There is an indication that the PFAS acids found in brown trout from Lake Femunden come from long-range atmospheric transport (LRAT) as its catchment is exclusively within arid mountain and forest areas with limited anthropogenic impact. In addition, the brown trout in Lake Femunden are opportunistic, as it preys on insects (terrestrial), pelagic, and benthic organisms. In Lake Mjøsa, the brown trout prey more exclusively on the pelagic food web, resulting in a more complex PFAS pattern, also indicating more active PFAS sources within the catchment to this lake.

***Table 15**. Supplementary analyses of PFAS in cod liver from the Inner Oslofjord (St. 30B) 1990-2018. "x" under MILKYS indicates those compounds routinely monitored under MILKYS.*

		MILKYS	Carbon count	MILKYS LOQ	1990	1991	1994	1997	2000	2005	2006	2008	2009	2015	2016	2017	2018	Total count over LOQ	Average % pr. year	Significant slope
	Sample count (sum=129)				15	15	15	15	15	1	1	1	2	12	15	12	10			
Code	Name																			
PFHxA	perfluoro-n-hexanoic acid		C6	<0.5	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1.5	O
PFHpA	perfluoro-n-heptanoic acid	X	C7	<0.5	0	0	0	0	0	0	0	0	0	0	0	0	5	5	3.8	↑
PFOA	perfluoro-n-octanoic acid	X	C8	<0.5	0	0	0	0	0	0	0	0	0	0	0	0	7	7	5.4	↑
PFNA	perfluoro-n-nonanoic acid	X	C9	<0.5	0	1	0	0	0	1	0	1	1	0	0	0	1	5	20.5	O
PFDA	perfluoro-n-decanoic acid	X	C10	<0.5	0	0	7	12	15	1	1	1	2	12	8	6	8	73	70.0	↑
PFUnDA	perfluoro-n-undecanoic acid		C11	<0.4	15	15	14	14	15	1	1	1	2	12	10	12	8	120	94.9	↑
PFDoA	perfluoro-n-dodecanoic acid	X	C12	<0.4	0	1	10	13	15	1	1	1	2	12	5	12	8	81	74.9	↑
PFTrDA	perfluoro-n-tridecanoic acid		C13	<0.4	1	4	7	12	15	1	1	1	2	11	4	12	10	81	75.3	↑
PFTeDA	perfluoro-n-tetradecanoic acid		C14	<0.4	0	0	4	12	15	1	1	1	2	8	2	2	8	56	60.3	O
PFPeDA	perfluoro-n-pentadecanoic acid		C15	<0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
PFBS	perfluoro-1-butanesulfonate	X	C4	<0.2	0	0	0	0	0	0	0	0	0	0	0	2	0	2	1.3	O
PFPS	perfluoro-1-pentanesulfonate		C5	<0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
PFHxS	perfluoro-1-hexanesulfonate	X	C6	<0.1	1	3	11	6	0	1	0	0	0	2	0	0	0	24	19.7	↓
PFHpS	perfluoro-1-heptanesulfonate		C7	<0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
PFOS	perfluoro-1-octanesulfonate	X	C8	<0.1	15	15	15	15	15	1	1	1	2	12	15	12	10	129	100.0	↓
8Cl-PFOS	8Cl-perfluoro-1-octanesulfonate		C8	<0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
PFNS	perfluoro-1-nonanesulfonate		C9	<0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
PFDS	perfluoro-1-decanesulfonate	X	C10	<0.2	0	0	12	15	15	1	1	1	2	12	9	12	10	90	80.0	↑
PFDoS	perfluoro-1-dodecansulfonate	X	C12	<0.2	0	0	0	9	4	0	1	1	1	1	0	0	0	17	26.5	O
PFOSA	perfluoro-1-octanesulfonamide	X	C8	<0.1	15	15	15	15	15	1	1	1	2	12	15	12	10	129	100.0	↓
meFOSA	N-methylperfluoro-1-octanesulfonamide		C8	<0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
etFOSA	N-ethylperfluoro-1-octanesulfonamide		C8	<0.3	0	0	7	2	0	0	0	0	0	0	0	0	0	9	4.6	↓
meFOSE	2-(N-methylperfluoro-1-octanesulfonamido)-ethanol		C8	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
etFOSE	2-(N-ethylperfluoro-1-octanesulfonamido)·ethanol		C8	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
4:2 FTS	1H,2H-perfluorohexan sulfonate (4:2)		C4	<0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
6:2 FTS	1H,2H-perfluorooctane sulfonate (6:2)	X	C6	<0.3	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.6	↑
8:2 FTS	1H,2H-perfluorodecan sulfonate (8:2)	X	C8	<0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
10:2 FTS	1H,2H-perfluorododecan sulfonate (10:2)		C10	<0.3	0	0	0	11	1	0	0	0	0	0	0	0	0	12	6.2	O
12:2 FTS	1H,2H-perfluorododecan sulfonate (12:2)		C12	<0.3	0	0	2	13	11	1	1	1	1	0	0	0	0	30	40.3	↓
FOSAA	perfluoro-1-octansulfonamidoacetic acid		C8	<0.3	0	0	4	5	0	0	0	0	0	0	0	0	0	9	4.6	O
meFOSAA	2-(N-methylperfluoro-1-octansulfonamido)acetic acid		C8	<0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	O
etFOSAA	2-(N-ethylperfluoro-1-octansulfonamido)acetic acid		C8	<0.3	1	0	12	12	1	0	0	0	0	0	0	0	0	26	13.3	↓

A



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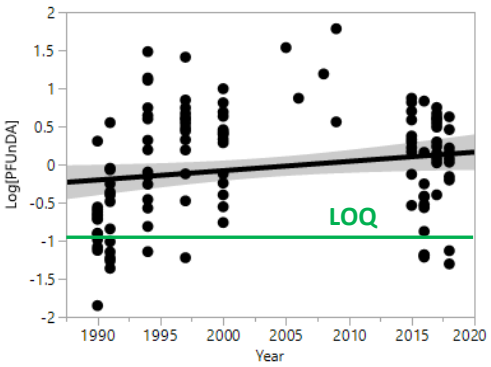

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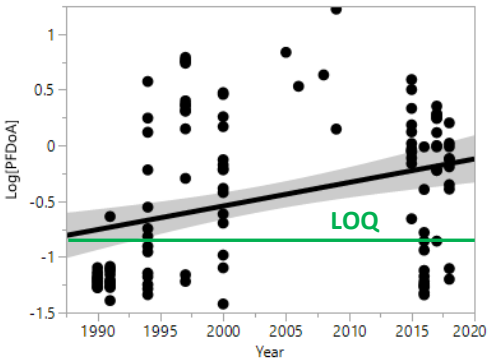

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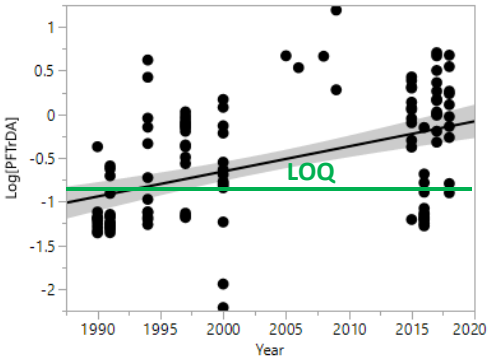
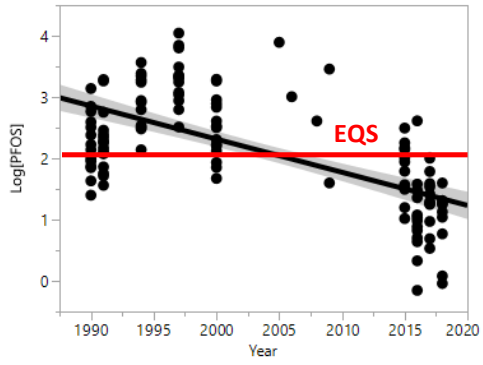


Figure 52. *Supplementary analyses of PFAS in cod liver from the Inner Oslofjord (st.30B) 1990-2018 for PFOA (**A**), PFUnDA (**B**), PFDoA (**C**) and PFTrDA (**D**). The black line indicates the linear trend on log-transformed concentrations. All three analyses indicated a significant upward trend. (see **Table 15**) The EQS for PFOA (log(91.3)=4.51) is off scale.*

A



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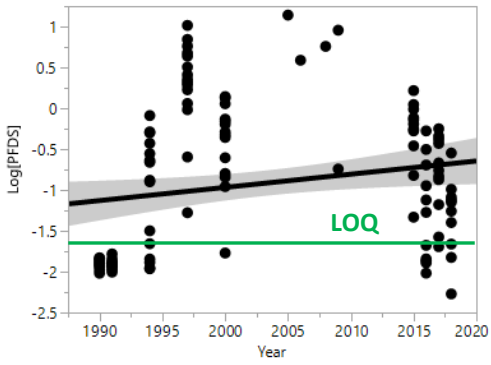

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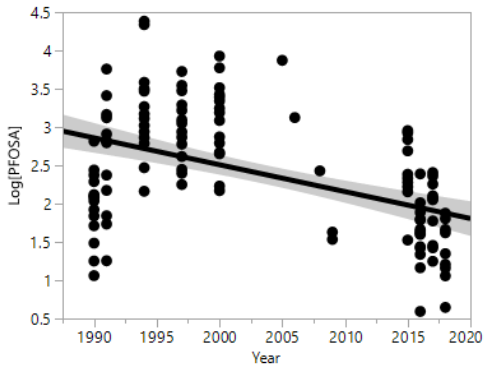


Figure 53. *Supplementary analyses of PFAS in cod liver from the Inner Oslofjord (st.30B) 1990-2018 for PFOS (**A**), PFDS (**B**) and PFOSA (**C**). The black line indicates the linear trend on log-transformed concentrations. The trend analyses for PFOS and PFOSA indicated a significant downward trend, whereas the results for PFDS indicate a significant upward trend. (see **Table 15**) The EQS for PFOS is indicated with a horizontal red line. LOQ for PFOS and PFOSA is offscale (below).*

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 13 stations, in blue mussel from 12 stations, and in blood and eggs of eider from one station (***Table 2***).

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 2018 (***Table 10***). 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 up to two.

Upward trends

There were no upward trends for HBCD in cod or blue mussel in 2018.

Decrease in PROREF since 2017

Median concentration of HBCD in blue mussel from Bodø harbour (st. 97A3) decreased from 2017 to 2018. In 2017 the HBCD concentration exceeded PROREF by a factor of two to five, and in 2018 the exceedance was reduced to a factor of up to two. Median concentration of HBCD in blue mussel from Nordnes (st. I241) in Bergen harbour also decreased from 2017 to 2018. In 2017 the HBCD concentration exceeded PROREF by a factor of two to five, and in 2018 the concentration was lower than the PROREF for HBCD.

The median concentration of HBCD in liver of cod from the Inner Oslofjord (st. 30B) decreased from 2017 to 2018. In 2017 the concentration of HBCD exceeded PROREF by a factor of up to two. In 2018 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 55 A***), Kirkøy, Hvaler (st. 02B) 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 trend was found for HBCD in blue mussel from Gressholmen, Inner Oslofjord (st. 30A) (***Figure 55 B***).

Levels in eider

The concentration of HBCD in eider egg decreased from 0.150 µg/kg in 2017 to 0.133 µg/kg in 2018. The concentration of HBCD in eider blood was below the limit of quantification.

General, large scale trends

Cod from the Inner Oslofjord (st. 30B) had the highest concentration of HBCD (here defined as the sum of the α–, β–, and γ–diastereomers) in liver (***Figure 54***, ***Table 16***). Median concentration of HBCD in cod liver from the Inner Oslofjord was 6.16 µg/kg w.w.

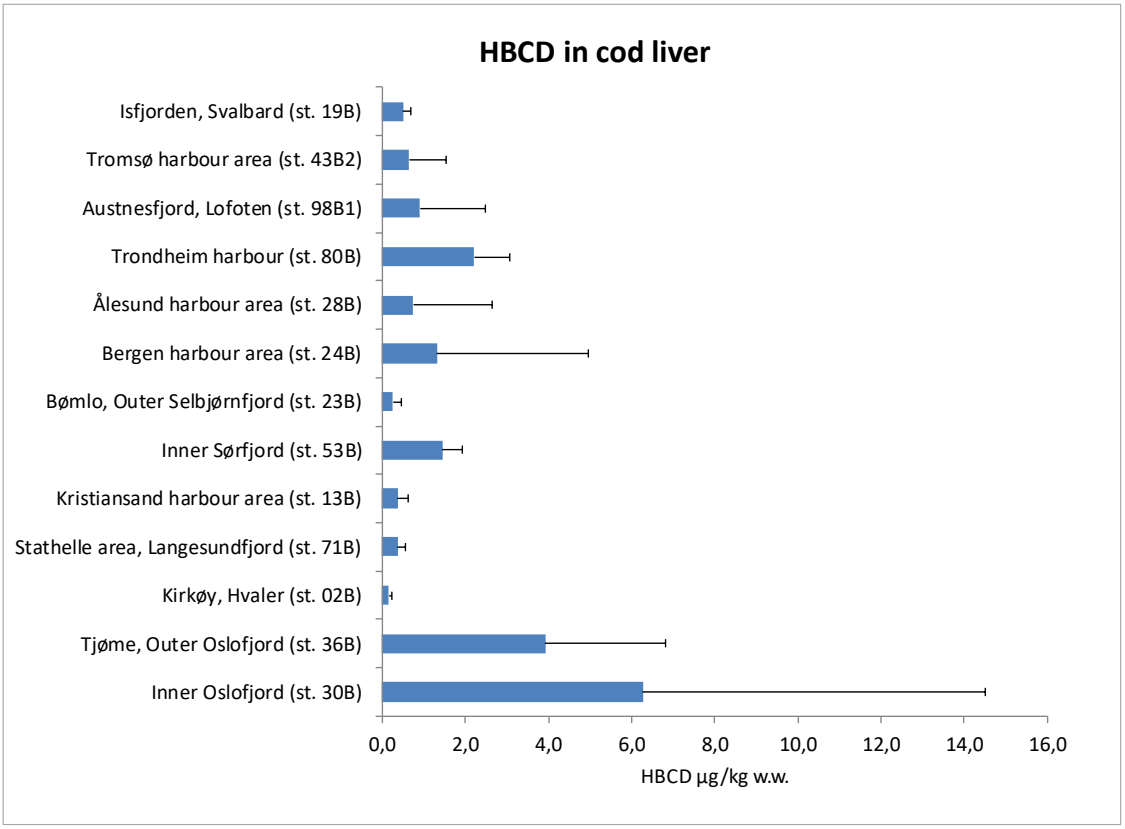
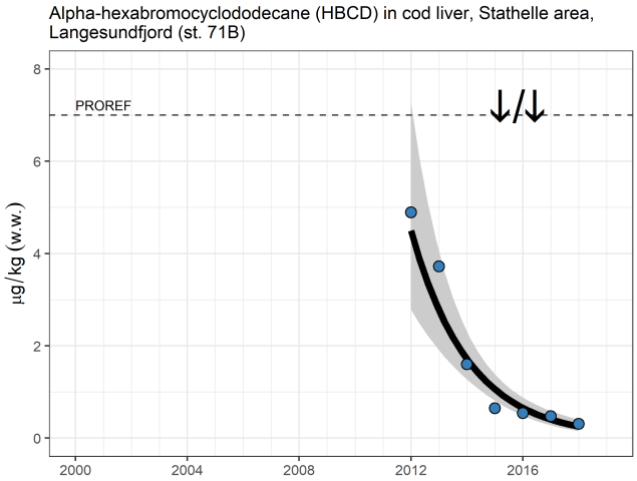


***Figure 54**. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver in 2018. The error bar indicates one standard deviation above the median.*

A



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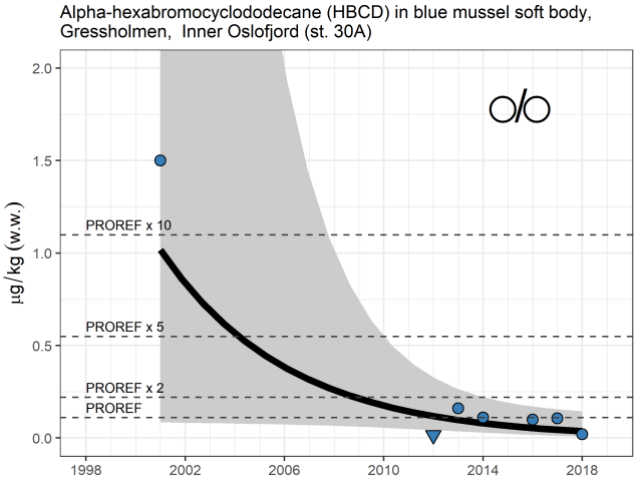


Figure 55. *Median concentrations (mg/kg w.w.) of α–HBCD (HBCDA) in cod liver from 2001 or 2012 to 2018 in Stathelle area (st. 71B) in the Langesundfjord (**A**) and in blue mussel from Gressholmen (st. 30A) in the Inner Oslofjord (**B**). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

***Table 16**. Median concentration (µg/kg w.w.) with standard deviation of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver, blue mussel and eider in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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 **Chapter 2.10** for more details and **Appendix B** for description of chemical codes.)*

Component	Count	a-HBCD			g-HBCD			b-HBCD			HBCD		
Species and sampling locality	2018	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)	0.020	0.005	3 (0.0187-0.0273)	0.006	0.000		0.006	0.000		0.032	0.005	3 (0.0307-0.0393)
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.010	0.002	3 (0.0086-0.0124)	0.006	0.000		0.006	0.000		0.022	0.002	3 (0.0206-0.0244)
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.022	0.002	3 (0.0204-0.0246)	0.029	0.002	3 (0.0248-0.0286)	0.006	0.000		0.057	0.004	3 (0.0512-0.0592)
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.023	0.002	3 (0.0215-0.0245)	0.028	0.013	3 (0.0078-0.0326)	0.006	0.000		0.059	0.013	3 (0.0367-0.0601)
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.073	0.028	3 (0.0642-0.116)	0.018	0.011	3 (0.0155-0.0351)	0.006	0.001		0.094	0.039	3 (0.0882-0.1589)
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.051	0.006	3 (0.042-0.0536)	0.019	0.002	3 (0.0161-0.0206)	0.006	0.001	1 (0.007)	0.073	0.007	3 (0.0672-0.0812)
Ålesund harbour (st. 28A2)	3 (3-50)	0.061	0.008	3 (0.0489-0.064)	0.047	0.008	3 (0.0333-0.0483)	0.009	0.002	2 (0.009-0.0093)	0.119	0.018	3 (0.0882-0.1199)
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	0.012	0.000	3 (0.0114-0.0121)	0.006	0.000		0.006	0.000		0.024	0.000	3 (0.0234-0.0241)
Bodø harbour (st. 97A3)	3 (3-50)	0.196	0.042	3 (0.167-0.249)	0.056	0.045	3 (0.0497-0.13)	0.025	0.015	3 (0.0202-0.0486)	0.277	0.101	3 (0.2369-0.4276)
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.023	0.006	3 (0.0143-0.0268)	0.008	0.002	2 (0.0083-0.0091)	0.006	0.000		0.037	0.008	3 (0.0263-0.0419)
Svolvær airport area (st. 98A2)	3 (3-50)	0.006	0.002	1 (0.0091)	0.006	0.000		0.006	0.000		0.018	0.002	1 (0.0211)
Cod, liver													
Inner Oslofjord (st. 30B)	10 (7-4)	6.160	8.150	10 (3.76-28.5)	0.072	0.104	8 (0.0328-0.345)	0.030	0.003	1 (0.0338)	6.270	8.250	10 (3.8234-28.878
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	3.850	2.834	15 (1.77-12)	0.076	0.078	14 (0.03-0.287)	0.029	0.024	4 (0.0303-0.119)	3.920	2.896	15 (1.8383-12.273
Kirkøy, Hvaler (st. 02B)	4 (4-3)	0.101	0.079	3 (0.0901-0.219)	0.029	0.001		0.029	0.001		0.157	0.078	3 (0.1489-0.2762)
Stathelle area, Langesundfjord (st. 71B)	15 (7-4)	0.309	0.190	15 (0.0387-0.765)	0.029	0.044	3 (0.0311-0.2)	0.029	0.002		0.369	0.200	15 (0.0963-0.8206)
Kristiansand harbour area (st. 13B)	9 (5-4)	0.299	0.225	9 (0.134-0.76)	0.029	0.044	4 (0.0728-0.149)	0.029	0.015		0.370	0.253	9 (0.1922-0.8659)
Inner Sørfjord (st. 53B)	15 (1-4)	1.380	0.482	15 (0.378-2.01)	0.042	0.015	8 (0.0391-0.0821)	0.029	0.001		1.453	0.484	15 (0.4791-2.0965)
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	0.205	0.191	14 (0.0662-0.636)	0.028	0.005	1 (0.0473)	0.028	0.001		0.262	0.190	14 (0.1212-0.6936)
Bergen harbour area (st. 24B)	12 (2-3)	1.225	3.541	12 (0.562-10.3)	0.056	0.096	12 (0.029-0.323)	0.029	0.003	1 (0.0356)	1.318	3.634	12 (0.6426-10.658
Ålesund harbour area (st. 28B)	15	0.658	1.829	15 (0.124-6.18)	0.072	0.086	13 (0.0141-0.296)	0.028	0.011		0.743	1.896	15 (0.1441-6.5035)
Trondheim harbour (st. 80B)	15	2.060	0.823	15 (0.317-2.82)	0.089	0.076	11 (0.048-0.23)	0.029	0.002		2.212	0.874	15 (0.3716-3.0794)
Austnesfjord, Lofoten (st. 98B1)	12 (3-3)	0.852	1.579	11 (0.208-4.66)	0.028	0.006	2 (0.0301-0.0464)	0.028	0.002		0.909	1.578	11 (0.2636-4.7172)
Tromsø harbour area (st. 43B2)	15	0.592	0.874	15 (0.152-2.79)	0.029	0.014	1 (0.0808)	0.029	0.001		0.656	0.881	15 (0.2114-2.861)
Isfjorden, Svalbard (st. 19B)	15	0.441	0.200	15 (0.12-0.784)	0.029	0.003		0.029	0.003		0.498	0.203	15 (0.1794-0.8428)
Eider, blood													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.022	0.006		0.028	0.009		0.014	0.003		0.065	0.013	
Eider, egg													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.133	0.088	15 (0.0352-0.3267)	0.014	0.144	1 (0.573)	0.005	0.008	1 (0.0369)	0.152	0.193	15 (0.0563-0.8323)

Analysis of cod liver showed that α–HBCD was about-100 times higher than in blue mussel on a wet weight basis (compare ***Figure 56*** and ***Figure 57***). 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) had concentrations of α–HBCD that were significantly higher than for all the other stations (Tukey-Kramer HSD test, see also ***Figure 56***).

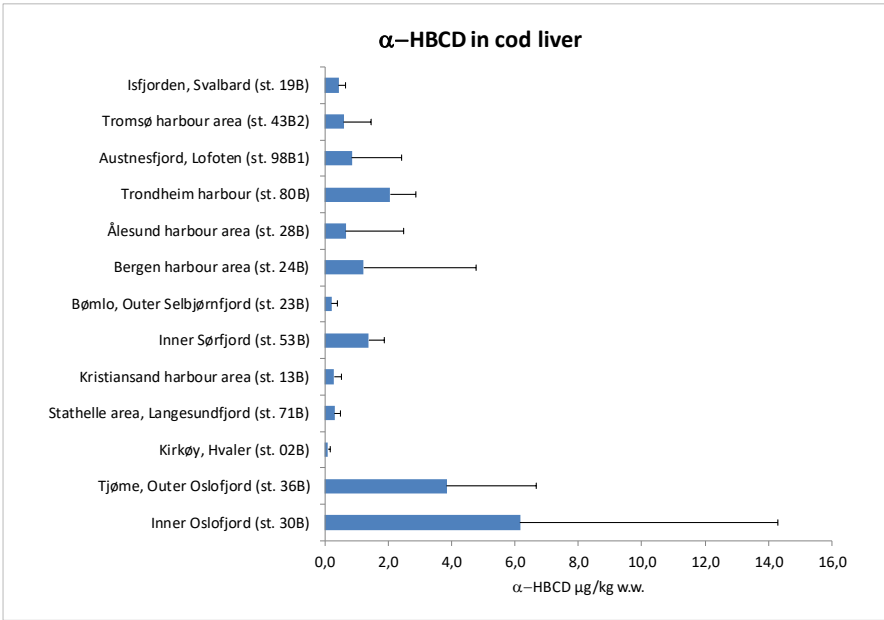


Figure 56*. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2018. The error bar indicates one standard deviation above the mean.*

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 57***).

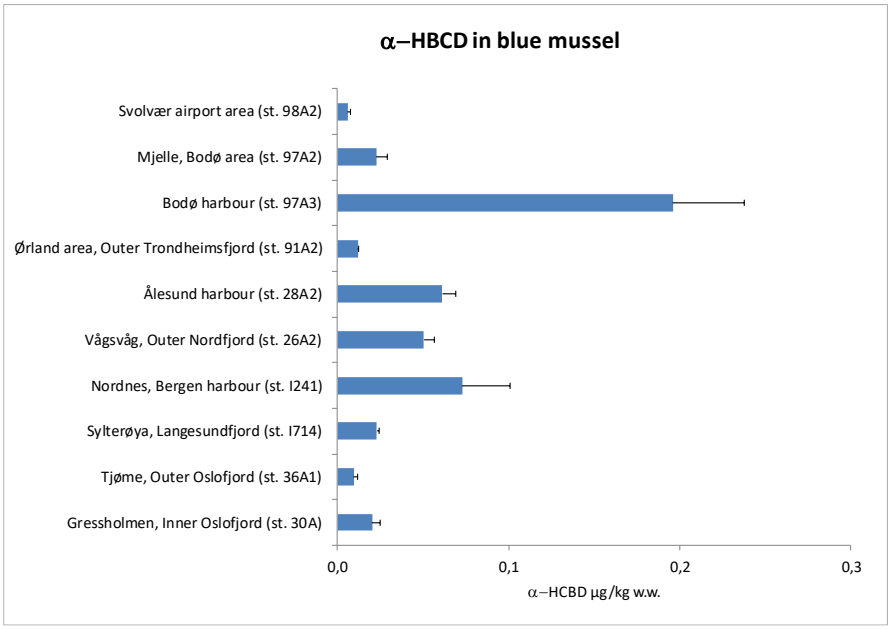


Figure 57*. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2018. The error bar indicates one standard deviation above the mean.*

Median concentration of HBCD in eggs of eider from Kongsfjord, Svalbard (st. 19N) was 0.316 µg/kg w.w. The concentrations of HBCD in eider blood was below the level of quantification.

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 58***). In 2006, the discharge to water was 0.51 kg and during the following years the discharges have gradually decreased to 0 kg 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).

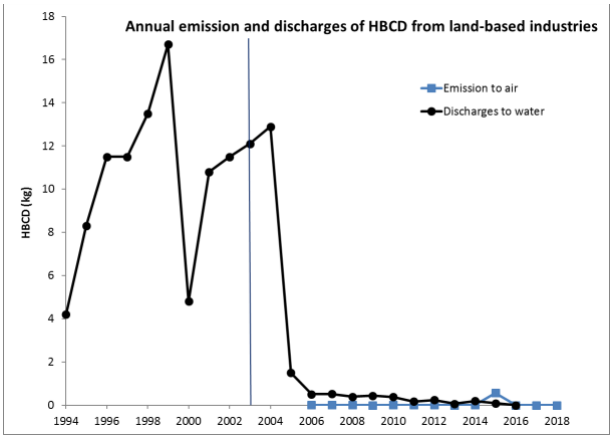


Figure 58*. Annual emissions of HBCD to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 25 June 2019). HBCD has been monitored in this project since 2001 (indicated with a vertical line). No data for emissions to air are reported for 2002-2005. Discharges to water in 2017 and 2018 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, HBCDD was found in freshwater fish in 13 lakes in Norway, in the range 0.0 (below LOQ) to 11.89 ng/g w.w. (Jartun et al. 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 2018 through the Stockholm Convention. In the present study, chlorinated paraffins were analysed in liver of cod from 13 stations, in blue mussel from 11 stations, and in blood and eggs of eider from one station (***Table 2***).

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

(NorwegianEnvironmentAgency 2016). 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 10***). Cod from Ålesund harbour (st. 28B) had highest concentration of SCCP, with median concentration of 172 µg/kg w.w., and high individual variation. Blue mussel from Bodø harbour (st. 97A3) had highest concentration of SCCP, with median concentration of 77.30 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, no median concentrations of MCCP in cod, blue mussel or eider exceeded EQS. However, the median concentration of MCCPs in blue mussel from Bodø harbour (st. 97A3) was at the EQS. There was high individual variation, especially in cod from Tromsø harbour area (st. 98B1) and Bergen harbour (st. 25B). Cod from Austnesfjord, Lofoten (st. 98B1) had highest concentration of MCCPs with median concentration of 124.5 µg/kg w.w. High individual variation was observed (***Figure 63***, ***Table 17***). The source of this level of MCCPs might be runoff from the local airport (Dick, Gallagher, and Gregg 2010).

Levels exceeding PROREF

The median concentration of SCCP in cod liver ranged from 27 to 172 µg/kg w.w., with highest concentrations in cod from Ålesund harbour area (st. 28B, ***Figure 61***, ***Table 17***). The median concentration of SCCPs in cod liver from Ålesund harbour area exceeded the Norwegian provisional high reference contaminant concentration (PROREF) by a factor of up to two. The median concentration of SCCPs in blue mussel from Nordnes (st. I241) and Bodø harbour (st. 97A3) exceeded the PROREF by a factor of up to two and from two to five, respectively.

No median concentrations of MCCPs in cod liver exceeded the PROREF. The median concentration of MCCPs in blue mussel from Bodø harbour (st. 97A3) exceeded the PROREF by a factor of up to two.

Increase in PROREF factor since 2017

The median concentration of SCCPs in liver of cod from Ålesund harbour (st. 28B) increased from 2017 to 2018. The concentration increased from below PROREF in 2017 to exceedance of PROREF by a factor of up to two in 2018.

The median concentration of MCCPs in blue mussel increased from 2017 to 2018. The concentration increased from below PROREF in 2017 to an exceedance of PROREF by a factor of up to two in 2018.

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

The median concentration of SCCPs in blue mussel from Bodø harbour (st. 97A3) increased from 2017 to 2018. The median concentration increased from exceedance of PROREF by a factor of up to two in 2017, to exceedance of PROREF by a factor of two to five in 2018. The median concentration of SCCPs in blue mussel from Nordnes, Bergen harbour (st. I241) also increased from 2017 to 2018. The concentration increased from below PROREF in 2017 to exceedance of PROREF by a factor of up to two in 2018.

Upward trends

There were significant long-term and short-term upward trends for SCCP in blue mussel from Svolvær airport area (st. 98A2) (***Figure 59 A***), and in addition, SCCP in liver of cod from Austnesfjord, Lofoten (st.98B1) (***Figure 59 B***). There was a significant short-term upward trend for SCCP in liver of cod from the Inner Oslofjord (st. 30B) when using data adjusted for fish length (***Figure 60***).

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

Decrease in PROREF factor since 2017

The median concentration of MCCPs in liver of cod from Ålesund harbour (st. 28B) has decreased from 2017 to 2018. In 2017 the median concentration exceeded PROREF by a factor of two to five, and in 2018 the median concentration was below the PROREF.

Cod from the Inner Oslofjord (st. 30B) also had lower median concentration of MCCPs in 2018 than in 2017. In 2017 the median concentration of MCCPs exceeded PROREF by a factor of up to two, and in 2018 the concentration was below the PROREF.

The median concentrations of SCCPs in liver of cod from Bergen harbour (st. 24B) and Inner Oslofjord (st. 30B) decreased from 2017 to 2018. In 2017 the median concentrations exceeded PROREF by a factor of up to two, and in 2018 the median concentrations were below the PROREF.

The median concentration of SCCPs in blue mussel from Ålesund (st. 28A2) and Gressholmen, Inner Oslofjord (st. 30A) decreased from 2017 to 2018. In 2017 the median concentration of SCCPs in blue mussel from Ålesund exceeded PROREF by a factor of greater than 20, and in 2018 the median concentration was below PROREF. In 2017 the median concentration of SCCPs in blue mussel from Gressholmen exceeded PROREF by a factor of up to two, and in 2018 the median concentration was below PROREF.

Downward trends

A significant long-term downward trend was found for SCCP in liver of cod from the Inner Sørfjord (st. 53B).

Levels in eider

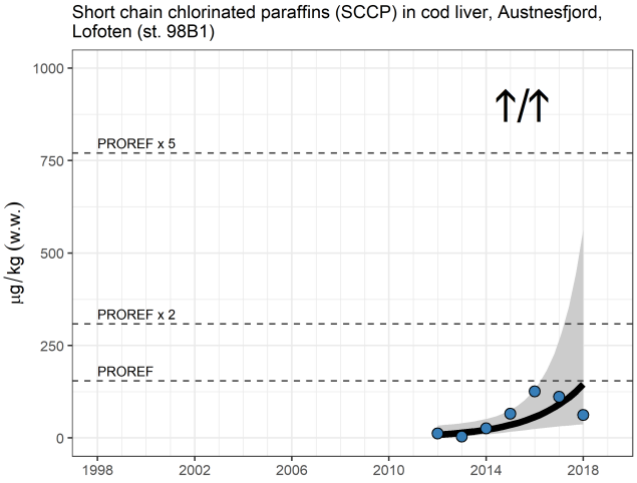
Median concentration of SCCP was 11.16 µg/kg w.w. in eider blood, and 21.37 µg/kg w.w. in eider egg from Kongsfjord, Svalbard (st. 19N). This was a decrease from 2017. Median concentration of MCCP was 34.62 µg/kg w.w. in eider blood and 14.0 µg/kg w.w. in eider egg from the same station, an increase from 2017.

General, large scale trends

The median concentration of SCCP in blue mussel ranged from 1.91 to 77.30 µg/kg w.w. in the present study and the highest concentration was found in the samples from Bodø harbour (st. 97A2, ***Figure 62***).

The concentrations of MCCPs in blue mussel were lower than in cod, and ranged from 2.81 to 170.0 µg/kg w.w. Blue mussel from Bodø harbour (st. 97A3) had the highest concentrations of MCCPs (***Figure 64***).

A



B

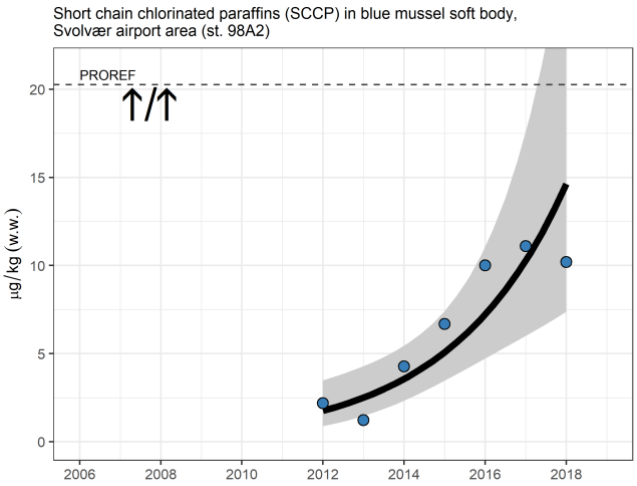


Figure 59. *Median concentrations (mg/kg w.w.) of SCCP in cod liver from 2012 to 2018 in Austnesfjord, Lofoten (st.98B1) (**A**) and in blue mussel from Svolvær airport area (st. 98A2) (**B**). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 4 and* **Appendix** C*).*

Comparison with other studies

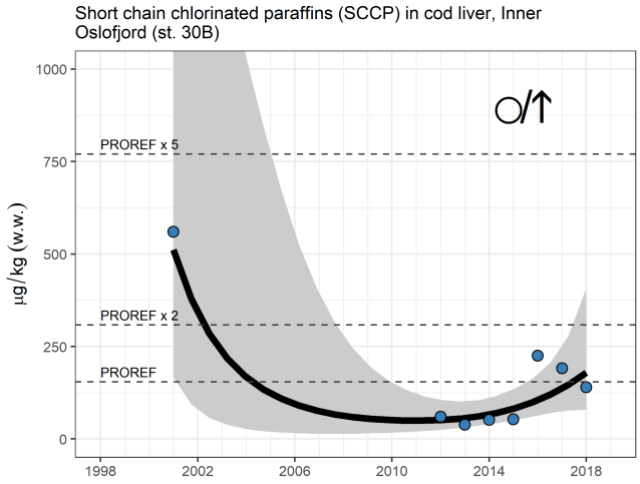
Cod from the Inner Oslofjord had median concentration of SCCP in liver of 140 µg/kg w.w. and ranging between 60.5 to 209 µg/kg w.w. Ruus et al. (2019) found higher levels of SCCP in cod from the Inner Oslofjord (236.6 to 728.4 µg/kg w.w.). The concentrations of MCCP in cod liver found by -(Ruus, Bæk, et al. 2019) were from 102.5 to 750.3 µg/kg w.w. 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 et al. 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 (21.37 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, Herzke, and Kaasa 2013). The similar pattern was seen for the median concentration of MCCP (14.0 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 has 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 has been estimated to 0.25 kg/year for river Alna, 19 kg/year for river Drammenselva and 420 kg/year for river Glomma.

A



B

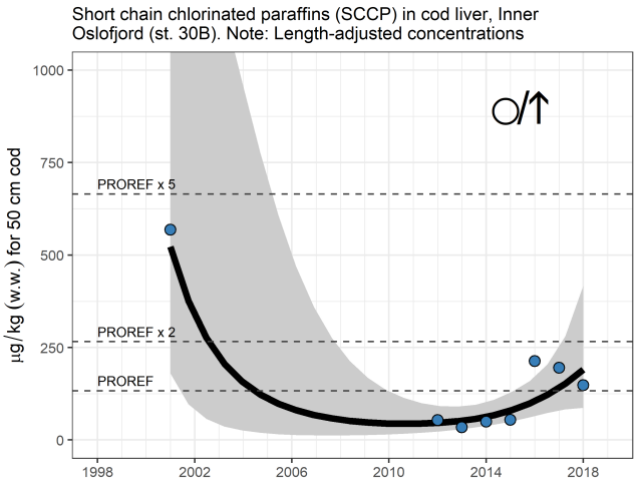


Figure 60. *Median concentrations (mg/kg w.w.) of SCCP in cod liver from 2001 to 2018 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* ***Figure 4*** *and* **Appendix** C*). Note that even though the two figures are quite similar, where there is no adjustment for length (***A***) the p-value for the trend analysis is 0.0592 and where there is an adjusted for length (***B***) the p-values is 0.0379, and hence significant.*

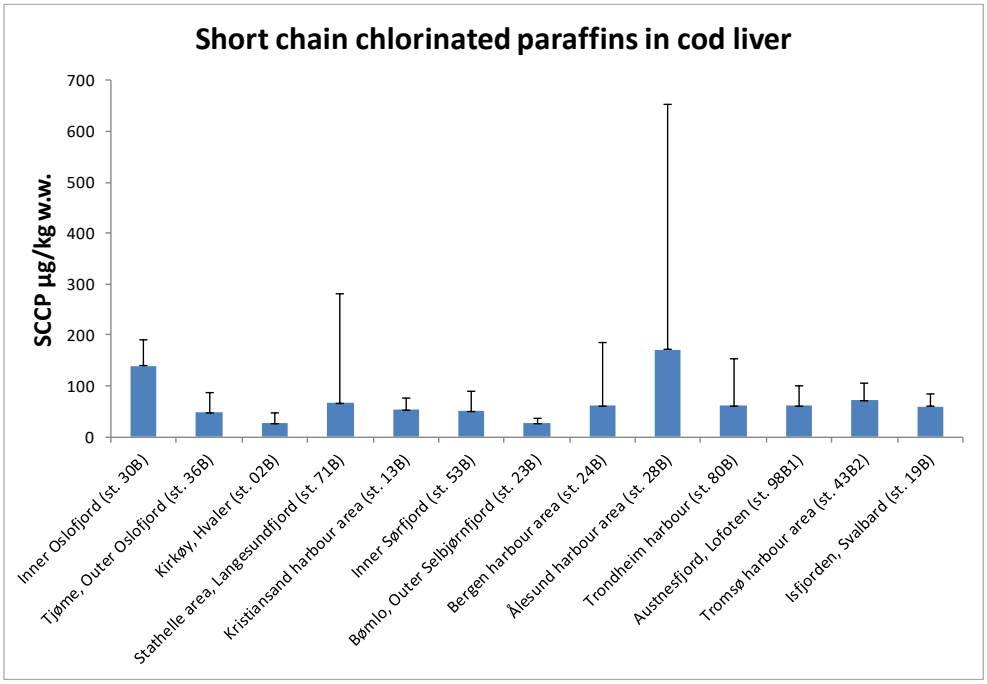


***Figure 61**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in cod liver in 2018. The error bar indicates one standard deviation above the median.*

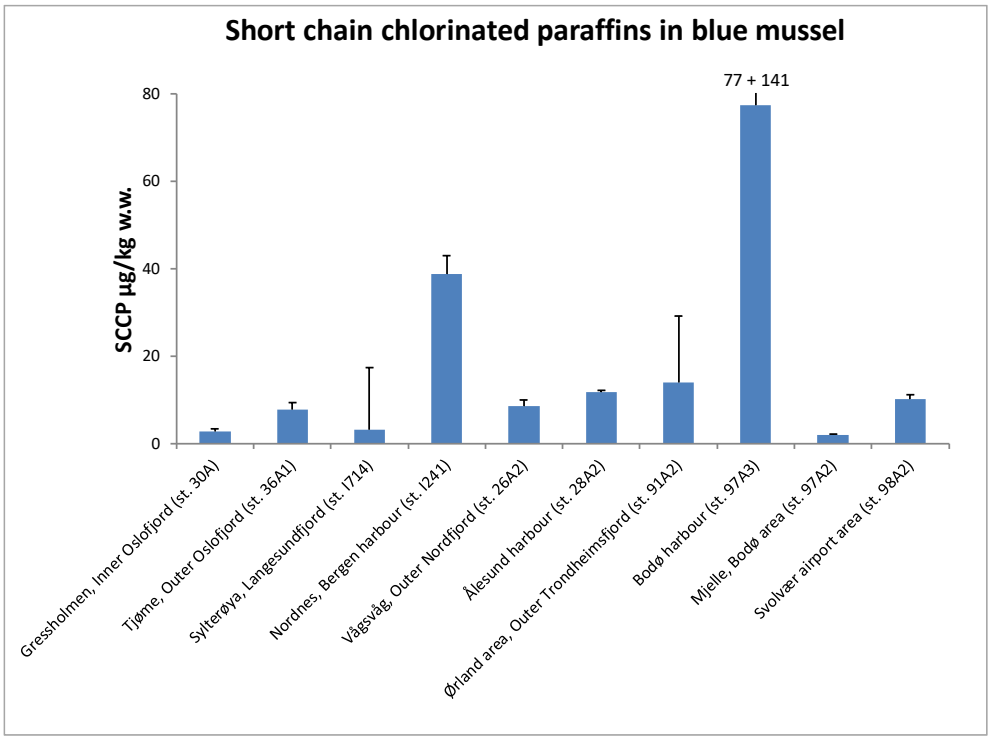


***Figure 62**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in blue mussel in 2018. The error bar indicates one standard deviation above the median.*

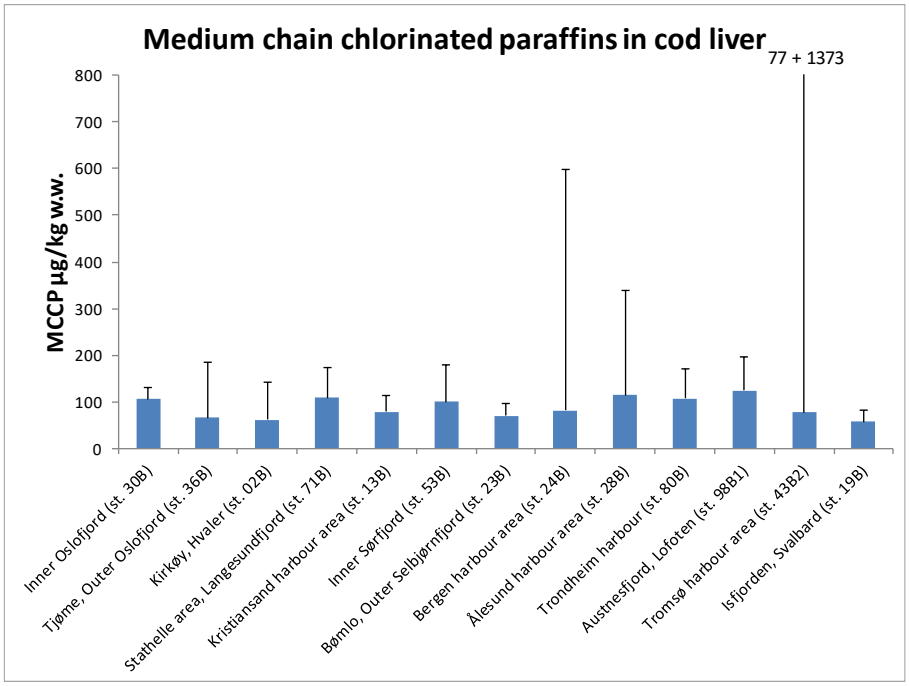


***Figure 63**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in cod liver in 2018. The error bar indicates one standard deviation above the median.*

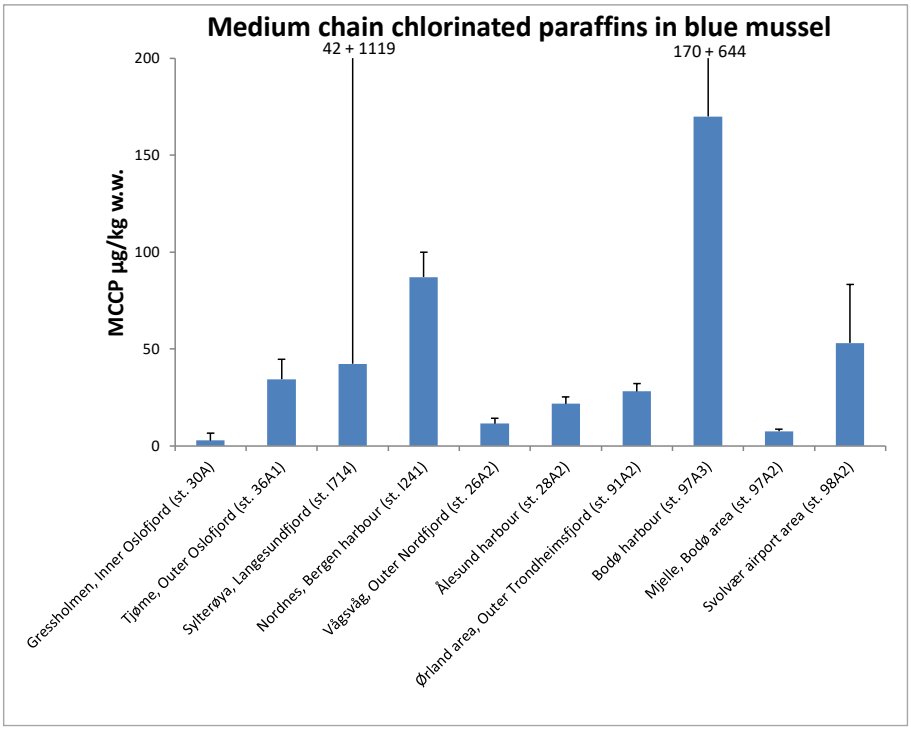


***Figure 64**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in blue mussel in 2018. The error bar indicates one standard deviation above the median.*

***Table 17**. 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 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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 **Chapter 2.10** for more details.*)

Component	Count	SCCP			MCCP		
Species and sampling locality	2018	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel							
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	2.63	0.71	3 (2.11-3.51)	2.81	4	3 (2.76-9.52)
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	7.77	1.47	3 (5.97-8.88)	34.40	10	3 (30.2-49.7)
Singlekalven, Hvaler (st. I023)	3 (3-50)	2.46	7.88	3 (2.26-16)	7.21	12	3 (7.16-27.6)
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	3.18	14.10	3 (2.19-27.1)	42.40	1119	3 (3.27-1960)
Nordnes, Bergen harbour (st. I241)	3 (3-50)	38.80	4.09	3 (33-40.9)	87.10	13	3 (67.3-91.4)
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	8.46	1.52	3 (7.07-10.1)	11.50	3	3 (10.9-16.1)
Ålesund harbour (st. 28A2)	3 (3-50)	11.70	0.38	3 (11.1-11.8)	21.70	4	3 (19.7-26.8)
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	14.00	15.12	3 (11.4-38.8)	28.10	4	3 (23.5-31.5)
Bodø harbour (st. 97A3)	3 (3-50)	77.30	141.04	3 (17.3-286)	170.00	644	3 (33.3-1210)
Mjelle, Bodø area (st. 97A2)	3 (3-50)	1.91	0.24	3 (1.51-1.93)	7.61	1	3 (6.04-7.9)
Svolvær airport area (st. 98A2)	3 (3-50)	10.20	1.01	3 (9.19-11.2)	53.10	30	3 (48.2-103)
Cod, liver							
Inner Oslofjord (st. 30B)	10 (7-4)	140.00	50.03	10 (63.5-209)	105.50	25	10 (66.8-146)
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	47.4	40.02	15 (23.6-174)	65.9	117.7	15 (50.5-474)
Kirkøy, Hvaler (st. 02B)	4 (4-3)	27.00	20.04	4 (24.4-66)	60.95	82	4 (57.3-224)
Stathelle area, Langesundfjord (st. 71B)	15 (7-4)	67.00	213.78	15 (27.5-728)	108.00	66	15 (70.2-266)
Kristiansand harbour area (st. 13B)	9 (5-4)	53.80	22.74	9 (30.2-110)	77.80	35	9 (65.6-171)
Inner Sørfjord (st. 53B)	15 (1-4)	51.90	36.93	15 (23.2-183)	99.60	79	15 (52.7-331)
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	28.15	8.03	14 (20.1-48.5)	69.50	28	14 (49.5-131)
Bergen harbour area (st. 24B)	12 (2-3)	62.45	123.80	12 (24.8-443)	80.80	516	12 (58.5-1830)
Ålesund harbour area (st. 28B)	15	172.00	482.07	15 (54.7-1500)	114.00	225	15 (50-957)
Trondheim harbour (st. 80B)	15	61.30	92.70	15 (28.2-376)	107.00	62	15 (62.3-288)
Austnesfjord, Lofoten (st. 98B1)	12 (3-3)	62.00	37.73	12 (23.6-142)	124.50	72	12 (68.4-320)
Tromsø harbour area (st. 43B2)	15	71.20	33.35	15 (31.8-131)	77.00	1373	15 (50-5390)
Isfjorden, Svalbard (st. 19B)	15	60.40	24.05	15 (24.6-98.5)	56.60	25	15 (49.5-127)
Eider, blood							
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	11.16	6.52	15 (7.1717-31.7895)	34.62	72	15 (2.3559-278.9574)
Eider, egg							
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	21.37	7.49	15 (6.8976-31.303)	14.00	15	14 (4.0577-54.2343)

3.2.28 Bisphenol A (BPA)

Bisphenol A (BPA) is derived from epoxy resins and polycarbonate plastics (Belfroid et al. 2002). BPA has been produced in large quantities world-wide and therefore can be considered ubiquitous (Flint et al. 2012). It is an endocrine disruptor which can mimic oestrogen and is also carcinogenic. Studies have shown that BPA can affect growth, reproduction, and development in aquatic organisms. BPA is on the priority list of Norwegian Environment Agency[1].

BPA was analysed in cod liver from three stations and in blue mussel from one station (***Table 2***). The concentrations of BPA in cod liver and blue mussel were below the quantification limits (***Table 18***). Hence, no conclusion can be drawn regarding possible differences between stations.

Table 18. *Median concentrations (µg/kg w.w.) with standard deviation of bisphenol A (BPA) in blue mussel and cod liver in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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). (See* ***Chapter 2.10*** *for more details.)*

Component	Count	BPA		
Species and sampling locality	2018	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	1.0	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	10 (7-4)	1.0	0.0	
Stathelle area, Langesundfjord (st. 71B)	15 (7-4)	1.0	0.0	
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	1.0	0.0	

3.2.29 Alkylphenols

These substances are used in manufacturing antioxidants, lubricating oil additives, household detergents. They are also precursors for commercially important surfactants. Nonylphenol and octylphenol are two alklyphenols and are on the Environmental Quality Standards Directive (EQSD, 2013/39/EU) list of priority hazardous substances. EQS for nonylphenol is 3000 µg/kg w.w., and EQS for octylphenol is 0.004 µg/kg w.w. In the MILKYS programme, these two compounds were analysed for the first time in samples from 2012. In Norway it has since 2005 been prohibited to produce, import, export, sell or use nonylphenols, octylphenols and their ethoxylates with the exception of paints, varnish, lubricants and finished products.

Alkylphenols were analysed in cod liver from 12 stations and in blue mussel from 10 stations (***Table 2***).

Environmental Quality Standards (EQS) for priority substances

When applying the EQS for nonylphenol in biota (3000 µg/kg w.w.), all concentrations were below the EQS in 2018. When applying the EQS for octylphenol (0.004 µg/kg w.w.) in biota (blue mussel and cod liver), many concentrations were above the EQS in 2018 (***Table 19***). Since the EQS for octylphenol is much lower than the quantification limit, it is not possible to classify this substance correctly.

The concentrations of alkylphenols in cod liver and blue mussel were low. Many of the median concentrations were below the quantification limits (***Table 19***). For 4-t-nonylphenol, median concentration in cod liver ranged between 5 to 36.9 µg/kg w.w., with high individual variation.

[1] http://www.miljostatus.no/prioritetslisten

Since the analyses has been performed with lower LOQ than for the samples in 2017, it is difficult to compare the results for these years.

Comparison with other studies

Nonylphenol and octylphenol have also been found in freshwater fish in Norway. In 2017, 4-t-octylphenol was found in the range 0.05 to 0.22 ng/g w.w., and p-nonylphenol was found in the range 0.0 to 14.84 ng/g w.w. (Jartun et al. 2018).

General, large scale trends

The discharges of phenols from land-based industries to water increased in the period from 2002 to 2008 (4730 kg) and then gradually decreased to 1007 kg in 2017 (***Figure 65***).

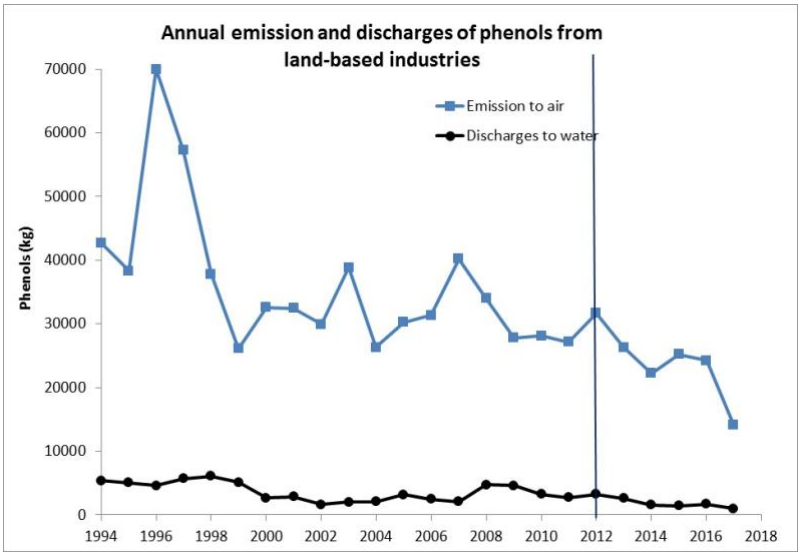


Figure 65. *Annual emissions of phenols to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27th June 2018). Phenols have been monitored in this project since 2012 (indicated with a vertical line). Note that emissions and discharges from 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.*

***Table 19**. Median concentrations (µg/kg w.w.) with standard deviation of alkylphenols in blue mussel and cod liver in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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 **Chapter 2.10** for more details and **Appendix B** for description of chemical codes.)*

Component	Count	4-N-NP			4-N-OP			4-T-NP			4-T-OP		
Species and sampling locality	2018	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)	2.9	0.62		2.9	0.62			0.00		2.9	0.62	
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	2.6	0.40		2.6	0.40			0.00		2.6	0.40	
Singlekalven, Hvaler (st. I023)	3 (3-50)	2.9	0.23		2.9	0.23			0.00		2.9	0.23	
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	2.1	0.23		2.1	0.23			0.00		2.1	0.23	
Nordnes, Bergen harbour (st. I241)	3 (3-50)	2.9	0.52		2.9	0.52			0.00		2.9	0.52	
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	2.0	0.55		2.0	0.55			0.00		2.0	0.55	
Ålesund harbour (st. 28A2)	3 (3-50)	2.3	0.23		2.3	0.23			0.00		2.3	0.23	
Ørland area, Outer Trondheimsfjord (st. 91A2	3 (3-50)	2.6	0.74		2.6	0.74			0.00		2.6	0.74	
Bodø harbour (st. 97A3)	3 (3-50)	3.1	0.26		3.1	0.26		7.0	3.49	3 (3.63-10.6)	3.1	0.26	
Mjelle, Bodø area (st. 97A2)	3 (3-50)	2.7	0.21		2.7	0.21		2.9	0.00	1 (2.91)	2.7	0.21	
Svolvær airport area (st. 98A2)	3 (3-50)	2.3	0.08		2.3	0.08			0.00		2.3	0.08	
Cod, liver													
Inner Oslofjord (st. 30B)	10 (7-4)	4.7	1.82		4.7	0.14		27.8	33.07	10 (12-103)	4.7	0.14	
Tjøme, Outer Oslofjord (st. 36B)	15 (10-4)	3.9	0.92	3 (3.01-6.48)	3.8	0.60		5.4	5.89	7 (3.83-20.3)	3.8	0.60	
Kirkøy, Hvaler (st. 02B)	4 (4-3)	4.0	1.73	1 (7.32)	4.1	0.23		36.9	14.67	4 (16.3-49.3)	4.1	0.23	
Stathelle area, Langesundfjord (st. 71B)	15 (7-4)	4.3	0.61	1 (4.37)	4.4	1.02		14.1	24.38	10 (4.77-86.2)	4.2	0.51	
Kristiansand harbour area (st. 13B)	9 (5-4)	4.3	0.70	1 (3.99)	4.2	0.48		12.2	12.62	9 (6.14-41.1)	4.2	0.48	
Inner Sørfjord (st. 53B)	15 (1-4)	4.1	3.55		4.0	2.03	1 (11.8)	15.2	13.81	11 (10.5-57.5)	4.0	0.48	
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	4.4	0.49	1 (4.83)	4.4	0.53	1 (3.27)	16.3	12.74	14 (4.58-54.8)	4.3	0.53	
Bergen harbour area (st. 24B)	12 (2-3)	3.6	0.50	1 (3.88)	4.7	2.69	1 (10.2)	13.3	12.36	9 (5.23-45.6)	3.5	0.49	
Ålesund harbour area (st. 28B)	15	4.3	5.39	1 (4.81)	4.2	0.95		21.7	19.47	15 (4.92-68.9)	4.2	0.51	
Trondheim harbour (st. 80B)	15	4.2	2.48		4.0	0.47		5.0	4.31	10 (4.05-15.7)	4.0	0.47	
Tromsø harbour area (st. 43B2)	15	4.3	1.07	5 (3.8-7.02)	4.2	0.46		15.9	8.01	14 (4.34-26.6)	4.2	0.46	
Isfjorden, Svalbard (st. 19B)	15	4.3	0.88	8 (4.31-6.13)	3.7	0.47		15.1	12.91	13 (5.44-54.1)	3.7	0.47	

3.2.30 Tetrabrombisphenol A (TBBPA)

Tetrabrombisphenol A (TBBPA) is a polybrominated flame retardant and is an endocrine disruptor and immunotoxicant. TBBPA was analysed in cod liver from three stations, in blue mussel from two stations and in eider blood and eggs from one station (***Table 2***).

Concentrations of TBBPA found in cod liver and blue mussel were generally low. For all the stations the median concentrations were below the limit of quantification (***Table 20***). Only one sample of cod liver from the Inner Oslofjord (st. 30B), had a detectable concentration of TBBPA.

Table 20*. Median concentrations (µg/kg w.w.) with standard deviation of TBBPA in blue mussel and cod liver in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of 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* ***Chapter 2.10*** *for more details.)*

Component	Count	TBBPA		
Species and sampling locality	2018	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.0	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	10 (7-4)	0.2	0.1	1 (0.0397)
Stathelle area, Langesundfjord (st. 71B)	15 (7-4)	0.2	0.0	
Bømlo, Outer Selbjørnfjord (st. 23B)	14 (6-4)	0.2	0.0	

3.2.31 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 (L) and cyclic (D) 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.

Siloxanes, i.e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver at the five stations (***Table 2***) in the Inner Oslofjord (st. 30B), Bergen harbour (st. 24B), Tromsø harbour (st. 43B2), Kjøfjord (st. 10B) in the Outer Varangerfjord and the Isfjord (st. 19B) at Svalbard (***Table 21***, **Figure 66**). Siloxanes were also analysed in eider blood and eggs at one station at Svalbard (st. 19N Breøyane).

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 10***). No individual D5-concentration exceeded EQS (**Table 20**).

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 2018-samples (***Table 10***).

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 at all stations. Median D5-concentrations in cod liver were highest in the Inner Oslofjord (876.1 µg/kg w.w.), and lowest at Svalbard (3.96 µg/kg w.w.). The same pattern was found for 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 <2.0, <0.9 and 1.7 µg/kg, respectively. The concentrations of D4, D5 and D6 in eggs were 3.1, 4.1 and 3.0 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.* (2016; 2017; 2018; 2019), Schlabach *et al.* (2008) and Schøyen *et al.* (2016).

In 2018, median D5 concentration in cod liver from the Inner Oslofjord was 876.1 µg/kg w.w., while the mean D5 concentration was 1169.2 µg/kg w.w. in the study performed by Ruus et al. (2019). In the current study, median concentrations of D4 and D6 in cod liver from the Inner Oslofjord were 60.1 and 166.2 µg/kg w.w., respectively, while the mean concentrations were 65.8 and 149.5 µg/kg w.w., respectively, in the comparable study. 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, Bæk, et al. 2016).

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 et al. 2016). There was a positive correlation between lipid content and lipid-normalized D4, D5 and D6 in cod, but a negative correlation in herring. Lipid-normalized concentrations of D4, D5 and D6 were lowest in cod, herring and shrimp 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 et al. 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 et al. 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 et al. 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 and Ågerstrand 2018).

In Mjøsa, D5 was detected in highest concentrations (Jartun et al. 2019). The mean concentrations were highest in brown trout (*Salmo trutta*) (42 µg/kg w.w.), vendace (*Coregonus albula*) (29 µg/kg w.w.), European smelt (*Osmerus eperlanus*) (25 µg/kg w.w.), zooplankton (23 µg/kg w.w.) and Mysis (*Mysis relicta*) (11 µg/kg w.w.) (Jartun et al. 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 2018 (42 µg/kg w.w.) (Jartun et al. 2019).

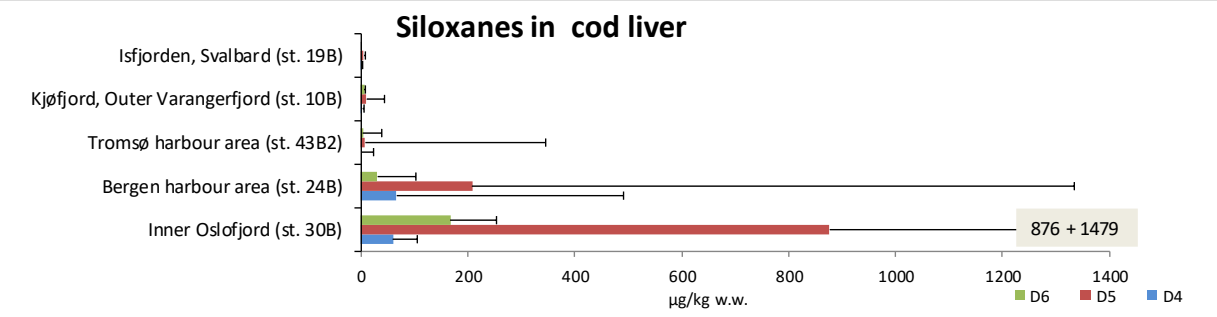


***Figure 66**. Median concentration (µg/kg w.w.) of siloxanes D4, D5 and D6 in cod liver in 2018. The error bar indicates one standard deviation above the median.*

***Table 21**. Median concentrations (µg/kg w.w.) with standard deviation of siloxanes (D4, D5 and D6) in cod liver and eider in 2018. 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 one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of 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 **Chapter 2.10** for more details.)*

Component	Count	D4			D5			D6		
Species and sampling locality	2018	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Cod, liver										
Inner Oslofjord (st. 30B)	10 (7-4)	60.1	44.00	14 (9.4044-	876.1	1479.00	15 (33.1781-	166.5	86.99	15 (8.7311-
Bergen harbour area (st. 24B)	12 (2-3)	65.3	426.54	15 (12.7197-	208.1	1125.50	15 (57.1674-	30.6	71.02	15 (6.1455-
Tromsø harbour area (st. 43B2)	15	0.0	23.26	15 (0-78.5594)	7.1	338.48	15 (0-1027.634)	3.3	36.23	13 (0-104.5332)
Kjøfjord, Outer Varangerfjord (st. 10B)	8 (6-3)	2.4	2.80	2 (9.6241-10.0793)	9.0	34.71	14 (5.0755-	6.2	1.84	14 (2.8437-9.9248)
Isfjorden, Svalbard (st. 19B)	15	1.0	0.42	11 (0-0)	4.0	3.42	15 (0-11.5026)	0.0	0.00	15 (0-0)
Eider, blood										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	2.0	2.17	1 (9.462)	0.9	2.14	2 (2.6596-9.2419)	1.7	1.86	13 (1.2628-8.6918)
Eider, egg										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	3.1	1.25	10 (2.2802-5.824)	4.1	1.22	15 (1.8498-5.9318)	3.0	0.83	14 (2.0879-4.3874)

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/).

3.2.32 Dechlorane plus

Dechloranes are a group of highly chlorinated and lipophilic flame retardants. Dechlorane plus (DDC-CO) is the sum of syn- and anti-isomers. Dechlorane plus is used in plastics and polymers, such as nylon, polyurethane, polypropylene, neoprene and silicone rubber. It can be used in electronic wires and cables, cars, plastic roofing materials and hard plastic couplings, and can function as a softener. Dechlorane plus is marketed as an alternative to deca-BDE (BDE-209). Dechlorane plus has been found in dust from indoor environments in Norway (Cequier et al. 2014).

Dechloranes were analysed in cod liver at five stations for the first time in this project; the Inner Oslofjord (st. 30B), Bergen harbour (st. 24B), Tromsø harbour (st. 43B2), the Varangerfjord (st. 10B) and in the Isfjord (st. 19B) at Svalbard (***Table 2***, **Table 22**).

Levels in cod liver

The concentrations were low, and many cases below the limit of quantification (**Table 22**). The concentration of dechloranes were slightly higher in cod from the Inner Oslofjord (st. 30B) than in cod from Bergen harbour area (st. 24B).

Table 22. Median concentrations (µg/kg w.w.) of dechloranes in cod liver and in 2018. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit.

Component	Dibromoaldrin	Dechlorane 602	Dechlorane 603	Dechlorane 604	Dechlorane 601	Dechlorane plus syn	Dechlorane plus anti
Species and sampling locality	Med.	Med.	Med.	Med.	Med.	Med.	Med.
Cod liver							
Inner Oslofjord (st. 30B)	0.111	0.533	0.171	0.424	0.031	0.135	0.231
Bergen harbour area (st. 24B)	0.052	0.107	0.019	0.198	0.017	0.178	0.203
Tromsø harbour area (st. 43B2)	0.078	0.060	0.007	0.297	0.020	0.078	0.117
Kjøfjord, Outer Varangerfjord (st. 10B)	0.110	0.037	0.009	0.421	0.028	0.110	0.165
Isfjorden, Svalbard (st. 19B)	0.065	0.020	0.006	0.248	0.015	0.065	0.097

General, large scale trends

In the EU, the registered use of dechlorane plus is 100-1000 tons per year (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/dekloraner/).

Comparison with other studies

The Inner Oslofjord

In cod liver from the Inner Oslofjord in 2018, the mean concentration of dechlorane plus syn was 0.029 ng/g w.w. while it was 0.531 ng/g w.w. for dechlorane plus anti (Ruus, Bæk, et al. 2019).

In brown trout from Lake Mjøsa in 2017, the mean concentration of dechlorane plus syn was 6.8 pg/g w.w. while it was 13 pg/g w.w. for dechlorane plus anti (Jartun et al. 2018).

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 cannot 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 newly 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 2018 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) was significantly lower than in 2017 (Tukey-Kramer HSD test), and resembled the concentrations most recent years. Median OH-pyrene bile concentration in 2018 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) and in Farsund (st. 15B). Median OH-pyrene bile concentration in 2018 was not exceeding the ICES/OSPAR assessment criterion at Bømlo north (st. 23B, reference station), the station where concentrations were lowest. Note that the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380 nm. Also, in the Inner Sørfjord (st. 53B), the median concentration of OH-pyrene metabolites in bile from cod was significantly lower (by a factor of 10) than in 2017 (Tukey-Kramer HSD test), and resembled the median concentration in 2015. Among the four stations, OH-pyrene concentrations were highest in the Inner Oslofjord (st. 30B) (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.

Trend analyses suggest a significant downward temporal trend in ALA-D activity over the last 10 years (n = 8) at the reference station (Bømlo area; 23B; **Appendix F**). The median ALA-D activity at this station appeared, however, slightly higher than the previous four years.

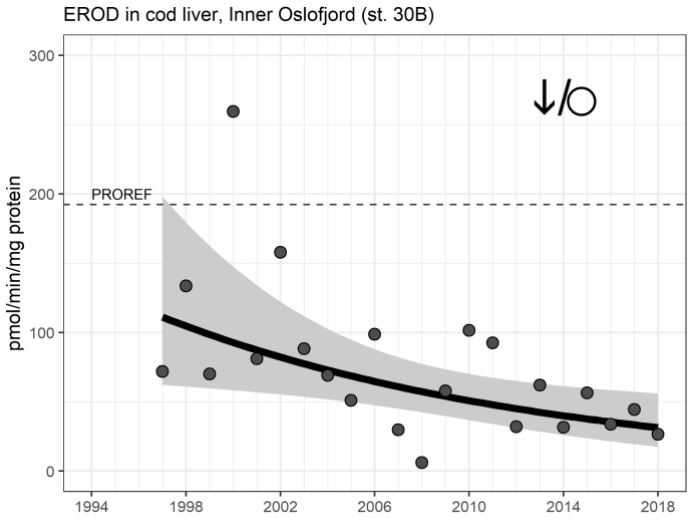
As previously noted, most years up to 2011 the activity of ALA-D in cod was somewhat inhibited in the Inner Oslofjord (st. 30B), compared to reference stations, i.e. Outer Oslofjord (st. 36B; only data to 2001), Bømlo north (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Green et al. 2016). The median ALA-D activity in the Inner Oslofjord (st. 30B) in 2018 was lower (but not significantly so, Tukey-Kramer HSD test) than in the Bømlo north (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 2013-2018) 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 0.066 mg/kg and 0.046 mg/kg, respectively, in 2018. In the Bømlo north (st. 23B) the concentration was below the limit of detection (<0.03 mg/kg). In cod liver, significant downward long-term trends were found in the Inner Oslofjord (st. 30B) and in the Inner Sørfjord (st. 53B) (***Table 11***).

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 5***. 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 north, 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). Statistically significant downward trends in EROD activity were observed on a long-term basis (whole data series) at Bømlo north (st. 23B) and the Inner Oslofjord (st. 30B) (***Figure 67***). A downward long-term trend could also be observed in the Inner Sørfjord (***Table 11***). 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.

A



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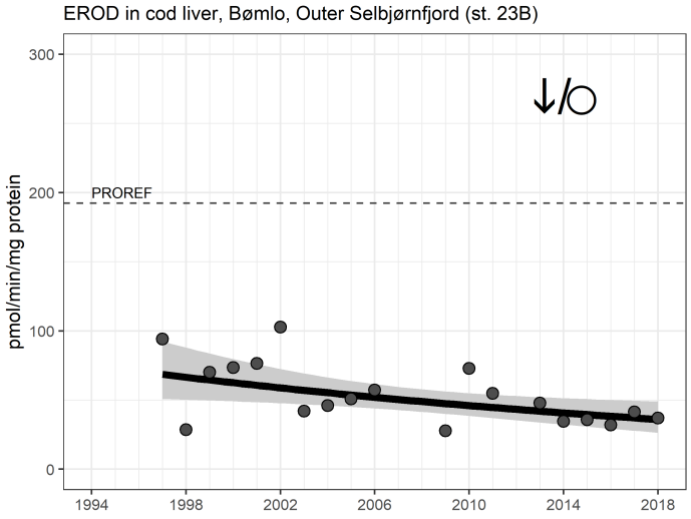


Figure 67. *Median activity (pmol/min/mg-protein) of EROD in cod liver from 1990 to 2018 in the Inner Oslofjord (st. 30B) (***A***) and from 1997 to 2018 in Bømlo north (st. 23B) (***B***). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are 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 or a food web. For instance, it is in principle possible to detect differences in the importance of autochthonous (native marine) and allochthonous (watershed/origin on land) carbon sources in the food web, since the $\delta^{13}C$ signature of the land-based energy sources is lower (greater negative number) 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 *et al.* 2002), but more important, it increases in organisms with higher trophic level because of a greater retention of the heavier isotope (^{15}N). The relative increase of ^{15}N over ^{14}N ($\delta^{15}N$) 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 = $a + b * (\text{Trophic Level})$

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 merely been reviewed to indicate any possibilities that spatial differences in contaminant concentrations may partially be attributed to different energy sources between stations, or that the same species 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 seven years. Future areas of application for this database may e.g. be to investigate the possible influence of trophic position (baseline normalized) on the short-term concentration time trends, in the same manner as fish length has been included in the models in the recent few years. So far for the period 2012-2017 (Green et al. 2018) the results of the stable isotope analysis 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. been used to normalize trophic positions of herring gulls, when geographic comparisons have been made (Keilen 2017).

In the following, the $\delta_{15}N$ data (Atlantic cod) are also assessed in relation to concentrations of selected contaminants. As fish grow, they feed on larger prey organisms, thus a small increase in trophic level is likely to occur. It is of interest to assess whether concentrations of specific contaminants correlate with $\delta_{15}N$, since this will warrant further scrutiny of the contaminant's potential to biomagnify.

For selected contaminants (BDE-47, -99, -100 and -209, SCCP and MCCP, PFOS and PFOSA), relationships between concentrations and $\delta_{15}N$ have been investigated to examine potential increase in concentration of the specific contaminants with increasing $\delta_{15}N$. Such correlation will give reason for future examination of the potential of the contaminant to increase in concentration with higher level in the food chain (biomagnification). It is previously shown that, for example, the concentration of Hg increases with $\delta_{15}N$ among individuals of the same species (more specifically tusk; *Brosme brosme*) in the Sørfjord (Ruus et al. 2013). For that reason, also concentrations of Hg, as well as PCB153 (another compound with known biomagnifying properties), is plotted against $\delta_{15}N$ in cod. The data material for PCB153 and especially Hg is larger, than for the other contaminants. Noteworthy observations from these regressions are referred to, below.

3.4.2 Results and discussion

The results of the stable isotope analysis generally show the same pattern as observed in 2012-2017 (Green et al. 2018), i.e. a continual geographical pattern, suggesting a spatial trend persistent in time. As such, the results still suggest that the different cod populations surveyed do not deviate much in trophic position. As mentioned, an increase in $\delta_{15}N$ of 3 to 5 ‰ represent one full trophic level. Although differences between stations situated at each end of the scale are higher, approximately the same differences can be seen between the mussels from the same areas (***Figure 68***). This indicates that there are geographical differences in the baseline isotopic signatures (see

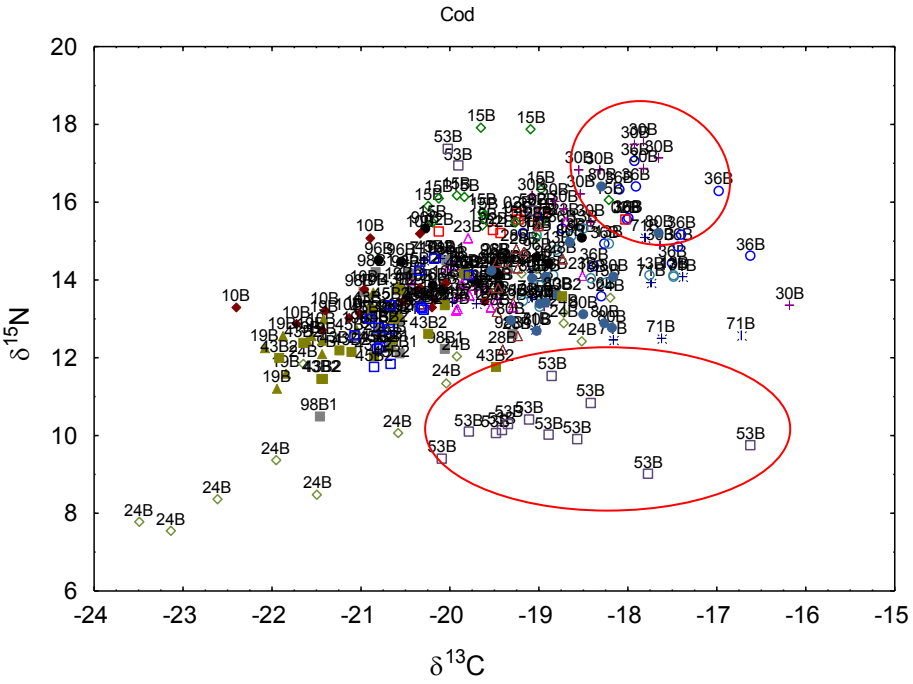
discussion below). It is therefore reasonable to assume that differences in the concentrations of substances between areas are largely due to differences in exposure (either from local sources or through long-range transport). It can be noted, however, that it has previously been shown that differences in e.g. mercury content in tusk from Sørfjord area could be partly attributed to small differences in trophic position (or $\delta_{15}N$) (less than one full trophic level) (Ruus et al. 2013), indicating that differences in $\delta_{15}N$, corresponding to less than one full trophic level also are of interest in terms of explaining differences in bioaccumulation.

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 68***); Bergen harbour, station 24B, was introduced in 2015). The same is shown for mussels from the Sørfjord (stations 51A, 52A and 56A), 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 I3014) from the Oslofjord are among the highest observed (***Figure 68***) indicating a high baseline (and not a higher trophic position of the Oslofjord cod). These geographic differences were also observed 2012-2017 (Green et al. 2018). Interestingly, cod from stations from the North of Norway (Lofoten, 98B1 and Varanger, 10B) show intermediate $\delta_{15}N$ values and low $\delta_{13}C$ values (***Figure 68***). The same can be observed in mussels from Northern Norway (Bodø, 97A2 and 97A3, and Varanger, 11X). 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, 2018. Statistics shown are count (n), mean and standard deviation.*

Station ID		$\delta^{13}C_{VPDB}$ n	$\delta^{13}C_{VPDB}$ mean	$\delta^{13}C_{VPDB}$ st.dev.	$\delta^{15}N_{AIR}$ n	$\delta^{15}N_{AIR}$ mean	$\delta^{15}N_{AIR}$ st.dev.
Presumed less impacted							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**3**	**-21.41**	**0.20**	**3**	**6.07**	**0.28**
Tjøme, Outer Oslofjord (st. 36A1)		3	-20.07	0.27	3	8.24	0.23
Singlekalven, Hvaler (st. I023)		3	-20.35	0.24	3	7.46	0.15
Gåsøya-Ullerøya, Farsund (st. 15A)		3	-21.16	0.27	3	7.17	0.53
Krossanes, Outer Sørfjord (st. 57A)		3	-20.36	0.17	3	3.01	0.25
Espevær, Outer Bømlafjord (st. 22A)		3	-21.87	0.22	3	5.71	0.15
Vågsvåg, Outer Nordfjord (st. 26A2)		3	-21.58	0.25	3	4.04	0.17
Ørland area, Outer Trondheimsfjord (st. 91A2)		3	-20.23	0.12	3	5.82	0.23
Mjelle, Bodø area (st. 97A2)		3	-22.83	0.11	3	6.83	0.47
Svolvær airport area (st. 98A2)		3	-22.71	0.07	3	6.48	0.01
Brashavn, Outer Varangerfjord (st. 11X)		3	-22.91	0.32	3	5.94	0.68
Atlantic cod (*Gadus morhua*)	**statistics >>**	**14**	**-19.83**	**0.59**	**14**	**14.28**	**0.69**
Tjøme, Outer Oslofjord (st. 36B)		15	-17.91	0.66	15	15.31	0.92
Kirkøy, Hvaler (st. 02B)		8	-19.19	0.59	8	15.47	0.21
Skågskjera, Farsund (st. 15B)		15	-19.49	0.57	15	16.06	0.83
Bømlo, Outer Selbjørnfjord (st. 23B)		15	-19.66	0.50	15	13.93	0.67
Sandnessjøen area (st. 96B)		15	-19.69	0.62	15	14.34	0.44
Austnesfjord, Lofoten (st. 98B1)		15	-20.56	0.50	15	12.96	1.02
Kjøfjord, Outer Varangerfjord (st. 10B)		15	-20.82	0.74	15	13.59	0.71
Isfjorden, Svalbard (st. 19B)		15	-21.31	0.54	15	12.57	0.69
Common eider (*Somateria mossillima*), blood	**statistics >>**	**15**	**-19.12**	**0.86**	**15**	**11.79**	**0.93**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-19.12	0.86	15	11.79	0.93
Common eider (*Somateria mossillima*), egg	**statistics >>**	**15**	**-23.38**	**1.05**	**15**	**11.02**	**0.91**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-23.38	1.05	15	11.02	0.91
Presumed more impacted, summary:							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**3**	**-20.85**	**0.23**	**3**	**5.57**	**0.12**
Gressholmen, Inner Oslofjord (st. 30A)		3	-20.97	0.31	3	7.98	0.01
Gåsøya, Inner Oslofjord (st. I304)		3	-19.89	0.28	3	7.99	0.11
Kirkøy, Hvaler (st. I024)		3	-20.77	0.11	3	6.74	0.08
Sylterøya, Langesundfjord (st. I714)		3	-20.90	0.18	3	5.39	0.03
Odderøya, Kristiansand harbour (st. I133)		3	-21.23	0.14	3	6.85	0.12
Byrkjenes, Inner Sørfjord (st. 51A)		3	-20.00	0.29	3	2.53	0.17
Eitrheimsneset, Inner Sørfjord (st. 52A)		3	-20.62	0.11	3	3.47	0.16
Kvalnes, Mid Sørfjord (st. 56A)		3	-19.69	0.09	3	2.37	0.26
Nordnes, Bergen harbour (st. I241)		3	-21.53	0.66	3	4.15	0.15
Ålesund harbour (st. 28A2)		3	-20.52	0.08	3	6.81	0.15
Bodø harbour (st. 97A3)		3	-23.18	0.30	3	6.96	0.09
0		0	0.00	0.00	0	0.00	0.00
0		0	0.00	0.00	0	0.00	0.00
Atlantic cod (*Gadus morhua*)	**statistics >>**	**15**	**-19.38**	**0.82**	**15**	**13.33**	**1.31**
Inner Oslofjord (st. 30B)		15	-18.28	0.83	15	15.85	1.43
Stathelle area, Langesundfjord (st. 71B)		15	-18.78	1.13	15	13.80	0.97
Kristiansand harbour area (st. 13B)		15	-18.53	0.59	15	14.32	0.62
Inner Sørfjord (st. 53B)		15	-19.02	0.92	15	11.44	2.80
Bergen harbour area (st. 24B)		15	-20.49	1.79	15	11.15	2.36
Ålesund harbour area (st. 28B)		15	-19.39	0.36	15	13.94	0.87
Trondheim harbour (st. 80B)		15	-18.68	0.50	15	13.86	1.04
Tromsø harbour area (st. 43B2)		15	-20.67	0.88	15	12.61	0.85
Hammerfest harbour area (st. 45B2)		15	-20.57	0.35	15	13.02	0.84
Average between the two groups for blue mussel	**statistics >>**	**3**	**-21.13**	**0.22**	**3**	**5.82**	**0.20**
Average between the two groups for Atlantic cod	**statistics >>**	**15**	**-19.60**	**0.70**	**15**	**13.80**	**1.00**

A



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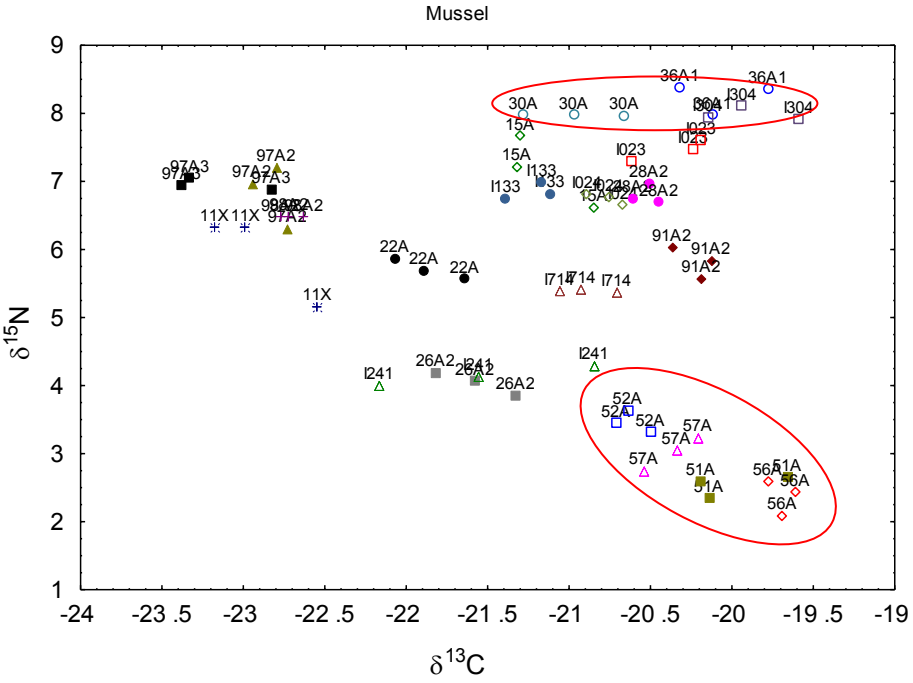


***Figure 68**. δ13C plotted against δ15N in for cod (**A**) and blue mussel (**B**). Station codes are superimposed. Red ellipses indicate the position of the majority of the samples of cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.*

The correlation between δ_{15}N and concentration of Hg in cod could suggest higher concentrations in individuals with higher δ_{15}N (significant linear regression between δ_{15}N and Log[Hg]; P<0.0001 R_2=0.2267; ***Figure 69***). However, this is likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations. However, linear regressions isolated for each station produced significant positive linear relationships between δ_{15}N and Log[Hg] for stations 36B, 30B, 13B, 24B, 28B, and 45B2.

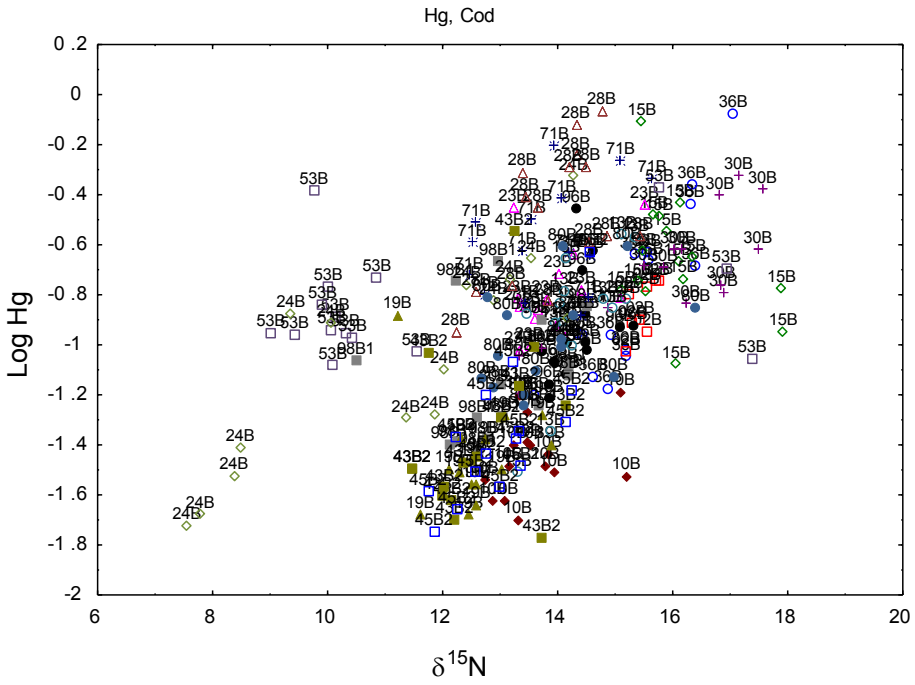


Figure 69. *δ_{15}N plotted against the log-transformed concentration of Hg in cod. Station codes are superimposed.*

As Hg, PCB153 is a compound with known biomagnifying properties (Ruus *et al*. 2019 – M-1441|2019), and there was a significant positive linear relationship between δ_{15}N and the (log-transformed) concentration of PCB153 in cod (P<0.00007), although with relatively poor goodness-of-fit (R_2=0.1037) (***Figure 70***). Again, this could partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations. Linear regressions isolated for each station yielded a significant positive relationship between δ_{15}N and Log[PCB153] at stations 28B, 53B2 and 45B2.

Plotting δ_{15}N against the concentration of BDE47 or BDE100 in cod could also suggest higher concentrations in individuals with higher δ_{15}N, as there were significant linear regressions between δ_{15}N and Log[BDE47] (P<0.00007) and between δ_{15}N and Log[BDE100] (P<0.0095; not shown), although with poor goodness-of-fit (R_2=0.0605 and R_2=0.0633, respectively). Linear regressions isolated for each station yielded a significant positive relationships between δ_{15}N and Log[BDE47], and between δ_{15}N and Log[BDE100] only at station 43B2.

When δ_{15}N is plotted against the concentration of PFOS or PFOSA in cod, higher concentrations in individuals with higher δ_{15}N could be suggested, as there were significant linear regressions between δ_{15}N and Log[PFOS] (R_2=0.2495; P<0.00001) and between δ_{15}N and Log[PFOSA] (R_2=0.2848; P<0.00001; ***Figure 71***). However, this is likely because of the high δ_{15}N in combination with high concentrations of PFOS and PFOSA in cod from the Oslofjord, and especially the Outer Oslofjord (***Figure 51***. *Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2018 in the Inner Oslofjord (st. 30B).****Figure 50***). Linear regressions isolated for each station yielded no significant relationships between δ_{15}N and neither Log[PFOS] nor Log[PFOSA].

δ_{15}N ratio in eiders from Svalbard (blood and egg) sampled in 2018 resembled those in 2017 (***Figure 72***). 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 72***) 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 3.73 ± 0.16 in blood and 9.88 ± 0.37 in egg, and a C:N ratio of >3.5 implies the presence of lipids, which may somewhat confound $\delta_{13}C$ interpretation, since lipids are $\delta_{13}C$-depleted relative to proteins (Sweeting *et al*. 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).

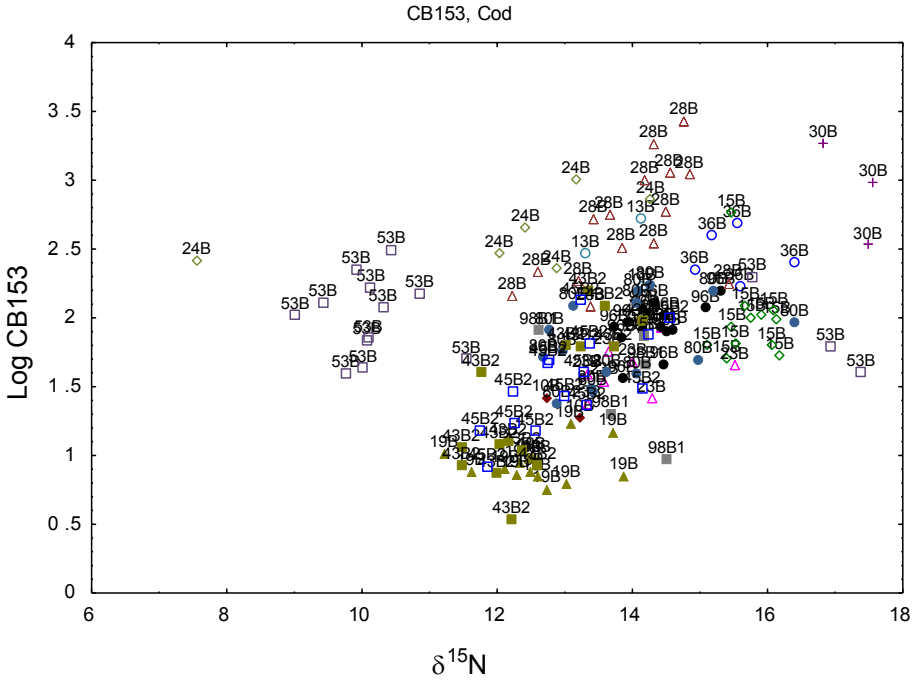
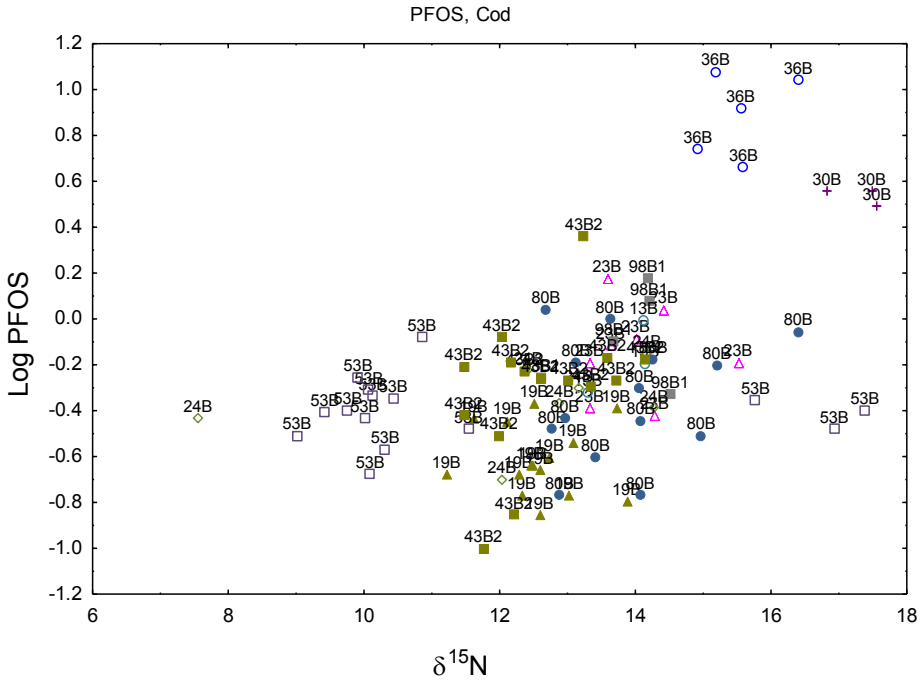


Figure 70. *$\delta_{15}N$ plotted against the log-transformed concentration of PCB153 in cod. Station codes are superimposed.*

A



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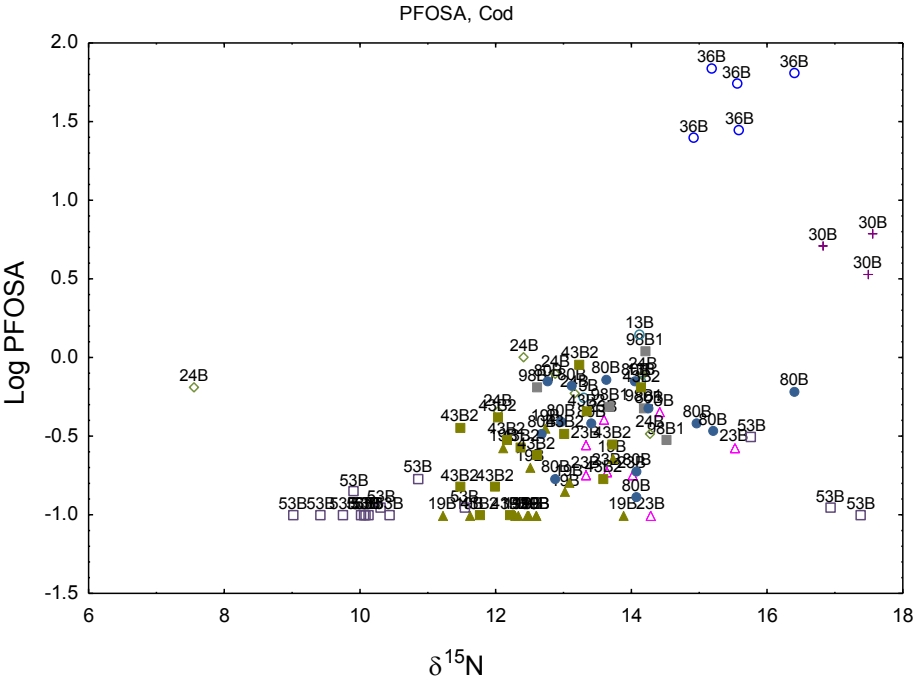

Figure 71. *δ_{15}N plotted against the log-transformed concentration of PFOS (**A**) and PFOSA (**B**) in cod. Station codes are superimposed.*

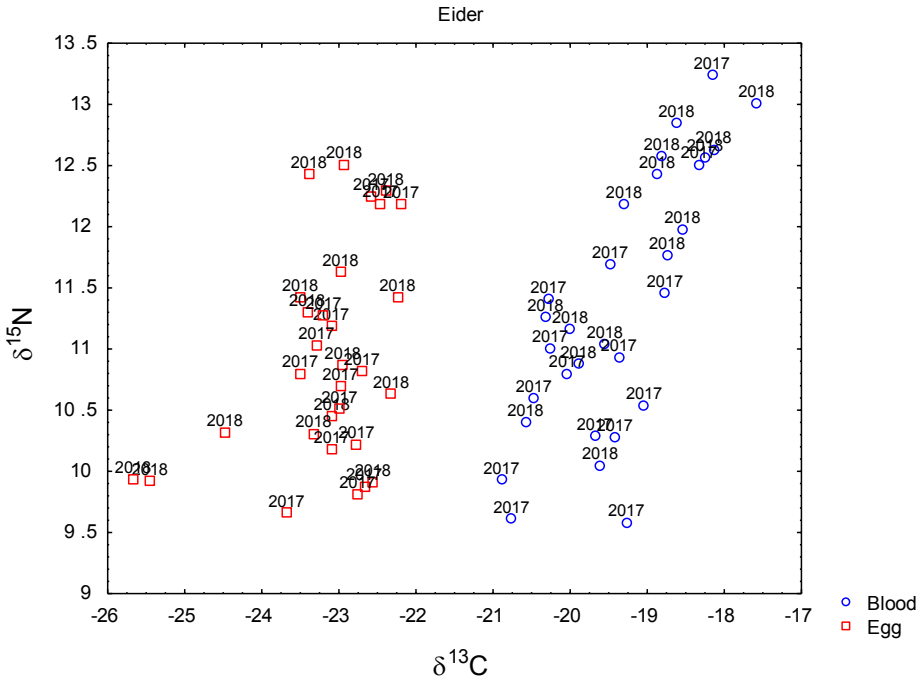

Figure 72. *δ_{15}C plotted against δ_{15}N in blood and egg of eider from Svalbard in 2017 and 2018. Sampling years are superimposed.*

3.5 Summary of results from Svalbard

Investigation of contaminants in Svalbard have been included since 2017 under the MILKYS programme. Samples from two species were used; muscle 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 24***). The results are reported in the preceding sections (see **Chapters 3.2** 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 most other cod stations, the median concentrations at Svalbard exceeded the EQS for Hg, PCB-7, BDE6S, BDE47, 4-N-OP, 4-T-OP, but were below the EQS for PFOA, PFOS, α–HBCD, SCCP, MCCP, 4-N-NP and 4-T-NP (***Table 10***). Median concentrations of contaminants in cod liver and cod muscle were generally low (below PROREF), the exception being for Cd which exceeded PROREF by a factor of two. (***Table 11***).

Siloxanes, i.e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver for the second time at the four stations, including Svalbard. D5, the most dominant cVMS, as well as D4 and D6 were lowest at Svalbard (**Figure 66**).

The correlation between δ_{15}N and contaminant concentration in cod could suggest higher concentrations in individuals with higher δ_{15}N. Linear regressions isolated for each station produced significant positive linear relationships between δ_{15}N and Log[Hg], as well as between δ_{15}N and Log[PFOS], for cod from Svalbard. The δ_{15}N ratio was fairly similar to that observed in another study from Svalbard, 2007 (Evenset et al. 2016).

Levels in eider
Median concentrations of Hg, Pb and As in eider eggs from Svalbard were on a similar level (within 60 %) as in a comparable study (Hill 2018). The median concentration of PCB153 in eider blood was below the LOQ, but the LOQ was close (within 40 %) to the concentration found in a comparable study in Svalbard (Bustnes et al. 2010). The Hg concentrations in eider blood and eggs at Svalbard in 2018 was almost within the same range as a comparable study in the Inner Oslofjord in 2017 (see **Chapter** Error! Reference source not found.).

In the present study, the median concentration of PBDE47, PFOS and PFOSA was lower than average concentrations found in another study of eider from three stations in northern Norway and one at Svalbard (Harju, Herzke, and Kaasa 2013). However, for SCCP and MCCP, median concentrations were higher (up to ten times) compared to the same study. The PFOS concentrations in eider blood and eggs are 10 times higher in the Inner Oslofjord than at Svalbard (see **Chapter** Error! Reference source not found.).

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 24**. Median concentrations (µg/kg w.w.) of parameters, with standard deviation, measured in cod liver (unless otherwise specified) from the Isfjord (st. 19B) in Svalbard and eider from Breøyane in Kongsfjord (st. 19N) in Svalbard in 2017. Units are: percent for fat and dry weight, permille for stabile isotopes, mg/kg for metals and µg/kg for the remaining substances. 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 one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of 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 **Chapter 2.10** 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)	
	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.
Dry weight (%)	53.000	6.820	15[36-63]					
Lipid content (%)	45.800	10.009	15[25.3-59.2]	0.430	0.190	15[0.13-0.78]	17.000	1.101
AG	0.250	0.152	15[0.12-0.67]	0.001	0.003	15[2e-04-0.0094]	0.003	0.006
AS	3.300	1.093	15[2.3-6]	0.030	0.023	15[0.0123-0.0808]	0.164	0.221
CD	0.170	0.135	15[0.098-0.63]	0.003	0.001	15[0.0015-0.0049]	0.000	0.000
CO	0.018	0.006	15[0.008-0.032]	0.003	0.002	15[0.0012-0.0065]	0.007	0.002
CR	0.039	0.024	10[0.033-0.11]	0.035	0.007		0.023	0.013
CU	3.600	1.669	15[2.1-8.9]	0.519	0.088	15[0.4747-0.7454]	1.440	0.132
HG (in muscle)	0.030	0.010	15[0.015-0.052]	146.573	48.673	15[57.3927-214.0177]	100.442	28.741
NI	0.045	0.011	10[0.04-0.08]	0.030	0.006		0.019	0.010
PB	0.030	0.000		0.051	0.104	15[0.0178-0.4198]	0.008	0.010
SN	0.060	0.000		0.005	0.003	2[0.0125-0.0134]	0.015	0.010
ZN	16.000	3.432	15[13-25]	6.881	1.737	15[5.4539-11.4881]	20.219	2.333
CB_S7	35.935	21.430	15[19.921-89.91]	0.692	0.165	7[0.6924-1.233]	12.811	2.416
CB18	0.000	0.000		0.024	0.000		0.024	0.002
CB28	1.190	0.347	15[0.844-2.06]	0.020	0.004	3[0.0204-0.0311]	0.390	0.187
CB31	0.000	0.000		0.021	0.000		0.032	0.013
CB33	0.000	0.000		0.025	0.000		0.025	0.000
CB37	0.000	0.000		0.030	0.000		0.030	0.000
CB47	0.000	0.000		0.019	0.000		0.132	0.076
CB52	3.180	1.216	15[2.15-6.46]	0.018	0.000		0.058	0.025
CB66	0.000	0.000		0.032	0.000		0.399	0.176
CB77	0.029	0.009	11[0.0235-0.0509]	0.000	0.000		0.000	0.000
CB81	0.002	0.006	11[0.0012-0.0116]	0.000	0.000		0.000	0.000
CB99	0.000	0.000		0.062	0.002	1[0.070]	1.060	0.275
CB101	5.520	3.142	15[3.17-14]	0.078	0.000		0.106	0.050
CB105	1.180	0.964	15[0.754-3.53]	0.030	0.002	2[0.0345-0.0389]	0.547	0.125
CB114	0.076	0.073	15[0.0521-0.265]	0.019	0.000		0.055	0.020
CB118	4.350	3.288	15[2.92-12.9]	0.101	0.013	3[0.107-0.15]	2.010	0.447
CB122	0.000	0.000		0.014	0.000		0.014	0.005
CB123	0.052	0.050	15[0.0324-0.179]	0.014	0.000		0.024	0.007
CB126	0.022	0.015	14[0.0125-0.0597]	0.000	0.000		0.000	0.000
CB128	0.000	0.000		0.021	0.007	5[0.0213-0.0417]	0.465	0.099
CB138	7.310	4.681	15[3.26-18.2]	0.164	0.045	3[0.174-0.307]	3.220	0.829
CB141	0.000	0.000		0.023	0.000		0.023	0.017
CB149	0.000	0.000		0.080	0.000		0.305	0.147
CB153	11.400	7.548	15[5.21-30.7]	0.255	0.082	6[0.26-0.529]	5.930	1.141
CB156	0.330	0.297	15[0.202-0.998]	0.009	0.003	3[0.01-0.0181]	0.161	0.046
CB157	0.096	0.085	15[0.059-0.329]	0.008	0.000		0.045	0.011
CB167	0.239	0.184	15[0.133-0.678]	0.008	0.001	3[0.0089-0.0125]	0.147	0.042
CB169	0.006	0.005	11[0.004-0.0245]	0.000	0.000		0.000	0.000
CB170	0.000	0.000		0.015	0.007	3[0.0236-0.039]	0.214	0.060
CB180	2.710	1.625	15[1.35-6.25]	0.056	0.033	4[0.0567-0.163]	0.964	0.218
CB183	0.000	0.000		0.013	0.006	7[0.0137-0.0315]	0.288	0.172
CB187	0.000	0.000		0.037	0.030	10[0.0307-0.134]	1.090	0.384
CB189	0.024	0.022	15[0.0138-0.0826]	0.013	0.000		0.013	0.006
CB194	0.000	0.000		0.009	0.002	2[0.0097-0.0156]	0.078	0.026
CB209	0.000	0.000		0.005	0.000		0.013	0.008
HCB	0.000	0.000		0.397	0.171	15[0.126-0.799]	10.100	3.427

Table 24. *(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)		
	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
4-N-NP	25.000	0.000		0.000	0.000		0.000	0.000	
4-N-OP	25.000	0.000		0.000	0.000		0.000	0.000	
4-T-NP	100.000	0.000		0.500	0.000		4.000	0.000	
4-T-OP	25.000	0.000		550.000	0.000		500.000	0.000	
HBCDA	0.645	0.415	15[0.438-2.03]	0.094	0.000		0.150	0.073	
HBCDG	0.029	0.016		0.066	0.000		0.066	0.000	
HBCDB	0.029	0.016		0.089	0.007		0.089	0.011	
HBCDD	0.760	0.419	15[0.4968-2.0882]	0.249	0.007		0.316	0.071	
BDE5S	3.327	1.094	15[2.5221-6.8778]	0.313	0.089	6[0.3169-0.6242]	0.550	0.496	
SCCP	103.000	22.874	15[64.6-162]	27.000	143.510	15[7.2-580]	31.000	7.380	
BDE6S	1.170	0.891	15[0.7449-4.119]	0.070	0.000	2[0.0701-0.071]	0.208	0.101	
MCCP	35.400	19.408	15[24.1-94.2]	2.500	6.289	15[0.1-26]	8.600	10.888	
BDE28	0.053	0.044	15[0.0416-0.2]	0.004	0.000		0.004	0.031	
BDE47	0.750	0.658	15[0.501-2.98]	0.032	0.000		0.064	0.038	
BDE49	0.187	0.179	15[0.151-0.853]	0.003	0.000		0.005	0.011	
BDE66	0.010	0.007	4[0.0101-0.0365]	0.019	0.000		0.019	0.006	
BDE71	0.010	0.002	1[0.010]	0.002	0.000		0.002	0.010	
BDE77	0.010	0.001		0.001	0.000		0.001	0.000	
BDE85	0.020	0.003		0.002	0.000		0.005	0.002	
BDE99	0.020	0.001		0.019	0.000		0.027	0.028	
BDE100	0.162	0.135	15[0.0959-0.612]	0.005	0.000	1[0.005]	0.042	0.027	
BDE119	0.020	0.007	3[0.0231-0.0471]	0.002	0.000		0.004	0.004	
BDE126	0.020	0.003	2[0.0208-0.0326]	0.002	0.000		0.003	0.001	
BDE138	0.029	0.002		0.006	0.000		0.006	0.000	
BDE153	0.029	0.002		0.006	0.000		0.014	0.007	
BDE154	0.078	0.061	15[0.0576-0.279]	0.004	0.000	1[0.004]	0.034	0.011	
BDE183	0.049	0.003		0.005	0.001	1[0.0]	0.005	0.000	
BDE196	0.097	0.005		0.009	0.000		0.009	0.000	
BDE209	0.971	0.051		0.134	0.079	3[0.169-0.414]	0.187	0.326	
PFAS	0.300	0.042	15[0.22-0.37]	0.350	0.201	14[0.23-0.99]	2.200	2.287	
PFDcA	0.500	0.127	1[0.9]	0.500	0.000		0.500	0.081	
PFHpA	0.500	0.000		0.500	0.000		0.500	0.000	
PFHxA	0.500	0.077	1[0.]	0.500	0.000		0.500	0.000	
PFHxS	0.100	0.000		0.110	0.041	8[0.11-0.22]	0.100	0.069	
PFNA	0.500	0.000		0.500	0.000		0.630	0.644	
PFOA	0.500	0.000		0.500	0.000		0.500	0.000	
PFOS	0.200	0.041	15[0.12-0.27]	0.250	0.201	14[0.13-0.89]	2.100	2.287	
PFOSA	0.100	0.008	1[0.1]	0.100	0.000		0.100	0.000	
PFBS	0.200	0.951	4[0.25-3.9]	0.200	0.000		0.200	0.000	
PFUdA	0.400	0.129	5[0.49-0.85]	0.400	0.000		0.720	0.232	
D4	3.453	7.002	4[NA-NA]	0.000	0.000		0.000	0.000	
D5	11.575	4.087	15[6.8966-23.0016]	0.000	0.000		0.000	0.000	
D6	6.730	4.224	15[4.8806-18.0066]	0.000	0.000		0.000	0.000	
BPA	0.000	0.000		5.000	0.000		30.000	0.000	
TBBPA	0.000	0.000		6.000	0.000		20.000	0.000	
C/N (in muscle)	3.350	0.131	15[3.23-3.63]	3.340	0.169	15[3.25-3.88]	8.570	0.392	
Delta13C (in muscle)	0.000	0.454	15[-22.11--20.52]	0.000	0.835	15[-20.89--18.16]	0.000	0.398	
Delta15N (in muscle)	13.370	0.262	15[12.81-13.54]	10.800	1.021	15[9.58-13.24]	10.800	0.857	

4. Conclusions

This programme examines long-term changes for legacy contaminants in biota along the coast of Norway in both polluted areas and areas remote from point sources. In addition, the programme includes supplementary investigations funded by the Ministry of Climate and Environment. As such, the programme provides a basis for assessing the state of the environment for the coastal waters with respect to contaminants and changes over time. In this annual report the primary concern is in relation to environmental quality standards (EQS) and the secondary concern is in relation to a new concept denoted Norwegian provisional high reference contaminant concentrations (PROREF). The main conclusions from the 2018 investigations were (based on wet weight basis):

- Of the 713 median values from 2018 for the 30 selected contaminants, 323 values could be assessed against the EQS of which 203 (62.8 %) were below the EQS.
- Of the 713 median values from 2018 for the 30 selected contaminants, 641 could be assessed against the Norwegian provisional high reference contaminant concentration (PROREF) of which 463 (72.2 %) were below PROREF.
- Most temporal trends are downwards, predominantly for metals, including TBT and its effect (imposex), but also PFOS and PFOSA downward trends were observed.
- The decrease in TBT can be related to legislation banning the use of this substance.
- The effects of TBT on dogwhelk, the imposex parameter VDSI, were zero at all eight stations except for at Karmsundet (VDSI=0.129) due to one imposexed individual.
- No trends for mercury (Hg) were found in cod fillet from the Inner Oslofjord. Both significant upward long- and short-term trends for Hg were found in the harbours of Kristiansand, while significant upward short-term trends were found at Farsund and Bømlo. While Hg concentration is strongly linked to fish length, these trends were significant also after adjusting for cod length for Kristiansand harbour, Farsund and Bømlo.
- Highest concentrations of PBDEs, predominantly BDE47, were found in the Inner and Outer Oslofjord for cod liver, and in the harbours of Bergen (Nordnes) and Bodø for blue mussel.
- The highest PCB-7 concentrations were found in blue mussel and cod from the Inner Oslofjord.
- Blue mussel from three 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 levels of PFOSA.
- The dominant hexabromocyclododecane (HBCD) in cod liver was α–HBCD. The concentration of α–HBCD was significantly highest in cod liver from the Inner Oslofjord of all cod stations and in blue mussel from Bodø harbour of all blue mussel stations; probably related to urban activities.
- Short chain chlorinated paraffins (SCCP) were highest in cod liver in Ålesund harbour whereas medium chain chlorinated paraffins (MCCP) were highest in Lofoten. Both SCCP and MCCP were highest in blue mussel from Bodø harbour. Cod from Svalbard had the same level of SCCP and MCCP as cod from some urban areas along the coast of Norway.
- There were both significant upward long- and short-term trends for SCCP in cod liver from Lofoten.
- The median concentrations of bisphenol A and alkylphenols were below the quantification limit in cod liver and blue mussel.
- The median concentrations of tetrabrombisphenol (TBBPA) were generally below the quantification limit in cod liver and blue mussel, except for cod liver from the Inner Oslofjord.
- For siloxanes in cod liver, 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 D6.
- Median concentrations of contaminants in cod liver and cod muscle from Svalbard were generally low (below PROREF).

- Contaminants were analyzed in the blood and eggs (homogenate of yolk and albumin) of the eider duck from Svalbard. This was the second time this species was used under the MILKYS programme. Concentrations of Hg, Pb, As, PCB153, 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 2018 was almost within the same range as 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 2018.
- The ICES/OSPAR Background Assessment Criteria (BAC) for OH-pyrene in cod bile was exceeded at all stations investigated, except at the reference station at Bømlo.
- Inhibited ALA-D activity in cod liver from the Inner Oslofjord and Inner Sørfjord indicated exposure to lead.
- Median EROD-activities were below the ICES/OSPAR assessment criterion at all stations investigated, and downward long-term trends in EROD activities could be observed at all stations investigated.
- The Inner Oslofjord, and to a lesser degree the harbour areas of Bergen, Kristiansand, Trondheim and Bodø seems all together to be an area where contaminants tend to appear in high concentrations. This is probably caused by a high population in watershed area, 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 levels in water and biota.
- High levels 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 (neither long- or short-term) were observed, 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 2018 in terms of isotopic signatures, indicating a geographical trend, persistent in time.
- The concentrations of dechlorane plus were low, and in many cases below the limit of quantification (***Table* 22**). The concentrations were slightly higher in cod liver from the Inner Oslofjord than from the harbour area of Bergen.
- Supplementary analysis of PFAS in cod liver from the Inner Oslofjord from 1990 to 2009 showed significant upward trends for PFDA, PFUnDA, PFDoA, PFTrDA and PFDS, and significant downward trends for PFOS and PFOSA.

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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 2018-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 2017 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 25***). Fish protein (DORM-4 and DOLT-5) was used as SRM for the control of the determination of metals. The reference material for determination of BDEs and HBCDDs in blue mussel was an internal reference (fish oil). For determination of PCBs, DDTs and PAHs in blue mussel, as well as HBCDDs, PCBs, DDTs and BDEs in liver, internal reference materials provided by EF GfA Lab services were used, these consisted of fish meal and feedingstuff. For TBBPA, spiked fish oil was used for quality assurance, and for chlorinated paraffines and octyl/nonylphenols, spiked fish meal was used. For organophosphorous flame retardants, spiked internal reference material was used.

Table 25. Summary of the quality control of results for the 2018 biota samples analysed in 2018-2019. The Standard Reference Materials (SRM) were DORM-4* (fish protein) and DOLT-5* for blue mussel, fish liver and fish fillet. The in-house reference materials were, spiked fish oil, spiked fish meal and spiked internal reference material (Pool 74, Pool 74 spiked with TBBPA, Pool 107, Pool 109 and Pool 122). For BPA, reference materials REFBP007 (olive oil) REFBP010 (apple purée) and REFBP005 (Liquor) were analysed and for tin organic compounds reference material ZRM 81 (mussel tissue) was used. 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 (mg/kg), BDE (pg/g), PCB (µg/kg), DDTs (µg/kg), HBCDDs (ng/g), PAH (µg/kg), TBBPA (ng/sample), BPA (µg/kg), octyl/nonylphenol (ng/sample), organophosphorus flame retardants (pg/sample) and PFCs (% recovery). 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	SB/LI	DOLT-5	2.05 ± 0.08	53	17	1.49	0.11
As	Arsenic	SB/LI	DORM-4	6.80±0.64	55	17	6.34	0.250
Cd	Cadmium	SB/LI	DORM-4	0.306±0.015	54	16	0.304	0.012
Cr	Chromium	SB/LI	DORM-4	1.87±0.16	54	17	1.745	0.16
Co	Cobalt	SB/LI	DOLT-5	0.267 ± 0.026	52	16	0.225	0.019
Cu	Copper	SB/LI	DORM-4	15.9±0.9	55	16	14.21	0.87
Hg	Mercury	SB/MU	DORM-4	0.41±0.055	64	17	0.41	0.029
Ni	Nickel	SB/LI	DORM-4	1.36±0.22	51	17	1.18	0.081
Pb	Lead	SB/LI	DORM-4	0.416±0.053	55	17	0.37	0.024
Zn	Zinc	SB/LI	DORM-4	52.2±3.2	54	16	50.33	2.99
Sn	Tin	SB/LI	DOLT-5	0.069 ± 0.036	53	17	0.095	0.025
BDE-28	2.2.4' Tribromodiphenylether	SB/LI	Pool 74		47	26	86.4411	5.049
BDE-47	2.2'.4.4'.-Tetrabromodiphenylether	SB/LI	Pool 74		47	26	1605.988	39.309
BDE-100	2.2'.4.4'.6-Pentabromodiphenylether	SB/LI	Pool 74		47	26	323.1465	14.186
BDE-99	2.2'.4.4'.5-Pentabromodiphenylether	SB/LI	Pool 74		47	26	250.6408	6.815
BDE-154	2.2'.4.4'.5.6'-Hexabromodiphenylether	SB/LI	Pool 74		47	26	202.1234	20.735
BDE-153	2.2'.4.4'5.5'-Hexabromodiphenylether	SB/LI	Pool 74		47	26	61.4060	3.622
BDE-209	Decabromodiphenylether	SB/LI	Pool 74		8	26	551.2245	325.006
BDE-49	2.2'.4.5'-tetrabromodiphenyleter	SB/LI	Pool 74		47	26	434.4130	22.258
BDE-66	2.3'.4.4'-Tetrabromodiphenyleter	SB/LI	Pool 74		47	26	58.4452	8.118
BDE-119	2.3'.4.4'.6-Pentabromodiphenyl ether	SB/LI	Pool 74		47	26	34.5222	3.744
PCB 77	PCB congener CB-77	SB/LI	Pool 109		58	25	9.68	2.19
PCB 52	PCB congener CB-52	SB/LI	Pool 109		59	25	269.38	15.11
PCB 28	PCB congener CB-28	SB/LI	Pool 109		59	25	104.58	15.11
PCB 189	PCB congener CB-189	SB/LI	Pool 109		59	25	6.28	0.33
PCB 180	PCB congener CB-180	SB/LI	Pool 109		59	25	480.06	28.13
PCB 169	PCB congener CB-169	SB/LI	Pool 109		58	25	0.73	0.08
PCB 167	PCB congener CB-167	SB/LI	Pool 109		59	25	29.58	3.60
PCB 157	PCB congener CB-157	SB/LI	Pool 109		59	25	13.58	0.41
PCB 156	PCB congener CB-156	SB/LI	Pool 109		59	25	49.33	1.23
PCB 153	PCB congener CB-153	SB/LI	Pool 109		59	25	1505.87	110.33
PCB 138	PCB congener CB-138	SB/LI	Pool 109		59	25	909.37	54.39
PCB 126	PCB congener CB-126	SB/LI	Pool 109		59	25	2.87	0.42
PCB 123	PCB congener CB-123	SB/LI	Pool 109		59	25	4.80	0.89
PCB 118	PCB congener CB-118	SB/LI	Pool 109		59	25	449.06	18.02
PCB 114	PCB congener CB-114	SB/LI	Pool 109		59	25	7.76	1.01
PCB 105	PCB congener CB-105	SB/LI	Pool 109		59	25	137.3	5.02
PCB 101	PCB congener CB-101	SB/LI	Pool 109		59	25	613.61	49.92
DDEOP	o.p'-DDE	SB/LI	Pool 122		72	29	0.116	0.0116
TDEOP	o.p'-DDD	SB/LI	Pool 122		73	29	0.258	0.0276
DDTOP	o.p'-DDT	SB/LI	Pool 122		73	29	0.228	0.0497
DDEPP	p.p'-DDE	SB/LI	Pool 122		73	29	5.12	0.39
TDEPP	p.p'-DDD	SB/LI	Pool 122		73	29	1.57	0.15
DDTPP	p.p'-DDT	SB/LI	Pool 122		73	29	0.611	0.0443
α-HBCDD	α-Hexabromocyclododecane	SB/LI	Pool 74		54	29	0.955	0.079
ß-HBCDD	ß- Hexabromocyclododecane	SB/LI	Pool 74		54	29	0.056	0.010
γ-HBCDD	γ- Hexabromocyclododecane	SB/LI	Pool 74		54	29	0.289	0.041
BGHIP	Benzo[ghi]perylene	SB/LI	Pool 107		31	35	0.53	0.06
ICDP	Indeno[1.2.3-cd]pyrene	SB/LI	Pool 107		31	35	0.44	0.05
BBJF	Benzo[b+j]fluoranthene	SB/LI	Pool 107		31	35	0.32	0.04
DBA3A	Dibenzo[ac.ah]anthracene	SB/LI	Pool 107	-	9	35	0.16	0.02
BKF	Benzo[k]fluoranthene	SB/LI	Pool 107		31	35	1.12	0.15
ACNLE	Acenaphthylene	SB/LI	Pool 107		29	35	1.62	0.32
ANT	Anthracene	SB/LI	Pool 107		30	35	0.99	0.15
BAA	Benzo[a]anthracene	SB/LI	Pool 107		31	35	1.14	0.15
BAP	Benzo[a]pyrene	SB/LI	Pool 107		31	35	0.59	0.05
CHR	Chrysene	SB/LI	Pool 107		31	35	1.10	0.17
FLU	Fluoranthene	SB/LI	Pool 107		31	35	3.22	0.50
FLE	Fluorene	SB/LI	Pool 107		31	35	12.7	2.1
NAP	Naphthalene	SB/LI	Pool 107		23	35	28.9	16.0
PA	Phenanthrene	SB/LI	Pool 107		31	35	9.55	1.62

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
PYR	**Pyrene**	SB/LI	Pool 107		31	35	3.49	0.46
ACNE	**Acenaphthene**	SB/LI	Pool 107		31	35	23.7	3.9
TBBPA	**Tetrabromobisphenol-A**	SB/LI	Pool 74 (spiked)	-	34	29	0.87	0.21
BPA	**Bisphenol-A**	SB/LI	REFBP007 Olive oil	40.0 ± 6.0	21	10	41.8	6.0
BPA	**Bisphenol-A**	SB/LI	REFBP010 Apple puree	40.0 ± 0.7	81	14	4.3	1.0
BPA	**Bisphenol-A**	SB/LI	REFBP005 Rum	22.9 ± 2.8	77	26	21.9	2.5
APO	**4-tert-oktylfenol**	LI/SB	Internal RM (spiked blank)		8	14	41206	9022
APO	**4-n-oktylfenol**	LI/SB	Internal RM (spiked blank)		8	14	39602	1274
APO	**4-n-nonylfenol**	LI/SB	Internal RM (spiked blank)		8	14	42383	871
MBT	**Monobutyltinn (MBT)**	LI/SB	ZRM 81		41	27	2.02	0.22
DBT	**Dibutyltinn (DBT)**	LI/SB	ZRM 81		41	27	1.12	0.16
TBT	**Tributyltinn (TBT)**	LI/SB	ZRM 81		41	27	1.70	0.29
TPhT	**Trifenyltinn (TPhT)**	LI/SB	ZRM 81		41	27	1.40	0.23
PFBS	**Perfluorobutane sulphonate**	LI	In-house spiked liver	100%[1)]	8		93	6.3%
PFHxA	**Perfluorohexane acid**	LI	In-house spiked liver	100%[1)]	8		100	5.7%
PFHpA	**Perfluoroheptane acid**	LI	In-house spiked liver	100%[1)]	8		107	17.8%
PFOA	**Perfluorooctane acid**	LI	In-house spiked liver	100%[1)]	8		108	9.0%
PFNA	**Perfluorononane acid**	LI	In-house spiked liver	100%[1)]	8		101	10.7%
PFOS	**Perfluorooctane sulphonate**	LI	In-house spiked liver	100%[1)]	8		96	3.3%
PFOSA	**Perfluorooctane sulphone amide**	LI	In-house spiked liver	100%[1)]	8		94	8.2%
PFHxS	**Perfluorohexane sulphonate**	LI	In-house spiked liver	100%[1)]	8		89	5.4%
PFDA	**Perfluorodecanoic acid**	LI	In-house spiked liver	100%[1)]	8		98	9.5%
PFUDA	**Perfluoroundecanoic acid**	LI	In-house spiked liver	100%[1)]	8		95	5.2%
PFDS	**Perfluorodecanesulphonate**	LI	In-house spiked liver	100%[1)]	8		81	9.8%

* National Research Council Canada, Division of Chemistry, Marine Analytical Chemistry Standards.

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
TPTIN	triphenyltin	*trifenyltinn*	O-MET
TTBT	tetrabutyltin	*tetrabutyltinn*	O-MET
PAHs			
PAH	polycyclic aromatic hydrocarbons	*polysykliske aromatiske hydrokarboner*	
ACNE [3]	acenaphthene	*acenaften*	PAH
ACNLE [3]	acenaphthylene	*acenaftylen*	PAH

Abbreviation[1]	English	*Norwegian*	Param. group
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
BBJF [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
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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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*	

Abbreviation[1]	English	*Norwegian*	Param. group
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
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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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

Abbreviation[1]	English	*Norwegian*	Param. group
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}*	
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*	

Abbreviation[1]	English	*Norwegian*	Param. group
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	*D<ibromoaldrin*	
DDC_ANT	dechlorane 603	*dekloran 603*	
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

Abbreviation[1]	English	*Norwegian*	Param. group
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*	
SIIF	Fondation 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:	*"Toxisitetsekvivalentfaktorer" for de giftigste forbindelsene innen følgende grupper.*
	• 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	• *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-ortho and mono-ortho substituted chlorobiphenyls after WHO model (Ahlborg *et al.* 1994) 3 or Safe (1994, cf. NILU pers. comm.)	• *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., 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 26. *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 muscle 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 (NorwegianEnvironmentAgency 2016) 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-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
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				

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
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		
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		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
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		
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	**Lever**	80B,10B	**2**	229	mg/kg	0.930	0.9256	0.9953		
AS	Gadus morhua	**Lever**	10B,13B,80B,43B2,71B,15B	**6**	721	mg/kg	12.800	12.8000	1.0000		
CD	Gadus morhua	**Lever**	80B,67B,15B,23B	**4**	1655	mg/kg	0.137	0.1365	1.0000		
CO	Gadus morhua	**Lever**	43B2	**1**	145	mg/kg	0.060	0.0584	0.9733		
CR	Gadus morhua	**Lever**	10B,15B,71B,43B2,80B,13B,36B,30B,98B1	**9**	1176	mg/kg	0.400	0.4025	1.0063		
CU	Gadus morhua	**Lever**	10B,15B,80B	**3**	1101	mg/kg	14.000	14.0000	1.0000		
NI	Gadus morhua	**Lever**	15B,23B,43B2,10B,71B,80B,53B,36B	**8**	973	mg/kg	0.650	0.6500	1.0000		
PB	Gadus morhua	**Lever**	92B,36B,67B,43B,15B,43B2,98B1,10B,23B,80B	**10**	3588	mg/kg	0.050	0.0500	1.0000		
SN	Gadus morhua	**Lever**	10B,15B,23B,36B,43B2,53B,71B,80B,13B,98B1,30B	**11**	1381	mg/kg	0.300	0.3000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
ZN	Gadus morhua	**Lever**	98B1,10B,92B,43B2,80B	**5**	1351	mg/kg	35.000	35.0000	1.0000		
PCB-7	Gadus morhua	**Lever**	98B1,10B,92B,43B	**4**	1229	µg/kg	614.000	614.0000	1.0000	0.600	0.0010
CB28	Gadus morhua	**Lever**	80B,98B1,23B,67B,10B,43B,92B,53B,43B2	**9**	3039	µg/kg	8.000	8.0000	1.0000		
CB52	Gadus morhua	**Lever**	67B,23B,98B1	**3**	1385	µg/kg	16.000	16.0000	1.0000		
CB101	Gadus morhua	**Lever**	23B	**1**	554	µg/kg	32.350	32.3500	1.0000		
CB118	Gadus morhua	**Lever**	98B1,23B,10B,92B,43B,67B,80B	**7**	2359	µg/kg	100.000	100.0000	1.0000		
CB138	Gadus morhua	**Lever**	98B1,10B,43B,92B	**4**	1282	µg/kg	157.950	157.9500	1.0000		
CB153	Gadus morhua	**Lever**	98B1,10B,92B,43B	**4**	1282	µg/kg	189.950	189.9500	1.0000		
CB180	Gadus morhua	**Lever**	98B1,10B,92B	**3**	1165	µg/kg	45.800	45.8000	1.0000		
DDEPP	Gadus morhua	**Lever**	23B,10B,98B1	**3**	1498	µg/kg	160.750	160.7500	1.0000	610.000	3.7947
DDTPP	Gadus morhua	**Lever**	10B,23B,36B,98B1	**4**	885	µg/kg	13.000	13.0000	1.0000		
TDEPP	Gadus morhua	**Lever**	23B,92B,36B	**3**	1303	µg/kg	32.000	32.0000	1.0000		
HCHA	Gadus morhua	**Lever**	53B,15B,36B,10B,23B,30B,67B,92B,43B,98B1	**10**	4071	µg/kg	8.000	8.0000	1.0000		
HCHG	Gadus morhua	**Lever**	53B,10B,92B,36B	**4**	1602	µg/kg	11.000	12.0000	1.0909	61.000	5.5455
HCB	Gadus morhua	**Lever**	36B,53B	**2**	1079	µg/kg	14.000	14.0000	1.0000	10.000	0.7143
4-N-NP	Gadus morhua	**Lever**	80B,43B2	**2**	135	µg/kg	131.000	131.0000	1.0000	3 000.000	22.9008
4-N-OP	Gadus morhua	**Lever**	43B2,80B	**2**	135	µg/kg	23.500	23.5000	1.0000	0.004	0.0002
4-T-NP	Gadus morhua	**Lever**	43B2,80B	**2**	135	µg/kg	240.900	240.9000	1.0000	3 000.000	12.4533
4-T-OP	Gadus morhua	**Lever**	80B,43B2	**2**	135	µg/kg	20.000	20.0000	1.0000	0.004	0.0002
CYP1A	Gadus morhua	**Lever**	23B,53B	**2**	487		2.070	2.0669	0.9985		
EROD	Gadus morhua	**Lever**	23B,53B,36B,30B	**4**	1303	pmol/min/mg protein	192.290	192.2861	1.0000		
HBCDA	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	7.000	7.0000	1.0000	167.000	23.8571
HBCDG	Gadus morhua	**Lever**	43B2,80B	**2**	135	µg/kg	0.890	0.8948	1.0054		
HBCDB	Gadus morhua	**Lever**	43B2,80B	**2**	135	µg/kg	0.400	0.4030	1.0075		
HBCDD	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	7.180	7.1960	1.0022		
BDESS	Gadus morhua	**Lever**	98B1	**1**	173	µg/kg	21.420	21.4200	1.0000		
BDE6S	Gadus morhua	**Lever**	98B1	**1**	173	µg/kg	19.882	19.8800	1.0000	0.009	0.0004
BDE28	Gadus morhua	**Lever**	36B,13B,98B1,23B,43B2	**5**	701	µg/kg	1.400	1.4000	1.0000		
BDE47	Gadus morhua	**Lever**	98B1,36B,23B	**3**	557	µg/kg	16.000	16.0000	1.0000	0.009	0.0005
BDE49	Gadus morhua	**Lever**	23B,98B1	**2**	266	µg/kg	3.950				
BDE66	Gadus morhua	**Lever**	23B,98B1	**2**	266	µg/kg	0.595				
BDE71	Gadus morhua	**Lever**	98B1,23B,53B,30B	**4**	553	µg/kg	0.400				
BDE77	Gadus morhua	**Lever**	30B	**1**	122	µg/kg	1.690				
BDE85	Gadus morhua	**Lever**	98B1,53B,23B,30B	**4**	536	µg/kg	1.725				
BDE99	Gadus morhua	**Lever**	13B,23B	**2**	363	µg/kg	0.750	0.7540	1.0053		
BDE100	Gadus morhua	**Lever**	98B1	**1**	173	µg/kg	2.600	2.6000	1.0000		
BDE126	Gadus morhua	**Lever**	13B,23B,30B,36B,43B2,80B	**6**	419	µg/kg	0.100	0.1000	1.0000		
BDE138	Gadus morhua	**Lever**	30B,23B,53B,98B1	**4**	561	µg/kg	0.300				
BDE153	Gadus morhua	**Lever**	13B,23B	**2**	363	µg/kg	0.150	0.1490	0.9933		
BDE154	Gadus morhua	**Lever**	98B1,36B	**2**	323	µg/kg	1.500	1.5000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2018	PROREF-2017	PROREF-2017 / PROREF-2018	EQS	EQS/ PROREF-2018
BDE183	Gadus morhua	**Lever**	13B,23B,30B,36B,43B2,53B,80B,98B1	**8**	1360	µg/kg	0.600	0.6005	1.0008		
BDE196	Gadus morhua	**Lever**	13B,23B,30B,36B,43B2,53B,80B,98B1	**8**	1142	µg/kg	1.000	1.0000	1.0000		
BDE205	Gadus morhua	**Lever**	23B,30B,98B1,53B	**4**	559	µg/kg	1.500				
BDE209	Gadus morhua	**Lever**	13B	**1**	131	µg/kg	2.000	2.0000	1.0000		
SCCP	Gadus morhua	**Lever**	23B,43B2,80B	**3**	245	µg/kg	154.000	154.0000	1.0000	6 000.000	38.9610
MCCP	Gadus morhua	**Lever**	23B,43B2	**2**	174	µg/kg	392.800	392.8000	1.0000	170.000	0.4328
PFAS	Gadus morhua	**Lever**	43B2,80B	**2**	251	µg/kg	11.000	20.0000	1.8182		
PFNA	Gadus morhua	**Lever**	13B,23B,30B,36B,43B2,80B,98B1,53B	**8**	1315	µg/kg	5.000	5.0000	1.0000		
PFOA	Gadus morhua	**Lever**	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	**Lever**	43B2,80B	**2**	251	µg/kg	10.250	10.2500	1.0000	9.100	0.8878
PFOSA	Gadus morhua	**Lever**	43B2,98B1,53B,80B,23B	**5**	718	µg/kg	6.245	6.2450	1.0000		
PFBS	Gadus morhua	**Lever**	13B,36B,43B2,53B,80B,23B,30B,98B1	**8**	1316	µg/kg	8.000	8.0000	1.0000		
TBEP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
TBP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
TCEP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	477.200	477.2000	1.0000		
TCPP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	67.600	67.6000	1.0000		
TDCP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	71.120	71.1200	1.0000		
TEHP	Gadus morhua	**Lever**	43B2	**1**	64	µg/kg	334.150	334.1500	1.0000		
TIBP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
EHDPP	Gadus morhua	**Lever**	43B2	**1**	65	µg/kg	66.420	66.4200	1.0000		
BPA	Gadus morhua	**Lever**	43B2,80B	**2**	134	µg/kg	2.000	2.0000	1.0000		
TBBPA	Gadus morhua	**Lever**	80B,43B2	**2**	135	µg/kg	0.570	0.5675	0.9956		
HG	Gadus morhua	**Muskel**	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 1981-2018
(cf. Appendix E)

Appendix D (cont.) Map of stations

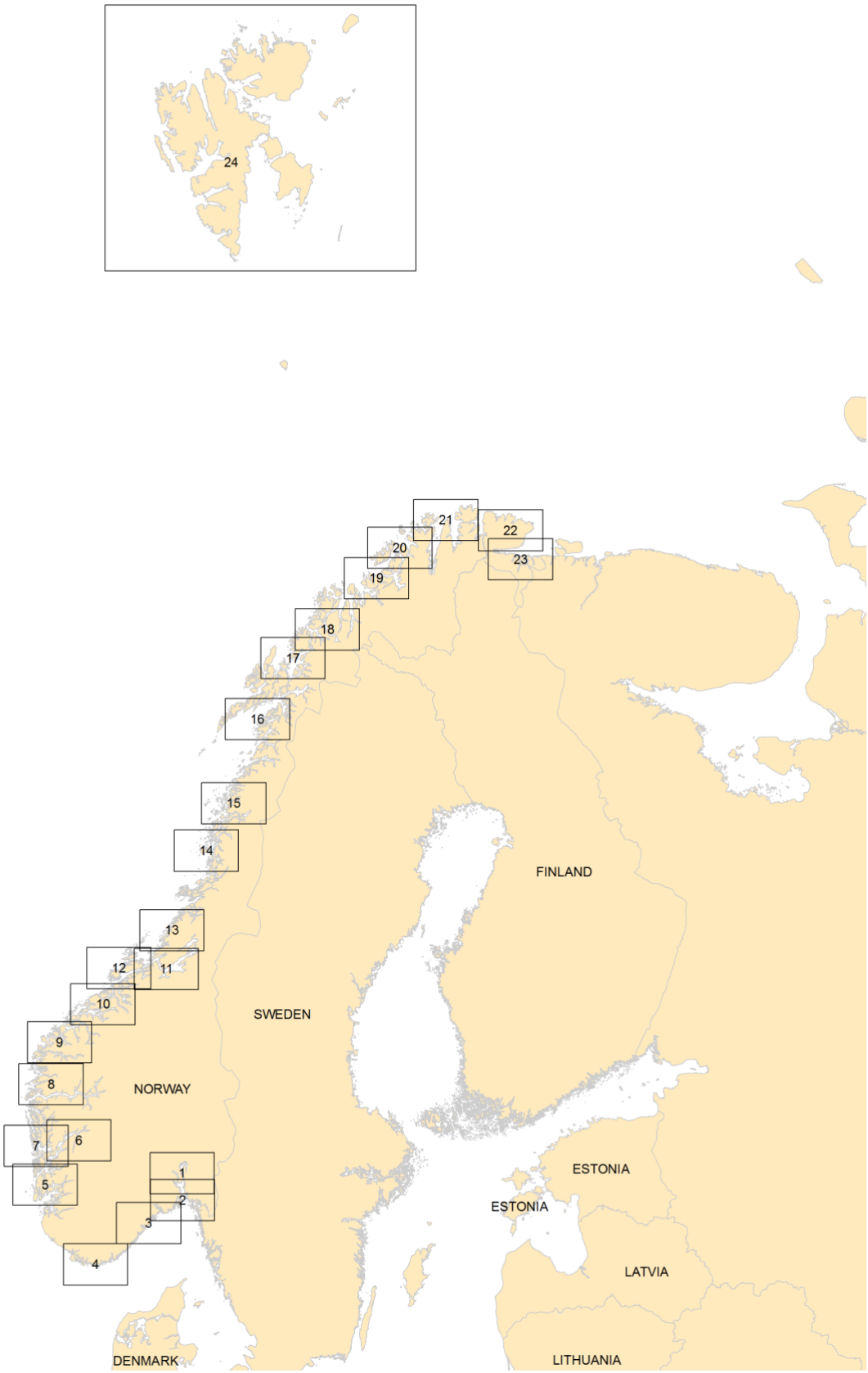
NOTES

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.

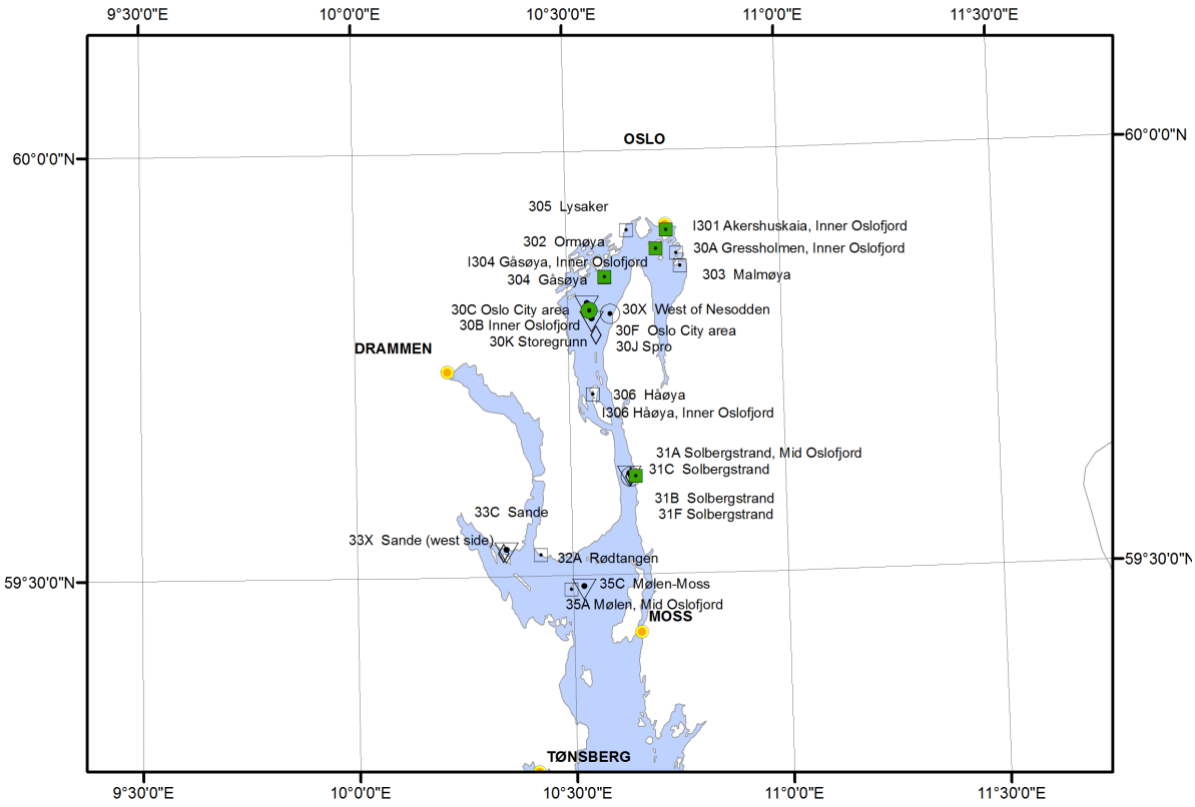
The following symbols and codes apply:

All years	2017	Explanation	Station code
		Sediment	<number>S
		Blue mussel	<number>A
		Blue mussel	I<number/letter> 1)
		Blue mussel	R<number/letter> 1)
		Dogwhelk	<number>G
		Prawn	<number>C
		Atlantic cod	<number>A
		Flatfish	<number>D/E
		Other round fish	
		Common eider duck	<number>N
		Town or city	

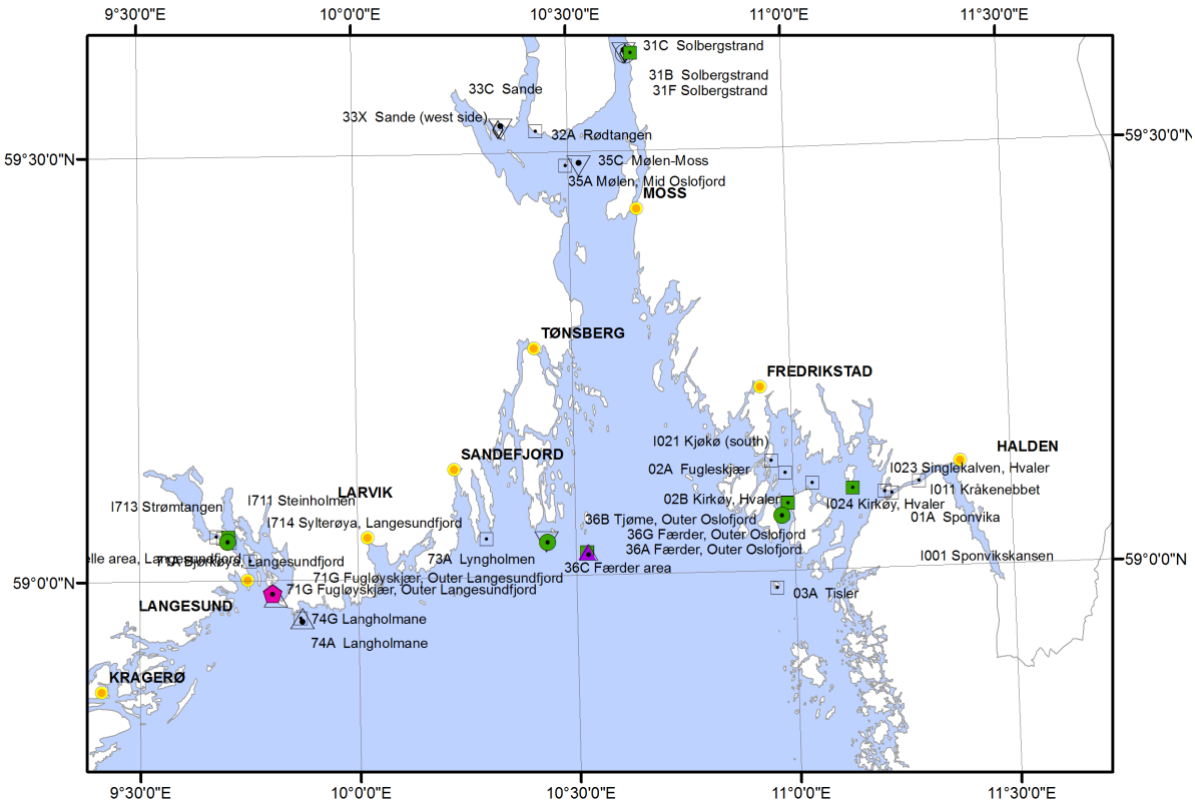
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (Green, Schøyen, et al. 2011).



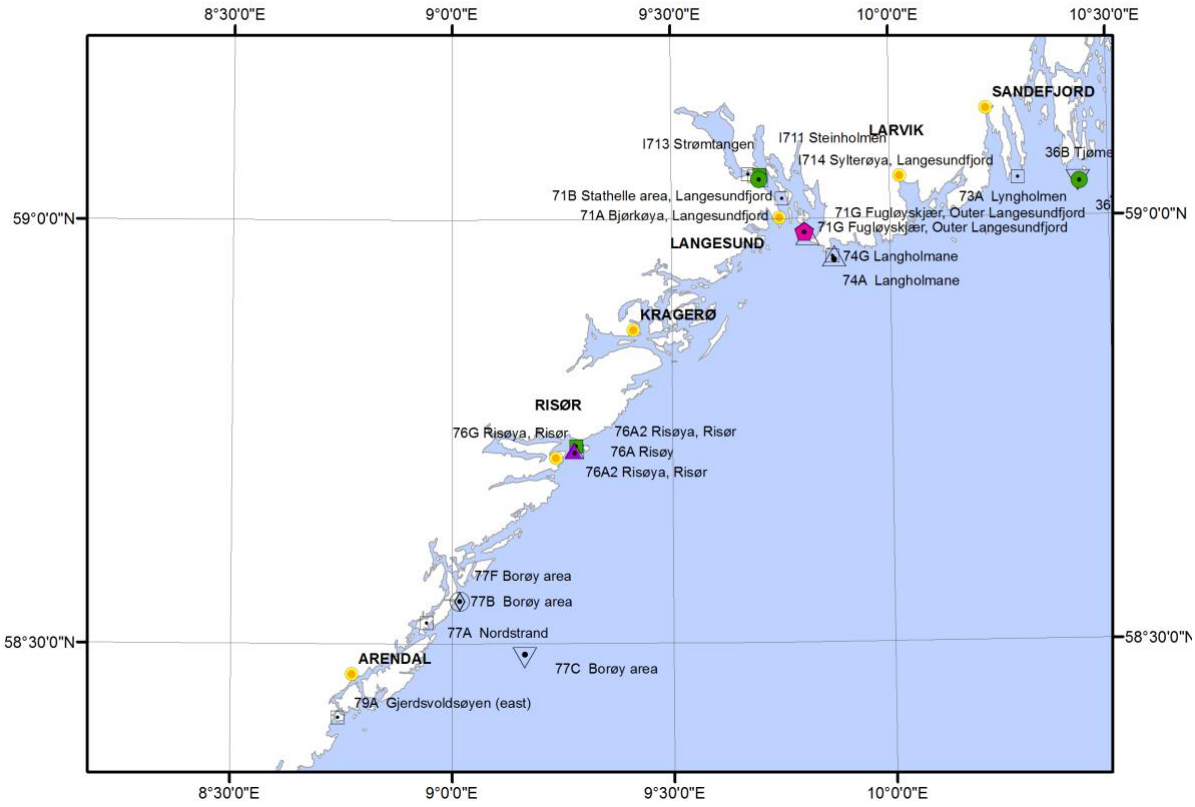
Maps presenting MILKYS stations in Norway. Numbers refer to map references that follow. Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


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
305 Lysaker
I301 Akershuskaia, Inner Oslofjord
302 Ormøya
30A Gressholmen, Inner Oslofjord
I304 Gåsøya, Inner Oslofjord
304 Gåsøya
303 Malmøya
30C Oslo City area
30X West of Nesodden
30B Inner Oslofjord
30F Oslo City area
30K Storegrunn
30J Spro
DRAMMEN
306 Håøya
I306 Håøya, Inner Oslofjord
31A Solbergstrand, Mid Oslofjord
31C Solbergstrand
31B Solbergstrand
31F Solbergstrand
33C Sande
33X Sande (west side)
32A Rødtangen
35C Mølen-Moss
35A Mølen, Mid Oslofjord
MOSS
TØNSBERG

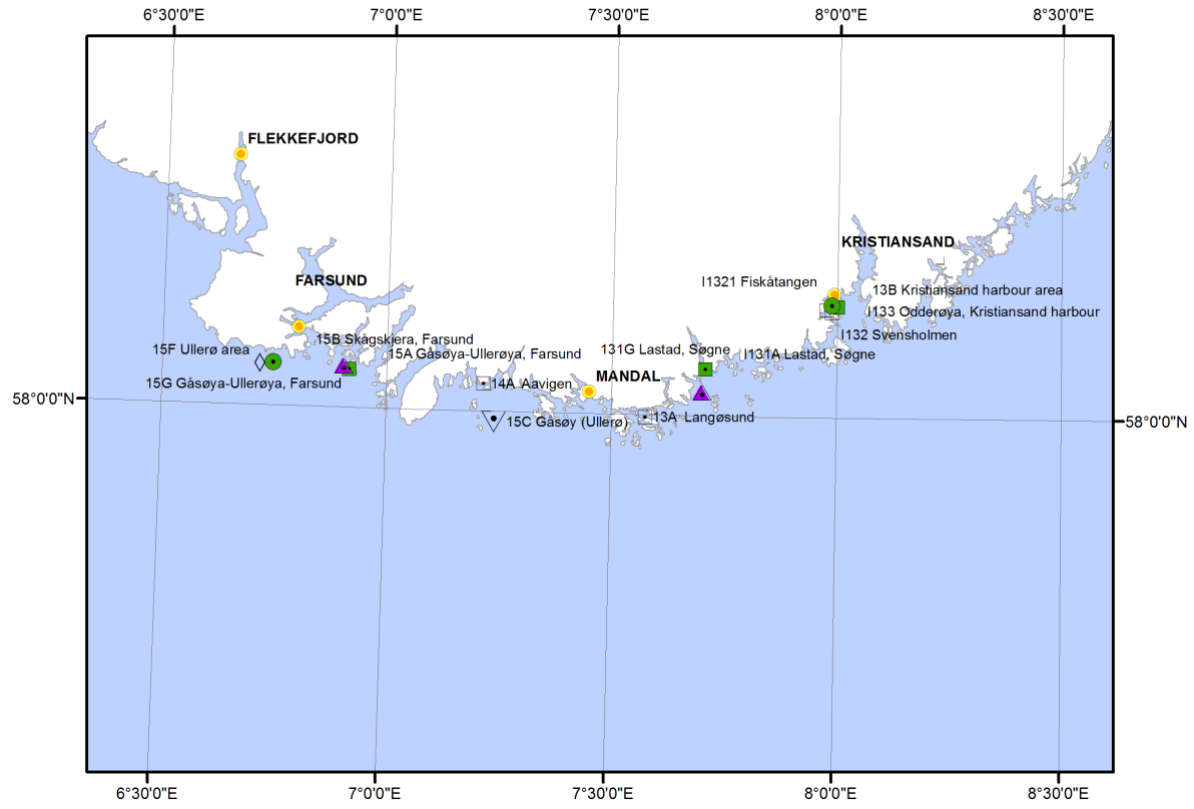
MAP 1


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)
32A Rødtangen
35C Mølen-Moss
35A Mølen, Mid Oslofjord
MOSS
TØNSBERG
FREDRIKSTAD
I021 Kjøkø (south)
02A Fugleskjær
HALDEN
I023 Singlekalven, Hvaler
I011 Kråkenebbet
SANDEFJORD
02B Kirkøy, Hvaler
I024 Kirkøy, Hvaler
01A Spønvika
LARVIK
I713 Strømtangen
I711 Steinholmen
I714 Sylterøya, Langesundfjord
36B Tjøme, Outer Oslofjord
36G Færder, Outer Oslofjord
36A Færder, Outer Oslofjord
I001 Spønvikskansen
73A Lyngholmen
36C Færder area
71G Fugløyskjær, Outer Langesundfjord
03A Tisler
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ

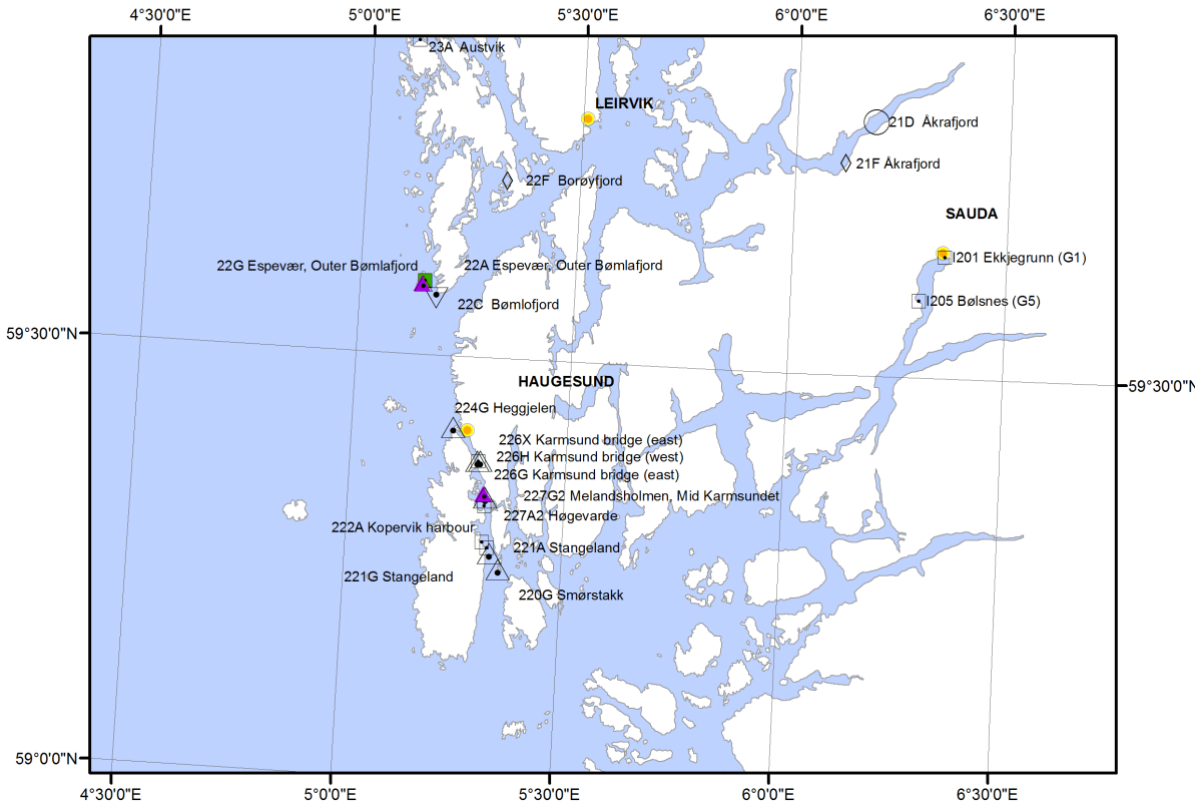
MAP 2


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
71G Fugløyskjær, Outer Langesundfjord
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ
RISØR
76G Risøya, Risør
76A2 Risøya, Risør
76A Risøy
76A2 Risøya, Risør
77F Borøy area
77B Borøy area
77A Nordstrand
ARENDAL
77C Borøy area
79A Gjerdsvoldsøyen (east)

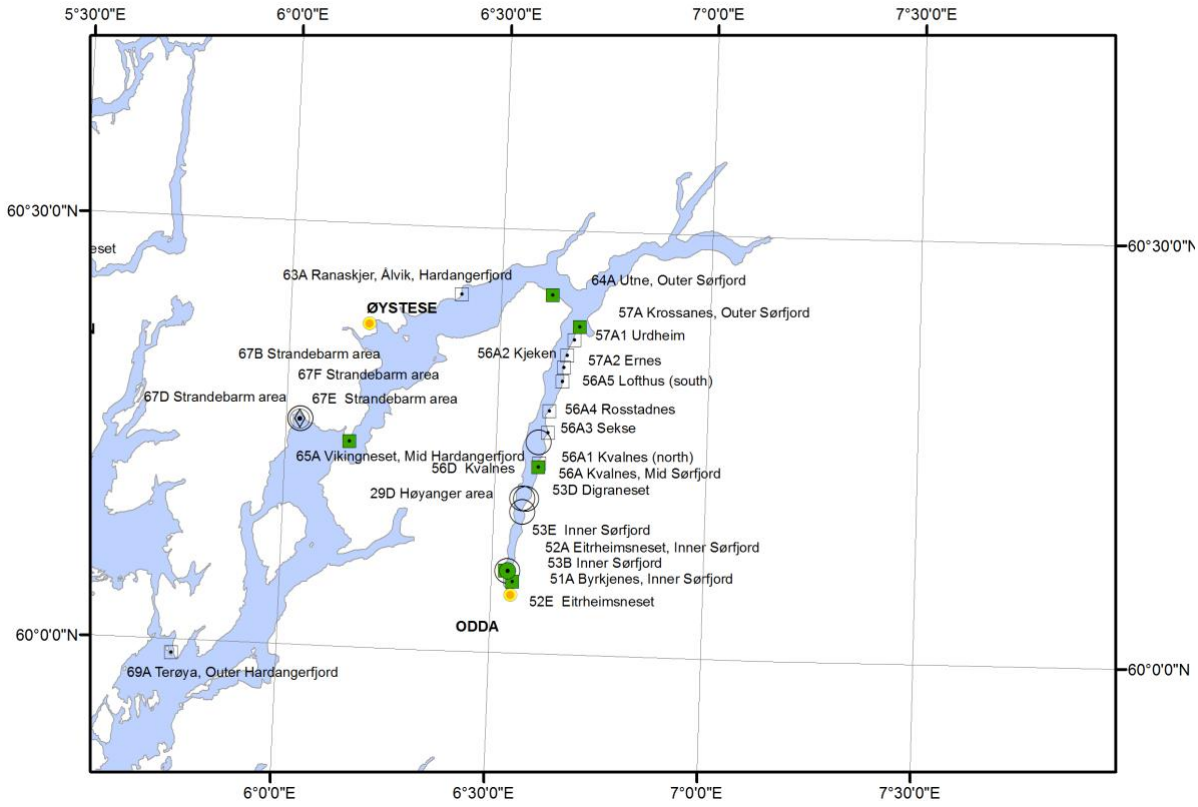
MAP 3


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 Skagskjera, 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

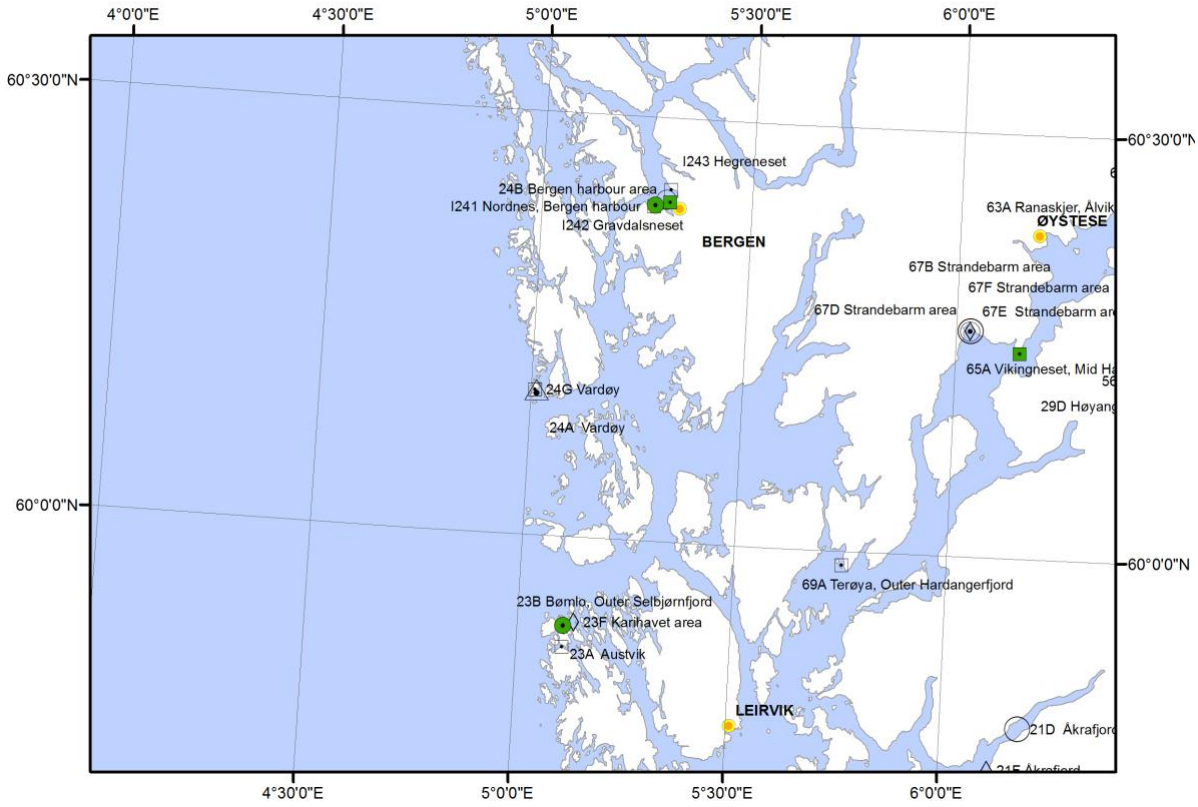
MAP 4


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

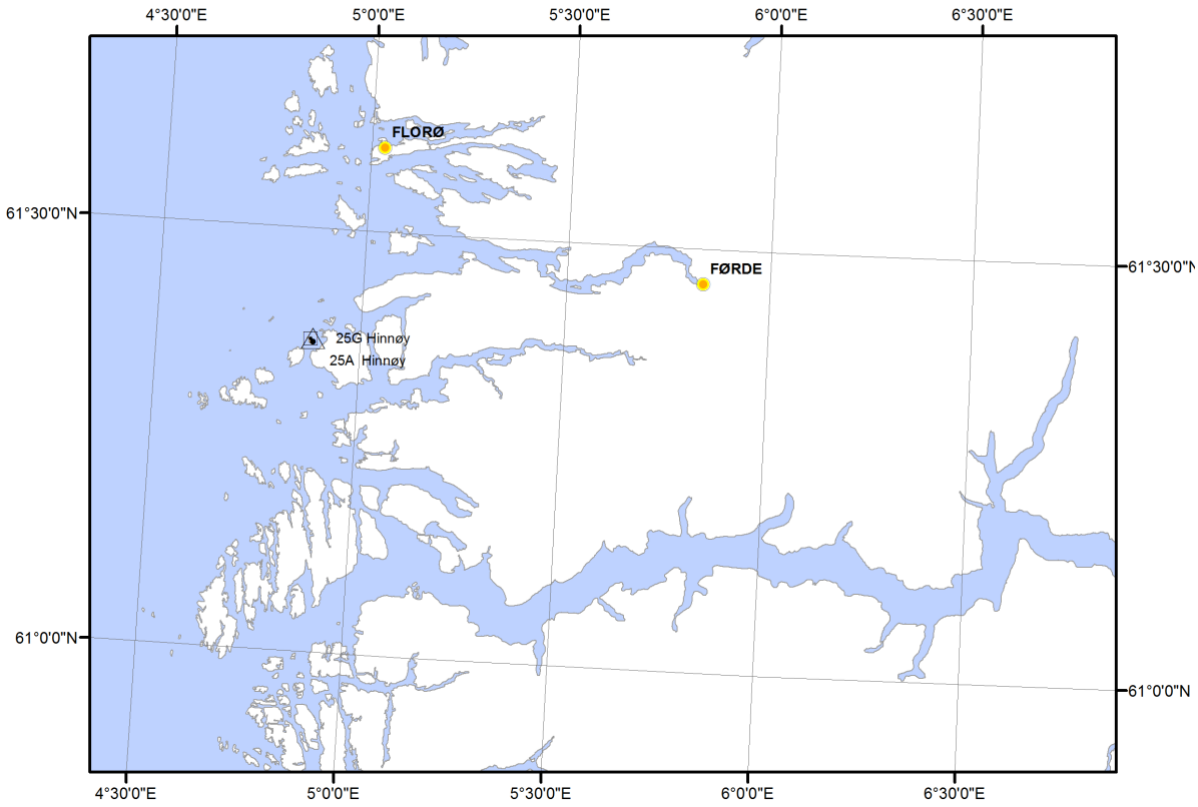
MAP 5


5°30'0"E
6°0'0"E
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
52A Eitrheimsneset, Inner Sørfjord
53B Inner Sørfjord
51A Byrkjenes, Inner Sørfjord
52E Eitrheimsneset
ODDA
69A Terøya, Outer Hardangerfjord

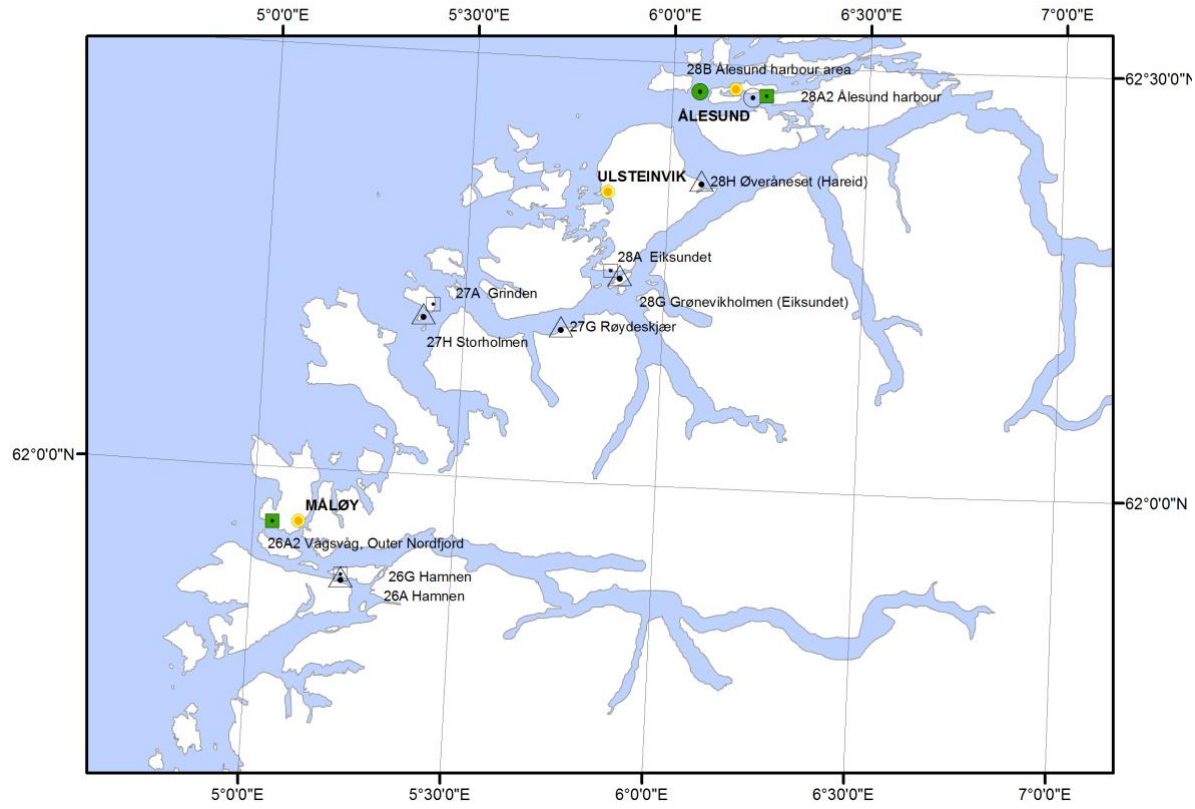
MAP 6


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 Karihavet area
23A Austvik
LEIRVIK
21D Åkrafjord

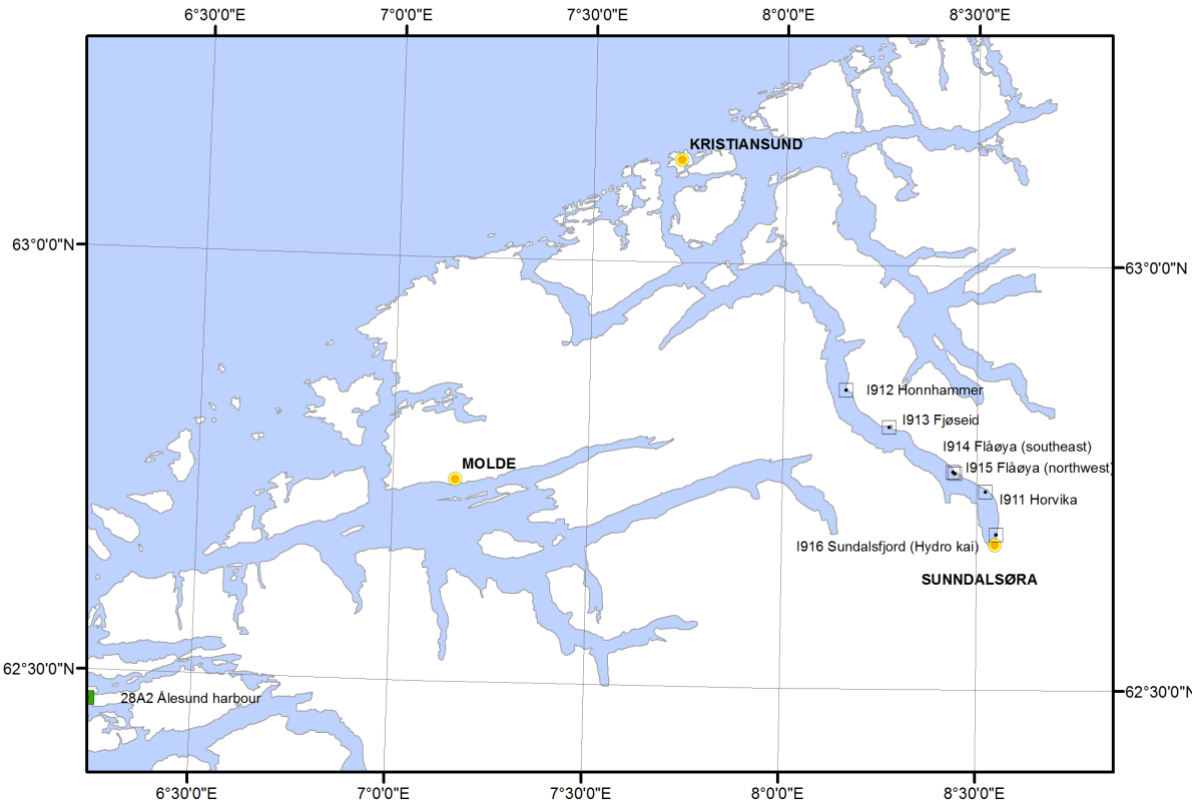
MAP 7


4°30'0"E
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
25G Hinnøy
25A Hinnøy

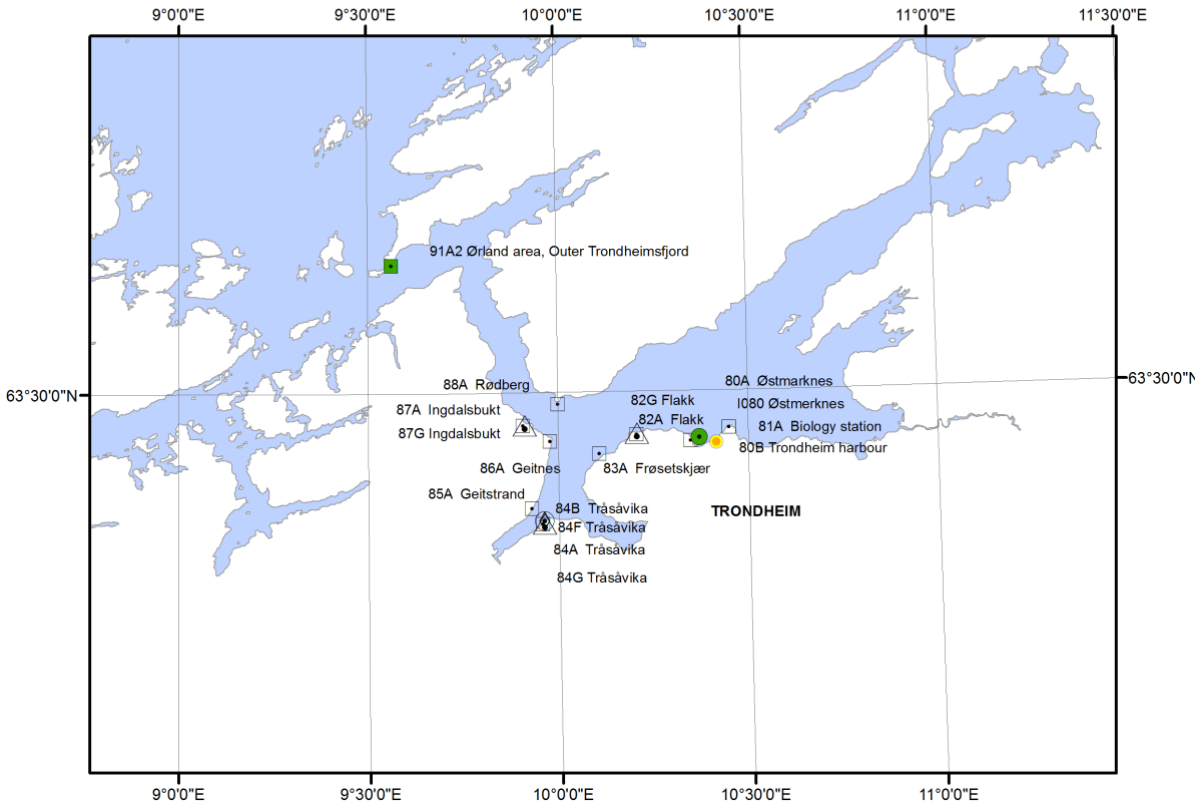
MAP 8


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)
27H Storholmen
27G Røydeskjær
MÅLØY
26A2 Vågsvåg, Outer Nordfjord
26G Hamnen
26A Hamnen

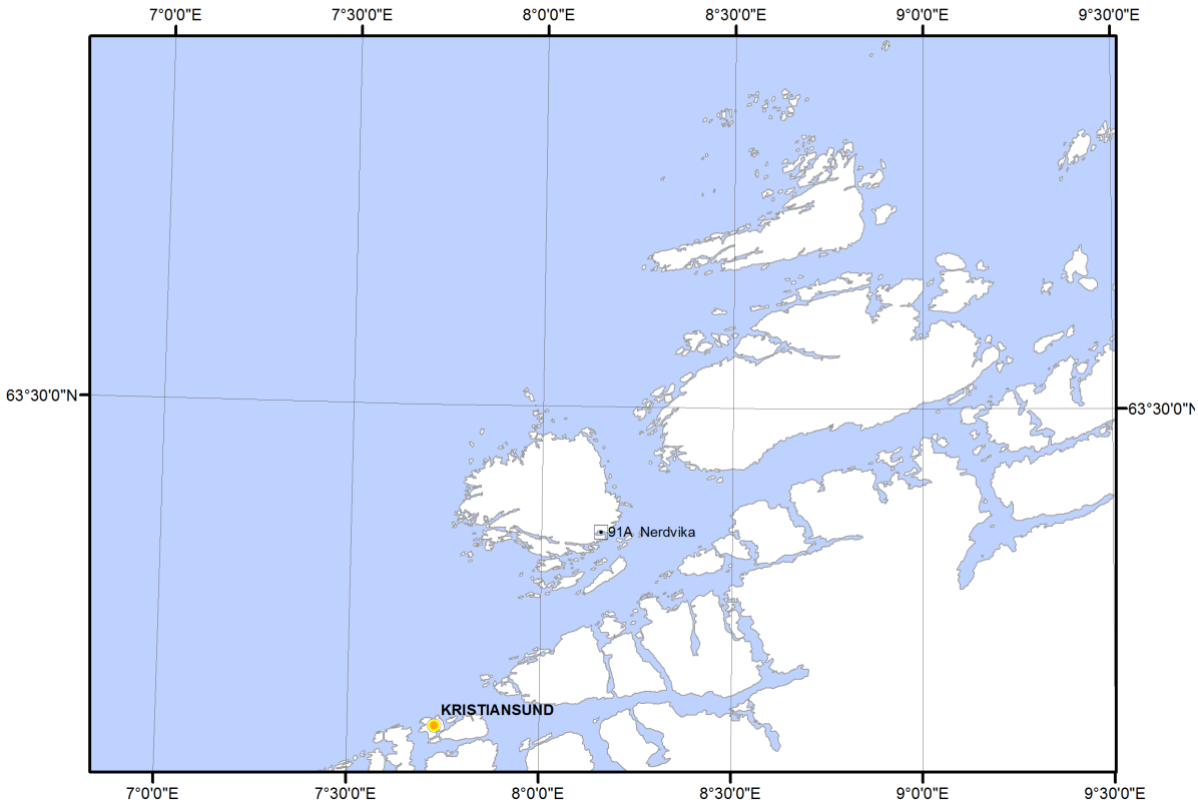
MAP 9


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

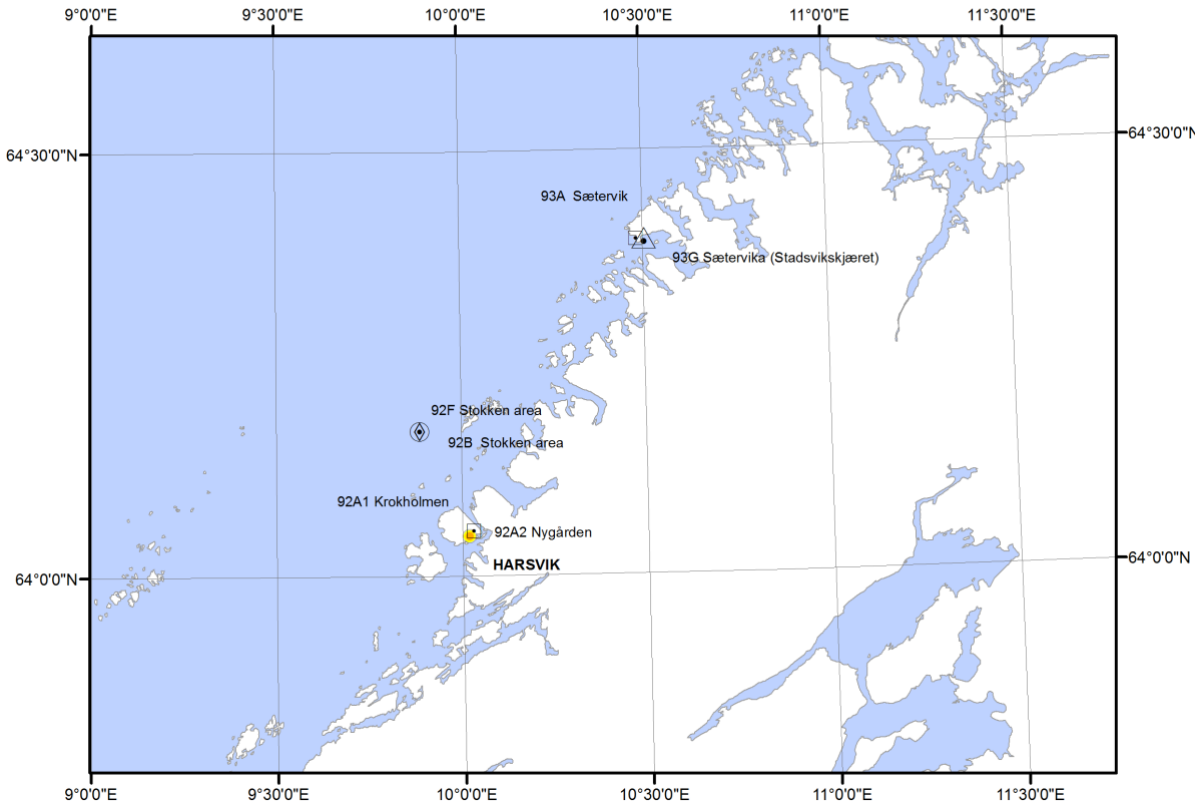
MAP 10


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
I080 Østmerknes
81A Biology station
80B Trondheim harbour
83A Frøsetskjær
TRONDHEIM

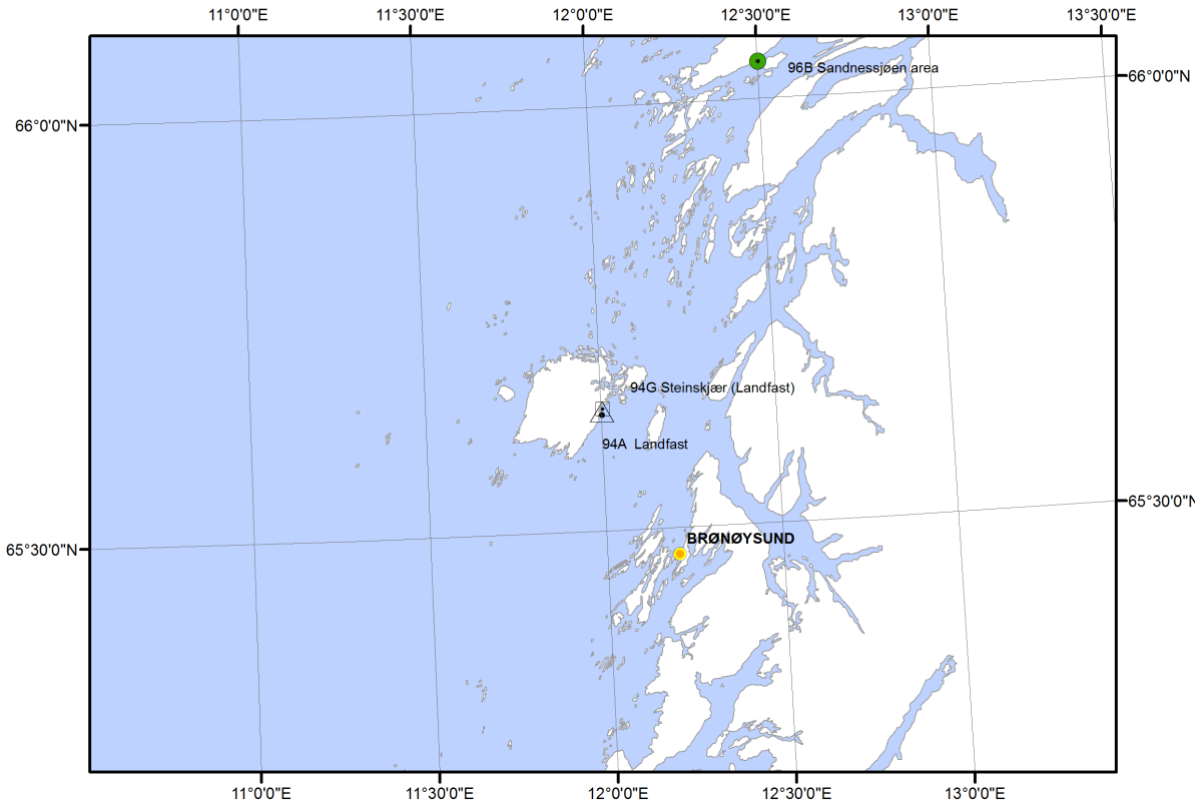
MAP 11


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


9°0'0"E
9°30'0"E
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 Krokhölmen
92A2 Nygården
HARSVIK

MAP 13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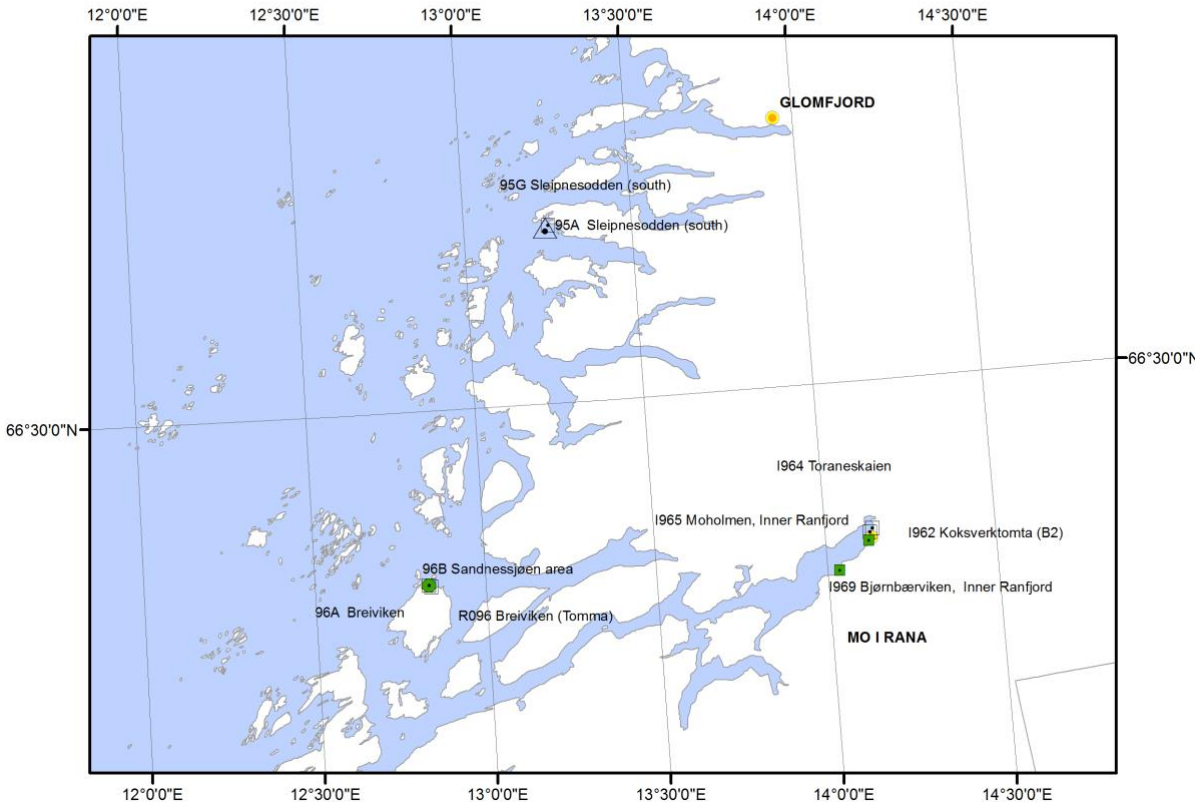
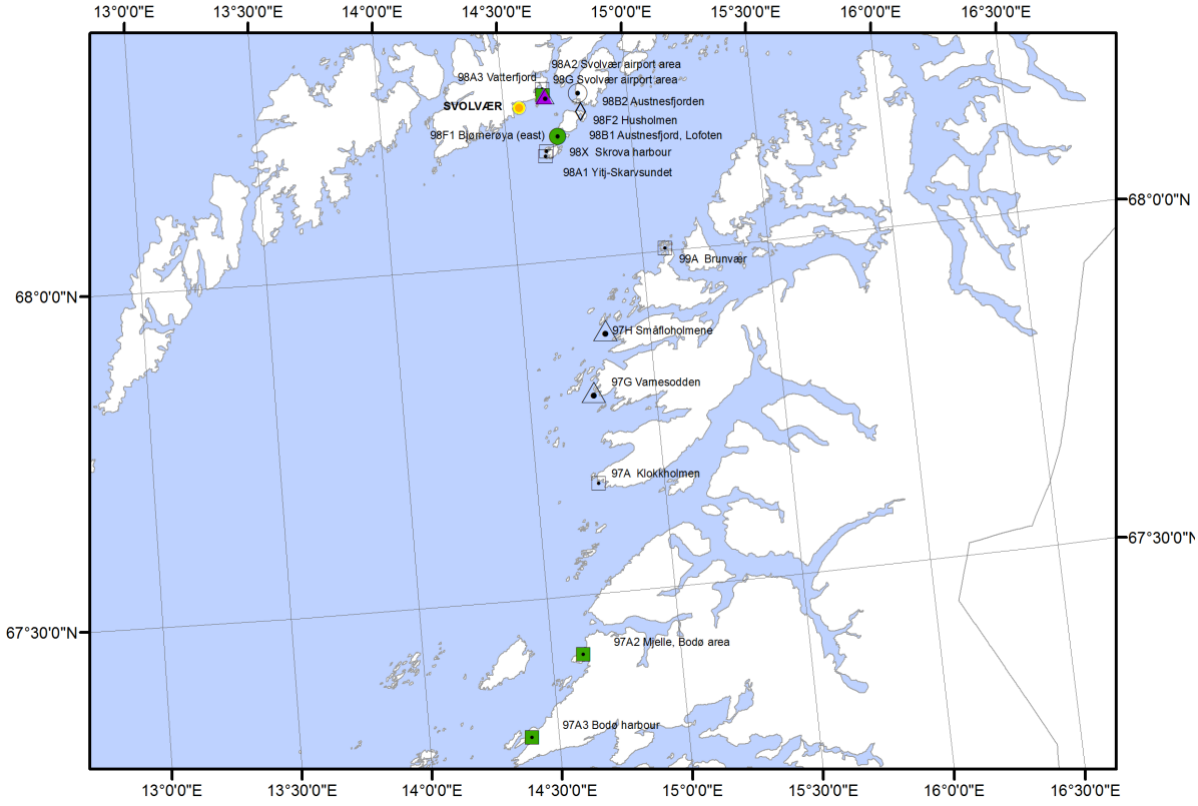
12°30'0"E
13°0'0"E
13°30'0"E
66°0'0"N
65°30'0"N
96B Sandnessjøen area
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

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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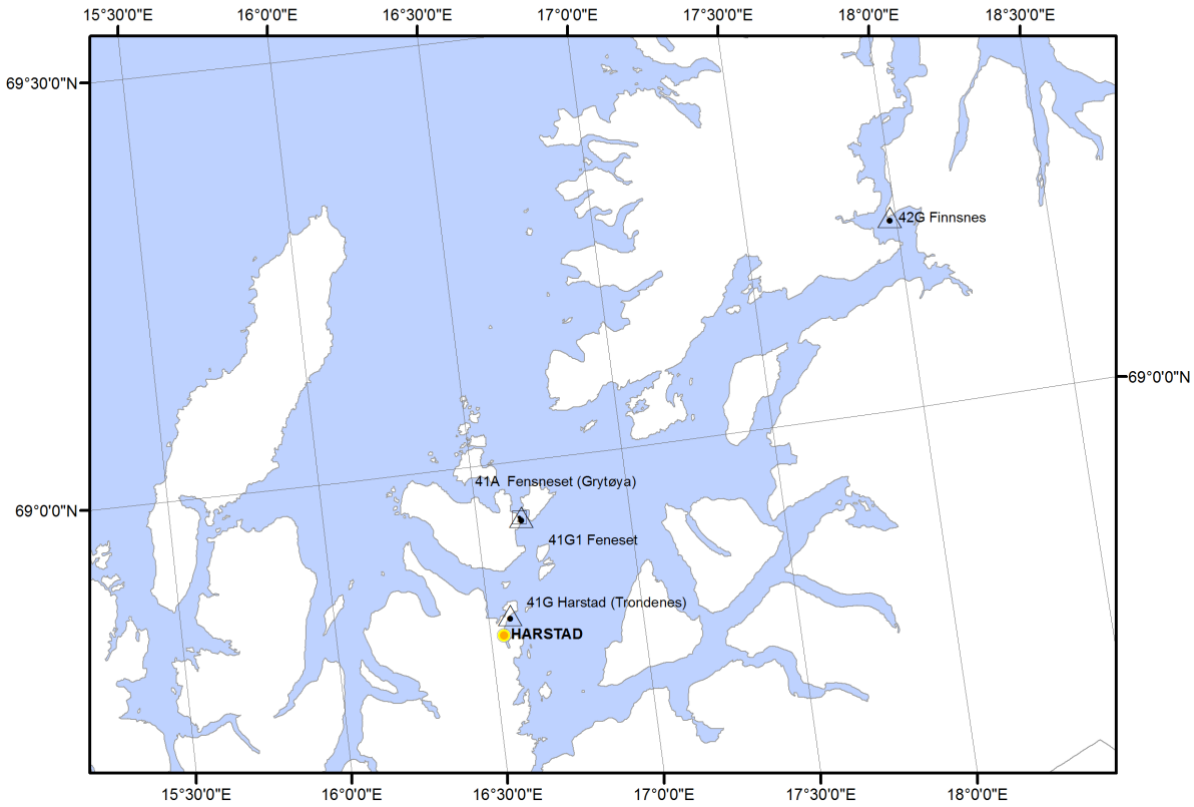
14°30'0"E
15°0'0"E
15°30'0"E
16°0'0"E
16°30'0"E
68°0'0"N
67°30'0"N
98A2 Svolvær airport area
98A3 Valterfjord
98G Svolvær airport area
SVOLVÆR
98B2 Austnesfjorden
98F2 Husholmen
98F1 Bjørnerøya (east)
98B1 Austnesfjord, Lofoten
98X Skrova harbour
98A1 Yttj-Skarvsundet
99A Brunvær
97H Småfloholmene
97G Vamesodden
97A Klokkholmen
97A2 Mjelle, Bodø area
97A3 Bodø harbour

MAP 16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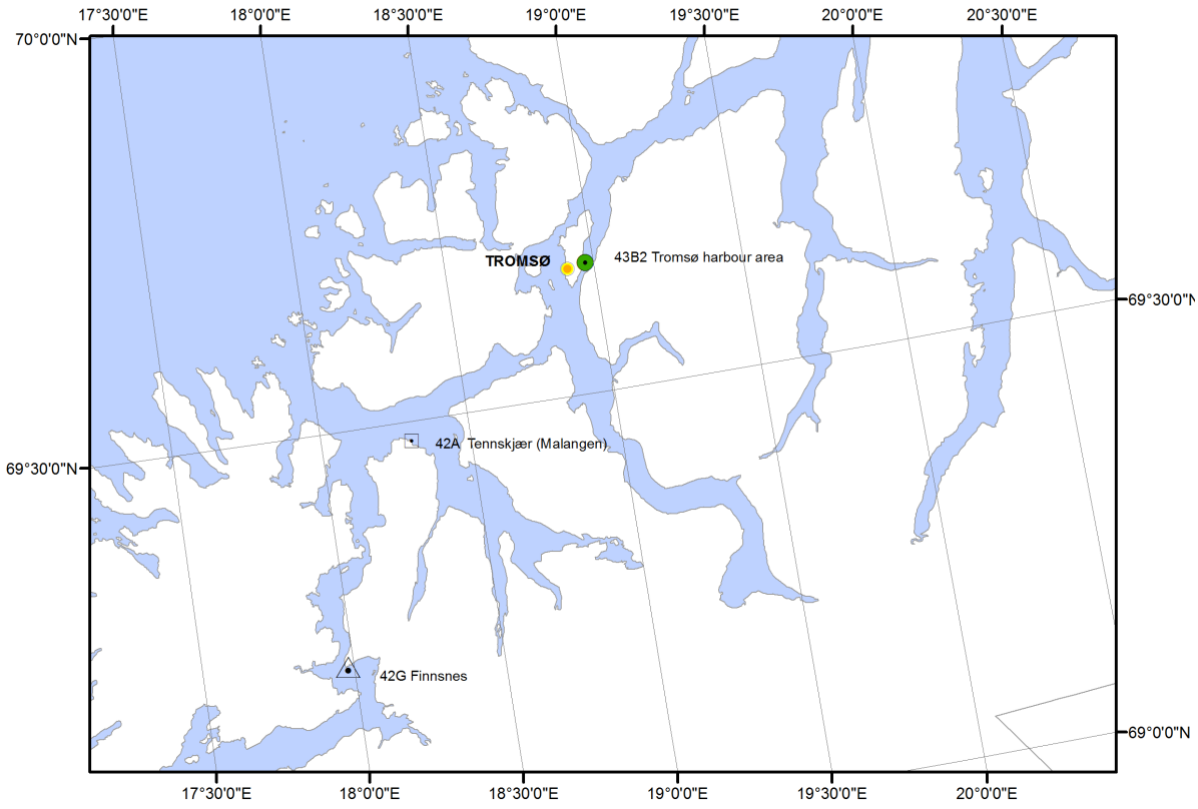
16°0'0"E
16°30'0"E
17°0'0"E
17°30'0"E
18°0'0"E
18°30'0"E
69°30'0"N
69°0'0"N
42G Finnsnes
41A Fensneset (Grytøya)
41G1 Feneset
41G Harstad (Trondenes)
HARSTAD

MAP 17


17°30'0"E
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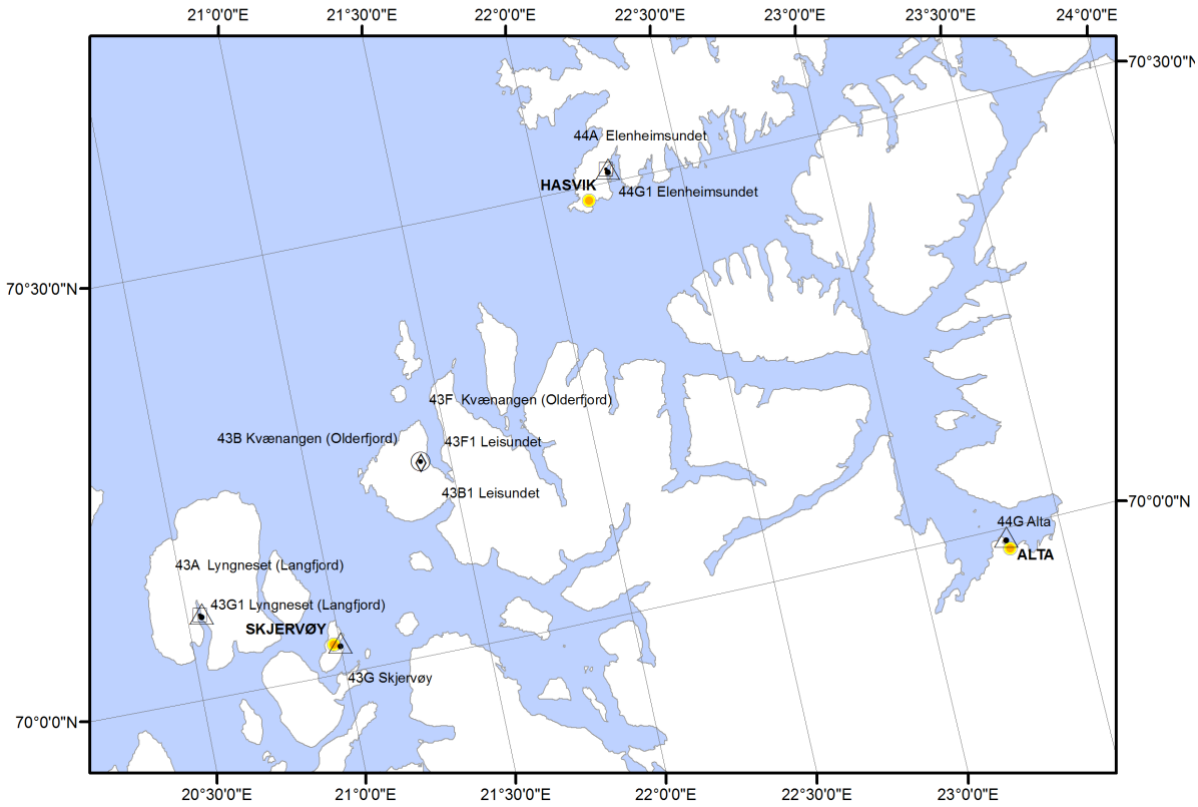
19°0'0"E
19°30'0"E
20°0'0"E
20°30'0"E
70°0'0"N
69°30'0"N
69°0'0"N
TROMSØ
43B2 Tromsø harbour area
42A Tennskjær (Malangen)
42G Finnsnes

MAP 18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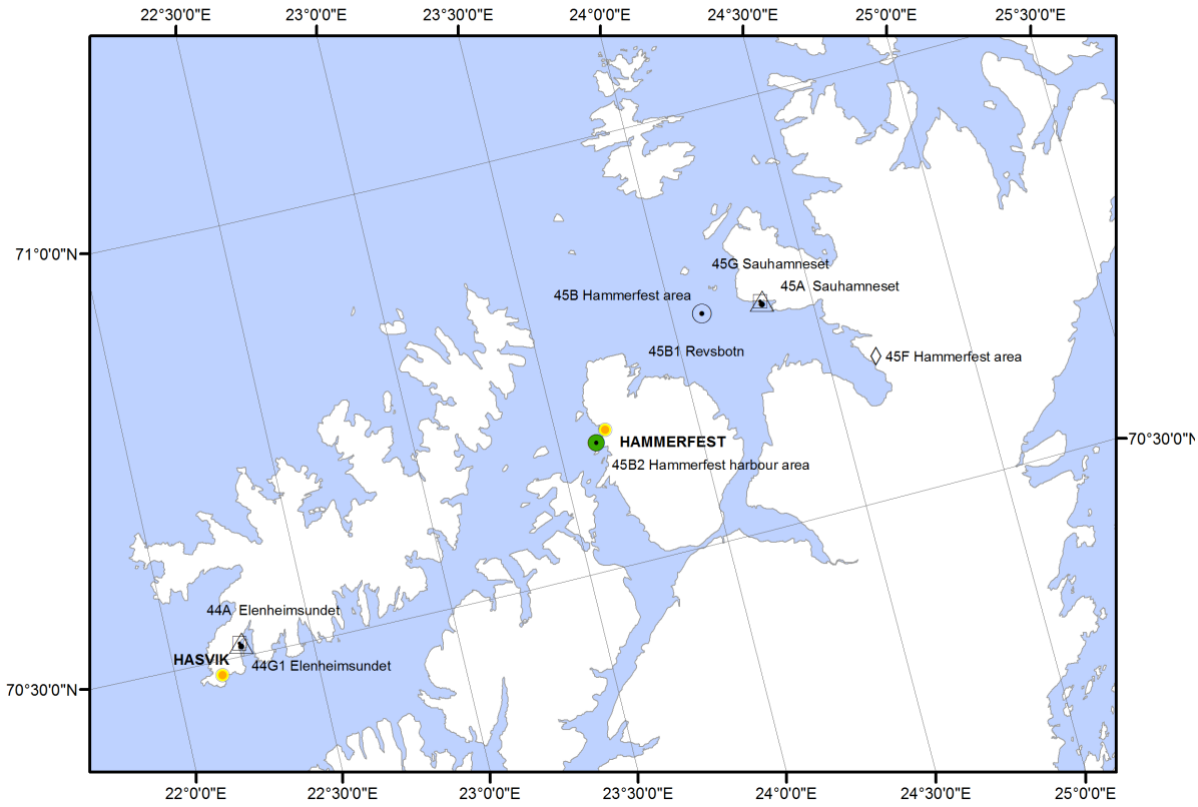
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
70°30'0"N
70°0'0"N
20°30'0"E
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet
43F Kvænangen (Olderfjord)
43B Kvænangen (Olderfjord)
43F1 Leisundet
43B1 Leisundet
44G Alta
ALTA
43A Lyngneset (Langfjord)
43G1 Lyngneset (Langfjord)
SKJERVØY
43G Skjervøy

MAP 19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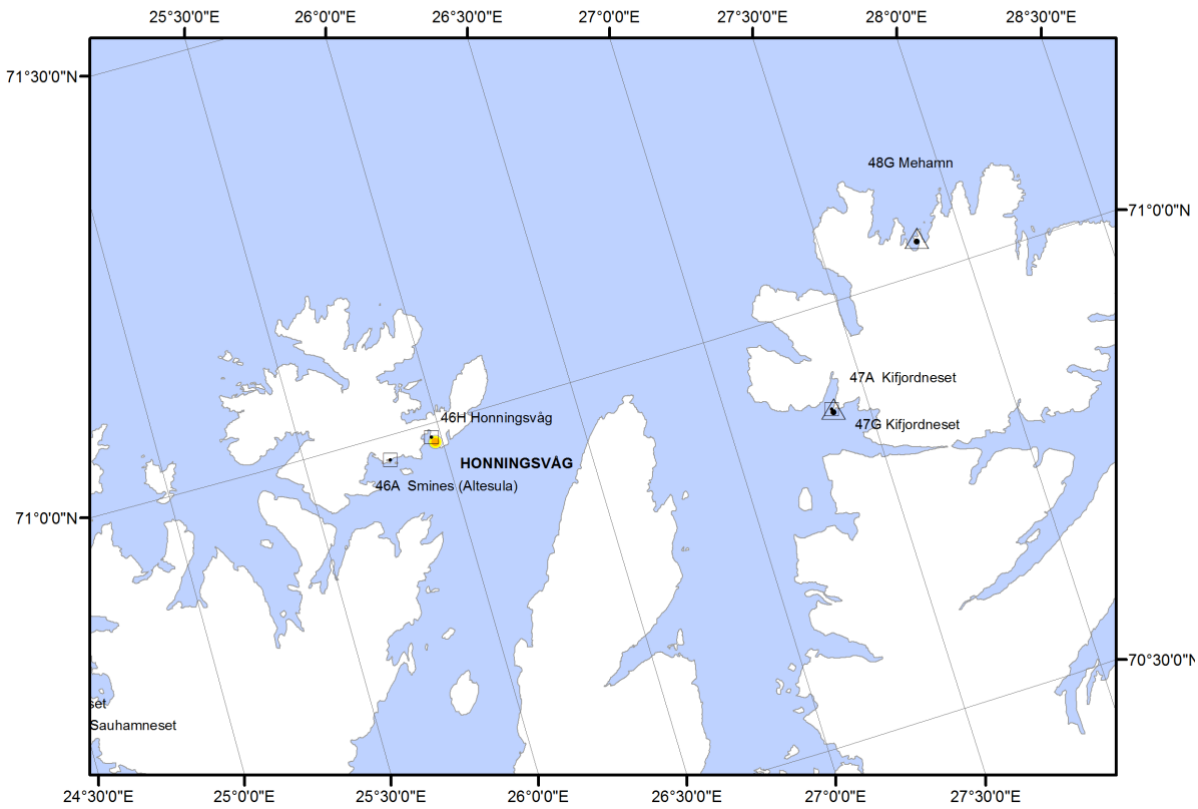
23°30'0"E
24°0'0"E
24°30'0"E
25°0'0"E
25°30'0"E
71°0'0"N
70°30'0"N
22°0'0"E
45G Sauhamneset
45A Sauhamneset
45B Hammerfest area
45B1 Revsbotn
45F Hammerfest area
HAMMERFEST
45B2 Hammerfest harbour area
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet

MAP 20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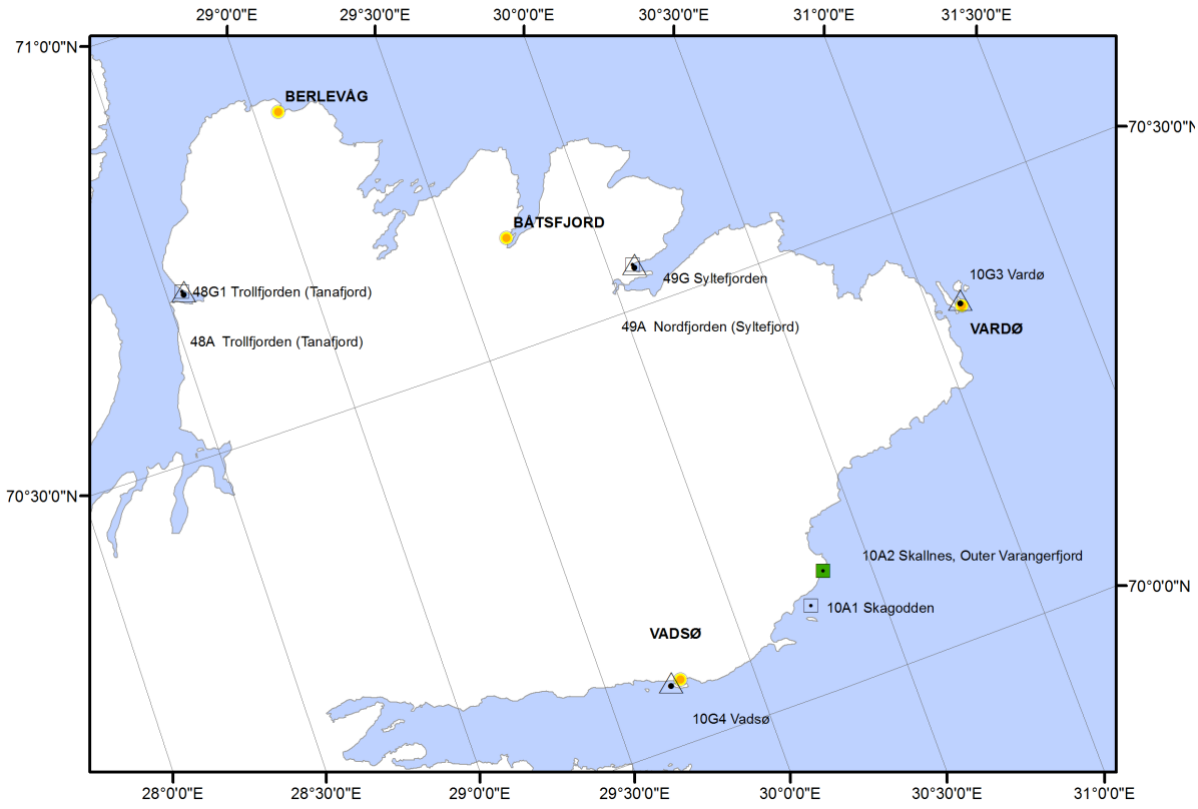
26°30'0"E
27°0'0"E
27°30'0"E
28°0'0"E
28°30'0"E
71°30'0"N
71°0'0"N
70°30'0"N
48G Mehamn
47A Kifjordneset
47G Kifjordneset
46H Honningsvåg
HONNINGSVÅG
46A Smines (Altesula)
Sauhamneset
24°30'0"E
25°0'0"E
25°30'0"E
26°0'0"E
26°30'0"E
27°0'0"E
27°30'0"E

MAP 21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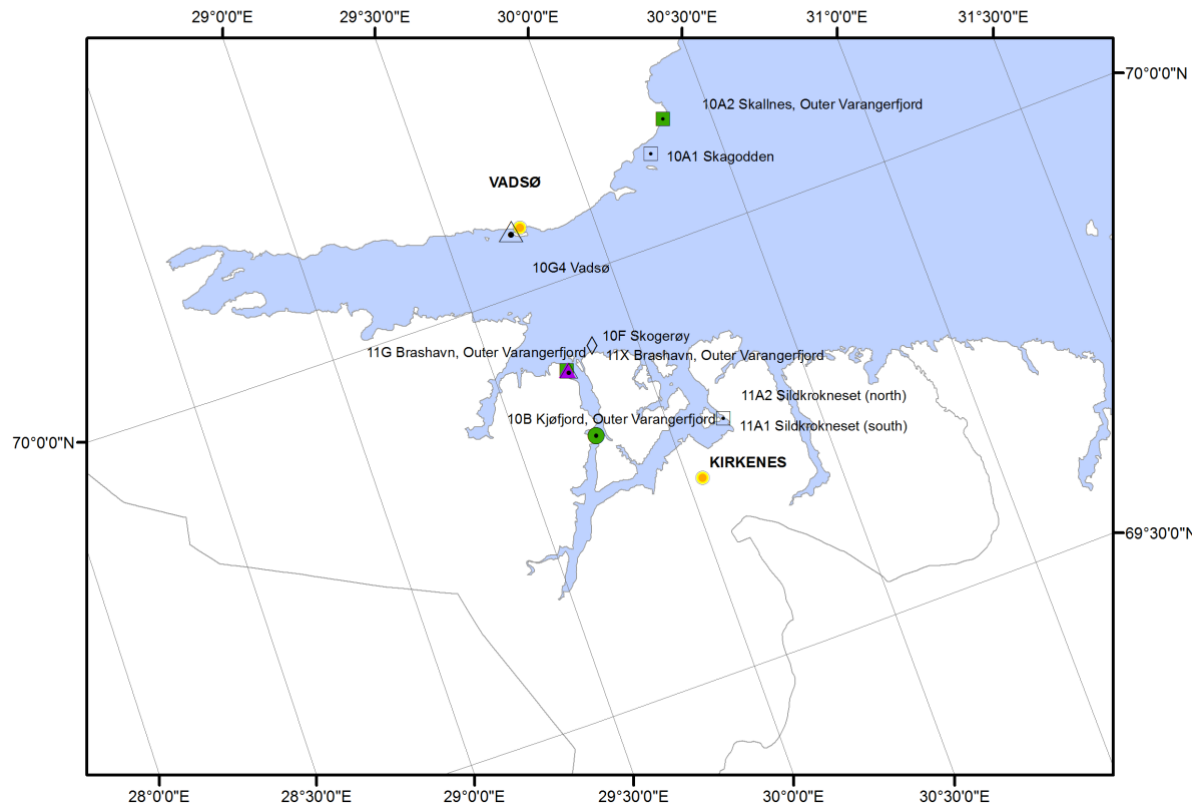
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
71°0'0"N
70°30'0"N
70°0'0"N
BERLEVÅG
BÅTSFJORD
48G1 Trollfjorden (Tanafjord)
48A Trollfjorden (Tanafjord)
49G Syltefjorden
49A Nordfjorden (Syltefjord)
10G3 Vardø
VARDØ
10A2 Skallnes, Outer Varangerfjord
10A1 Skagodden
VADSØ
10G4 Vadsø
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E

MAP 22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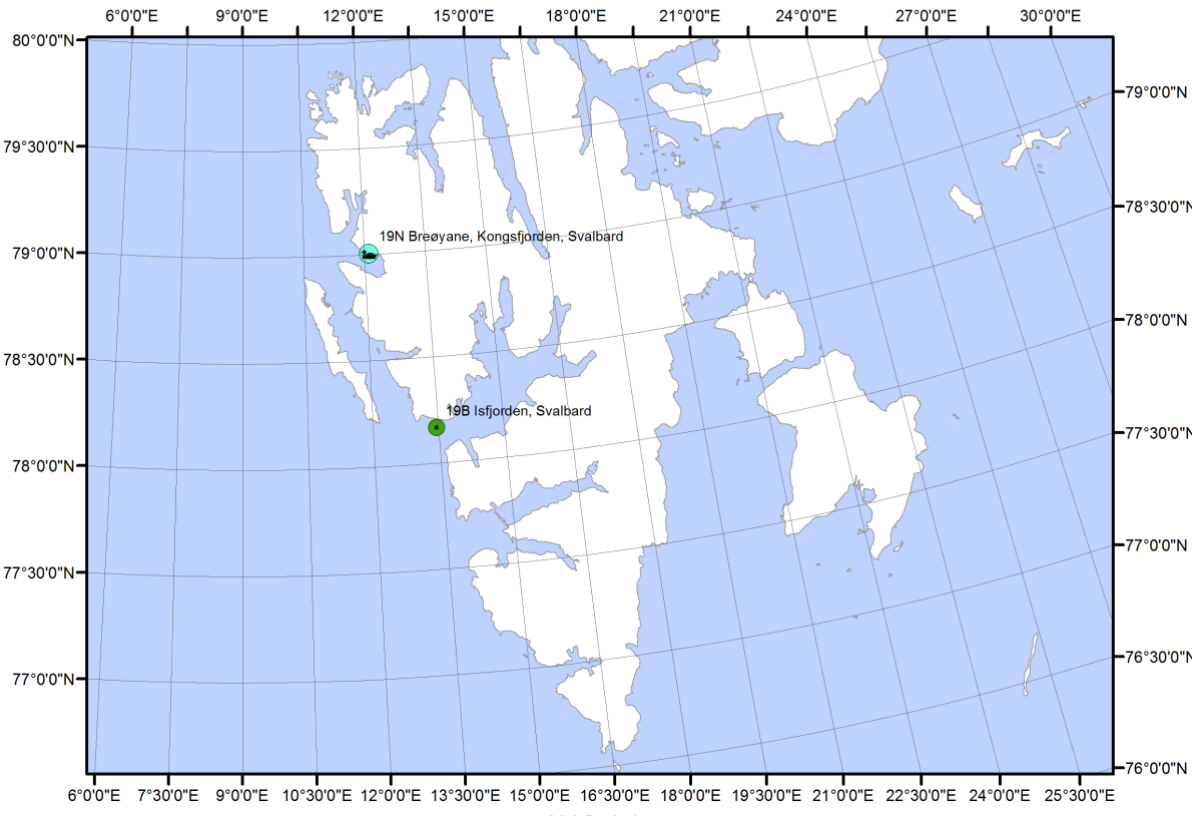
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
70°0'0"N
69°30'0"N
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
10A2 Skallnes, Outer Varangerfjord
10A1 Skagodden
VADSØ
10G4 Vadsø
10F Skogerøy
11G Brashavn, Outer Varangerfjord
11X Brashavn, Outer Varangerfjord
11A2 Sildkrokneset (north)
10B Kjøfjord, Outer Varangerfjord
11A1 Sildkrokneset (south)
KIRKENES

MAP 23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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
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
19N Breøyane, Kongsfjorden, Svalbard
19B Isfjorden, Svalbard

MAP 24

Appendix E
Overview of materials and analyses 2017-2018

Nominal station positions are shown on maps in Appendix D

Year:
2017t - samples taken in 2017
2018p – samples planned in 2018
2018t – samples taken in 2018

Species:
Atlantic cod (*Gadus morhua***)**
Blue Mussel (*Mytilus edulis***)**
Dogwhelk (*Nucella lapillus***)**
Common periwinkle (*Littorina littorea)*
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

Red numbers indicate Supplementary investigations funded by the Ministry of Climate and Environment and these involved additional analyses on samples from blue mussel stations 30A, I301, I304, 31A, 36A1, 71A, I712, 51A, 56A, 65A, 22A, 10A2 and 11X; cod stations 30B, 36B, 15B, 53B, 23B, 98B1 and 10B; as well as all analyses for blue mussel stations: 35A, 52A, 57A, 63A, 69A, I133, I306, I307

Overview follows on next page

Parameter-group codes (see **Appendix B** for descriptions of codes) 2017-2018:

code	Description	Me-SB	Nl/Ll-SB	Gm-Bl	Gm-BL	Gm-Ll	Gm-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			
O-DC	Dechlorane plus 4)								
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	Siloxanes11)					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 for 2017 samples.

***Appendix E**. Sampling and analyses for 2017-2018 – 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	O-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2017t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3			3						
2018p	**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	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3			3						
2017t	**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		
2018p	**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		
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		
2017t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3			3				3		
2018p	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3			3				3		
2018t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3			3				3		
2017t	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	3			3											3		
2018p	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	0			0											0		
2018t	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	0			0											0		
2017t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3									
2018p	**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	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3									
2017t	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	3			3											3		
2018p	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	0			0											0		
2018t	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	0			0											0		
2017t	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3								3		
2018p	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3		3		3			3		
2018t	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3		3		3			3		
2017t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3					3	3			3		
2018p	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	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		
2017t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	2			2											2		
2018p	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	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	O-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2018t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	2			2											2		
2017t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	1		1		1	1	1	1			1	1		1	1		
2018p	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	3		3		3	3	3	3			3	3		3	3		
2018t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	1		1		1	1	1	1			1	1		1	1		
2017t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3				3	3			3		
2018p	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3			3	3			3		
2018t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3			3	3			3		
2017t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3									
2018p	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3									
2018t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3									
2017t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3										3						
2018p	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3										3						
2018t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3										3						
2017t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3							3		
2018p	**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	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3							3		
2017t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3											3		
2018p	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3											3		
2018t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3											3		
2017t	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	3			3	3		3	3		3					3		
2018p	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	3			3	3		3	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		
2017t	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3	3							3		
2018p	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3	3							3		
2018t	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3	3							3		
2017t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3							3		
2018p	**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	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3							3		

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2017t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3							3		
2018p	**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	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3							3		
2017t	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	3			3	3		3	3							3		
2018p	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	0			3	3		3	3							0		
2018t	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	0			3	3		3	3							0		
2017t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3										
2018p	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3										
2018t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3										
2017t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3									
2018p	**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	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3									
2017t	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	3			3											3		
2018p	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	0			0											0		
2018t	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	0			0											0		
2017t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3		3					3		
2018p	**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	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3		3					3		
2017t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3				3		3	3	3	3		
2018p	**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	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3				3		3			3		
2017t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3						3			3		
2018p	**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	**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		
2018p	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		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		
2017t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3						3			3		

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2018p	**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	**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		
2018p	**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	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3						3			3		
2017t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3						3			3		
2018p	**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	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3						3			3		
2017t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3				3	3	3			3		
2018p	**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	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3				3	3	3			3		
2017t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	3		3	3							3		
2018p	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	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		
2017t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3									
2018p	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3									
2018t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3									
2017t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1															1
2018p	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1															1
2018t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1															1
2017t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1															1
2018p	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1															1
2018t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1															1
2017t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1															1
2018p	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1															1
2018t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1															1
2017t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1															1
2018p	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1															1

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2018t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1															1
2017t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1															1
2018p	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1															1
2018t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1															1
2017t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1															1
2018p	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1															1
2018t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1															1
2017t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1															1
2018p	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1															1
2018t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1															1
2017t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1															1
2018p	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1															1
2018t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1															1
2017t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1															1
2018p	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1															1
2018t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1															1
2017t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	12		12	12	**12**	12	**12**	12		12		12		12		12	12
2018p	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15		15	15	**15**	15	**15**	15		15		15		15		15	15
2018t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	12		10	10	**10**	10	**10**	10		10		10		10		10	10
2017t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	10		10	10	**10**	10	**10**			10		10					
2018p	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15		15	15	**15**	15	**15**	15		15		15					
2018t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	10		15	15	**15**	15	**15**	15		15		15					
2017t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	9		9	9		9						9					
2018p	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15			15		15						15					
2018t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	8			8		4						4					
2017t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15					15						15		15			
2018p	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15					15						15		15			
2018t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15					4						15		15			

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2017t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	12		12	12		12				12		12					
2018p	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15		15	15		15				15		15					
2018t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15		9	9		9				9		9					
2017t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15									
2018p	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15									
2018t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15									
2017t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15		15		15					15
2018p	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	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
2017t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		13	13	13	13	13	13		13		13		13			13
2018p	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		15	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
2017t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15				15		15				15	
2018p	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15				15		15				15	
2018t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		12	12		12				12		12				12	
2017t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15						15					
2018p	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15						15					
2018t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15						15					
2017t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15				15		15					
2018p	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15				15		15					
2018t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15				14		15					
2017t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15													
2018p	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15													
2018t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15													
2017t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	11		11	11	11	11	11			11							
2018p	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	15	15	15	15		15							
2018t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	11		12	11	11	11	11	11		12							
2017t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15				15		15				15	

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2018p	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15				15		15				15	
2018t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15				15		15				15	
2017t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	14			14													
2018p	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15			15													
2018t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	14			14													
2017t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	**15**		**15**	15									
2018p	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	**15**		**15**	15								15	
2018t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	**15**		**15**	15								8	
2018t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15				15		15				15	
2018p	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15				15		15				15	
2018t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15				15		15				15	
2017t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15														15		
2018p	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15								7						15		
2018t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15								7						15		
2017t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15														15		
2018p	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15														15		
2018t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15														15		
2017t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15														15		
2018p	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15														15		
2018t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15														15		
2017t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15														15		
2018p	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15														15		
2018t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15														15		
2017t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15														15		
2018p	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15														15		
2018t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15														15		
2017t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15														15		
2018p	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	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	O-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2018t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15														15		
2017t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15														15		
2018p	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15														15		
2018t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15														15		
2017t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15														15		
2018p	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15														15		
2018t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15														15		
2017t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15														15		
2018p	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15								11						15		
2018t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15								11						15		
2017t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15														15		
2018p	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15														15		
2018t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15														15		
2017t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15														15		
2018p	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15														15		
2018t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15														15		
2017t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15														15		
2018p	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15														15		
2018t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15														15		
2017t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15														15		
2018p	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15														15		
2018t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15														15		
2017t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15														15		
2018p	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15								5						15		
2018t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15								5						15		
2017t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15														15		
2018p	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15														15		
2018t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	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	O-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2017t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15														15		
2018p	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15								2						15		
2018t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15								2						15		
2018p	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15														15		
2018t	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15														15		
2017t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2018p	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2018t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2017t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690																	15
2018p	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690																	15
2018t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690																	15
2017t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2018p	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2018t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2017t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2018p	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2018t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2017t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2018p	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2018t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183																	15
2017t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2018p	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2018t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972																	15
2017t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857																	15
2018p	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857									9								15
2018t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857									9								15
2018p	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				15		15		15	15		
2018t	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15				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	O-DC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	SLX	BEM
2018p	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	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		

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2018

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 2017 or 2018 is shown. The column headings are as follows:

Parameter Code: are described in **Appendix B**
IUPAC: Internation 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*)
- **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
Yr_[Year columns]: median value for years 1981-2018. The gray-shade coding refers to relation to exceedences 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
EQS [Year columns]: median value for years 1981-2018 with indication of relation to Environmental Quality Standards (2013/39/EU 2013) and other risk-based standards developed nationally (NorwegianEnvironmentAgency 2016), and these are referred to collectively in this report as Environmental Quality Standards (EQS). Green-filled circle indicates no exceedences and red-filled circle indicates exceedences of the quality standard.

Sample count [year]: 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 [year]: standard deviation.
PROREF [year]: exceedences 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 [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
Trend p(long)[year]: The statistical significance (p)[year] of the trend for the entire time series.
Detectable % change(long)[year]: the percent change that can be detected with 90 % confidence.
First Year(long)[year]: first year in time series.
Last Year(long)[year]: last year in time series.
Number of Years(long)[year]: number of years with data.

Trend p(short)[year]: The statistical significance (p)[year] of the trend for the last 10-year sampling period.
Detectable % change(short)[year]: the percent change that can be detected with 90 % confidence.
First Year(short)[year]: first year in time series for the last 10-year sampling period.
Last Year(short)[year]: last year in time series for the last 10-year sampling period.
Number of Years(short)[year]: number of years with data in time series for the last 10-year sampling period.

Trends [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 either the results were insufficient to do a trend analysis. Results marked with a star (★) indicate 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_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
PROREF_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
EQS_CHANGE_[year]-[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 perfluorinated alkylated substances (PFAS), regression statistics

Table 27. Summary statistics of regression analyses on supplementary perfluorinated alkylated substances (PFAS). The analyses include PFAS measured in cod liver from 80 cod caught during from 1990 to 2009, in addition data acquired by reviewing archived full-scan-mass spectrometry results from analyses of 2015-2018 samples. In total, 129 samples were analysed for 32 PFAS compounds. Regression analyses were performed using the JMP statistical package (see **Chapter 2.9**). A negative "t ratio" for "year" indicates a downward trend. A value <0.05 "Prob>[t]" indicates that the trend was statistically significant. (See also ***Table 15***).

Parameter Estimates							
X	**Y**	**Parameter**	**Term**	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Year	**Log[PFHxA]**	**Log[PFHxA]Intercept**	**Intercept**	-5.732276559	2.473990572	-2.32	0.0221
Year	**Log[PFHxA]**	**Log[PFHxA]Year**	**Year**	0.0023784192	0.0012349615	1.93	0.0564
Year	**Log[PFHpA]**	**Log[PFHpA]Intercept**	**Intercept**	-13.50931088	4.4690126932	-3.02	0.0030
Year	**Log[PFHpA]**	**Log[PFHpA]Year**	**Year**	0.0062770256	0.0022308326	2.81	0.0057
Year	**Log[PFOA]**	**Log[PFOA]Intercept**	**Intercept**	-19.26289825	5.1922095766	-3.71	0.0003
Year	**Log[PFOA]**	**Log[PFOA]Year**	**Year**	0.0091640549	0.0025918365	3.54	0.0006
Year	**Log[PFNA]**	**Log[PFNA]Intercept**	**Intercept**	0.647624694	1.8890431507	0.34	0.7323
Year	**Log[PFNA]**	**Log[PFNA]Year**	**Year**	0.000156964	0.0009429687	0.17	0.8681
Year	**Log[PFDA]**	**Log[PFDA]Intercept**	**Intercept**	-35.35885202	8.006582915	-4.42	<.0001
Year	**Log[PFDA]**	**Log[PFDA]Year**	**Year**	0.0173617218	0.0039967096	4.34	<.0001
Year	**Log[PFUnDA]**	**Log[PFUnDA]Intercept**	**Intercept**	-24.42377562	11.787405703	-2.07	0.0403
Year	**Log[PFUnDA]**	**Log[PFUnDA]Year**	**Year**	0.0121715232	0.0058840129	2.07	0.0406
Year	**Log[PFDoA]**	**Log[PFDoA]Intercept**	**Intercept**	-42.82737338	10.716333424	-4.00	0.0001
Year	**Log[PFDoA]**	**Log[PFDoA]Year**	**Year**	0.021141938	0.0053493572	3.95	0.0001
Year	**Log[PFTrDA]**	**Log[PFTrDA]Intercept**	**Intercept**	-58.00345633	9.6642143109	-6.00	<.0001
Year	**Log[PFTrDA]**	**Log[PFTrDA]Year**	**Year**	0.0286746614	0.0048241626	5.94	<.0001
Year	**Log[PFTeDA]**	**Log[PFTeDA]Intercept**	**Intercept**	-12.78152561	6.9031368814	-1.85	0.0664
Year	**Log[PFTeDA]**	**Log[PFTeDA]Year**	**Year**	0.0059145729	0.0034458936	1.72	0.0885
Year	**Log[PFPeDA]**	**Log[PFPeDA]Intercept**	**Intercept**	0.4456864761	0.9890397502	0.45	0.6530
Year	**Log[PFPeDA]**	**Log[PFPeDA]Year**	**Year**	0.000823614	0.0004937068	-1.67	0.0977
Year	**Log[PFBS]**	**Log[PFBS]Intercept**	**Intercept**	-7.53189388	4.1394419837	-1.82	0.0712
Year	**Log[PFBS]**	**Log[PFBS]Year**	**Year**	0.0028226508	0.0020663181	1.37	0.1743
Year	**Log[PFPS]**	**Log[PFPS]Intercept**	**Intercept**	-2.516349204	0.9710692941	-2.59	0.0107
Year	**Log[PFPS]**	**Log[PFPS]Year**	**Year**	0.0003080659	0.0004847364	0.64	0.5262
Year	**Log[PFHxS]**	**Log[PFHxS]Intercept**	**Intercept**	17.126668111	5.7271350535	2.99	0.0033
Year	**Log[PFHxS]**	**Log[PFHxS]Year**	**Year**	0.009770161	0.0028588595	-3.42	0.0008
Year	**Log[PFHpS]**	**Log[PFHpS]Intercept**	**Intercept**	-3.196038519	1.1618007407	-2.75	0.0068
Year	**Log[PFHpS]**	**Log[PFHpS]Year**	**Year**	0.0006514789	0.0005799453	1.12	0.2634
Year	**Log[PFOS]**	**Log[PFOS]Intercept**	**Intercept**	110.46512296	11.297042226	9.78	<.0001
Year	**Log[PFOS]**	**Log[PFOS]Year**	**Year**	0.054074702	0.0056392343	-9.59	<.0001
Year	**Log[8Cl-PFOS]**	**Log[8Cl-PFOS]Intercept**	**Intercept**	-3.288065717	0.9875509564	-3.33	0.0011
Year	**Log[8Cl-PFOS]**	**Log[8Cl-PFOS]Year**	**Year**	0.0006977855	0.0004929637	1.42	0.1594
Year	**Log[PFNS]**	**Log[PFNS]Intercept**	**Intercept**	0.446876456	0.9453993861	0.47	0.6372

Parameter Estimates

X	Y	Parameter	Term	Estimate	Std Error	t Ratio	Prob>|t|
Year	Log[PFNS]	Log[PFNS]Year	Year	0.000724616	0.0004719225	-1.54	0.1272
Year	Log[PFDS]	Log[PFDS]Intercept	Intercept	-33.25443087	14.283721237	-2.33	0.0215
Year	Log[PFDS]	Log[PFDS]Year	Year	0.0161435841	0.0071301185	2.26	0.0253
Year	Log[PFDoS]	Log[PFDoS]Intercept	Intercept	1.4644536232	3.4315204881	0.43	0.6703
Year	Log[PFDoS]	Log[PFDoS]Year	Year	0.00163871	0.0017129393	0.96	0.3406
Year	Log[PFOSA]	Log[PFOSA]Intercept	Intercept	72.718920133	11.415830982	6.37	<.0001
Year	Log[PFOSA]	Log[PFOSA]Year	Year	0.035104919	0.005698531	-6.16	<.0001
Year	Log[meFOSA]	Log[meFOSA]Intercept	Intercept	0.1272099495	0.9722237627	0.13	0.8961
Year	Log[meFOSA]	Log[meFOSA]Year	Year	0.000805696	0.0004853127	-1.66	0.0993
Year	Log[etFOSA]	Log[etFOSA]Intercept	Intercept	5.9961213419	3.4359270527	1.75	0.0834
Year	Log[etFOSA]	Log[etFOSA]Year	Year	0.003710545	0.001715139	-2.16	0.0324
Year	Log[meFOSE]	Log[meFOSE]Intercept	Intercept	0.0134582439	0.9850483353	0.01	0.9891
Year	Log[meFOSE]	Log[meFOSE]Year	Year	0.000148799	0.0004917144	0.30	0.7627
Year	Log[etFOSE]	Log[etFOSE]Intercept	Intercept	-1.933132103	0.9243394746	-2.09	0.0385
Year	Log[etFOSE]	Log[etFOSE]Year	Year	0.0008238906	0.0004614099	1.79	0.0766
Year	Log[4:2 FTS]	Log[4:2 FTS]Intercept	Intercept	0.2128206732	0.9295840987	0.23	0.8193
Year	Log[4:2 FTS]	Log[4:2 FTS]Year	Year	0.00084864	0.0004640279	-1.83	0.0698
Year	Log[6:2 FTS]	Log[6:2 FTS]Intercept	Intercept	-5.060464196	1.6468676184	-3.07	0.0026
Year	Log[6:2 FTS]	Log[6:2 FTS]Year	Year	0.0017825949	0.00082208	2.17	0.0320
Year	Log[8:2 FTS]	Log[8:2 FTS]Intercept	Intercept	0.309777193	0.9003863901	0.34	0.7314
Year	Log[8:2 FTS]	Log[8:2 FTS]Year	Year	0.000594976	0.000449453	-1.32	0.1880
Year	Log[10:2 FTS]	Log[10:2 FTS]Intercept	Intercept	4.460704974	4.8144007186	0.93	0.3559
Year	Log[10:2 FTS]	Log[10:2 FTS]Year	Year	0.002944403	0.0024032426	-1.23	0.2228
Year	Log[12:2 FTS]	Log[12:2 FTS]Intercept	Intercept	18.477793036	8.7963848139	2.10	0.0377
Year	Log[12:2 FTS]	Log[12:2 FTS]Year	Year	0.009834778	0.0043909613	-2.24	0.0268
Year	Log[FOSAA]	Log[FOSAA]Intercept	Intercept	4.7615487947	3.8672471115	1.23	0.2205
Year	Log[FOSAA]	Log[FOSAA]Year	Year	0.00309542	0.0019304444	-1.60	0.1113
Year	Log[meFOSAA]	Log[meFOSAA]Intercept	Intercept	-1.568434169	1.0384527022	-1.51	0.1334
Year	Log[meFOSAA]	Log[meFOSAA]Year	Year	0.0000299311	0.0005183727	0.06	0.9540
Year	Log[etFOSAA]	Log[etFOSAA]Intercept	Intercept	22.735792244	6.7777542257	3.35	0.0010
Year	Log[etFOSAA]	Log[etFOSAA]Year	Year	0.012007593	0.0033833054	-3.55	0.0005

NIVA: Norges ledende kompetansesenter på vannmiljø

NIVA gir offentlig vannforvaltning, næringsliv og allmennheten grunnlag for god vannforvaltning gjennom oppdragsbasert forsknings-, utrednings- og utviklingsarbeid. NIVA kjennetegnes ved stor faglig bredde og godt kontaktnett til fagmiljøer i inn- og utland. Faglig tyngde, tverrfaglig arbeidsform og en helhetlig tilnærmingsmåte er vårt grunnlag for å være en god rådgiver for forvaltning og samfunnsliv.

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