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Contaminants in coastal waters of Norway 2020

Miljøgifter i norske kystområder 2020

Photo: Merete Schøyen, NIVA

Norwegian Institute for Water Research

REPORT

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Summary

The monitoring programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) examines levels, trends and effects of contaminants in biota. The 2020-investigation included analyses of more than 176 different contaminants or biological effect parameters in six species (blue mussel, cod, dogwhelk, common periwinkle, flounder and common eider). The contaminants measured includes metals (Hg, Cd, Pb, Cu, Zn, Ag, As, Ni, Cr and Co), tributyltin (TBT), organochlorines (e.g. PCBs (PCB-7), DDT, HCB, OCS and QCB), PAHs, polybrominated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS), hexabromocyclododecane (α-, γ- and β HBCD), chlorinated paraffins (SCCP, MCCP) and siloxanes (D4, D5 and D6). Biological effects parameters includes imposex (VDSI) and intersex (ISI), OH-pyrene metabolites as a marker of PAH-exposure, ALA-D as a marker of exposure to lead, and EROD as a marker to exposure to planar PCBs, PAHs and dioxines.

In this report, 30 contaminants or biological effects parameters were chosen for statistical analyses of 739 time series (short-term trends for the last 10 years). Of these, there were statistically significant trends in 96 cases: 67 (9.1 %) were downwards and 29 (3.9 %) upwards. The dominance of downward trends indicated that contamination was decreasing. The downward trends were primarily accociated with metals, α-HBCD and PBDEs, and the upward trends with metals. Of the 2020-medians for all 739 time series, 380 cases could be classified against EQS, of which 264 (35.7 %) were below the EQS and 116 (15.7 %) were above. Of the 739 time series, 644 cases could be classified using Norwegian provisional high reference contaminant concentrations (PROREF). Of these, 447 (69.4 %) were below PROREF. The remaining 197 (30.6 %) cases exceeded PROREF: 105 (16.3 %) by a factor of less than two, 57 (8.9 %) by a factor between two and five, 30 (4.7 %) by a factor between five and 10, three (0.5 %) by a factor between 10 and 20, and two (0.3 %) 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.

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Contaminants in coastal waters of Norway 2020

Preface

The monitoring programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) investigates contaminants in coastal waters of Norway on a yearly basis. This report presents the findings from monitoring performed in 2020. MILKYS provides Norwegian authorities with valuable information on pollutant levels in Norwegian costal waters. Data from MILKYS are also reported to OSPAR Commission, where 15 Governments and the EU cooperate to protect the marine environment of the North-East Atlantic. The results from Norway and other OSPAR countries provide a basis for evaluating the state of the marine environment in the North-East Atlantic. OSPAR receives guidance from the International Council for the Exploration of the Sea (ICES). The data are available via the public database Vannmiljø (https://vannmiljo.miljodirektoratet.no).

The 2020 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 Eivind Farmen) and the project manager at NIVA is Merete Schøyen (deputy project manager Merete Grung).

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Oslo, 20 December 2021.

Merete Schøyen
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Contents

Summary

The monitoring programme “Contaminants in coastal waters of Norway” (*Miljøgifter i norske kystområder* - MILKYS) examines the levels, trends and effects of contaminants along the coast of Norway from the Oslofjord and Hvaler region in the southeast to the Varangerfjord in the northeast. The programme provides a basis for assessing the state of the environment in Norwegian coastal waters. The monitoring contributes to the Oslo and Paris Commissions (OSPAR’s) Coordinated Environmental Monitoring Programme (CEMP).

The main finding in 2020 is that most contaminant concentrations in marine organisms showed downward trends where trends can be detected. In the Inner Oslofjord more contaminants have higher concentrations than in other areas along the coast and this area warrants special concern. Furthermore, in this area the investigation found a significant upward long-term (>10 years) trend for mercury (Hg) in cod fillet (*Gadus morhua*).

The 2020-investigation monitored blue mussel (*Mytilus edulis*) at 26 stations, Atlantic cod (*Gadus morhua*) at 17 stations, European flounder (*Platichthys flesus*) at one station, dogwhelk (*Nucella lapillus*) at eight stations, common periwinkle (*Littorina littorea*) at one station and common eider (*Somateria mollissima*) at one station. The stations are located both in areas with known or presumed point sources of contaminants, in areas of diffuse load of contamination like city harbour areas, and in more remote areas with presumed low exposure to pollution. In 2020 the following contaminants were monitored: metals (mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), nickel (Ni), chromium (Cr) and cobalt (Co)), tributyltin (TBT), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT, using dichlorodiphenyldichloroethylene (DDE) - principle metabolite of DDT as an indicator), hexachlorobenzene (HCB), pentachlorobenzene (QCB), octachlorostyrene (OCS), polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), per- and polyfluoroalkyl substances (PFAS), hexabromocyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP) and siloxanes (the cyclic volatile methyl siloxanes, cVMS: D4, D5 and D6). Biological effects parameters were also monitored. These were imposex and intersex parameters in marine snails as biomarkes of TBT-exposure, OH-pyrene in cod bile as a marker of PAH-exposure, δ-aminolevulinic acid dehydrase inhibition (ALA-D) in red blood cells from cod as a marker of exposure to lead, and cytochrome P450 1A-activity (ethoxyresorufin-O-deethylase, EROD) in cod liver as a marker of exposure to planar PCBs, PAHs and dioxins.

The monitoring in 2020 supplied data for a total of 3259 data sets (contaminant-station-species) on 176 different contaminants. All results are available via the public database Vannmiljø (https://vannmiljo.miljodirektoratet.no). 30 of the most important contaminants and biological effect parameters of the total 176 were chosen for presentation in this report. This selection gave 739 time series; combinations of contaminants, stations, species and tissues. Of these 739, there were statistically significant temporal short-term trends for the last 10 years (2011-2020) in 96 cases: 67 (9.1 %) were downward trends and 29 (3.9 %) upward trends. The dominance of downward trends indicated that contamination was decreasing. The downward trends were largely associated with concentrations of metals, α-HBCD and BDEs.The upward trends were mainly associated with metals, while many upward short-term trends for PCB-7 were caused by methodical (artificial) results due to higher limits of quantifications (LOQ).

The results were assessed using Environmental Quality Standards (EQS). 380 measured time series were classified, of these 36 % were below and 16 % were above EQS. For 359 time series no EQS has been developed.

In 2020, medians for 644 time series could be compared to assumed reference levels, by a NIVA-developed tool denoted Norwegian provisional high reference contaminant concentration (PROREF). PROREF is a comprehensive set of species-tissue-basis-specific contaminant concentrations that are statistically low when considering all MILKYS-results for the period 1991-2016. This tool sets reference concentrations for contaminants, mostly in areas presumed remote from point sources of contamination, and thus provides a valuable method for assessing contaminants levels in addition to the risk based EQS. Of the assessed time series, 69 % were lower than the PROREF and 31 % exceeded the PROREF.

Levels and trends in blue mussel

The concentration of lead in blue mussel was highest at Odderøya in the Kristiansandsfjord. There were both significant upward long- and short-term trends for lead at Gressholmen and Gåsøya in the Inner Oslofjord and at Risøy at Risør. There were both significant upward long- and short-term trends for chromium at Gressholmen and Brashavn in the Varangerfjord.

PCB-7 in blue mussel at all stations exceeded the EQS. The highest PCB-7 concentration was found in blue mussel at Gressholmen (17.4 µg/kg wet weight, w.w.). In 2020, two new upward long-term trends and seven new upward short-term trends were found for PCB-7 in blue mussel compared to 2019. However, this is a methodical (artificial) result as described in chapter 2.6. The LOQ increased from 0.05 to 0.3 µg/kg in 2017.

Applying EQS for PAH in blue mussel, all stations had concentrations below this limit for the PAHs anthracene, fluoranthene, benzo(a)pyrene, napthalene and benzo(a)anthracene. The highest concentrations of PAHs in blue mussel were found in the Oslo harbour area.

Concentrations of PBDEs (sum of six compounds – BDE6[1]) in blue mussel were highest in Bodø harbour area. Except for in Bodø harbour, all blue mussel stations were below PROREF for PBDEs. Except for at Svolvær airport, all other mussel stations exceeded the EQS for BDE47. All mussel stations exceeded the EQS for BDE6.

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

All concentrations of SCCPs and MCCPs were below the EQS, except for MCCP in blue mussel from Bodø harbour. There was a significant downward long-term trend for SCCP in mussels from Tjøme in the Outer Oslofjord. There were both significant upward long- and short-term trends for SCCPs in blue mussel from Singlekalven in the Hvaler area.

There were only low concentrations of HCB, OCS and QCB, and all concentrations in blue mussels were lower than the limit of quantification (LOQ). Downward long-term trends were found for HCB in blue mussel from Færder, Bjørkøya in the Grenlandfjord and Odderøya in the Kristiansandfjord.

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

Levels and trends in cod

For mercury, the concentrations in cod fillet at all stations exceeded the EQS, except for the reference station at Svalbard. Significant upward long-term (1984-2020) trends for mercury in cod fillet from the Inner Oslofjord were found both when using the OSPAR method which targets specific length-groups and when adjusting for fish-length. There were significant upward long-term trends for mercury in cod fillet from Skågskjera in Farsund, at Bømlo and from Tromsø. Trends were significant also after adjusting for cod length for the Kristiansand harbour and Farsund. The highest concentration of mercury was found in cod fillet from the Ålesund harbour (0.210 mg Hg/kg w.w.). Reasons could be related to factors such as; climate change, more favourable conditions for methyl Hg formation, increased bioavailability of Hg stored in the sediments, increased access of cod to contaminated feeding areas due to improved oxygen levels in deep water, changes in what the cod eat, etc.

All concentrations of PCB-7 in cod liver exceeded the EQS. The highest concentrations of PCB-7 in cod liver from the Inner Oslofjord is probably related to urban activities in the past in combination with little water exchange with the outer fjord.

All concentrations of DDE in cod liver were below the EQS. Contamination of this substance is related to earlier use of DDT as pesticide in agriculture, forestry and orchards along the fjords (ca. 1945-1970).

All concentrations of PBDEs in cod liver exceeded the EQS for BDE6 and BDE47. The highest median concentrations of BDE6 were found in Bergen harbour and the Inner Oslofjord, and 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 at Færder and Bømlo. As for PCB-7, the high concentrations of PBDEs are probably related to urban activities and insufficient water exchange.

PFAS in cod liver has been investigated in several fjords since 2005. PFOS and PFOSA were highest in cod liver from the Inner Oslofjord. The lowest PFAS concentrations were found in cod from Svalbard.

All concentrations of hexabromocyclododecanes (HBCD) in cod liver were below the EQS in 2020, 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 HBCD concentrations in the Inner Oslofjord is probably related to urban activities. There were significant long- and short-term downward trends for HBCD in cod liver from Stathelle area in the Langesundfjord, from Kirkøy, Hvaler and from Bømlo. A significant downward short-term trend was also found for HBCD in cod liver from the Inner Oslofjord.

Cod liver from Svalbard had highest concentrations of SCCP, and cod from the Inner Oslofjord had highest concentrations of MCCP. The high concentrations in cod from Svalbard might be a result of long-range transported pollution. These substances have been found in high concentrations in air at Svalbard. A significant upward long-term trend was found for MCCP in cod liver from Bømlo. Both significant downward long- and short-term trends were found for SCCP in cod liver from Bergen harbour area. There was also a significant downward long-term trend for SCCP in cod liver from the Inner Sørfjord.

Cod from the Autnesfjord in Lofoten had concentrations of HCB that exceeded the EQS. Significant downward long-term trends were found for median concentration of HCB in liver of cod from the Inner Oslofjord, Tjøme in the Outer Oslofjord and from Farsund.

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

Levels in flounder
In liver of flounder from Sande in the mid Oslofjord, significant upward short-term trends were found for cadmium and mercury, and significant downward long-term trends were found for lead and HCB.

Levels in eider
Contaminants have been analysed in the blood and eggs (homogenate of yolk and albumin) of eider from Svalbard in this programme since 2017. Concentrations of mercury, lead, arsenic, PFOS and PFOSA in eggs were almost at the same level as previous years.

For several of the environmental contaminants, the levels were far lower in eider from Svalbard than in eider from another study in the Inner Oslofjord (Ruus 2018). Concentration of PCB-7 was 19 to 39 times lower in blood and eggs in eider from Svalbard than in eider from the Inner Oslofjord, respectively. The concentration of BDE47 was 10 times lower in eider eggs from Svalbard compared with eider eggs from the Inner Oslofjord. The concentrations of PFOS in eider eggs and blood were also lower in Svalbard than in eider from the Inner Oslofjord, 21- and 25-times lower concentrations in Svalbard, respectively.

There is a downward tendency for concentration of HCB in blood and eggs of eider for the monitoring period 2017 to 2020.

Biological effects
The ICES/OSPARs assessment criterion[1] (background assessment criteria, BAC) for OH-pyrene in cod bile was exceeded at all stations investigated (Inner Oslofjord, Inner Sørfjord and Farsund area), exept for the reference station at Bømlo. This indicates that the fish have been exposed to PAH compounds. Among the four stations, OH-pyrene concentrations were highest in the Inner Oslofjord and lowest at Bømlo. Pyrene-concentrations in blue mussels were highest in the Oslofjord (Akershuskaia), compared to all stations where PAHs were analysed.

The ALA-D activity in the Inner Oslofjord in 2020 was lower than at Bømlo. Reduced activities of ALA-D reflect higher exposure to Pb. Higher concentrations of Pb in cod liver have generally been observed in the Inner Oslofjord and Inner Sørfjord compared to Bømlo, as was also the case in 2020.

The median EROD activity was lower in the Inner Sørfjord than in the Inner Oslofjord and at Bømlo, while the stations in the Inner Oslofjord and Bømlo were not statistically different. High activity of hepatic cytochrome P450 1A-activity (EROD-activity) normally occurs as a response to planar organic molecules, such as certain PCBs, PAHs and dioxins. The EROD activities were below the ICES/OSPARs BAC. Concentrations over BAC would indicate possible impact by planar PCBs, PCNs, PAHs or dioxins. No concentrations of PAHs in blue mussel exceeded the EQS. Statistically significant downward trends in EROD activity were observed at all stations investigated.

There were significant downward long-term trends for both TBT concentrations and the imposex parameter VDSI at seven of eight dogwhelk stations. No effects on dogwhelk (imposex parameter

[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.

VDSI=0) were observed. For the first time since 1991, there were no effects of TBT on dogwhelk (imposex parameter VDSI=0) at any of the eight stations in 2017. The 2020 data also confirmed these results. The synchronous decreases in both TBT concentrations and imposex parameters in dogwhelk coincides with the TBT bans for longer vessels than 25 meters in 2003 and the global total ban in 2008. The results shows how regulations, like TBT-bans, can be effective in reducing levels and effects of environmental contaminants.

Stable isotopes

Stable isotopes of carbon and nitrogen are useful indicators of food origin and trophic levels. The isotopic signatures were different among stations (geographical variation). However, the results indicate that the stations show very similar patterns, for both blue mussel and cod, from 2012 to 2020 in terms of isotopic signatures, indicating a geographical difference consistent over time. The isotopic signatures in mussels from the programme thus provide valuable information about the isotopic baselines along the Norwegian coast.

Sammendrag

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Overvåkingsprogrammet «Miljøgifter i norske kystområder – MILKYS» (Contaminants in coastal waters of Norway) undersøker nivåer, trender og effekter av miljøgifter langs norskekysten fra Oslofjorden og Hvaler-regionen i sørøst til Varangerfjorden i nordøst. Programmet gir grunnlag for å vurdere miljøtilstanden i norske kystfarvann. Overvåkingen gir bidrag til Oslo- og Pariskonvensjonen (OSPAR) og Coordinated Environmental Monitoring Programme (CEMP).

Resultatene for 2020 viser at det hovedsakelig var nedadgående trender, der hvor trender kan påvises, for konsentrasjoner av de undersøkte miljøgiftene i marine organismer. Indre Oslofjord peker seg ut som et område der flere miljøgifter har relativt høye konsentrasjoner sammenliknet med andre områder langs kysten. Dette gir grunnlag for bekymring og behov for nærmere undersøkelser. I indre Oslofjord ble det observert en signifikant oppadgående langtidstrend (> 10 år) for kvikksølv (Hg) i torskefilét.

Undersøkelsen inngår som en del av Oslo og Paris konvensjonens (OSPARs) koordinerte miljøovervåkingsprogram Coordinated Environmental Monitoring Programme (CEMP). I 2020 omfattet overvåkingen miljøgifter i blåskjell (*Mytilus edulis*) fra 26 stasjoner, torsk (*Gadus morhua*) fra 17 stasjoner, skrubbe (*Platichthys flesus*) fra én stasjon, purpursnegl (*Nucella lapillus*) fra åtte stasjoner, strandsnegl (*Littorina littorea*) fra én stasjon og ærfugl (*Somateria mollissima*) fra én stasjon. Stasjonene er plassert i områder med kjente eller antatt kjente punktkilder for tilførsler av miljøgifter, i områder med diffus tilførsel av miljøgifter slik som byens havneområder og i fjerntliggende områder med antatt lav eksponering for miljøgifter. Overvåkingen i 2020 omfattet analyser av bl.a. metaller (kvikksølv (Hg), kadmium (Cd), bly (Pb), kobber (Cu), sink (Zn), sølv (Ag), arsen (As), nikkel (Ni), krom (Cr) og kobolt (Co)), tributyltinn (TBT), polyklorerte bifenyler (PCBer), pestisider (DDE og heksaklorbenzen (HCB)), pentaklorbenzen (QCB), oktaklorbenzen (OCB), polysykliske aromatiske hydrokarboner (PAHer), polybromerte difenyletere (PBDEer), perfluorerte alkylforbindelser (PFAS), heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP) og siloksaner (sykliske flyktige metylsiloksaner, cVMS: D4, D5 og D6). Det ble også gjort overvåking av biologiske effekt-parametere. Dette var imposex og intersex i marine snegler som biomarkører for TBT-eksponering, OH-pyren i torskegalle som markør for PAH-eksponering, δ-aminolevulinsyre dehydrase (ALA-D) i røde blodceller fra torsk som markør for eksponering for bly, og cytokrom P450 1A-aktivitet (ethoxyresorufin-O-deethylase, EROD) i torskelever som markør for eksponering for planare PCBer, PAHer og dioksiner.

2020-resultatene omfatter totalt 3259 datasett (miljøgifter-stasjoner-arter) for 176 forskjellige miljøgifter. Alle resultater er tilgjengelige i den offentlige databasen Vannmiljø (https://vannmiljo.miljodirektoratet.no). Et utvalg av 30 miljøgifter og biologiske parametere presenteres i denne rapporten. Dette utvalget består av 739 tidsserier hvorav 96 viste statistisk signifikante korttidstrender for de siste 10 årene i perioden 2011 til 2020: 67 (9,1 %) var nedadgående og 29 (3,9 %) var oppadgående. Dominansen av nedadgående trender indikerer avtagende nivåer av miljøgifter. De nedadgående trendene omfattet metaller, HBCDA og PBDEer. De oppadgående trendene var i hovedsak for metaller, mens mange oppadgående korttidstrender

for PCB-7 ble forårsaket av metodiske (kunstige) resultater på grunn av høyere kvantifiseringsgrenser (LOQ).

I denne rapporten er resultatene primært vurdert i forhold til miljøkvalitetsstandarder (Environmental Quality Standards, EQS). 380 av de 739 tidsseriene kunne klassifiseres i forhold til en EQS, og 264 (35,7 %) av disse var lavere enn EQS og 116 (15,7 %) var over EQS. Det fins ikke EQS for 359 (48,6 %) av tidsseriene.

I 2020 kunne medianer for 644 tidsserier vurderes i forhold til antatte referansenivåer, ved et NIVA-utviklet verktøy betegnet norsk provisorisk høy referansekonsentrasjon for miljøgifter (PROREF). PROREF er et omfattende sett med arts-vev-basis-spesifikke miljøgiftkonsentrasjoner som er statistisk lave når alle MILKYS-resultater for perioden 1991 til 2016 tas i betraktning. Dette verktøyet angir referansekonsentrasjoner for miljøgifter, hovedsakelig i områder som antas fjernt fra punktkilder, og er dermed en verdifull metode for å vurdere nivåer av miljøgifter i tillegg til de risikobaserte EQS. Av de vurderte tidsseriene var 69 % lavere enn PROREF, mens 31 % overskred denne.

Konsentrasjoner og trender av miljøgifter i blåskjell
Blåskjell fra Odderøya i Kristiansandsfjorden hadde høyest konsentrasjon av bly i denne undersøkelsen. Det var signifikant oppadgående langtids- og kortidstrend for bly på Gressholmen og Gåsøya i indre Oslofjord og på Risøy ved Risør. Det var signifikant oppadgående langtids- og korttidstrend for krom i blåskjell fra Gressholmen og Brashavn i Varangerfjorden.

Konsentrasjoner av PCB-7 i blåskjell overskred EQS ved alle stasjonene. Den høyeste PCB-7 konsentrasjonen var i blåskjell fra Gressholmen (17,4 µg/kg våtvekt, v.v.). I 2020 ble det funnet to nye oppadgående langtidstrender og syv nye oppadgående korttidstrender for PCB-7 i blåskjell sammenliknet med 2019. Dette er imidlertid et metodisk (kunstig) resultat som beskrevet i kapittel 2.6. LOQ økte fra 0,05 til 0,3 µg/kg i 2017.

Blåskjell fra Kvalnes i midtre del av Sørfjorden og Utne i ytre del av Sørfjorden hadde konsentrasjoner av DDE som var mer enn 20 ganger høyrere enn PROREF. Forurensning av denne miljøgiften i både blåskjell og torsk skyldes tidligere bruk av DDT som sprøytemiddel.

Ingen blåskjellstasjoner hadde konsentrasjoner som overskred EQS for antracen, fluoranten, benzo(a)pyren, naftalen eller benzo(a)antracen. Det var høyest konsentrasjoner av PAH-forbindelser i blåskjell fra havneområdet i indre Oslofjord. På Akershuskaia og Gressholmen var det overskridelse av PROREF for PAHer med en faktor mindre enn to. Nivået av KPAH var høyest i blåskjell fra Akershuskaia og Gressholmen.

Det var høyest nivå av PBDEer (sum av seks PBDE-forbindelser[1]) i blåskjell fra Bodø havn. Med unntak av området ved Svolvær flyplass, var det overskridelse av EQS[1] for BDE47 ved alle blåskjellstasjonene. Det var også overskridelse av EQS for BDE6 på alle blåskjellstasjonene.

Alle konsentrasjonene av HBCD i blåskjell var lavere enn EQS. Det var høyest konsentrasjon av α-HBCD i blåskjell fra Bodø havn. Det ble funnet nedadgående nivåer for HBCD i blåskjell, bl.a. var det signifikant nedadgående langtidstrend for HBCD i blåskjell fra Gressholmen i indre Oslofjord.

De fleste konsentrasjonene av SCCP og MCCP var lavere enn EQS, bortsett for MCCP i blåskjell fra Bodø havneområde. Det var en signifikant nedadgående trend for SCCP i blåskjell fra Tjøme i ytre

[1] Sum av BDE kongenerer nummer 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) og 154 (hexa)

Oslofjord. Det ble påvist både signifikante oppadgående lang- og korttidstrender for SCCP i blåskjell fra Singlekalven i Hvaler.

Det var kun lave konsenrasjoner av HCB, OCS og QCB, og alle mediankonsentrasjonene i blåskjell var lavere enn LOQ. Det var nedadgående langtidstrend for HCB i blåskjell fra Færder i ytre Oslofjord, Bjørkøya i Grenlandsfjorden og ved Odderøya i Kristiansandsfjorden.

Konsentrasjoner og trender av miljøgifter i torsk
Det var overskridelse av EQS for kvikksølv i torskefilét fra samtlige stasjoner, unntatt referansestasjonen på Svalbard. Torsk fra indre Oslofjord hadde konsentrasjon av kvikksølv i filét som var mer enn to ganger høyere enn PROREF, og det var signifikante oppadgående langtidstrender (1984-2020) både med OSPARs metode for spesifikke lengdegrupper og ved beregning med metode som tar hensyn til fiskelengde. Det var signifikant oppadgående langtidstrend for kvikksølv i torskefilét fra Skågskjera ved Farsund, Bømlo og Tromsø. Trender for kvikksølv i torsk fra Kristiansand havn og Farsund var signifikante også etter justering for fiskelengde. Den høyeste kvikksølvkonsentrasjonen ble funnet i torskefilét fra Ålesund havn (0,210 mg Hg/kg v.v.). Årsaker kan være relatert til faktorer som; klimaendringer, gunstigere forhold for metyl Hg-dannelse, økt biotilgjengelighet av Hg lagret i sedimentene, økt tilgang av torsk til forurensede fôringsområder på grunn av forbedret oksygennivå på dypt vann, endringer i torskens diett m.m.

Konsentrasjonene av PCB-7 i torskelever var høyere enn EQS. Det var forhøyede nivåer av PCB-7 i torskelever fra indre Oslofjord og Bergen havn. 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. Forurensning av dette stoffet skyldes tidligere bruk av DDT i jordbruk, skogbruk og som plantevernmiddel i forbindelse med fruktdyrking langs fjordene (ca. 1945-1970).

Konsentrasjonene av PBDEer i torskelever var høyere enn EQS for BDE6 and BDE47. De høyeste nivåene av BDE6 i torskelever ble funnet fra henholdsvis Bergen havn og indre Oslofjord, og lavest nivå ble observert i torsk fra Svalbard. BDE47 var den dominerende PBDE-forbindelsen i alle prøvene, og det var signifikant høyere nivåer av denne forbindelsen i torskelever fra indre Oslofjord og Bergen havn enn i torsk fra Færder og Bømlo. Som for PCB-7, er urban påvirkning og utilstrekkelig vannutskifting trolig årsaker til de høye nivåene.

Konsentrasjoner av PFAS-forbindelser i torskelever har blitt overvåket i mange fjorder siden 2005. PFOS og PFOSA var høyest i torskelever fra indre Oslofjord. De laveste PFAS konsentrasjonene ble registrert i torsk fra Svalbard.

Alle konsentrasjonene av heksabromsyklododekaner (HBCD) i torskelever var lavere enn EQS. Av HBCDene var α-HBCD den mest dominerende diastereomeren. Konsentrasjonen av α–HBCD i torskelever var signifikant høyere i indre Oslofjord enn for de 12 andre undersøkte stasjonene. De høye konsentrasjonene av HBCD i indre Oslofjord har trolig sammenheng med urbane aktiviteter. Det var nedadgående nivåer av HBCD på flere stasjoner, bl.a. for Stathelle i Langesundsfjorden, Kirkøy i Hvaler og fra Bømlo. Det var både signifikante nedadgående lang- og korttidstrender for HBCD i torskelever fra Kirkøy på Hvaler. Det var også signifikant nedadgående korttidstrend for HBCD i lever av torsk fra indre Oslofjord.

Det var høyest konsentrasjon av SCCP i torsk fra Svalbard, og det var høyest konsentrasjon av MCCP i lever av torsk fra indre Oslofjord. De høye konsentrasjonene av SCCP i torsk fra Svalbard kan skyldes langtransportert forurensning. Det er målt høye konsentrasjoner av klorparafiner i luft på Svalbard. Signifikant oppadgående langtidstrend ble påvist for MCCP i torskelever fra Bømlo. Det var både signifikante nedadgående lang- og kortidstrender for SCCP i torskelever fra Bergen havn. Også torsk fra Indre Sørfjorden hadde signifikant nedadgående langtidstrend for konsentrasjon av SCCP.

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

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

Konsentrasjoner av miljøgifter i skrubbe
Det ble funnet signifikant oppadgående korttidstrender for kadmium og kvikksølv i skrubbelever fra Sande i midtre Oslofjord, og nedadgående langtidstrender for bly og HCB.

Konsentrasjoner av miljøgifter i ærfugl
Det ble gjort analyser av miljøgifter i blodprøver og egg fra ærfugl fra Svalbard. For flere av miljøgiftene var nivåene langt lavere enn i ærfugl fra Oslofjorden målt i en annen undersøkelse (Ruus 2018). Konsentrasjon av PCB-7 var 19 til 39 ganger lavere i henholdsvis blod og egg i ærfugl fra Svalbard enn i ærfugl fra et annet studie fra indre Oslofjord. Konsentrasjonen av BDE47 var 10 ganger lavere i ærfuglegg fra Svalbard sammenlignet med ærfuglegg fra indre Oslofjord. Konsentrasjonene av PFOS i ærfuglegg og blod var lavere på Svalbard enn i ærfugl fra indre Oslofjord, henholdsvis 21 og 25 ganger lavere konsentrasjoner på Svalbard. Det er nedadgående tendens for konsentrasjon av HCB i prøver av blod og egg av ærfugl fra Svalbard.

Biologiske effekter
ICES/OSPARs vurderingskriterium for bakgrunnsnivå[1] («background assessment criteria», BAC) for OH-pyren i torskegalle ble overskredet på alle undersøkte stasjoner (indre Oslofjord, indre Sørfjorden, Farsund-området), unntatt på referansestasjonen på Bømlo. Dette viser at fisken har vært eksponert for PAH. Blant de fire stasjonene var konsentrasjonene av OH-pyren høyest i indre Oslofjord og lavest ved Bømlo. Pyren-konsentrasjoner i blåskjell var høyest i Oslofjorden (Akershuskaia), sammenlignet med øvrige stasjoner hvor PAH ble analysert.

ALA-D aktivitet i torsk fra indre Oslofjord var lavere enn i torsk fra Bømlo. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly. Det har generelt vært høyere konsentrasjoner av bly i torskelever fra indre Oslofjord og indre Sørfjorden enn i torsk fra Bømlo, hvilket også var tilfelle i 2020.

Median EROD-aktivitet i lever fra indre Sørfjorden var lavere enn i indre Oslofjord og på referansestasjonen på Bømlo. Det var ingen statistisk forskjell i EROD-aktivitet mellom Oslofjorden og Bømlo. Høy aktivitet av hepatisk cytokrom P450 1A-aktivitet (EROD-aktivitet) skjer normalt som en respons på plane organiske molekyler som PCBer, PAH-forbindelser og dioksiner. EROD-aktiviteten var lavere enn ICES/OSPARs bakgrunnsnivå (BAC). Konsentrasjoner over dette nivået vil

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

indikere mulig påvirkning fra plane PCBer, PCNer, PAHer eller dioksiner. Ingen PAH-konsentrasjoner i blåskjell overskred EQS. Statistisk signifikante nedadgående trender i EROD-aktivitet ble observert på alle tre stasjoner.

Det ble registrert signifikante nedadgående langtidstrender for både TBT konsentrasjoner og imposex parameter (VDSI) på syv av de åtte purpursnegl stasjonene. Ingen effekt av TBT i purpursnegl (imposex parameter VDSI=0) ble funnet. I 2017 var det for første gang siden 1991 ingen effekter av TBT på purpursnegl (imposex parameter VDSI=0) på noen av de åtte stasjonene. Undersøkelsen i 2020 bekreftet disse resultatene. Den synkrone nedgangen i både TBT-konsentrasjoner og imposex-parametere i purpursnegl samsvarer med TBT-forbudene i 2003 for skip lenger enn 25 meter og det globale totalforbudet i 2008. Resultatene er et godt eksempel på at lovgivningen som forbyr miljøgifter, slik som TBT, har vært effektiv.

Stabile isotoper

Stabile isotoper av karbon og nitrogen er nyttige indikatorer for opprinnelse av føde, samt av trofisk posisjon. Isotop-signaturene var forskjellige blant stasjonene (geografiske forskjeller). Resultatene viste imidlertid at forskjellene i isotopsignatur mellom stasjoner er like i årene 2012-2020, både for blåskjell og torsk. Dette tyder på at den romlige trenden er stabil over tid. Isotopsignaturer i blåskjell gir verdifull informasjon om bakgrunnsnivået for isotopsignaturer langs norskekysten.

1. Introduction

1.1 Background

The monitoring programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) is administered by the Norwegian Environment Agency (NEA), that monitors on the levels, trends and effects of hazardous substances in fjords and coastal waters in Norway on an annually basis. The objective of this monitoring programme is to obtain updated information on levels and trends of selected environmental pollutants in Norway. The programme also provides a basis for assessing the state of the environment in Norwegian coastal waters. The monitoring contributes to the Oslo and Paris Commissions (OSPAR's) Coordinated Environmental Monitoring Programme (CEMP). All the results in this report are considered part of the Norwegian contribution to the CEMP programme as well as to the European Environment Agency (EEA) as part of the assessment under the EU Water Framework Directive (WFD).

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

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

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

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

The previous investigations carried out as part of this monitoring program have shown that the Inner Oslofjord has elevated levels of polychlorinated biphenyls (PCB-7) in cod liver, mercury (Hg), lead (Pb) and zinc (Zn) in sediments and elevated concentrations of Hg in cod fillet. Cod liver in the Inner Oslofjord also revealed the highest median concentration of α–HBCD in 2014. Investigations of the Sørfjord/Hardangerfjord have shown elevated levels of PCB-7, dichlorodiphenyltrichloroethane (DDT, using dichlorodiphenyldichloroethylene (DDE) - principle metabolite of DDT as an indicator), cadmium (Cd), Hg and Pb. Investigations in the Orkdalsfjord focused on three blue mussel stations. The results from these investigations have been reported earlier by Green et al. (2007; 2008). MILKYS reports from 2012 are collected on the website of the Norwegian Environment Agency; https://www.miljodirektoratet.no/ansvarsomrader/overvaking-arealplanlegging/miljoovervaking/overvakingsprogrammer/basisovervaking/miljogifter-langs-kysten/

Environmental status has in previous reports been classified according to environmental quality criteria based on the classification system of the Norwegian Environment Agency (Molvær et al. 1997), or presumed background levels applied in a previous report (Green et al. 2016) (***Appendix C***). In this report, the results were assessed primarily in relation to Environmental Quality Standards (EQS) for priority substances and river basin specific pollutants (Norwegian_Environment_Agency 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 monitoring the Oslofjord and the Sørfjord/Hardangerfjord, MILKYS also includes the annual monitoring of contaminants at selected stations in Lista and Bømlo on the Norwegian South- and West coast, respectively. During the periods 1993-1996 and 2006-2007, MILKYS also included sampling of blue mussel from reference areas along the coast from Lofoten to the Russian border. Fish is also sampled from four key areas north of Lofoten in the Finnsnes-Skjervøy area, Hammerfest-Honningsvåg area and Varanger Peninsula area. Fish from the Lofoten and Varanger Peninsula areas are sampled annually. The intention is to assess the level of contaminants in less polluted reference areas, and to assess possible temporal trends. ***Figure 1***, ***Figure 2*** and ***Figure 3*** indicates which stations were monitored for the 2020-investigation and discussed in this report, and ***Appendix D*** provides maps which also show stations that have been monitored previously.

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

In MILKYS, the state of contamination is assessed by examining levels, trends and effects (biomarkers) (OSPAR 2018). Biota is sampled annually. Based on an evaluation of the Norwegian environmental monitoring (Miljødirektoratet 2012), the programme underwent an extensive revision in 2012 and again in 2017 in regard to stations and choice of contaminants to be analysed. Monitoring of flatfish was discontinued in 2012, and only one station at Sande was investigated in 2020. 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 from Svalbard were also added in 2017.

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

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

All monitoring results from this monitoring programme are made publicly available via annually reports and Vannmiljø[1] and are included in the submission to ICES (including results for eider). Where possible, MILKYS is integrated with other national monitoring programmes to achieve a better practical and scientific approach for assessing the levels, trends and effects of contaminants. In particularly, this concerns sampling for the Norwegian Environmental Specimen Bank (Miljøprøvebanken, MPB), a programme funded by the Norwegian Ministry of Climate and Environment to sustain time trend monitoring and local (county) investigations. Other programmes and monitoring activities that can be relevant are: The Norwegian river monitoring programme – water quality status and trends (*Elveovervåkingsprogrammet – vannkvalitet og -trender*), Ecosystem Monitoring in Coastal Waters (*Økosystemovervåking i kystvann* (ØKOKYST)), Environmental Contaminants in an Urban Fjord (*Miljøgifter i en urban fjord*) as well as MAREANO[2] and the Arctic Monitoring and Assessment Programme (AMAP)[3], an Arctic Council Working Group. The first three programmes are operated by NIVA on behalf of the Norwegian Environment Agency.

1.2 Purpose

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

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

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

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

MILKYS provides data to State of the Environment Norway (https://www.environment.no/) which provides the latest information about the state and development of the environment in Norway and is important as input to Norway's national and international efforts to protect the environment against pollution and to reduce existing pollution. MILKYS data is part of the Norwegian contribution to CEMP which aims to deliver comparable data from across the OSPAR Maritime Area, which can be used in assessments to address the specific questions raised in the OSPAR's Joint Assessment and Monitoring Programme, and is designed to address issues relevant to OSPAR (2014) including also OSPAR priority substances (OSPAR 2007). The OSPAR Hazardous Substances Strategy is to prevent pollution by hazardous substances, by eliminating their emissions, discharges and losses, to achieve levels that do not give rise to adverse effects on human health or the marine environment. Under OSPAR, data from MILKYS and other monitoring programmes support this strategy by:

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

MILKYS also contributes data to support the implementation of the Water Framework Directive (WFD) (2000/60/EC 2000) and its daughter directive the Environmental Quality Standards Directive (EQSD) (2013/39/EU 2013) to achieve good chemical status by assessing the results using EU EQSD in Norway. In this regard, Norway has supplemented the EQS with their own EQS for River Basin Specific Pollutants assessed for Ecological status. 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 the WFD and MSFD is to achieve concentrations of hazardous substances in the marine environment near background values for naturally occurring substances and close to zero for manmade synthetic substances. OSPAR has also adopted this goal (OSPAR 1998).

2. Material and methods

2.1 Sampling

2.1.1 Stations

Samples for the investigation of contaminants were collected along the Norwegian coast, from the Swedish border in the south and to the Russian border in the north, as well as Svalbard (***Figure 1***, ***Figure 2***, ***Figure 3***, ***Appendix D***). The sampling involved blue mussel at 26 stations (whereof two were completely funded by the Ministry of Climate and Environment, see **Chapter 1.1**), dogwhelk at eight stations, common periwinkle at one station, cod at 17 stations, flounder at one station and the common eider at one station.

Samples were collected during 2020 and analysed according to OSPAR guidelines (OSPAR 2003, 2018)[1] where these could be applied. The data was screened and submitted to ICES by agreed procedures ICES (1996) as well as to the national database Vannmiljø. Blue mussel (*Mytilus edulis*), dogwhelk (*Nucella lapillus*), common periwinkle (*Littorina littorea*) and Atlantic cod (*Gadus morhua*) are the target species selected for MILKYS to indicate the degree of contamination in the sea. Blue mussel is attached to shallow-water surfaces, thus reflecting exposure at a fixed point (local pollution). Mussels and snails are usually abundant, robust and widely monitored in a comparable way. The species are, however, restricted to the shallow waters of the shoreline. Cod is widely distributed and commercially important fish species. It is a predator and, as such, will for hydrophobic compounds mainly reflect contamination levels in their prey. Recently, however, it has become increasingly difficult to catch sufficient numbers of adequate size of both blue mussel and cod. The 2020-programme also included investigation of contaminants in the European flounder (*Platichthys flesus*) and the common eider (*Somateria mollissima*). Deviations from what was planned for the 2020 sampling and analyses and what was realized, together with what was realized in the 2019 investigation is shown in ***Appendix E***.

As mentioned above (see ***Chapter 1.1***) the results from some supplementary monitoring to maintain long-term trends are included in this report. These concern some contaminants in blue mussel and cod (cf. ***Table 1***).

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

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

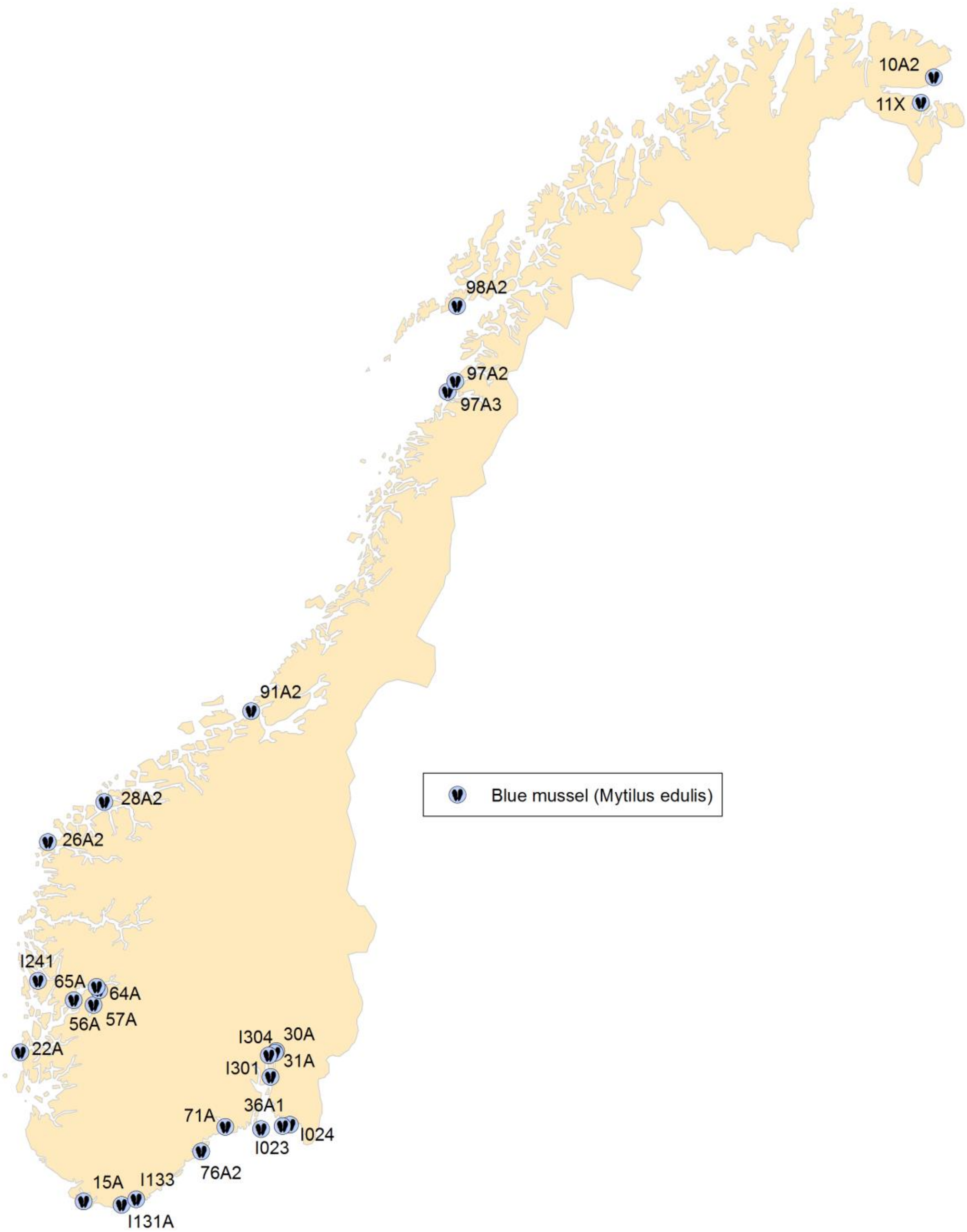

***Figure 1**. Stations where blue mussel were sampled in 2020. See also station information in detailed maps in **Appendix D**.*

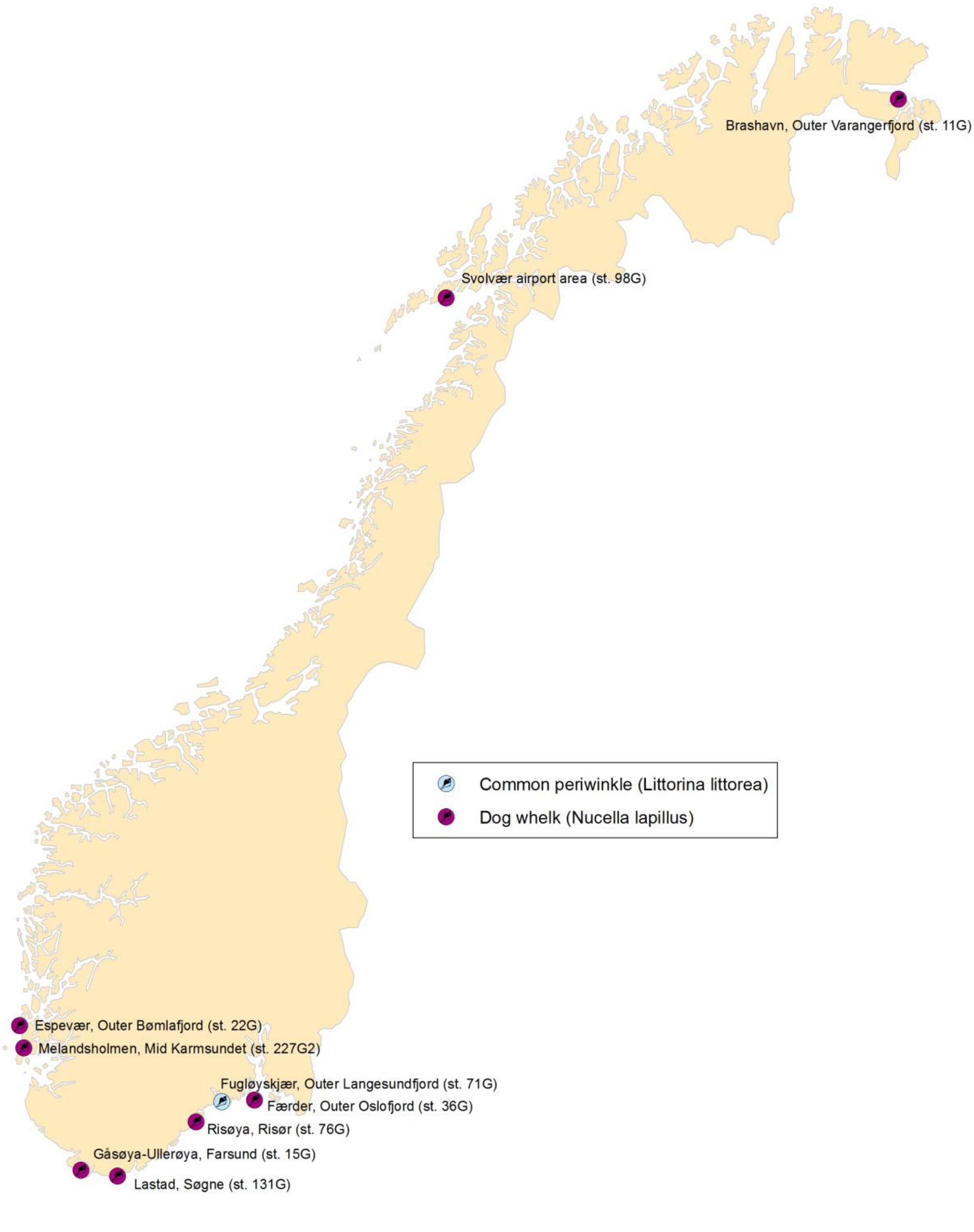

Figure 2*. Stations where dogwhelk and common periwinkle were sampled in 2020. See also station information in detailed maps in* ***Appendix D****.*

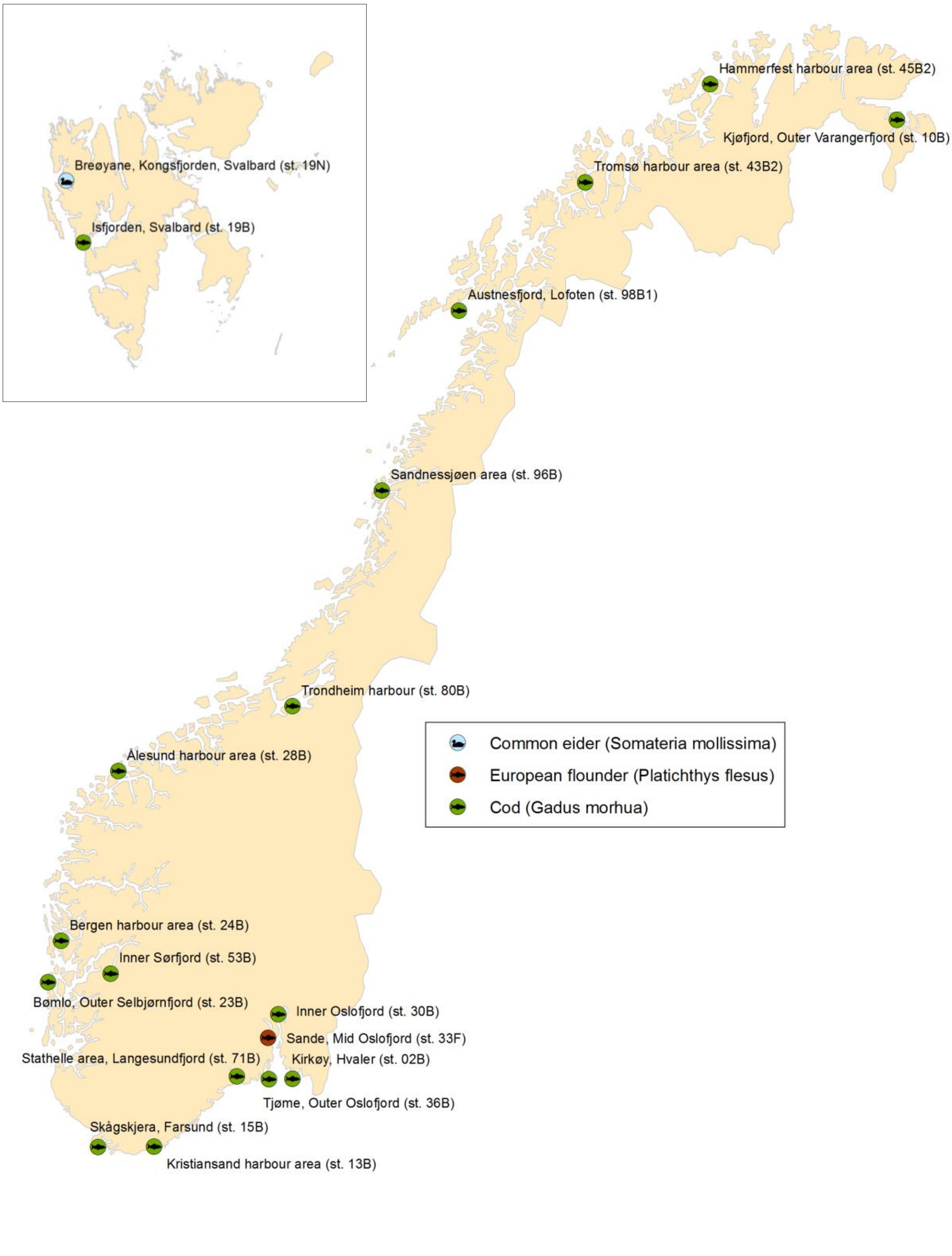

Figure 3*. Stations where cod, flounder and the common eider were sampled in 2020. Note insert map of Svalbard and see also station information in detailed maps in* ***Appendix D****.*

2.1.2 Blue mussel

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

A sufficient number of individuals for three pooled samples of blue mussel were found at nearly all of the 26 stations. The exceptions being the station in the Grenlandfjord area at Bjørkøya (st. 71A) where, even after intensive search, only insufficient quantities were found.

In 2020, blue mussel of sufficient size and quantity were found at Færder in the Outer Oslofjord (st. 36A). For the years 2013-2015 and 2018-2019, mussels were sampled at the alternative site at Tjøme (st. 36A1) [1] due to insufficient numbers. The two sites are separated by 7.7 km. However, earlier tests have provided some indication that the results can be viewed collectively with respect to time trends[2]. Where time-trend series are presented in this report both stations are referred to collectively as station 36A.

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

The blue mussel samples were collected from 24th August to 19th December 2020. 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 mussels collected in Lofoten and the Varangerfjord, which were collected by local contacts.

The method for collecting and preparing blue mussel was based on the National Standard for mussel collection (NS 2017). Three pooled samples of approximately 50 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 2018), cf. (Green et al. 2012). There is some evidence that for a specific population/place the depuration has no significant influence on the body burden of the contaminants measured (Green 1989; 1996; 2001). The practice of depuration was discontinued in 2012.

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

[2] In 2015 one sample from Færder, Outer Oslofjord (st. 36A) was obtained and analyzed in addition to the three samples from Tjøme, Outer Oslofjord (st. 36A1). The results, where concentrations were above the LOQ, indicated no statistically difference for Hg, TBT, p-p`-DDE, MCCP and SCCP, but st. 36A1 had significantly higher concentrations of PCB-7, and lower concentrations of sum of six PBDEs (BDE6) and BDE47. The differences in all cases was less than two.

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 irreversible male sex-characters in female dogwhelk, known as imposex, was quantified by the *Vas Deferens Sequence Index* (VDSI) analysed according to OSPAR-CEMP guidelines. The VDSI ranges from zero (no effect) to six (maximum imposex effect) (Gibbs et al. 1987). Detailed information about the chemical analyses of the animals is given in Følsvik et al. (1999).

Dogwhelk lives on wave-exposed hard bottom areas in the tidal zone. 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, and about 25 females were analysed. All snails were sampled by NIVA except for the dogwhelk collected in Lofoten and in the Varangerfjord. The snail samples were collected from 7nd September to 15th October 2020.

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

2.1.4 Atlantic cod

Atlantic cod was caught from 17 stations (***Figure 3***). The goal was to get a minimum of 15 cod from each station, but for four stations that was not possible. The cod was sampled from 16th August to 1th December 2020. Cod was caught by local fishermen except for the cod in the Inner Oslofjord (st. 30B) which was collected by NIVA by trawling from the research vessel *F/F Trygve Braarud* owned and operated by the University of Oslo (UiO). Instructions were given to the fishermen to catch coastal cod. Coastal cod is more attached to one place than open ocean cod which migrate considerably farther than coastal cod. Some spot checks were taken looking at the cross-section pattern of the otoliths (Stransky et al. 2007) which confirmed, at least for these samples, that only coastal cod was caught. The otoliths are stored for further verification if necessary. 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.

Livers were in general not large enough to accommodate all the analyses planned (see ***Appendix E***). Tjøme in the Outer Oslofjord (st. 36B), Skågskjera near Farsund (st. 15B), the Inner Sørfjord (st. 53B), Bømlo in the Outer Selbjørnfjord (st. 23B), Trondheim harbour (st. 80B), Sandnessjøen area (st. 96B), Austnesfjord in Lofoten (st. 98B1), Tromsø harbour (st. 43B2), Kjøfjord in the Outer Varangerfjord (st. 10B) and Svalbard (st. 19B) were the 10 stations where all 15 individuals had sufficient liver size to complete all of the intended analyses. The general lack of material was partially compensated for by making pooled samples of livers. These are noted in the tables below (e.g. ***Table 10***). The concerns using pooled samples or small sample size in cod are discussed in an earlier report (Green et al. 2015).

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

2.1.5 European flounder

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

Flounder was caught 26th August 2020 by a local fisherman, then frozen and sent to NIVA. Tissue samples from each fish were prepared at NIVA.

2.1.6 Common eider

Contaminants in the Common eider were investigated at one station in Svalbard (Breøyane st. 19N), which the present study considered as a reference station. Blood samples were collected from 15 individuals (two subsamples from each) and eggs from 15 other individuals on 5th June 2020 (***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 2020-samples is shown in ***Table 1***. In the present study, total Hg (organic and inorganic, here abbreviated to Hg) is reported.

***Table 1**. Analyses and target organisms of 2020. The numbers indicate the total of stations investigated. (See also **Appendix B** for complete list of chemical codes.)*

Parameter	Blue mussel	Dogwhelk	Common periwinkle	Cod liver	Cod fillet	Flounder liver	Flounder fillet	Eider blood	Eider egg*
Metals Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)	25		1**	17		1		1	1
Mercury (total Hg)	26		1**		17		1	1	1
Organotin (MBT, DBT, TBT, TPhT)	7	8	1						
PCB-7 (PCB-28, -52, -101, -118, -138, -153, and -180**)**	24			16		1		1	1
ΣDDT (p-p`-DDT, p-p`-DDE***, p-p`-DDD**)**	15		1**	7		1			
PAH** and KPAH** ACNE, ACNLE, ANT, BAA, BAP, BBJF, BKF, BGHIP, CHR, DBA3A, FLE, FLU, ICDP, NAP, PA, PYR	7		1**						
Polybrominated diphenyl ethers (PBDEs) BDE28, 47, 99, 100, 126, 153, 154, 183, 196 and 209	11			11				1	1
Perfluorinated alkylated substances (PFAS) PFNA, PFOA, PFHpA, PFHxA, PFHxS, PFOS, PFBS, PFOSA	6			10				1	1
Hexabromocyclododecane (HBCD: α-, β-, γ-HBCD**)**	11			13				1	1
Chlorinated paraffins (SCCP (C10-C13) and MCCP (C14-C17)**)**	11			13				1	1
Siloxanes (D4, D5 and D6)				5				1	1
HCB, OCS, QCB	14		1**	7		1		1*****	1*****

*) Homogenate of yolk and albumin.
**) Extra analysis of common periwinkle in 2020.
***) Referred to as DDE in the report.
****) 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 (see ***Appendix B***).

An overview of the applied analytic methods is presented in ***Table 2***. Metal analyses were moved to another Eurofins laboratory (WEJ) and a different method was applied[1]. The new method had LOQs that were the same or lower with the exception for Ag, which had a LOQ of 0.004 mg/kg w.w. before and 0.05 mg/kg w.w. with the new methods. This was accepted by Norwegian Environment Agency on 20th November 2019. Chemical analyses were performed separately for each cod liver, if possible, otherwise a pooled sampled was taken (see «count» for the relevant tables, e.g. ***Table 12****)*. Mercury was analysed on a fillet sample from each cod. Furthermore, Biological Effects Methods (BEM) were performed on individual cod.

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

***Table 2**. Overview of method of analyses (see **Appendix B** for description of chemical codes). Limit of quantification (LOQ) is indicated. See **Chapter 2.2.2** for description of the labs used for the different analysis.*

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

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

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

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

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

2.2.2 Laboratories and brief method descriptions

The 2020-samples were analysed by Eurofins by Eurofins Environment Testing Norway AS in Moss (EFM) (dry matter), Eurofins GfA Lab Service GmbH (GFA) (organic parameters including SnOrg) Hamburg in Germany and Eurofins WEJ Contaminants GmbH (WEJ) (metals) also in Hamburg (see ***Table 2***). 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. Stable isotopes of nitrogen and carbon were analysed by the Institute for Energy Technology (IFE). A brief description of the analytical methods can be found in an earlier report (Green et al. 2008).

Metals were analysed at WEJ according to NS EN ISO 17025. Metals were extracted using nitric acid and quantified using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), except for Cr, which was determined using GAAS or ICP-Atomic Emission Spectroscopy (ICP-AES). Mercury (total) has been analysed using Cold-Vapour AAS (CVAAS). Metal analyzed at NILU where added with acid and digested with high pressure and temperature before determination with ICP-MS.

Polychlorinated biphenyls (PCB-7), BDEs and other halogenated substances were analysed at Eurofins GFA using GC-MS, except for HBCD that were analysed by LC-MS/MS to be able to determine the different congeners. The sample where extracted with organic solvent and the extract cleaned up prior to instrumental analysis.

Samples for analyses of PCB-7, PBDEs and the other halogenated organic contaminants at NILU were extracted with a suitable organic solvent. The lipid and other interferences are removed with the use of sulfuric acid and silica SPE (solid phase extraction) before the compounds are detected with help of GC-HRMS or GC-QTOf-MS. One exception is the determination of HBCD, they were extracted and cleaned together with the PBDEs, but the quantification was done with LC-TOF-MS.

Polycyclic aromatic hydrocarbons (PAH) were analysed at GFA using a gas chromatograph (GC) coupled to a mass-selective detector (MSD). The individual PAHs are distinguished by the retention time and/or significant ions. From 2016 to 2017 there was an increase in LOQs for naphthalene, which might impact results for this group of compounds but also where they are included in other summations of PAHs (see ***Table 2***).

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

Analysis of organotin (TBT, MBT, DBT and TPhT) 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 Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) international intercalibration exercises of organotin analyses with acceptable results Green et al. (2017).

Analysis of perfluorinated alkylated substances (PFAS) in blue mussel and cod liver (including supplementary analyses of stored cod liver 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 LOQ 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.

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

Stabile Isotop Analysis (SIA) is performed by first drying the samples in at least 12 hours, before they are homogenized and incinerated at high temperature in an element analyzer. The gasses are separated on a GC column before the isotope ration mass are demined in an isotope ratio mass spectrometer (IRMS).

For fish, the target tissues for quantification of hazardous substances were liver and fillet (Hg only) (***Table 1***), whereas for the biological effects methods (BEM) liver, blood and bile were used (cf. ***Table 3***). 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 and common periwinkle were analysed for organotin compounds (see ***Table 2***).

2.3 Biological effects analysis

Four biological effects methods (BEM; biomarker analysis) are assessed using methods described by ICES (see ***Table 2***) 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 3***. 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 3. *The relevant contaminant-specific biological effects methods applied.*

Code	Name	Tissue sampled	Specificity
OH-pyrene	Pyrene metabolite	cod bile	PAH
ALA-D	δ-aminolevulinic acid dehydrase inhibition	cod red blood cells	Pb
EROD-activity	Cytochrome P450 1A-activity	cod 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.

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

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

2.3.1 Rationale and overview

A thorough analysis and review of BEM-results has been performed twice since their inclusion in 1997 (Ruus, Hylland, and Green 2003; Hylland et al. 2009). Clear relationships were shown between tissue contaminants, physiological status and responses in BEM parameters in cod (Hylland et al. 2009). Although metals contributed substantially to the models for ALA-D (and also for metallothionein (MT) included in the programme 1997-2001) and organochlorines in the model for CYP1A activity, other factors were also shown to be important. Liver lipid and liver somatic index (LSI) contributed for all three BEM-parameters, presumably reflecting the general health of the fish. Size or age of the fish also exerted significant contributions to the regression models. It was concluded that the biological effect methods clearly reflected relevant processes in the fish even if they may not be used alone to indicate pollution status for specific stations at given times. Furthermore, the study showed that it is important to integrate a range of biological and chemical methods in any assessment of contaminant impacts. Through continuous monitoring, 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 2***). 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 2020 included four biological effects methods (BEM) (cf. ***Table 3***). 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 affect the reproductive capabilities of dogwhelk and common periwinkle. This impact is assessed when dogwhelk and the common periwinkle are analysed for imposex and intersex[1], respectively see ***Table 2***).

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, BIPEA), international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, round 2020-1 apply to the 2020-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 2019 samples (cf. Green et al. 2020 – M-1894|2020).

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. NIVA also participated 12.10.2021, but the score is not reported yet.

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. Processing and measurement in CRM are comparable to sample matrices even though in certain cases the matrices differ. 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. However, the PFC analysis is not accredited according to this ISO-standard.

2.5 Stable isotopes

Stable isotopes of nitrogen and carbon were analysed by the Institute for Energy Technology (IFE). Analyses of nitrogen and carbon isotopes were done by combustion in an element analyser, reduction of NOx in Cu-oven, separation of N_2 and CO_2 on a GC-column and determination of $\delta^{13}C$ and $\delta^{15}N$ at IRMS (Isotope Ratio Mass Spectrometer). Stable isotope ratios were expressed in δ notation as the deviation from standard (Ruus 2015). Abundances were expressed in δ notation as parts per thousand (‰) according to the following:

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

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

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

2.6 Treatment of values below the quantification limit

Values below the limit of quantification (LOQ) are set to a random number between the LOQ and half of the value of this limit for calculation for use in time trends, using the median trend over 10 replicates as the trend. This is a simplified, pragmatic approach that often has been recommended. When most values are over LOQ, and LOQ is stable over time, this returns reasonable results. When most values are under LOQ, no upward or downward trend are detected, as desirable. We have previously judged this to be approximately in accordance to OSPAR protocol (OSPAR 2013). The exact procedure in OSPAR MIME has not been used as it has been in continuous development, and the code has not been published. However, this method is unreliable when LOQ changes (see below), and will be replaced by a more modern statistical method in future assessments. For “sum” variables, individual compounds below LOQ (e.g. PCB-7) have been set to LOQ. The annual median is classified as less-than if over half of the values are below the LOQ and is assigned the median value prefixed with a “<” sign in ***Appendix F***. When such values are presented in tables of the main text, then the cells are shaded, and the LOQ is shown. It should be noted that the LOQ for the same parameter can vary within and among sets of samples if all the conditions are not met.

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.

When evaluating time trends, care must be taken both when LOQs are changed and especially when several results are below LOQ. There are several reasons for changes of LOQs, but these are mainly a result of changing lab and/or changes in the analytical method. Traditionally, the determination of metals is very robust, and usually the LOQs don’t change much over time. A simple sample preparation will often give a relevant environmental LOQ for most metals assessed against EQS and other relevant environmental criteria. For the organic pollutants there is often higher LOQ than what is considered necessary with regards to relevant environmental guidelines (e.g. EQS) because of technical and cost issues. To achieve the necessary low LOQs the method is often pushed downwards, and therefore the LOQs can be dependent on the constituent of the sample. As a result, the LOQ can vary with the sample. To achieve a stable LOQ it must be able to account for the matrix differences and will therefore be set higher to include changes in matrices and method variability. This has been implemented to a lesser degree in analysis of organic environmental pollutants in organisms because of the low EQS for many pollutants. The lipid content of the sample and the levels of blank samples are typical factors that can affect the LOQ.

For this program, there have been changes in laboratories and methods the last 10 years. In the program period from 2012, the analytical provider was changed from NIVA to Eurofins Moss. However, the methods were mainly the same, and only minor changes of the LOQ occurred. For the program period (starting 2017) the organic pollutants were analysed at Eurofins GFA, leading to discrepancies in both methods employed and LOQs. For PCBs, the LOQs were increased somewhat (except CB118 which was lowered). For BDE, the LOQs were mainly lowered somewhat, while for PAHs they were increased for some of the congeners. The metal analyses were changed in 2019 where most LOQs were lowered, while for Ag the LOQ was increased.

Figure 4 gives the proportion over LOQ (detection frequency, in %) of the various compounds for each tissue and **Figure 5** gives the observed LOQ (median values) in blue mussel in the various compounds since 2000.

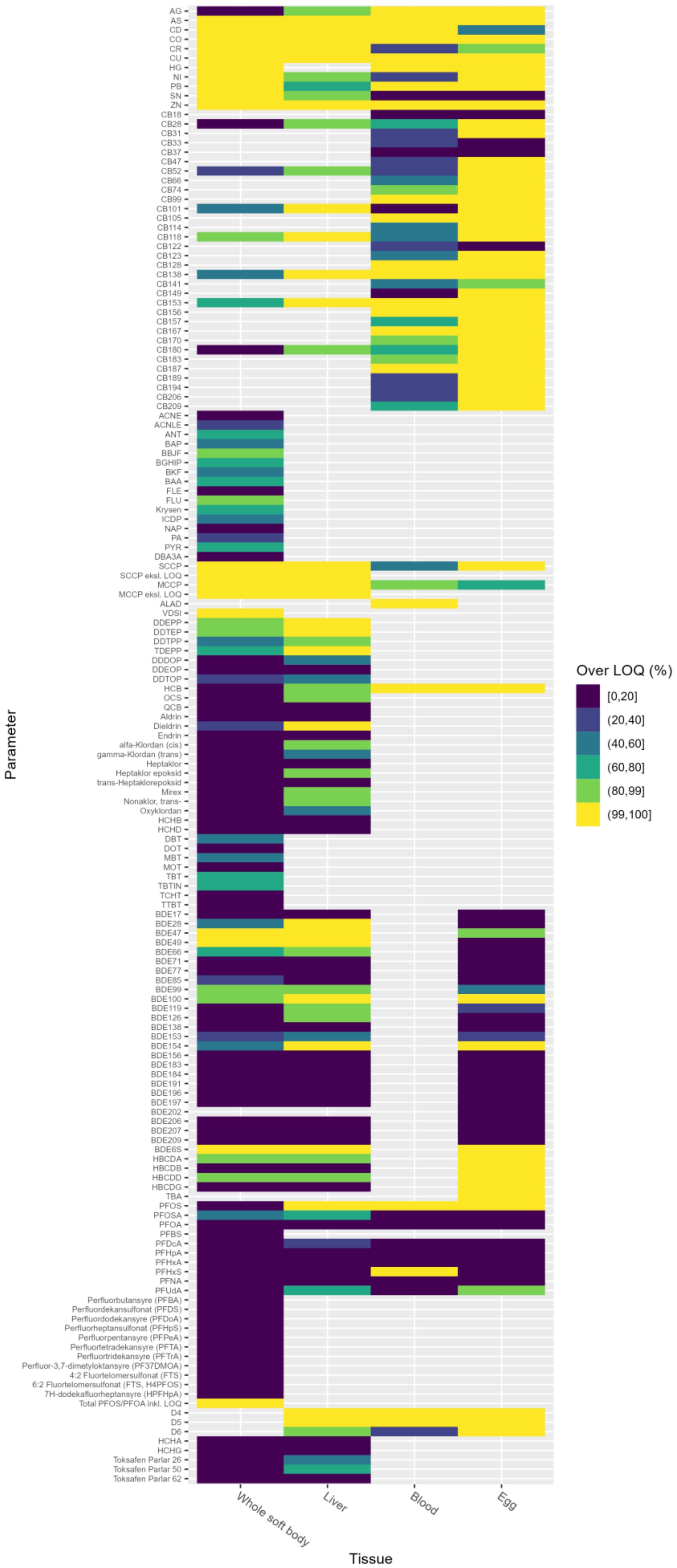

Figure 4. Proportion over LOQ (detection frequency, in %) of the compounds for each tissue.

Figure 5. Observed LOQ (median values) in blue mussel of the various compounds since 2000. The colors are factors vs. the latest year in the period 2010-2015, with blue colors showing improvement (lower LOQ) and red colors showing increased LOQ. For some groups, e.g. PFAS, there were no measurements in these years (shown in light yellow).

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 8***, ***Table 9***). There is a provision in this daughter directive which allows a country to develop their own EQS for water, sediment and biota provided these offer the same level of protection as the EQS set for water. Norway used this approach and developed their own EQS for biota, water and sediments for "river basin specific pollutants" not otherwise accounted for by the EU directives (Direktoratsgruppen 2018).

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

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

The application of these standards has been discussed previously (Green et al. 2016), and three main challenges were noted. The first is that the standards for biota are generally not species or tissue specific but refer to whole organisms. The second is that the standards are often in large conflict with the system based on background concentrations (see Chapter 3.8.3 in Green et al. 2016). And lastly, the standards do not address all the contaminants in all the tissues that are monitored, for example, there are no EQS for metals in biota except for Hg. To address this issue for this report, and in dialogue with the Norwegian Environment Agency, *Norwegian provisional high reference contaminant concentrations* (PROREF) were derived and used in parallel with the risk-based standards (see method description below).

This report of the 2020-investigations addresses the principle cases primarily where median concentrations exceeded EQS and secondarily where median concentrations exceeded PROREF (***Table 8***, ***Table 9***). Exceedances of PROREF (see derivation explained in **Chapter 2.7.2)** were grouped in six factor-intervals: <x, 1-2x (between PROREF and two times PROREF), 2-5x, 5-10x, 10-20x and >20x.

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

2.7.2 Derivation of PROREF

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

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

1. Selection of reference stations:
    a. Only data from 1991 to 2016 were considered (25 years) on the general assumption that prior to this time important discharge reductions were not in place.
    b. Annual median concentrations were determined for each combination of contaminant, station, species, tissue and basis (e.g. wet weight).
    c. The highest 10 % of these medians were discarded for each station; as this was considered a reasonable limit to remove medians which had substantially higher concentrations than other years.
    d. In order to get a robust set of stations, we considered only stations which had at least five years of data, counting only years with at least two analysed samples for blue mussel stations and 10 analysed samples for cod stations. I.e., we allowed for some deviance from standard sample size, which according to present procedures is three for blue mussel and 15 for cod.
    e. The stations were ordered by concentration from the lowest to the highest based on the median of the annual medians.
    f. Values below the limit of quantification (LOQ) were set to a random value between half the LOQ and the LOQ.
    g. The station with the lowest concentration was compared to the station with the next lowest using a t-test where the log-transformed annual medians were used to determine the variance at the station.
    h. If the two stations were not statistically different, these data were compared to the third lowest station, and this process continued until a significant difference was noted.
    i. All stations that were not statistically different formed the group of reference stations for a unique combination for contaminant, species, tissue and basis.
2. Application of raw data:
    j. All the raw data from the reference stations for the unique combination of contaminant, species, tissue and basis for the period 1991-2016 were used.
    k. PROREF was defined as the upper 95 percentile.

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

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

An overview of the PROREF applied in this report is shown in ***Appendix C***, and a summary comparing PROREF with the existing EQS and the national classification system used in previous reports is shown in ***Table 4***. PROREF values were adjusted slightly for the previous report to ensure that the values used are exclusively from the MILKYS programme. In only four cases did the revised PROREF lead to a difference of over 20 % and only restricted to blue mussel: 32 and 38 % lower for As and anthracene, respectively, and 46 and 47 % higher for PCB-7 and BDE6, respectively (***Table 4***, ***Appendix C***).

In this report assessment of the change in PROREF from 2019 to 2020 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, BDE6, HBCDA, PYR10 and ALAD in cod. PROREF could not be calculated for three PCBs (PCB-81, PCB-126 and PCB-169) and PFAS in blue mussel and perfluoroundecanoic acid (PFUdA) in cod liver because the data did not meet criteria “d” above.

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

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

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

Table 4*. Overview of Norwegian provisional high reference contaminant concentration (PROREF) used in this report for the stations from which PROREF was derived (in w.w.). Also shown are the Environmental Quality Standards (EQS) for "biota"* [1] *(2013/39/EU 2013) and national environmental quality standards* [2] *(Norwegian_Environment_Agency 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 weight. basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
As	*Mytilus edulis*	**Soft body**	31A,I301,I023,30A,I712	**5**	116	mg/kg	2.503	3.3150	1.3247		
Hg	*Mytilus edulis*	**Soft body**	36A,46A,10A2	**3**	137	mg/kg	0.012	0.0100	0.8197	0.020	1.6393
PCB-S7[3]	*Mytilus edulis*	**Soft body**	10A2,41A,11X,98A2,64A,97A2	**6**	194	µg/kg	1.157	0.4891	0.4228	0.600[4]	0.5187
DDE	*Mytilus edulis*	**Soft body**	43A,41A,10A2,11X	**4**	147	µg/kg	0.224	0.2240	1.0000	610.000[5]	2 723.2143
HCB	*Mytilus edulis*	**Soft body**	48A,43A,15A,22A,46A,41A,98A2,11X,30A,10A2,36A	**11**	473	µg/kg	0.100	0.1000	1.0000	10.000	100.0000
HBCDA	*Mytilus edulis*	**Soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.110	0.1099	1.0000	167.000	1 520.2549
BDE6[7]	*Mytilus edulis*	**Soft body**	98A2,26A2,91A2,71A,I023,97A2,30A	**7**	109	µg/kg	0.408	0.1900	0.4657	0.009	0.0208
BDE47	*Mytilus edulis*	**Soft body**	98A2,26A2,71A,I023,91A2,30A	**6**	94	µg/kg	0.171	0.1410	0.8270	0.009[8]	0.0499
SCCP	*Mytilus edulis*	**Soft body**	I023,71A,91A2,97A2,26A2,30A	**6**	90	µg/kg	20.260	20.2600	1.0000	6 000.000	296.1500
MCCP	*Mytilus edulis*	**Soft body**	I023,26A2,71A,91A2,97A2,30A	**6**	89	µg/kg	87.600	87.6000	1.0000	170.000	1.9406
ANT[6]	*Mytilus edulis*	**Soft body**	98A2,I131A,I307,I915,I913,71A	**6**	208	µg/kg	0.800	1.1000	1.3750	2 400.000	3 000.0000
BAA[6]	*Mytilus edulis*	**Soft body**	I023,98A2	**2**	32	µg/kg	1.490	1.4900	1.0000	300.000	201.3423
BAP[6]	*Mytilus edulis*	**Soft body**	98A2,I307,I131A,I306,I304,30A,I913	**7**	354	µg/kg	1.200	1.3000	1.0833	5.000	4.1667
FLU[6]	*Mytilus edulis*	**Soft body**	98A2,I023	**2**	32	µg/kg	5.350	5.3500	1.0000	30.000	5.6075
NAP[6]	*Mytilus edulis*	**Soft body**	I023,98A2,71A	**3**	47	µg/kg	17.300	17.3000	1.0000	2 400.000	138.7283
TBT	*Mytilus edulis*	**Soft body**	11X	**1**	20	µg/kg	7.107	7.1065	1.0000	150.000	21.1074
TBT	*Nucella lapillus*	**Soft body**	11G,131G,15G,98G	**4**	66	µg/kg	23.540	23.5350	0.9998	150.000	6.3721
PCB-7	*Gadus morhua*	**Liver**	98B1,10B,92B,43B	**4**	1229	µg/kg	614.000	614.0000	1.0000	0.600	0.0010
DDE	*Gadus morhua*	**Liver**	23B,10B,98B1	**3**	1498	µg/kg	160.750	160.7500	1.0000	610.000[5]	3.7947
HCB	*Gadus morhua*	**Liver**	36B,53B	**2**	1079	µg/kg	14.000	14.0000	1.0000	10.000	0.7143
4-N-NP	*Gadus morhua*	**Liver**	80B,43B2	**2**	135	µg/kg	131.000	131.0000	1.0000	3 000.000	22.9008
4-N-OP	*Gadus morhua*	**Liver**	43B2,80B	**2**	135	µg/kg	23.500	23.5000	1.0000	0.004	0.0002
4-T-NP	*Gadus morhua*	**Liver**	43B2,80B	**2**	135	µg/kg	240.900	240.9000	1.0000	3 000.000	12.4533
HBCDA	*Gadus morhua*	**Liver**	43B2	**1**	65	µg/kg	7.000	7.0000	1.0000	167.000	23.8571
BDE6[7]	*Gadus morhua*	**Liver**	98B1	**1**	173	µg/kg	19.882	19.8800	0.9999	0.009	0.0004
BDE47	*Gadus morhua*	**Liver**	98B1,36B,23B	**3**	557	µg/kg	16.000	16.0000	1.0000	0.009[8]	0.0005
SCCP	*Gadus morhua*	**Liver**	23B,43B2,80B	**3**	245	µg/kg	154.000	154.0000	1.0000	6 000.000	38.9610
MCCP	*Gadus morhua*	**Liver**	23B,43B2	**2**	174	µg/kg	392.800	392.8000	1.0000	170.000	0.4328
PFOA	*Gadus morhua*	**Liver**	43B2,13B,80B,53B,36B,98B1,23B,30B	**8**	1289	µg/kg	10.000	10.0000	1.0000	91.000	9.1000
PFOS	*Gadus morhua*	**Liver**	43B2,80B	**2**	251	µg/kg	10.250	10.2500	1.0000	9.100	0.8878
Hg	*Gadus morhua*	**Fillet**	10B	**1**	504	mg/kg	0.056	0.0600	1.0714	0.020	0.3571

1) Environmental Quality Standard (EQS) as derived from 2013/39/EU and compounds and national environmental quality standards as derived from Arp et al. (2014) and modified by the Norwegian Environment Agency and finalized (Norwegian_Environment_Agency 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) (Miljødirektoratet, pers. comm. 16th June 2017).
5) For the present study the same limit was applied to DDE (p,p DDE).
6) Applies to Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish). Benzo(a)pyrene is considered a marker for other PAHs (2013/39/EU).
7) Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa).
8) Not official EQS for BDE47, but this PBDE is often the most dominant BDE.

Proposed background assessment criteria (BAC) for EROD, OH-pyrene and VDSI (OSPAR 2013) were used to assess the results (***Table 5***).

Table 5*. 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	-	p mol/min/ mg microsomal protein
OH-pyrene	cod liver	0.8*	-	ng/ml; HPLC-F
VDSI	dogwhelk	0.3	2	

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

2.8 Statistical time trend analysis – the model approach

A simple model approach has been developed within OSPAR and ICES to study time trends for contaminants in biota based on median concentration (ASMO 1994). The method has been applied to Norwegian data and results are shown in ***Appendix F***. The results can be presented as shown in ***Figure 6***. It should be noted that this robust method has been developed so that it could provide a rough guide to possible trends in the OSPAR region. Further investigation is necessary to better understand the factors affecting a particular trend. This may lead to different conclusions. As an exercise in this respect the times series for Hg in cod fillet from the Inner Oslofjord were examined more closely (Green et al. 2015).

The model approach uses a Loess[1] smoother based on a running six-year interval where a non-parametric curve is fitted to median log-concentration as defined by Nicholson et al. (1991; 1994; 1997) with revisions (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 (ASMO 1994), (Nicholson, Fryer, and Larsen 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 (i.e. >LOQ, denoted N_+). If N_+ is 5-6, a linear trend is tested, if N_+ is ≥7, one tests whether there is a significant difference in the smoothed annual concentration at the beginning of the time series compared the smoothed annual

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

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 short-term trend may not necessarily include data for 2020. 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 <LOQ, 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.

As described in chapter 2.6, 10 upward short-term trends for PCB-7 and one upward short-term trend for Ag in blue mussel were caused by methodical (artificial) results due to higher limits of quantifications (LOQ). For each CB parameter, we defined robust increases as increase when there are at least two years among 2017-2020 that has >50% over LOQ. For each station, we defined robust PCB-7 increase as having three parameters with robust increase. In addition, we checked whether there was significant short-term increase of the sum of the medians of CB118, CB138 and CB153, using only years when all three had ≥50% concentrations over LOQ. The two stations Vågsvåg (st. 26A2) and Gressholmen (st. 30A) satisfied both criteria for a robust increase.

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

The statistical analysis of time trends was carried out on all the results, including those for biological effects parameters. These analyses as well as the figures similar to that shown in ***Figure* 6** were performed using R Statistical Software (R-Core-Team 2021) version 4.0.2 with the packages nlme (nonlinear mixed effects, version 3.1-148) and mgcv (Generalized Linear Models including Generalized Additive Models and Generalized Additive Mixed Models, version 1.8-31).

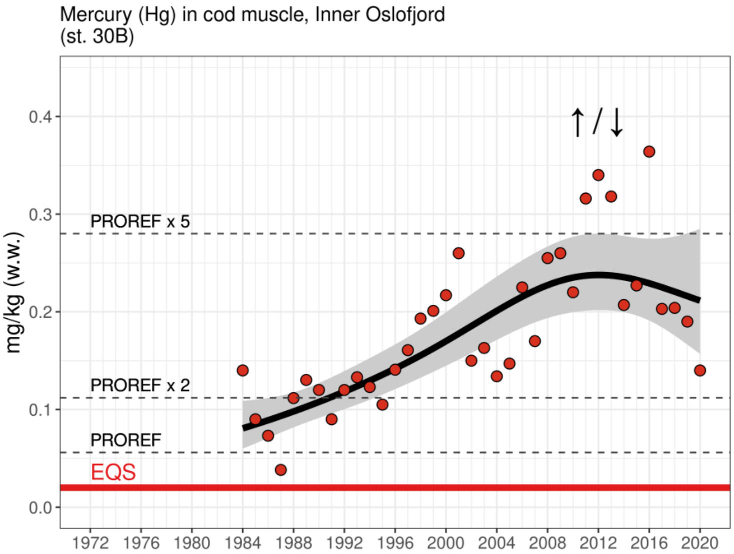

Figure 6. *Example of time series (Hg in cod fillet from the Inner Oslofjord, st. 30B) that shows the median concentration (dots), running mean of median values (Loess smoother – thick black line) and 95 % confidence intervals surrounding the running mean (grey zone). A horizontal thick red line indicates the Environmental Quality Standard (EQS) if it can be applied and if it can be shown on the scale of concentration provided. A red dot indicates that the median value is above the EQS, a blue dot indicates that the value is below the EQS (not shown in the example figure), and a grey dot (not shown in the example figure) indicates that EQS can not be applied. The horizontal dashed grey lines indicate the lower boundaries relative to PROREF[1]; where, in addition to values below PROREF, exceedances are indicated, by a factor of: 1-2, 2-5, 5-10, 10-20 and greater than 20 (the latter three categories are not shown in the example figure). Note that PROREF can vary depending on species, tissue and contaminant. A light blue triangle (see for example* ***Figure 60 B****) indicates that the median was below the LOQ. A summary of the trend analyses is indicated on time series with five or more years and the results, left side of 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 2011-2020 (short-term or recent trend) and the result is shown on the right side of the slash. A small filled square (▪) (not shown in the example figure) indicates that chemical analysis has been performed, but data either were insufficient to do a trend analysis or was not presented. Results marked with a star (★) (not shown in the example figure) indicate that there is insufficient data above the quantification limit (LOQ) 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

Specific analyses to test the differences between stations or years were done on the statistical package R using the non-parametric Tukey-Kramer HSD (Honestly Significant Difference). A significance level of α = 0.05 was chosen.

Statistical analyses (linear regression) on stable isotope data were performed using R software version 4.0.2 with the packages nlme (version 3.1-148) and mgcv (version 1.8-31). A significance level of α = 0.05 was chosen.

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

2.10 Note on presentation of contaminant tables

Summaries of the results for some organic contaminants are presented in ***10*** to ***Table 11***. These tables provide some extensive details and warrant explanation. Some of the analyses, especially of the “new” contaminants (e.g. HBCD, SCCP/MCCP, BPA and TBBPA), revealed a vast number of results that are below the limit of quantification (LOQ). This resulted in a number of median values below the LOQ. It was considered added-value to convey some information about the concentrations that were quantifiable even though the median was below the LOQ. To achieve this, *Detectable data information* (D.d.i.) was introduced. D.d.i. shows the count of concentrations above the LOQ and the minimum and maximum of these values.

An extract from ***Table 12*** is shown below in ***Table 6*** 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 12 samples whereof seven were pooled with a maximum of six fish livers in each pool. This means that analyses were done on five individual cod (12-7=5). Note that the values for median (“Med.”) and standard deviation (“S.d.”) are rounded, and for example “0.000” represents a number greater than zero but less than 0.0005. The “D.d.i.” for eider blood from Breøyane is blank and indicates that none of the 15 values were above LOQ, whereas for blue mussel from Gressholmen, the D.d.i. indicates that two of the three samples had concentrations of BDE28 above LOQ (0.001 µg/kg w.w.). Note that when a dataset contains values below LOQ, the median takes these as an average of ten random numbers between half the LOQ and the LOQ (see **Chapter 2.6**).

Table 6*. Example table – extract from* ***Table 12****. Count indicates number of samples analysed in 2020. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in any one of the pooled samples. Shaded cells indicate that the median (Med.) was the limit of quantification (LOQ) and value shown in these cells is this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See text for more detail).*

Component	Count	BDE28		
Species and sampling locality	2020	Med.	S.d.	D.d.i
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.001	0.000	2 [0.001-0.001]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.001	0.000	1 [0.001]
Cod, liver				
Inner Oslofjord (st. 30B)	12 (7-6)	0.298	0.135	12 [0.11-0.6]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	0.198	0.209	15 [0.01-0.74]
Eider, blood				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.006	0.015	0 [n.a.]
Eider, egg				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.006	0.002	1 [0.01]

3. Results and discussion

3.1 General information on measurements

3.1.1 Levels and temporal trends of contaminants

This report describes findings from monitoring activities conducted as part of MILKYS in 2020. A selected set of the contaminants (or groups of contaminants) monitored in biota as part of this monitoring programme is shown in ***Table 7***. A summary of levels and trends for the selected contaminants and effects in blue mussel, dogwhelk, common periwinkle, cod, flounder and common eider along the coast of Norway in 2020 is shown in ***Table 8*** and ***Table 9***, respectively. Details on trend analyses are shown in ***Appendix F***. These results include a total of 3259 data sets (contaminant[1]-station-species-tissue) for 176 individual chemical substances. Of these substances, 30 have been selected for particular review in this report. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period[2], whereas a short-term trend refers to the analysis on data for the last 10 years, i.e. 2011-2020 and can also be referred to as recent trend.

Assessment of levels and short-term trends were performed on a selection of 30 contaminants or their effects (VDSI/ISI), a total of 739 data series[3] for the 2020 data (***Table 7***). Of the 739 cases, 380 cases could be classified against EQS; 264 (35.7 %) were below the EQS and 116 (15.7 %) were above the EQS (***Figure 7 A***, ***Figure 8 A***). For 359 (48.6 %) cases, there are no EQS. Of the 739 cases, 644 could be compared to PROREF, and of these 447 (69.4 %) were below PROREF. The remaining 197 (30.6 %) cases exceeded PROREF: 105 (16.3 %) by a factor of less than two, 57 (8.9 %) by a factor between two and five, 30 (4.7 %) by a factor between five and 10, three (0.5 %) by a factor between 10 and 20, and two (0.3 %) by a factor greater than 20 (***Figure 7 B***, ***Figure 8 B***). Of the 739 data series, significant short-term trends were registered in 96 cases: 67 (9.1 %) were downward trends and 29 (3.9 %) were upwards (***Figure 7 C***). The downward trends were primarily associated with metals, HBCDA and BDEs (***Figure 8 C***). The upward trends were mainly associated with metals.

The primary focus in this report has been on identifying which of the 30 selected contaminants and biomarkers had a median concentration in 2020 that exceeded the EQS. The report secondarily focused on those contaminants where the Norwegian provisional high reference contaminant concentration (PROREF) was exceeded, and where significant upward trends were found. To a lesser extent, the report addressed those cases where no significant trends were found or significant downward trends were found, as well as those cases where median concentrations in 2020 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), (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 (Norwegian_Environment_Agency 2016) is presented in ***Appendix C***.

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

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

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

Table 7*. Selection of 30 contaminants/Biological Effect Methods (BEM) and number of time series assessed for each target species-tissue. The specific results are shown in* ***Table 9****.*

Environmental contaminants /Biomarker	Abbreviation	Blue mussel	Periwinkle	Dogwhelk	Cod, liver	Cod, fillet	Flounder, liver	Flounder, fillet	Eider, blood	Eider, egg*	TOTAL
Ag	Silver	25	1**		17		1		1	1	46
Cd	Cadmium	25	1**		17		1		1	1	46
Co	Cobalt	25	1**		17		1		1	1	46
Cr	Chromium	25	1**		17		1		1	1	46
Total-Hg	Mercury, inorganic and organic	26	1**			17		1	1	1	47
Ni	Nickel	25	1**		17		1		1	1	46
Pb	Lead	25	1**		17		1		1	1	46
PCB-7	Sum of PCB congeners 28+52+101+118+138+153+180	24			16		1		1	1	43
DDE	p,p'-DDE (a DDT metabolite)	15	1**		7		1				24
HCB	Hexachlorobenzene	14	1**		7		1		1	1	25
HBCDA	α–hexabromocyclododecane	11			13				1	1	26
BDE-6	Sum of PBDE congeners 28+47+99+100+153+154	11			11				1	1	24
BDE47	PBDE congener 47	11			11				1	1	24
BDE100	PBDE congener 100	11			11				1	1	24
BDE209	PBDE congener 209	11			11				1	1	24
SCCP	Short-chain chlorinated Paraffins (C10-C13)	11			13				1	1	26
MCCP	Medium-chain chlorinated Paraffins (C14-C17)	11			13				1	1	26
PAHs***	Sum nondicyclic PAHs	7	1**								8
ANT	Anthracene	7	1**								8
BAA	Benzo[a]anthracene	7	1**								8
B[a]P	Benzo[a]pyrene	7	1**								8
FLU	Fluoranthene	7	1**								8
NAP	Naphthalene	7	1**								8
PFOA	Perfluorooctanoic acid	6			10				1	1	18
PFOS	Perfluorooctanesulfonic acid	6			10				1	1	18
PFOSA	Perfluorooctanesulfonamide	6			10				1	1	18
TBT	Tributyltin (formulation basis)	7	1	8							16
TPhT	Triphenyltin	7	1	8							16
VDSI/ISI****	Vas Deferens Sequence Index/ Intersex Index		1	8							9
D5	Decamethylcyclopentasiloxane				5				1	1	7
TOTAL		**380**	**18**	**24**	**250**	**17**	**9**	**1**	**20**	**20**	**739**

*) Homogenate of yolk and albumin.
**) Extra analysis of common periwinkle in 2020.
) 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 (see ***Appendix B).
****) VDSI/ISI is referred to as VDSI in tables and figures.

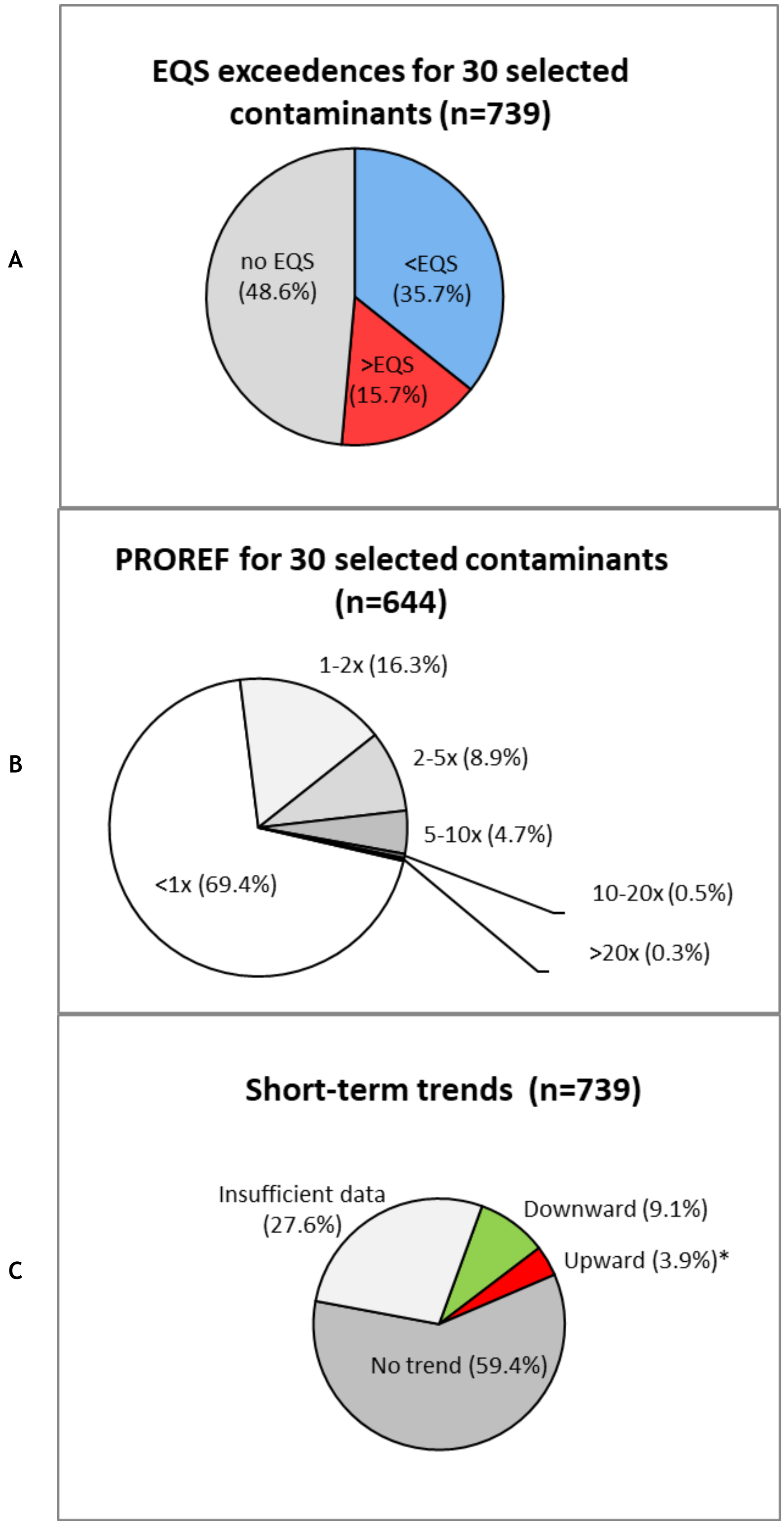


Figure 7. *Percent of samples (station-species-tissue) in 2020 exceeding EQS (A), in different categories relating to Norwegian provisional high reference contaminant concentration (PROREF) (**B**) and relating to the results from short-term trend analyses for 30 selected contaminants/Biological Effect Methods (BEM) (C). For blue mussel, 10 upward short-term trends for PCB-7 and one upward short-term trend for Ag are caused by methodical (artificial) results, as described in chapter 2.6. These are included in this overview figure (C) and are marked by a star (*). Details can be seen in **Table 9**.*

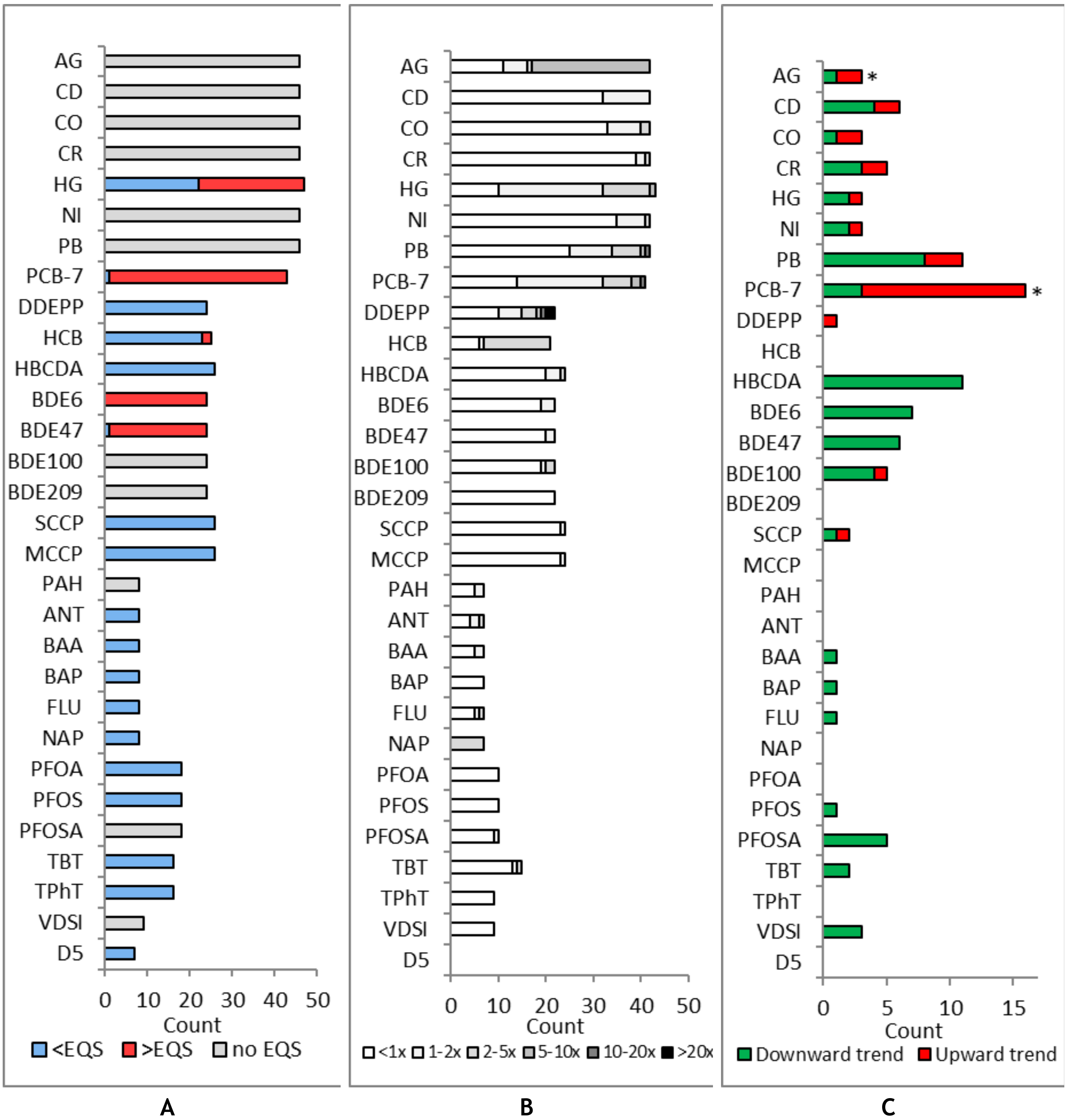


Figure 8. *Count of samples (station-species-tissue) in 2020 exceeding EQS (**A**), in different categories relating to Norwegian provisional high reference contaminant concentration (PROREF) (**B**) and relating to the results from short-term trends (**C**) for each of the 30 selected contaminants/Biological Effect Methods (BEM) (including results from the common eider, cf.* ***Table 7*** *(see* ***Appendix B*** *for description of chemical codes). For blue mussel, 10 upward short-term trends for PCB-7 and one upward short-term trend for Ag are caused by methodical (artificial) results, as described in chapter 2.6. These are included in this overview figure (C) and are marked by a star (*). Details can be seen in* ***Table 9****.*

Table 8**. 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 2020 in six species: blue mussel, cod, flounder, eider duck, common periwinkle and dogwhelk. Tissues: soft body (for blue mussel, dogwhelk and common periwinkle), liver*** (cod and flounder except for Hg***), fillet (cod and flounder, Hg), blood (eider duck) and eggs (eider duck). The grey-shade coding refers to exceedances of Norwegian provisional high reference contaminant concentration (PROREF): below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 20 (see **Appendix C**). Blue-filled circles ● indicate that the EQS was not exceeded and red-filled circles ● indicate that the EQS was exceeded. The EQS are set by the 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". Abbreviations for contaminants can be seen in **Appendix B**.*

Station name	Species	Tissue***	HG* ***	PCB-7**	DDEPP*	HCHG*	HBCDA*	BDE6*	BDE47	SCCP*	MCCP*	ANT*	BAA**	BAP*	FLU*	NAP*	PFOA*	PFOS*	TBT*	TPhT*	D5*	HCB*	QCB*
Gressholmen, Inner Oslofjord (st. 30A)	Blue mussel	Soft body	● blue	● red	● blue	● blue	● blue	● red	● red	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue		● blue	● blue
Akershuskaia, Inner Oslofjord (st. I301)	Blue mussel	Soft body	● blue	● red	● blue	● blue						● blue	● blue	● blue	● blue	● blue			● blue	● blue		● blue	● blue
Gåsøya, Inner Oslofjord (st. I304)	Blue mussel	Soft body	● blue	● red	● blue	● blue						● blue	● blue	● blue	● blue	● blue			● blue	● blue		● blue	● blue
Solbergstrand, Mid Oslofjord (st. 31A)	Blue mussel	Soft body	● blue	● red	● blue	● blue													● blue	● blue		● blue	● blue
Færder, Outer Oslofjord (st. 36A)	Blue mussel	Soft body	● blue	● red	● blue	● blue	● blue	● red	● red	● blue	● blue						● blue	● blue	● blue	● blue		● blue	● blue
Singlekalven, Hvaler (st. I023)	Blue mussel	Soft body	● blue	● red			● blue	● red	● red	● blue	● blue	● blue	● blue	● blue	● blue	● blue							
Kirkøy, Hvaler (st. I024)	Blue mussel	Soft body	● red	● red																			
Bjørkøya, Langesundfjord (st. 71A)	Blue mussel	Soft body	● red		● blue	● blue	● blue	● red	● red	● blue	● blue	● blue	● blue	● blue	● blue	● blue						● blue	● blue
Risøy (st. 76A2)	Blue mussel	Soft body	● blue	● red	● blue	● blue																● blue	● blue
Lastad, Søgne (st. I131A)	Blue mussel	Soft body	● blue									● blue	● blue	● blue	● blue	● blue							
Odderøya, Kristiansand harbour (st. I133)	Blue mussel	Soft body	● blue	● red	● blue	● blue													● blue	● blue		● blue	● blue
Gåsøya-Ullerøya, Farsund (st. 15A)	Blue mussel	Soft body	● blue	● red																			
Kvalnes, Mid Sørfjord (st. 56A)	Blue mussel	Soft body	● red	● red	● blue	● blue																● blue	● blue
Krossanes, Outer Sørfjord (st. 57A)	Blue mussel	Soft body	● red	● red	● blue	● blue																● blue	● blue
Utne, Outer Sørfjord (st. 64A)	Blue mussel	Soft body	● blue	● red	● blue																		
Vikingneset, Mid Hardangerfjord (st. 65A)	Blue mussel	Soft body	● blue	● red	● blue	● blue																● blue	● blue
Espevær, Outer Bømlafjord (st. 22A)	Blue mussel	Soft body	● blue	● red	● blue	● blue											● blue	● blue	● blue	● blue		● blue	● blue
Nordnes, Bergen harbour (st. I241)	Blue mussel	Soft body	● blue	● red			● blue	● red	● red	● blue	● blue						● blue	● blue					
Vågsvåg, Outer Nordfjord (st. 26A2)	Blue mussel	Soft body	● blue	● red			● blue	● red	● red	● blue	● blue												
Ålesund harbour (st. 28A2)	Blue mussel	Soft body	● blue	● red			● blue	● red	● red	● blue	● blue						● blue	● blue					
Ørland area, Outer Trondheimsfjord (st. 91A2)	Blue mussel	Soft body	● blue	● red			● blue	● red	● red	● blue	● blue												
Mjelle, Bodø area (st. 97A2)	Blue mussel	Soft body	● red	● red			● blue	● red	● red	● blue	● blue												
Bodø harbour (st. 97A3)	Blue mussel	Soft body	● blue	● red			● blue	● red	● red	● blue	● blue												
Svolvær airport area (st. 98A2)	Blue mussel	Soft body	● blue	● red			● blue	● red	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue	● blue					
Skallnes, Outer Varangerfjord (st. 10A2)	Blue mussel	Soft body	● blue	● red	● blue	● blue																● blue	● blue
Brashavn, Outer Varangerfjord (st. 11X)	Blue mussel	Soft body	● blue	● red	● blue	● blue																● blue	● blue
Inner Oslofjord (st. 30B)	Cod	Liver	● red	● red	● blue	● blue	● blue	● red	● red	● blue	● blue						● blue	● blue			● blue	● blue	● blue
Tjøme, Outer Oslofjord (st. 36B)	Cod	Liver	● red	● red	● blue	● blue	● blue	● red	● red	● blue	● blue						● blue	● blue				● blue	● blue
Kirkøy, Hvaler (st. 02B)	Cod	Liver	● red	● red			● blue			● blue	● blue												
Stathelle area, Langesundfjord (st. 71B)	Cod	Liver	● red				● blue			● blue	● blue												
Kristiansand harbour area (st. 13B)	Cod	Liver	● red	● red			● blue	● red	● red	● blue	● blue						● blue	● blue					
Skågskjera, Farsund (st. 15B)	Cod	Liver	● red	● red	● blue	● blue																● blue	● blue
Inner Sørfjord (st. 53B)	Cod	Liver	● red	● red	● blue	● blue	● blue	● red	● red	● blue	● blue						● blue	● blue				● blue	● blue
Bømlo, Outer Selbjørnfjord (st. 23B)	Cod	Liver	● red	● red	● blue	● blue	● blue	● red	● red	● blue	● blue						● blue	● blue				● blue	● blue
Bergen harbour area (st. 24B)	Cod	Liver	● red	● red			● blue	● red	● red	● blue	● blue						● blue	● blue			● blue		
Ålesund harbour area (st. 28B)	Cod	Liver	● red	● red			● blue	● red	● red	● blue	● blue												
Trondheim harbour (st. 80B)	Cod	Liver	● red	● red			● blue	● red	● red	● blue	● blue						● blue	● blue					
Sandnessjøen area (st. 96B)	Cod	Liver	● red	● red																			
Austnesfjord, Lofoten (st. 98B1)	Cod	Liver	● red	● red	● blue	● blue	● blue	● red	● red	● blue	● blue						● blue	● blue				● red	● blue
Tromsø harbour area (st. 43B2)	Cod	Liver	● red	● red			● blue	● red	● red	● blue	● blue						● blue	● blue			● blue		
Hammerfest harbour area (st. 45B2)	Cod	Liver	● red	● red																			
Kjøfjord, Outer Varangerfjord (st. 10B)	Cod	Liver	● red	● red	● blue	● blue															● blue	● red	● blue
Svalbard (st. 19B)	Cod	Liver	● blue	● red			● blue	● red	● red	● blue	● blue						● blue	● blue			● blue		
Sande, Mid Oslofjord (st. 33F)	Flounder	Liver	● red	● red	● blue	● blue																● blue	● blue
Breøyane (st. 19N)	Eider duck	Egg	● red	● red			● blue	● red	● red	● blue	● blue						● blue	● blue			● blue	● blue	
Breøyane (st. 19N)	Eider duck	Blood	● red	● blue			● blue	● red	● red	● blue	● blue						● blue	● blue			● blue	● blue	
Fugløyskjær, Outer Langesundfjord (st. 71G)	Periwinkle	Soft body	● red		● blue	● blue						● blue	● blue	● blue	● blue	● blue			● blue	● blue		● blue	● blue
Færder, Outer Oslofjord (st. 36G)	Dogwhelk	Soft body																	● blue	● blue			
Risøya, Risør (st. 76G)	Dogwhelk	Soft body																	● blue	● blue			
Lastad, Søgne (st. 131G)	Dogwhelk	Soft body																	● blue	● blue			
Gåsøya-Ulleröya, Farsund (st. 15G)	Dogwhelk	Soft body																	● blue	● blue			
Melandsholmen, Mid Karmsundet (st. 227G)	Dogwhelk	Soft body																	● blue	● blue			
Espevær, Outer Bømlafjord (st. 22G)	Dogwhelk	Soft body																	● blue	● blue			
Svolvær airport area (st. 98G)	Dogwhelk	Soft body																	● blue	● blue			
Brashavn, Outer Varangerfjord (st. 11G)	Dogwhelk	Soft body																	● blue	● blue			

***In cod and flounder, Hg measured in fillet

Table 9*. Assessment of levels and trends of median concentrations of 30 selected contaminants/Biological Effect Methods (BEM) with respect to the Norwegian provisional high reference contaminant concentration (PROREF) in samples collected in 2020 in six species: blue mussel, cod, flounder, eider, common periwinkle and dogwhelk. Tissues: soft body (for blue mussel, dogwhelk and common periwinkle), liver (cod except for Hg) and fillet (cod for Hg). The colour coding indicate to what degree the measured levels exceed PROREF, with levels below PROREF indicated in white and levels exceeding PROREF by a factor of 1-2, 2-5, 5-10, 10-20 or greater than 20 highlighted in shades from light grey to black (see also* ***Appendix C****). For biota, trend analyses were done on time series with data from five or more years. An upward (↑) or downward (↓) arrow indicates statistically significant trends, whereas a zero (O) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed but the results were insufficient to do a trend analysis. Results marked with a star (★) indicate that there is insufficient data above the quantification limit (LOQ) to perform a trend analysis. Methodical (artificial) results, as described in chapter 2.6, are marked both with parentheses and a star ((↑)★). The result from the trend analysis for the entire time series (long-term) is shown to the left of the slash "/", and the result for the last 10 years (short-term) is shown to the right of the slash. The results for the length-adjusted trend analyses (concerns only cod) are not shown. (See* ***Appendix B*** *for description of chemical codes). Abbreviations for contaminants can be seen in* ***Appendix B****. For common periwinkle, ISI and not VDSI was measured.*

Station name	Species	Tissue	AG	CD	CO	CR	HG	NI	PB	PCB-7	DDEPP	HCB	HBCDA	BDE6	BDE47	BDE100	BDE209	SCCP	MCCP	PAH	ANT	BAA	BAP	FLU	NAP	PFOA	PFOS	PFOSA	TBT	TPhT	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	↓/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/★				↓/↓	▪/▪		
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	★/★				↓/↓	▪/▪		
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	▪/▪		
Tjøme, Outer Oslofjord (st. 36A1)*	Blue mussel	Soft body	O/O	O/O	O/O	O/O	↓/O	O/O	O/O	O/O	↓/O	↓/★	↓/↓	↓/O	↓/O	O/O	▪/▪	↓/O	O/O							▪/▪	▪/▪	▪/▪	↓/O			
Singlekalven, Hvaler (st. I023)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/↓	O/O	O/O	O/(↑)★			O/O	O/O	O/O	O/O	▪/▪	↑/↑	O/O	O/O	★/★	★/★	★/★	↓/↓	★/★							
Kirkøy, Hvaler (st. I024)	Blue mussel	Soft body	★/★	O/O	↑/O	O/O	↓/O	O/O	O/O	↓/O																						
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	★/★							
Risøy (st. 76A2)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	O/O	↑/↑	↑/(↑)★	O/O	★/★																				
Lastad, Søgne (st. I131A)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	O/O	O/O											O/O	O/O	↓/O	★/★	O/O	★/★							
Odderøya, Kristiansand harbour (st. I133)	Blue mussel	Soft body	O/★	O/O	O/O	O/O	O/O	O/O	O/O	↓/O	O/O	↓/O																	↓/O	▪/▪		
Gåsøya-Ulleørøya, Farsund (st. 15A)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O																						
Kvalnes, Mid Sørfjord (st. 56A)	Blue mussel	Soft body					O/O			↓/(↑)★	↑/O	O/★																				
Krossanes, Outer Sørfjord (st. 57A)	Blue mussel	Soft body	O/O	↓/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																					
Vikingneset, Mid Hardangerfjord (st. 65A)	Blue mussel	Soft body	O/O	↓/O	O/O	O/O	↓/O	O/O	↓/O	O/(↑)★	O/O	O/★																				
Espevær, Outer Bømlafjord (st. 22A)	Blue mussel	Soft body	★/★	O/O	O/O	O/↓	O/O	O/O	↓/O	O/(↑)★	O/↑	★/★														▪/▪	▪/▪	▪/▪	↓/O	▪/▪		
Nordnes, Bergen harbour (st. I241)	Blue mussel	Soft body	★/★	↓/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													
Ålesund harbour (st. 28A2)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			O/O	▪/▪	▪/▪	O/O	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				
Ørland area, Outer Trondheimsfjord (st. 91A2)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O			↓/↓	O/O	O/O	O/O	▪/▪	O/O	O/O													
Mjelle, Bodø area (st. 97A2)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O			↓/↓	O/O	O/O	O/O	★/★	O/O	O/O													
Bodø harbour (st. 97A3)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	O/O	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪													
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/O	★/★	▪/▪	▪/▪	▪/▪				
Skallnes, Outer Varangerfjord (st. 10A2)	Blue mussel	Soft body	O/O	O/O	O/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/(↑)★	↓/O	O/★																				

Table 9 (cont.)

Station name	Species	Tissue	AG	CD	CO	CR	HG	NI	PB	PCB-7	DDEPP	HCB	HBCDA	BDE6	BDE47	BDE100	BDE209	SCCP	MCCP	PAH	ANT	BAA	BAP	FLU	NAP	PFOA	PFOS	PFOSA	TBT	TPhT	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	★/★	O/O	O/O							★/★	O/O	O/O				▪/▪
Tjøme, Outer Oslofjord (st. 36B)	Cod	Liver	O/O	O/O	O/O	↓/↓	O/O	↓/↓	↓/↓	↓/O	↓/O	↓/O	O/O	O/O	↓/O	O/O	★/★	O/O	O/O							★/★	↓/O	O/O				
Kirkøy, Hvaler (st. 02B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	↓/↓	↓/↓			↓/↓					O/O	O/O													
Stathelle area, Langesundfjord (st. 71B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/O				↓/↓					O/O	O/O													
Kristiansand harbour area (st. 13B)	Cod	Liver	O/O	O/O	O/O	↓/↓	O/O	↓/O	↓/↓	O/↓			↓/↓	↓/↓	↓/↓	O/↓	★/★	O/O	O/O							★/★	↓/O	↓/↓				
Skågskjera, Farsund (st. 15B)	Cod	Liver	↑/↑	O/O	↑/O	O/O	↑/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	↓/↓				
Bømlo, Outer Selbjørnfjord (st. 23B)	Cod	Liver	O/O	O/O	O/O	O/O	↑/O	O/O	↓/↓	↓/O	↓/O	O/O	↓/↓	↓/↓	↓/O	↓/↓	★/★	O/O	↑/O							★/★	O/O	↓/↓				
Bergen harbour area (st. 24B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O			O/O	O/O	O/O	O/O	▪/▪	↓/↓	O/O							★/★	O/O	O/O				O/O
Ålesund harbour area (st. 28B)	Cod	Liver	O/O	↓/↓	O/O	O/O	O/O	↓/↓	O/O	O/O			O/O	O/O	O/O	O/O	★/★	O/O	O/O													
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				
Sandnessjøen area (st. 96B)	Cod	Liver	O/O	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	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	↓/O	O/O																				▪/▪
Svalbard (st. 19B)	Cod	Liver	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	O/O	▪/▪							▪/▪	▪/▪	▪/▪				▪/▪
Sande, Mid Oslofjord (st. 33F)	Flounder	Liver	O/O	O/↑	O/O	O/O	O/↑	O/O	↓/O	O/O	O/O	↓/O																				
Breøyane (st. 19N)	Eider duck	Blood	O/O	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				▪/▪
Breøyane (st. 19N)	Eider duck	Egg	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	O/O	▪/▪	▪/▪	▪/▪							▪/▪	▪/▪	▪/▪				▪/▪
Fugløyskjær, Outer Langesundfjord (st. 71G)	Periwinkle	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪								▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪				O/O	▪/▪	↓/O	
Færder, Outer Oslofjord (st. 36G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Risøya, Risør (st. 76G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Lastad, Søgne (st. 131G)	Dogwhelk	Soft body																											↓/★	▪/▪	↓/↓	
Gåsøya-Ullerøya, Farsund (st. 15G)	Dogwhelk	Soft body																											↓/★	▪/▪	↓/O	
Melandsholmen, Mid Karmsundet (st. 227G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/↓	
Espevær, Outer Bømlafjord (st. 22G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/O	
Svolvær airport area (st. 98G)	Dogwhelk	Soft body																											↓/O	▪/▪	↓/↓	
Brashavn, Outer Varangerfjord (st. 11G)	Dogwhelk	Soft body																											★/★	▪/▪	O/O	

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

3.2 Levels and trends in contaminants

3.2.1 Overview of metals

In 2020, metals were analysed in blue mussel from 26 stations, in cod from 17 stations, in flounder from one station and in eider from one station (two tissues were analysed) (***Table 1***). The results are discussed in more detail in **Chapters 3.2.2 - 3.2.11**, and only a brief summary is provided here.

EQS for metals was only applicable for Hg, and it was exceeded at 25 (53 %) of the 47 stations where samples were taken (***Figure 8*** **A**). Applying PROREF to assess the 295 metal concentrations, 62.7 % of the measured metal concentrations were found to be below PROREF and the rest were above it (***Figure 9 A***). Two measurements exceeded PROREF by a factor of more than 10 (one case for Ag and one case for Pb). Analyses showed that 74.9 % of the data series for metals indicated no short-term trends, but for 10.5 % of these series for metals, a significant trend was found; 6.5 % downward and 4 % upward (***Figure 9 B***).

A

B

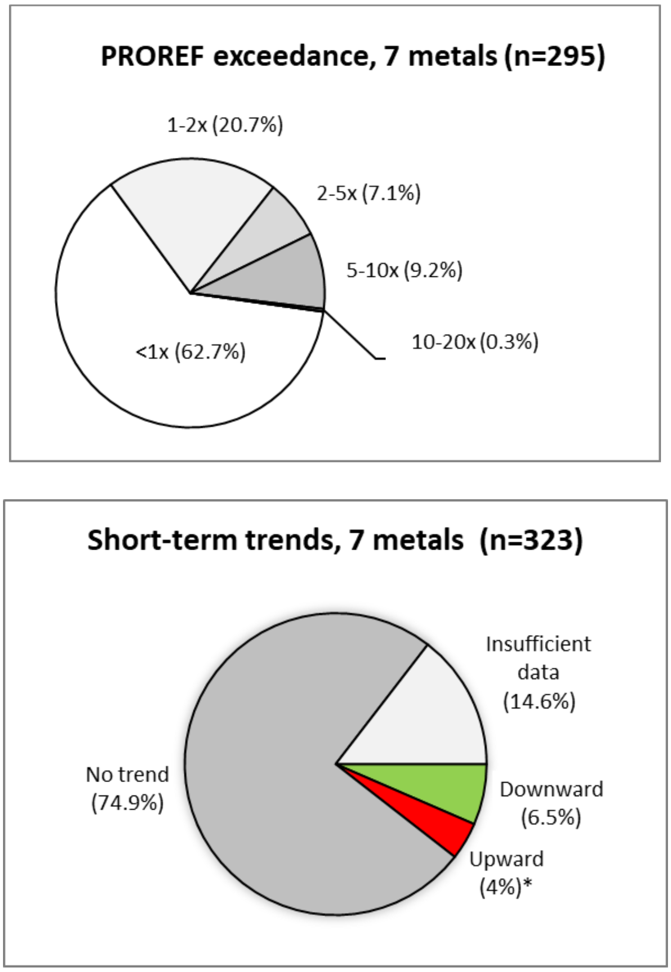


Figure 9. *Summary for 2020 showing the percent of samples (station-species-tissue) exceeding the Norwegian provisional high reference contaminant concentration (PROREF) (**A**) and relating to the results from short-term trend analyses for seven metals (**B**). Ten upward short-term trends for PCB-7 in blue mussel and one upward short-term trend for Ag in blue mussel are caused by methodical (artificial) results, as described in chapter 2.6. These are included in this overview figure (**B**) and are marked by a star (*). Details can be seen in **Table 9**.*

Table 10*. Median concentrations (mg/kg w.w.) and standard deviations for metals in blue mussel, cod liver/filet, flounder liver/filet and eider blood and eggs in 2020. 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 the value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See also* ***Chapter 2.10*** *for more details and* ***Appendix B*** *for description of chemical codes.)*

Component	Count	AG			AS			CD			CO			CR		
Species and sampling locality	2020	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																
Akershuskaia, Inner Oslofjord (st. I301)	3 (3-50)	0.050	0.000	0 [n.a.]	2.500	0.306	3 [2.1-2.7]	0.270	0.040	3 [0.24-0.32]	0.085	0.007	3 [0.08-0.09]	0.230	0.017	3 [0.23-0.26]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.050	0.000	0 [n.a.]	1.600	0.700	3 [1.4-2.7]	0.180	0.069	3 [0.18-0.3]	0.110	0.028	3 [0.09-0.14]	0.830	0.214	3 [0.83-1.2]
Gåsøya, Inner Oslofjord (st. I304)	3 (3-50)	0.050	0.000	0 [n.a.]	2.700	0.208	3 [2.4-2.8]	0.260	0.026	3 [0.22-0.27]	0.095	0.009	3 [0.09-0.11]	0.420	0.031	3 [0.4-0.46]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	0.050	0.000	0 [n.a.]	1.700	0.153	3 [1.6-1.9]	0.140	0.010	3 [0.13-0.15]	0.059	0.007	3 [0.06-0.07]	0.220	0.015	3 [0.2-0.23]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.050	0.000	0 [n.a.]	2.100	0.252	3 [1.8-2.3]	0.100	0.017	3 [0.09-0.12]	0.042	0.006	3 [0.04-0.05]	0.120	0.028	3 [0.08-0.14]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.050	0.000	0 [n.a.]	1.100	0.100	3 [1-1.2]	0.150	0.015	3 [0.14-0.17]	0.074	0.001	3 [0.07-0.07]	0.330	0.150	3 [0.31-0.58]
Kirkøy, Hvaler (st. I024)	3 (3-50)	0.050	0.000	0 [n.a.]	1.300	0.058	3 [1.3-1.4]	0.260	0.010	3 [0.25-0.27]	0.180	0.035	3 [0.12-0.18]	0.680	0.080	3 [0.61-0.77]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.050		0 [n.a.]	1.300		1 [1.3]	0.190		1 [0.19]	0.049		1 [0.05]	0.310		1 [0.31]
Risøya, Risør (st. 76A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.000	0.115	3 [2-2.2]	0.110	0.017	3 [0.1-0.13]	0.082	0.012	3 [0.06-0.08]	0.120	0.070	3 [0.09-0.22]
Lastad, Søgne (st. I131A)	3 (3-50)	0.050	0.000	0 [n.a.]	1.800	0.153	3 [1.6-1.9]	0.170	0.006	3 [0.17-0.18]	0.080	0.007	3 [0.08-0.09]	0.130	0.026	3 [0.09-0.13]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	0.050	0.000	0 [n.a.]	1.400	0.115	3 [1.4-1.6]	0.210	0.021	3 [0.2-0.24]	0.200	0.006	3 [0.2-0.21]	0.200	0.257	3 [0.19-0.64]
Gåsøya-Ullerøya, Farsund (st. 15A)	3 (3-50)	0.050	0.000	0 [n.a.]	3.700	0.351	3 [3.3-4]	0.150	0.010	3 [0.14-0.16]	0.078	0.005	3 [0.08-0.09]	0.092	0.057	3 [0.09-0.19]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)															
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	0.050	0.000	0 [n.a.]	3.800	0.000	3 [3.8-3.8]	0.240	0.029	3 [0.24-0.29]	0.063	0.019	3 [0.06-0.1]	0.140	0.021	3 [0.13-0.17]
Utne, Outer Sørfjord (st. 64A)	3 (3-50)	0.050	0.000	0 [n.a.]	4.000	0.666	3 [2.9-4.1]	0.160	0.040	3 [0.12-0.2]	0.058	0.013	3 [0.04-0.07]	0.098	0.031	3 [0.07-0.13]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	0.050	0.000	0 [n.a.]	3.300	0.058	3 [3.3-3.4]	0.160	0.017	3 [0.13-0.16]	0.066	0.014	3 [0.06-0.09]	0.160	0.051	3 [0.13-0.23]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.050	0.000	0 [n.a.]	8.000	1.793	3 [7.8-11]	0.170	0.035	3 [0.14-0.21]	0.078	0.014	3 [0.07-0.09]	0.100	0.029	3 [0.07-0.13]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.050	0.000	0 [n.a.]	3.200	0.200	3 [3-3.4]	0.130	0.006	3 [0.13-0.14]	0.048	0.002	3 [0.05-0.05]	0.180	0.025	3 [0.16-0.21]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.400	0.173	3 [2.1-2.4]	0.110	0.006	3 [0.11-0.12]	0.037	0.001	3 [0.04-0.04]	0.120	0.026	3 [0.11-0.16]
Ålesund harbour (st. 28A2)	3 (3-50)	0.050	0.000	0 [n.a.]	3.000	0.173	3 [2.7-3]	0.082	0.006	3 [0.08-0.09]	0.045	0.004	3 [0.04-0.05]	0.190	0.012	3 [0.17-0.19]
Ørland area, Outer Trondheimsfjord (st. 91	3 (3-50)	0.050	0.000	0 [n.a.]	2.300	0.058	3 [2.2-2.3]	0.150	0.017	3 [0.12-0.15]	0.100	0.011	3 [0.09-0.11]	0.250	0.248	3 [0.23-0.67]
Bodø harbour (st. 97A3)	3 (3-50)	0.050	0.000	0 [n.a.]	2.400	0.173	3 [2.1-2.4]	0.140	0.010	3 [0.13-0.15]	0.081	0.012	3 [0.07-0.1]	0.330	0.076	3 [0.31-0.45]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.900	0.208	3 [2.8-3.2]	0.170	0.010	3 [0.16-0.18]	0.060	0.006	3 [0.06-0.07]	0.300	0.031	3 [0.26-0.32]
Svolvær airport area (st. 98A2)	3 (3-50)	0.050	0.000	0 [n.a.]	2.100	0.058	3 [2-2.1]	0.190	0.010	3 [0.18-0.2]	0.044	0.003	3 [0.04-0.05]	0.180	0.020	3 [0.16-0.2]
Brashavn, Outer Varangerfjord (st. 11X)	3 (3-50)	0.050	0.000	0 [n.a.]	1.400	0.058	3 [1.3-1.4]	0.240	0.006	3 [0.24-0.25]	0.045	0.003	3 [0.04-0.05]	0.210	0.044	3 [0.2-0.28]
Skallnes, Outer Varangerfjord (st. 10A2)	3 (3-50)	0.050	0.000	0 [n.a.]	1.700	0.058	3 [1.6-1.7]	0.280	0.020	3 [0.26-0.3]	0.041	0.002	3 [0.04-0.04]	0.140	0.030	3 [0.11-0.17]
Cod, liver (all metals except Hg), filet (Hg)																
Inner Oslofjord (st. 30B)	12 (7-6)	4.450	4.075	12 [1.4-15]	15.000	9.173	12 [4.8-38]	0.073	0.033	12 [0.01-0.11]	0.080	0.037	12 [0.03-0.14]	0.075	0.012	12 [0.05-0.09]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	1.800	1.960	15 [0.3-6.1]	13.000	7.287	15 [4.6-35]	0.049	0.031	15 [0.02-0.14]	0.050	0.028	15 [0.02-0.12]	0.050	0.020	15 [0.04-0.11]
Kirkøy, Hvaler (st. 02B)	7 (5-2)	0.570	0.340	7 [0.17-1.2]	3.000	1.275	7 [2.3-5.9]	0.015	0.005	7 [0.01-0.02]	0.025	0.003	7 [0.02-0.03]	0.053	0.028	7 [0.03-0.11]
Stathelle area, Langesundfjord (st. 71B)	10 (5-5)	0.955	0.727	10 [0.29-2.5]	4.350	3.645	10 [1.4-14]	0.026	0.016	10 [0.003-0.05]	0.041	0.019	10 [0.01-0.07]	0.060	0.020	10 [0.01-0.08]
Kristiansand harbour area (st. 13B)	7 (5-2)	0.670	0.487	7 [0.4-1.8]	5.200	1.618	7 [2.1-6.2]	0.019	0.015	7 [0.003-0.05]	0.042	0.023	7 [0.01-0.08]	0.044	0.011	7 [0.04-0.07]
Skågskjera, Farsund (st. 15B)	15 (0-1)	1.100	0.864	15 [0.31-3.5]	7.100	3.854	15 [4-16]	0.027	0.014	15 [0.01-0.07]	0.052	0.021	15 [0.03-0.1]	0.022	0.005	15 [0.01-0.03]
Inner Sørfjord (st. 53B)	15 (4-3)	1.500	1.062	15 [0.6-4.1]	3.700	3.471	15 [1.5-15]	0.028	0.028	15 [0.01-0.09]	0.033	0.037	15 [0.008-0.12]	0.048	0.021	15 [0.02-0.1]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	0.290	0.567	15 [0.07-2.1]	5.000	3.457	15 [1.8-14]	0.019	0.028	15 [0.004-0.12]	0.028	0.020	15 [0.007-0.07]	0.059	0.029	15 [0.03-0.15]
Bergen harbour area (st. 24B)	14 (6-2)	1.100	0.596	14 [0.19-2.2]	2.350	2.730	14 [1.2-11]	0.015	0.028	13 [0.002-0.09]	0.043	0.021	13 [0.01-0.07]	0.065	0.038	13 [0.03-0.16]
Ålesund harbour area (st. 28B)	14 (2-2)	0.180	0.592	13 [0.09-1.9]	2.850	0.511	14 [2.2-4.1]	0.011	0.007	14 [0.007-0.03]	0.009	0.009	14 [0.003-0.03]	0.048	0.027	14 [0.02-0.1]
Trondheim harbour (st. 80B)	15 (0-1)	0.780	1.015	15 [0.15-4.1]	5.200	5.918	15 [3-25]	0.034	0.050	15 [0.01-0.2]	0.030	0.016	15 [0.006-0.07]	0.042	0.021	15 [0.01-0.1]
Sandnessjøen area (st. 96B)	15 (0-1)	0.170	0.326	15 [0.07-1.3]	4.100	1.654	15 [2.3-7.9]	0.035	0.031	15 [0.02-0.14]	0.012	0.006	15 [0.009-0.03]	0.043	0.023	15 [0.02-0.09]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	0.300	0.560	15 [0.1-2.2]	3.600	3.017	15 [1.7-14]	0.056	0.048	15 [0.01-0.16]	0.020	0.016	15 [0.009-0.06]	0.038	0.037	15 [0.01-0.13]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.380	2.225	15 [0.15-9]	4.400	6.789	15 [1.2-26]	0.120	0.589	15 [0.03-2.4]	0.013	0.010	15 [0.004-0.04]	0.033	0.015	15 [0.02-0.06]
Hammerfest harbour area (st. 45B2)	14 (5-3)	0.425	0.365	14 [0.07-1.1]	4.500	2.730	14 [3-13]	0.160	0.114	14 [0.03-0.43]	0.027	0.016	13 [0.008-0.05]	0.028	0.020	12 [0.01-0.08]
Kjøfjord, Outer Varangerfjord (st. 10B)	15 (5-2)	0.760	0.395	15 [0.08-1.3]	2.700	1.099	15 [1.9-6.3]	0.098	0.055	15 [0.02-0.21]	0.016	0.009	15 [0.004-0.03]	0.038	0.017	15 [0.01-0.07]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.130	0.334	12 [0.06-1.2]	2.400	1.311	15 [1.8-6.3]	0.110	0.256	15 [0.07-1.1]	0.012	0.006	15 [0.005-0.03]	0.033	0.015	15 [0.02-0.07]
Flounder, liver (all metals except Hg), filet (Hg)																
Sande, Mid Oslofjord (st. 33F)	3 (3-5)	0.060	0.006	3 [0.05-0.06]	4.000	0.833	3 [2.8-4.4]	0.240	0.200	3 [0.09-0.49]	0.120	0.071	3 [0.1-0.23]	0.052	0.022	3 [0.02-0.06]
Eider, blood																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.001	0.001	15 [4e-04-0.002]	0.020	0.022	15 [0.01-0.09]	0.003	0.002	15 [0.001-0.007]	0.003	0.001	15 [0.002-0.005]	0.003	0.055	4 [0.003-0.22]
Eider, egg																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.009	0.010	15 [0.004-0.04]	0.101	0.052	15 [0.06-0.25]	0.0002	0.0001	7 [3e-04-4e-04]	0.007	0.002	15 [0.004-0.01]	0.006	0.013	13 [0.003-0.05]

Component	Count	CU			HG			NI			PB			ZN		
Species and sampling locality	2020	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)	0.980	0.340	3 [0.86-1.5]	0.013	0.001	3 [0.01-0.01]	0.180	0.012	3 [0.16-0.18]	0.450	0.092	3 [0.39-0.57]	23	8.505	3 [20-36]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	2.100	0.643	3 [1.1-2.3]	0.015	0.006	3 [0.01-0.02]	0.490	0.254	3 [0.47-0.92]	1.600	0.608	3 [1.5-2.6]	23	3.055	3 [21-27]
Gåsøya, Inner Oslofjord (st. I304)	3 (3-50)	1.000	0.556	3 [0.73-1.8]	0.014	0.003	3 [0.01-0.02]	0.360	0.060	3 [0.3-0.42]	0.470	0.036	3 [0.45-0.52]	22	1.528	3 [21-24]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	1.600	0.100	3 [1.5-1.7]	0.013	0.002	3 [0.01-0.01]	0.240	0.021	3 [0.23-0.27]	0.100	0.006	3 [0.1-0.11]	19	1.528	3 [17-20]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	1.800	0.208	3 [1.5-1.9]	0.006	0.001	3 [0.006-0.008]	0.150	0.031	3 [0.11-0.17]	0.081	0.020	3 [0.07-0.11]	14	1.155	3 [12-14]
Singlekalven, Hvaler (st. I023)	3 (3-50)	1.100	0.590	3 [0.89-2]	0.019	0.004	3 [0.02-0.02]	0.310	0.036	3 [0.29-0.36]	0.110	0.009	3 [0.09-0.11]	18	1.000	3 [17-19]
Kirkøy, Hvaler (st. I024)	3 (3-50)	1.700	0.574	3 [0.89-2]	0.031	0.004	3 [0.03-0.04]	0.480	0.078	3 [0.44-0.59]	0.310	0.090	3 [0.21-0.39]	26	1.732	3 [23-26]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	1.500		1 [1.5]	0.027		1 [0.03]	0.330		1 [0.33]	0.310		1 [0.31]	17		1 [17]
Risøya, Risør (st. 76A2)	3 (3-50)	0.720	0.409	3 [0.51-1.3]	0.012	0.003	3 [0.007-0.01]	0.240	0.092	3 [0.18-0.36]	0.220	0.038	3 [0.16-0.23]	16	2.887	3 [11-16]
Lastad, Søgne (st. I131A)	3 (3-50)	1.100	0.289	3 [1.1-1.6]	0.014	0.003	3 [0.01-0.01]	0.160	0.006	3 [0.16-0.17]	0.190	0.026	3 [0.18-0.23]	14	1.528	3 [12-15]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	1.400	0.416	3 [1.2-2]	0.019	0.003	3 [0.02-0.02]	0.710	0.083	3 [0.67-0.83]	3.800	1.701	3 [2.2-5.6]	22	4.583	3 [16-25]
Gåsøya-Ullerøya, Farsund (st. 15A)	3 (3-50)	1.000	0.462	3 [1-1.8]	0.010	0.002	3 [0.01-0.01]	0.180	0.025	3 [0.16-0.21]	0.260	0.046	3 [0.18-0.26]	17	2.646	3 [16-21]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)				0.074	0.017	3 [0.06-0.1]									
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	0.800	1.175	3 [0.73-2.8]	0.028	0.004	3 [0.02-0.03]	0.130	0.015	3 [0.11-0.14]	0.600	0.102	3 [0.44-0.63]	12	1.000	3 [11-13]
Utne, Outer Sørfjord (st. 64A)	3 (3-50)	0.950	0.425	3 [0.55-1.4]	0.019	0.005	3 [0.01-0.02]	0.130	0.024	3 [0.09-0.13]	0.230	0.035	3 [0.17-0.23]	11	0.577	3 [11-12]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	1.000	0.176	3 [0.85-1.2]	0.016	0.005	3 [0.008-0.02]	0.200	0.006	3 [0.19-0.2]	0.260	0.055	3 [0.17-0.27]	17	0.577	3 [16-17]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	2.200	0.153	3 [2-2.3]	0.016	0.002	3 [0.01-0.02]	0.210	0.055	3 [0.16-0.27]	0.180	0.017	3 [0.15-0.18]	21	1.528	3 [19-22]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	2.500	0.462	3 [1.7-2.5]	0.017	0.001	3 [0.02-0.02]	0.120	0.006	3 [0.11-0.12]	0.570	0.044	3 [0.56-0.64]	19	1.000	3 [18-20]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	1.300	0.115	3 [1.3-1.5]	0.015	0.002	3 [0.01-0.02]	0.094	0.010	3 [0.09-0.11]	0.200	0.035	3 [0.17-0.24]	17	1.528	3 [15-18]
Ålesund harbour (st. 28A2)	3 (3-50)	2.300	0.289	3 [2.3-2.8]	0.016	0.001	3 [0.01-0.02]	0.200	0.025	3 [0.18-0.23]	0.320	0.006	3 [0.32-0.33]	21	0.577	3 [21-22]
Ørland area, Outer Trondheimsfjord (st. 91	3 (3-50)	1.100	0.293	3 [0.93-1.5]	0.010	0.001	3 [0.009-0.01]	0.360	0.051	3 [0.29-0.39]	0.170	0.031	3 [0.15-0.21]	15	0.577	3 [14-15]
Bodø harbour (st. 97A3)	3 (3-50)	3.100	0.666	3 [2-3.2]	0.014	0.002	3 [0.01-0.01]	0.250	0.065	3 [0.19-0.32]	0.440	0.061	3 [0.43-0.54]	24	0.577	3 [24-25]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	1.200	0.175	3 [0.96-1.3]	0.022	0.002	3 [0.02-0.02]	0.200	0.042	3 [0.18-0.26]	0.410	0.061	3 [0.4-0.51]	23	3.055	3 [21-27]
Svolvær airport area (st. 98A2)	3 (3-50)	0.890	0.445	3 [0.78-1.6]	0.013	0.002	3 [0.01-0.01]	0.170	0.010	3 [0.16-0.18]	0.180	0.021	3 [0.17-0.21]	14	1.528	3 [13-16]
Brashavn, Outer Varangerfjord (st. 11X)	3 (3-50)	0.710	0.465	3 [0.68-1.5]	0.007	0.001	3 [0.007-0.008]	0.200	0.038	3 [0.19-0.26]	0.120	0.010	3 [0.11-0.13]	13	1.000	3 [12-14]
Skallnes, Outer Varangerfjord (st. 10A2)	3 (3-50)	1.700	0.173	3 [1.4-1.7]	0.006	0.001	3 [0.005-0.007]	0.180	0.012	3 [0.16-0.18]	0.110	0.013	3 [0.1-0.12]	18	1.155	3 [16-18]
Cod, liver (all metals except Hg), filet (Hg)																
Inner Oslofjord (st. 30B)	12 (7-6)	5.400	1.700	12 [2.6-8.1]	0.140	0.052	15 [0.07-0.27]	0.101	0.045	12 [0.02-0.17]	0.095	0.066	12 [0.009-0.24]	28	6.900	12 [11-32]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	5.500	2.931	15 [2.5-14]	0.150	0.059	15 [0.04-0.29]	0.038	0.014	15 [0.02-0.07]	0.009	0.006	15 [0.007-0.03]	29	8.268	15 [19-43]
Kirkøy, Hvaler (st. 02B)	7 (5-2)	5.400	3.165	7 [1.3-9.4]	0.076	0.048	15 [0.04-0.2]	0.025	0.011	6 [0.01-0.04]	0.007	0.002	5 [0.007-0.01]	20	3.237	7 [16-25]
Stathelle area, Langesundfjord (st. 71B)	10 (5-5)	6.950	3.941	10 [2.6-15]	0.150	0.117	15 [0.05-0.49]	0.024	0.012	10 [0.02-0.05]	0.014	0.007	9 [0.009-0.03]	28	5.371	10 [19-38]
Kristiansand harbour area (st. 13B)	7 (5-2)	5.400	1.996	7 [3.7-10]	0.048	0.072	15 [0.03-0.32]	0.059	0.020	7 [0.02-0.08]	0.007	0.002	4 [0.007-0.009]	23	7.290	7 [16-35]
Skågskjera, Farsund (st. 15B)	15 (0-1)	12.000	4.692	15 [5.8-21]	0.120	0.045	15 [0.05-0.19]	0.038	0.014	15 [0.02-0.07]	0.005	0.001	9 [0.005-0.01]	34	7.316	15 [22-50]
Inner Sørfjord (st. 53B)	15 (4-3)	8.900	4.072	15 [2.7-20]	0.180	0.112	15 [0.07-0.44]	0.049	0.017	15 [0.02-0.08]	0.014	0.046	15 [0.007-0.19]	28	8.159	15 [19-47]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	3.700	4.594	15 [1.6-16]	0.140	0.061	15 [0.08-0.31]	0.032	0.018	15 [0.02-0.09]	0.006	0.002	8 [0.006-0.01]	20	6.850	15 [10-34]
Bergen harbour area (st. 24B)	14 (6-2)	6.500	3.608	14 [1.2-11]	0.088	0.184	15 [0.03-0.65]	0.053	0.033	13 [0.02-0.12]	0.015	0.007	14 [0.006-0.03]	26	7.979	14 [17-43]
Ålesund harbour area (st. 28B)	14 (2-2)	2.750	1.397	14 [1-5.7]	0.210	0.070	15 [0.01-0.25]	0.024	0.027	12 [0.02-0.12]	0.018	0.011	14 [0.007-0.05]	15	4.555	14 [11-27]
Trondheim harbour (st. 80B)	15 (0-1)	5.100	4.616	15 [0.92-14]	0.091	0.201	15 [0.01-0.68]	0.033	0.013	14 [0.01-0.06]	0.005	0.004	7 [0.007-0.02]	21	10.036	15 [4.5-40]
Sandnessjøen area (st. 96B)	15 (0-1)	2.600	1.564	15 [1.7-7.2]	0.069	0.028	15 [0.04-0.15]	0.029	0.015	15 [0.01-0.06]	0.006	0.002	9 [0.006-0.009]	15	2.330	15 [9.3-19]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	5.200	4.022	15 [1.7-15]	0.062	0.027	15 [0.05-0.15]	0.039	0.032	15 [0.01-0.11]	0.005	0.003	7 [0.006-0.01]	21	6.990	15 [14-38]
Tromsø harbour area (st. 43B2)	15 (0-1)	6.400	11.530	15 [0.82-50]	0.065	0.043	15 [0.02-0.17]	0.042	0.025	15 [0.02-0.1]	0.008	0.010	12 [0.006-0.05]	19	8.130	15 [15-48]
Hammerfest harbour area (st. 45B2)	14 (5-3)	5.450	2.518	14 [2-11]	0.042	0.013	15 [0.03-0.08]	0.070	0.041	13 [0.01-0.13]	0.011	0.010	11 [0.005-0.03]	18	4.823	14 [8.8-26]
Kjøfjord, Outer Varangerfjord (st. 10B)	15 (5-2)	3.100	1.584	15 [0.41-5.8]	0.025	0.010	15 [0.002-0.03]	0.036	0.037	13 [0.01-0.14]	0.007	0.002	10 [0.005-0.01]	15	6.776	15 [2.7-27]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	1.600	1.045	15 [0.55-5]	0.017	0.017	15 [0.01-0.07]	0.042	0.013	15 [0.02-0.07]	0.009	0.003	14 [0.008-0.02]	13	4.108	15 [8.1-24]
Flounder, liver (all metals except Hg), filet (Hg)																
Sande, Mid Oslofjord (st. 33F)	3 (3-5)	20.000	2.646	3 [19-24]	0.150	0.061	3 [0.06-0.17]	0.034	0.010	3 [0.03-0.05]	0.039	0.034	3 [0.02-0.09]	47	7.937	3 [35-50]
Eider, blood																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.453	0.081	15 [0.33-0.66]	0.111	0.040	15 [0.07-0.19]	0.003	0.030	4 [0.004-0.12]	0.046	0.061	15 [0.02-0.21]	5	0.503	15 [4.1-6]
Eider, egg																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	1.171	0.161	15 [0.93-1.41]	0.111	0.034	15 [0.08-0.19]	0.005	0.007	15 [0.004-0.03]	0.006	0.003	15 [0.002-0.01]	17	1.825	15 [14.1-20]

3.2.2 Mercury (Hg)

Mercury (Hg) is found naturally in the earth's crust and can be spread both from natural sources and through anthropogenic activity. Mercury can be organic (methylmercury and dimethylmercury), inorganic (Hg^0) or elemental (Hg^{2+}) and has toxic effects on *inter alia* the nerve system. The toxic substance can be transported by water and air over long distances and end up in the environment in completely different parts of the globe than where it was released. With a few exceptions, there is a general prohibition on the use of Hg in products in Norway. In the present study, total Hg (organic and inorganic, here abbreviated to Hg), was analysed in blue mussel at 26 stations, in cod fillet at 17 stations, in flounder fillet at one station and in eider blood and eggs at one station (***Table 1***).

Environmental Quality Standards (EQS) for priority substances

EU has established an EQS of 0.02 mg/kg w.w. in biota (cf. ***Table 4***). Applying this EQS for blue mussel, concentrations of Hg were above or at the EQS at Kirkøy (st. I024, 0.031 mg/kg w.w.) at Hvaler, Bjørkøya (st. 71A, 0.027 mg/kg w.w.) in the Langesundfjord, Kvalnes (st. 56A, 0.074 mg/kg w.w.) and Krossanes (st. 57A, 0.028 mg/kg w.w.) in the Sørfjord, and at Mjelle (st. 97A2, 0.022 mg/kg w.w.) in the Bodø area (***Table 8***).

The biota standards refer to fish (concentrations in whole fish), except in the case of PAHs, where reference is made of crustaceans and mollusc (EC 2014), (Fliedner 2018). Therefore, the EQS cannot be directly compared to concentrations found in specific tissues of fish or blue mussel. We have in the present study measured Hg in fish fillet, not in whole fish. Converting Hg concentrations in fish fillet to concentrations in whole fish is uncertain. Using fillet probably represents an overestimate of the whole fish concentration because Hg accumulates more in the fillet than in other tissues (Kwasniak and Falkowska 2012). If it is assumed, for this exercise, that the same concentration is found in all fish tissue types, then the results of Hg (in cod fillet) would have exceeded the EQS at all stations in 2020, except for the reference station (st. 19B) at Svalbard (0.017 mg/kg w.w.) (***Table 8***).

Applying this EQS for flounder liver, the Hg concentration would have exceeded the EQS at Sande (st. 33F, 0.150 mg/kg w.w.) in the mid Oslofjord (***Table 8***).

Applying this EQS for eider blood and eggs, the Hg concentrations would have exceeded the EQS (***Table 8***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Hg by a factor of five to 10 at Kvalnes (st. 56A) in the Sørfjord (***Table 9***). Mussels exceeded the PROREF by a factor of two to five at Kirkøy (st. I024) in the Outer Oslofjord, Bjørkøya (st. 71A) in the Grenlandfjord and Krossanes (st. 57A) in the Sørfjord. For blue mussel, the exceedances were a factor of up to two at Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord and at Solbergstrand (st. 31A) in the mid Oslofjord. This was also the result at Singlekalven (st. I023) in the Outer Oslofjord, at Odderøya (st. I133) in the Kristiansandfjord and at Lastad (st. I131A) at Søgne. This was also observed at Utne (st. 64A) in the Outer Sørfjord, Vikingneset (st. 65A) in the mid Hardangerfjord, Espevær (st. 22A) in the Outer Bømlafjord and Nordnes (st. I241) close to Bergen harbour. This was also the result in 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 of Hg by a factor of two to five in the Inner Oslofjord (st. 30B), Tjøme (st. 36B) in the Outer Oslofjord, Stathelle area in the Grenlandfjord (st. 71B), Skågskjera in Farsund (st. 15B), in the Inner Sørfjord (st. 53B), at Bømlo (st. 23B) and in Ålesund harbour (st. 28B). The exceedances were a factor up to two at Kirkøy (st. 02B) at Hvaler, Bergen harbour (st. 24B), Trondheim harbour (st. 80B), the Sandnessjøen area (st.96B), Tromsø harbour (st. 43B2) and Austnesfjord in Lofoten (st. 98B1).

Increase in PROREF factor since 2019
Blue mussel exceeded PROREF for Hg at Kvalnes (st. 56A) in the mid Sørfjord by a factor of five to 10 in 2020, compared to two to five in 2019. Mussels exceeded PROREF for Hg at Kirkøy (st. I024) at Hvaler by a factor of two to five in 2020, compared to a factor up to two times in 2019. The mussel at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, at Lastad (st. I131A) at Søgne and Vågsvåg (st. 26A2) in the Outer Nordfjord exceeded the PROREF by a factor up to two times in 2020, while there was no exceedance in 2019.

Cod fillet from Stathelle (st. 71B) exceeded the PROREF for Hg by a factor between two and five in 2020, compared to up to two in 2019. Cod fillet from the Sandnessjøen area (st.96B) and Tromsø harbour (st. 43B2*)* exceeded the PROREF for Hg by a factor up to two in 2020, compared to below PROREF in 2019.

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

A significant upward long-term trend for Hg was found in the Inner Oslofjord (st. 30B) (***Figure 10 A***), at Skågskjera (st. 15B) in Farsund (***Figure 11 A***), at Bømlo (st. 23B) (***Figure 12***) and in Tromsø harbour (st. 43B2) ***Figure 13***. When fish-length was taken into account only, both significant upward long- and short-term trends were also found for Hg in cod fillet from the Kristiansand harbour (st. 13B) (***Figure 14***) and at Skågskjera (st. 15B) in Farsund (***Figure 11 B***). A significant upward long-term trend was also found in the Inner Oslofjord (st. 30B) (***Figure 10 B***), while a significant upward short-term trend was found at Kjøfjord (st. 10B) in the Outer Varangerfjord when fish-length was taken into account.

A

B

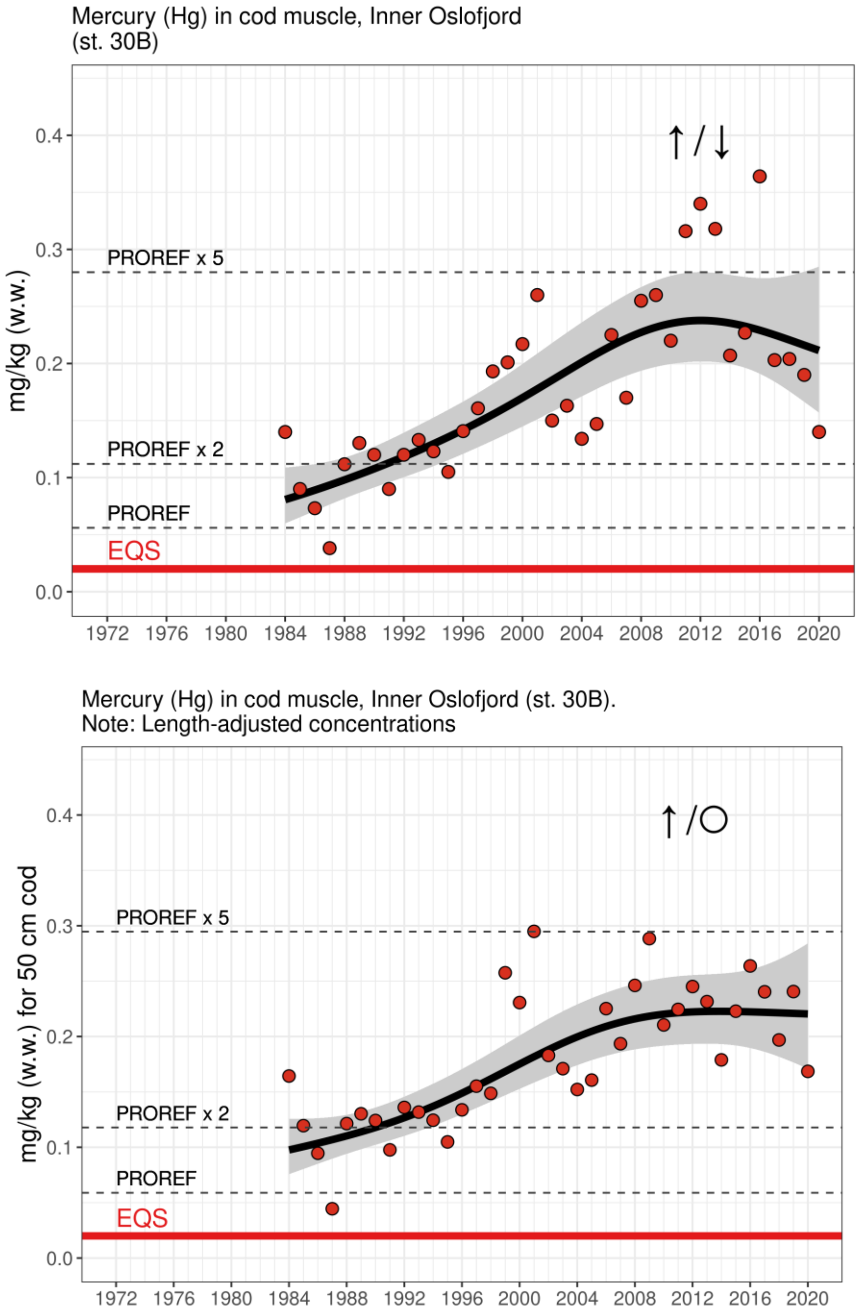


Figure 10. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from the Inner Oslofjord (st. 30B); no adjustment for length (**A**) and adjusted for length (**B**) (see **Figure 6** and **Appendix C**).*

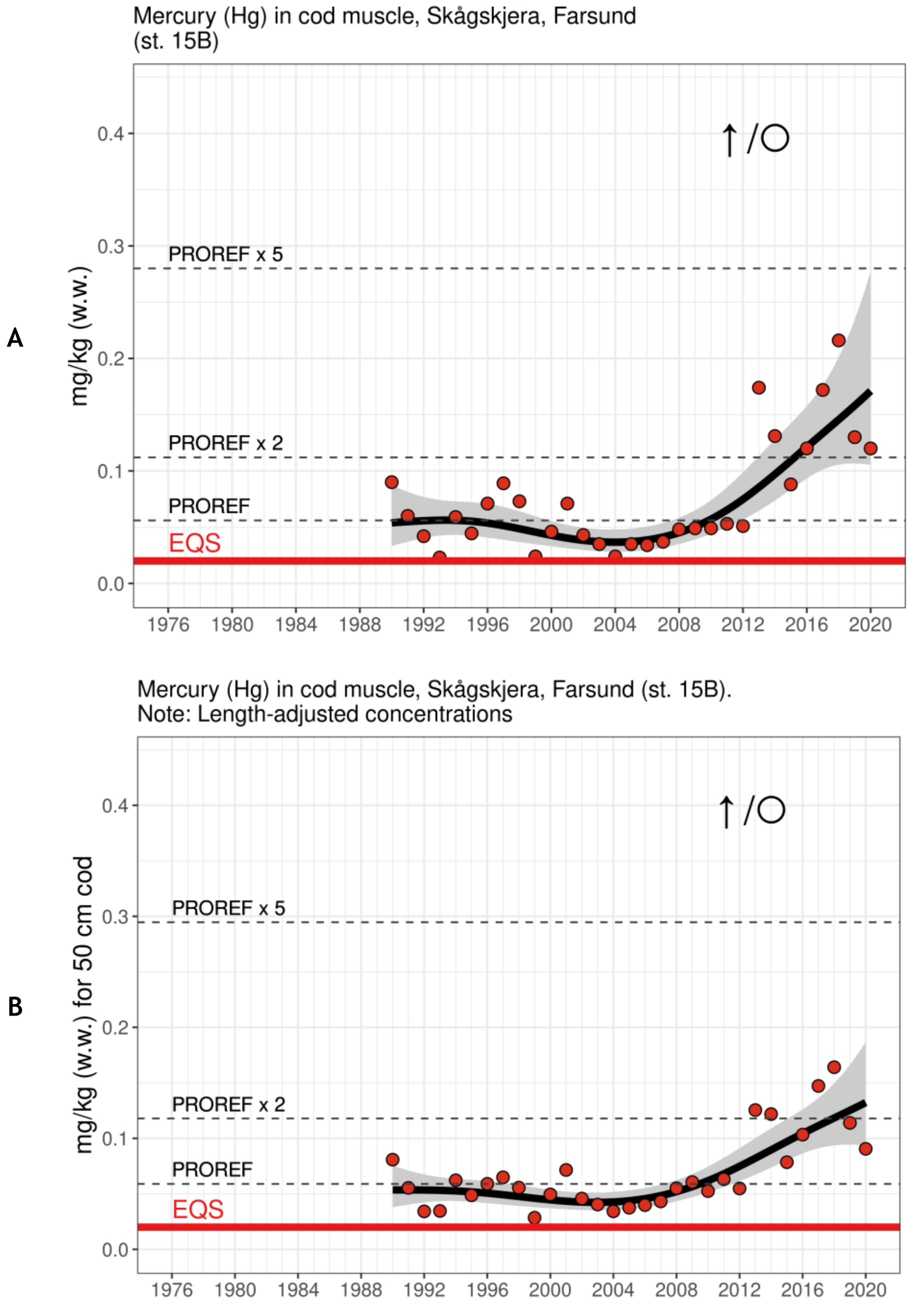


Figure 11. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Skågskjera (st. 15B) in Farsund; no adjustment for length (A) and adjusted for length (**B**) (see **Figure 6** and **Appendix C**).*

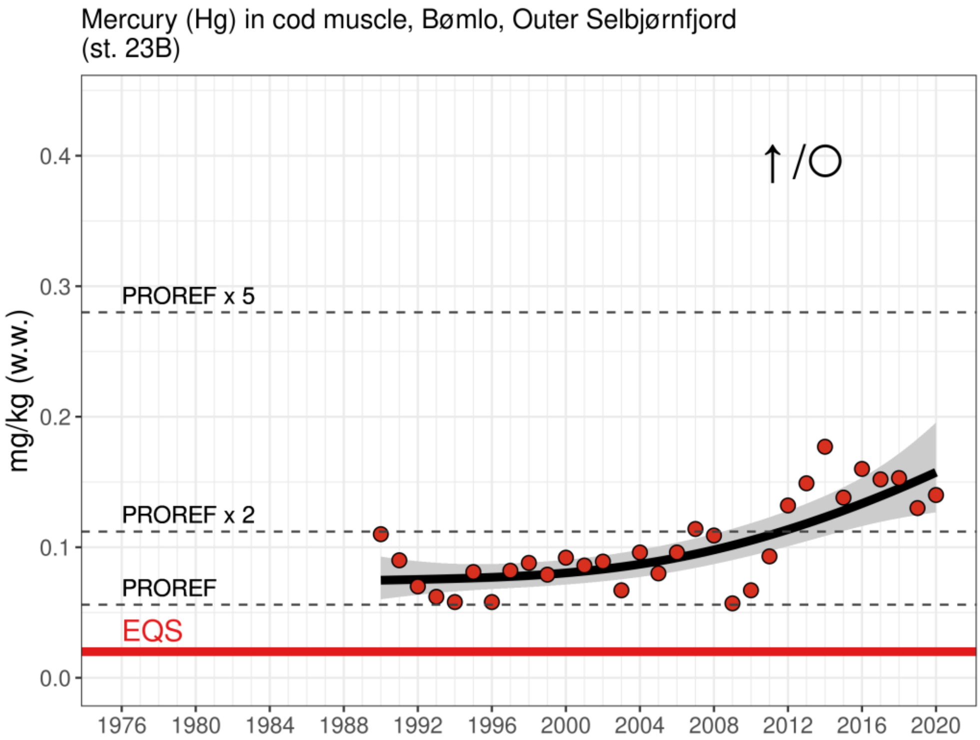
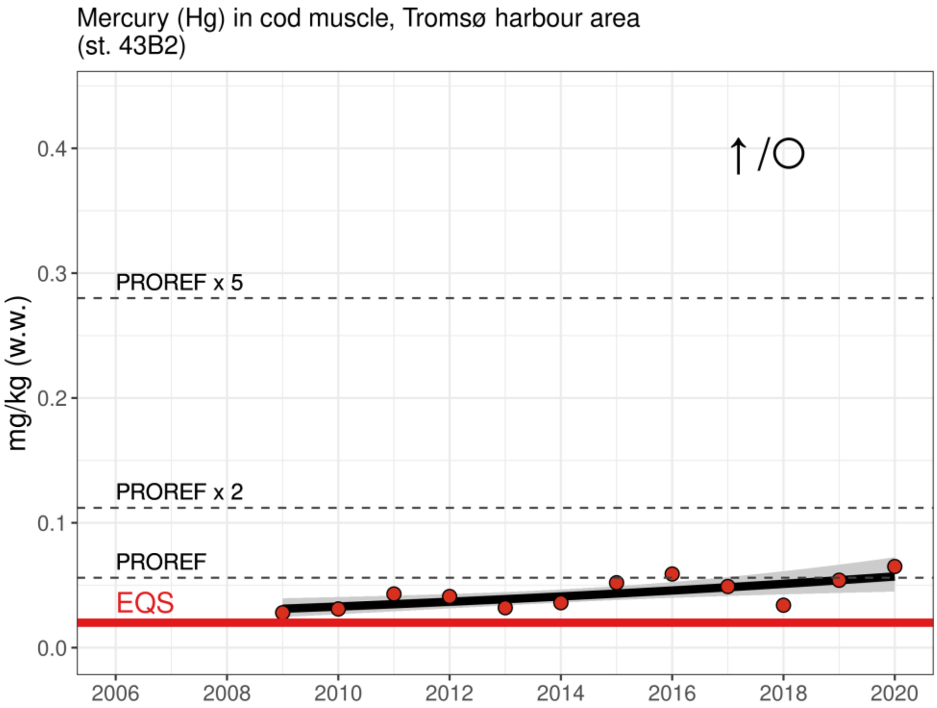


Figure 12. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Bømlo (st. 23B); in the Outer Selbjørnfjord; no adjustment for length (see* ***Figure 6*** *and* ***Appendix C****).*



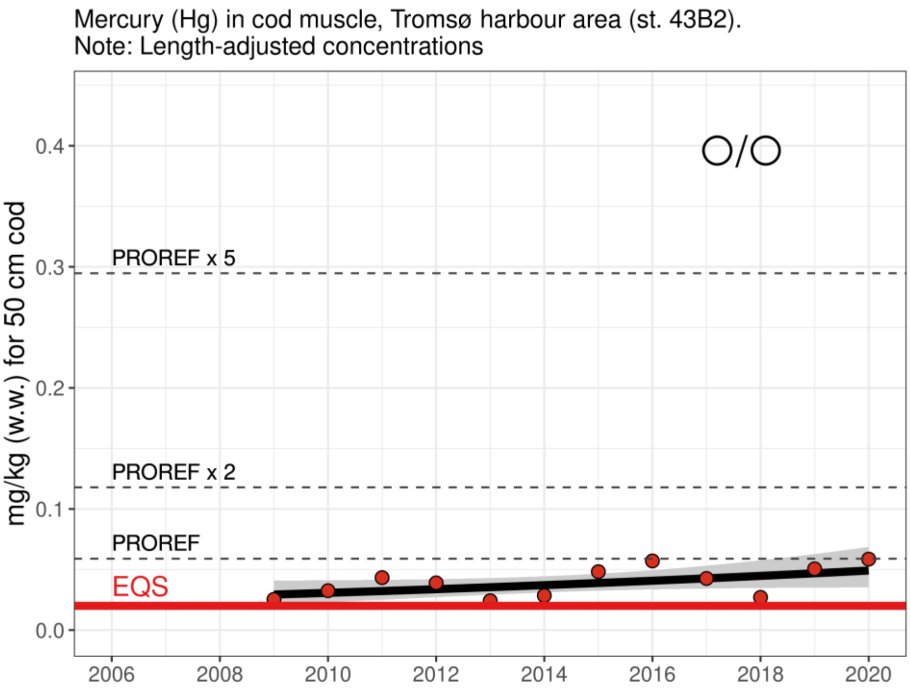


Figure 13. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from* Tromsø harbour *(st. 43B2); no adjustment for length (**A**) and adjusted for length (**B**) (see **Figure 6** and **Appendix C**).*

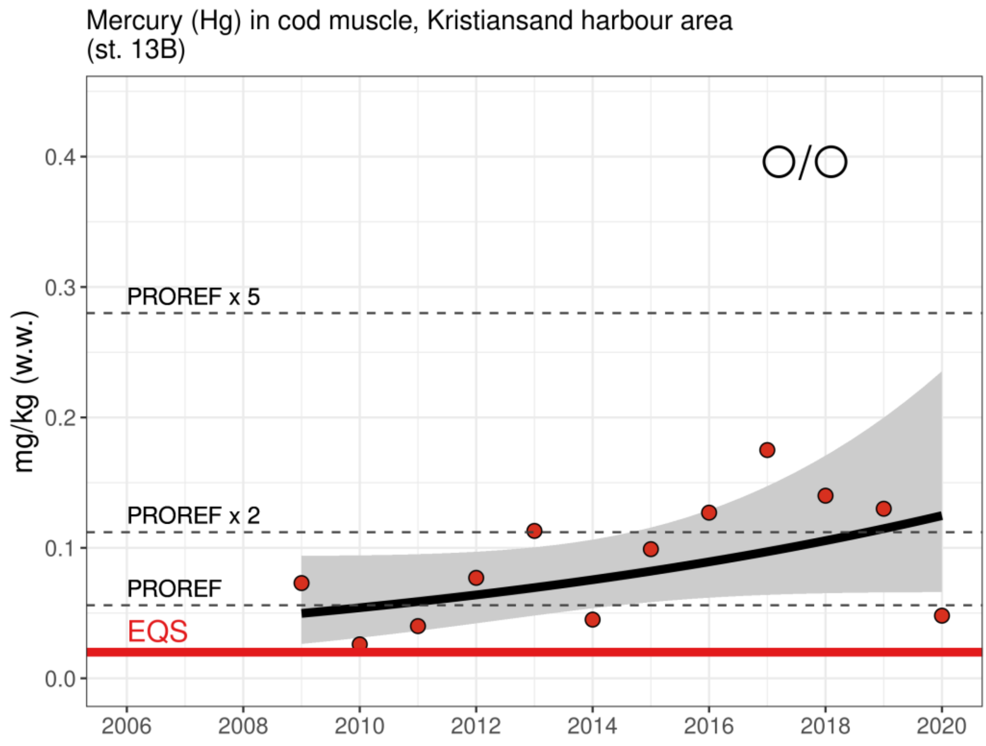


Figure 14. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from Kristiansand (st. 13B) (see **Figure 6** and **Appendix C**).*

In flounder at Sande (st. 33F) in the mid Oslofjord, the Hg concentration in fillet was 0.150 mg/kg w.w. and a significant upward short-term trend was observed.

Decrease in PROREF factor since 2019
The concentrations of Hg in cod fillet from the Kristiansand harbour (st. 13B) were below PROREF in 2020, compared to an exceedance of two to five in 2019.

Downward trends
In blue mussel, a significant downward long-term trend was found at Solbergstrand (st. 31A) in the mid Oslofjord, at Færder (st. 36A[1]) in the Outer Oslofjord and at Kirkøy (st. I024) at Hvaler. This was also observed in the Grenlandfjord at Bjørkøya (st. 71A), in the Sørfjord at Krossanes (st. 57A) (***Figure 15***) and in the mid Hardangerfjord at Vikingneset (st. 65A). The same result was seen at Skallnes (st. 10A2) in the Varangerfjord. A significant downward short-term trend was found at Singlekalven (st. I023) at Hvaler.

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

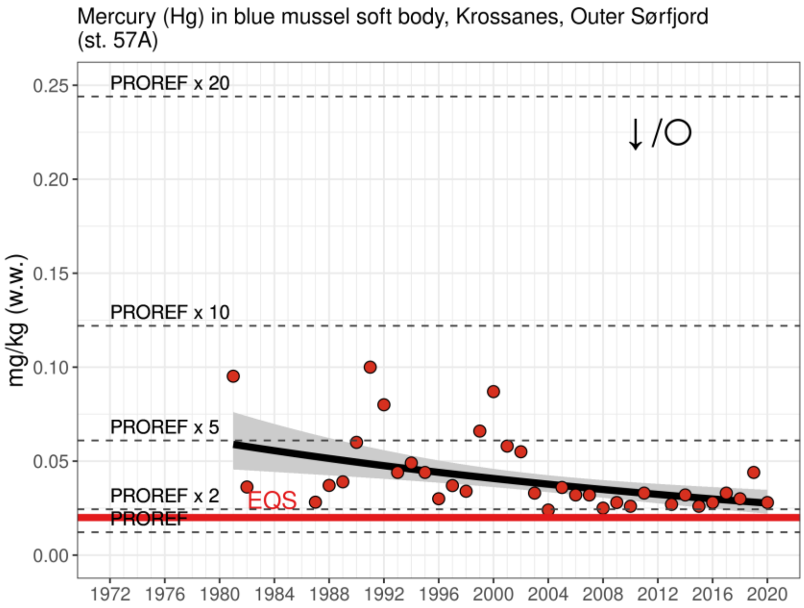


***Figure 15.** Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from Krossanes in the Outer Sørfjord (st. 57A) (see **Figure 6** and **Appendix C**).*

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Hg concentrations were 0.111 mg/kg w.w. in blood, and 0.111 mg/kg w.w. in eggs.

Comparison with other studies

In the present study, blue mussel at Kvalnes in the mid Sørfjord had lower Hg concentration (median 0.074 mg/kg w.w.) than at Byrkjenes in the Inner Sørfjord in 2019 (mean 0.1 mg/kg w.w.) in a comparable study (Ruus 2020b). Hg concentrations exceeded EQS at all three blue mussel stations in the Sørfjord in that survey. The collection of blue mussel in both studies took place during the autumn.

In the present study, the median concentration of Hg in cod fillet from the Inner Oslofjord was 0.140 mg/kg Hg w.w. In a comparable study from the Inner Oslofjord in 2020, the mean concentration was 0.153 mg/kg Hg w.w. (Grung et al. 2021), and the levels are within the same range. The collection of cod in both studies took place during the autumn.

EC maximum concentration levels for heavy metal concentrations in fish and shellfish are five times greater, or more, that background concentrations. In all OSPAR regions assessed since 2009 the average heavy metal concentrations are below EC maximum levels. Mercury concentrations in fish and shellfish are at or above background in all contaminants assessment areas. The highest concentrations are found in the Norwegian Trench, Northern North Sea, Southern North Sea and Irish Sea, at around twice the background concentration (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/metals-fish-shellfish/).

Most of the Hg-pollution in Norwegian lakes is now due to atmospherically deposited Hg originating from other parts of the world (Jartun 2021). The concentration of Hg in trout from Mjøsa showed a decreasing trend in the period 1980-2005, and showed more or less unchanged concentrations during the period 2006-2014 (Løvik 2016). Surveys from 2008 suggests that the length adjusted average Hg-concentrations in ten perch populations from forest lakes, increased with 63 % since the early 1990s (Fjeld 2009).

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

In the present study, Hg concentration (median 0.111 mg/kg w.w.) in eider eggs at Svalbard was almost 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 0.111 mg Hg/kg w.w. in blood and 0.111 mg Hg/kg w.w. in eider eggs from Svalbard. A study of eider from the Inner Oslofjord in 2017, found mean values of 0.187 mg Hg/kg w.w. in blood and 0.154 mg Hg/kg w.w. in eggs (Ruus 2018). The Hg concentrations in eider blood and eggs at Svalbard in 2020 was almost within the same range as in the Inner Oslofjord in 2017.

General, large scale trends

In 2019, 0.5 tons of Hg was released in Norway, and there has been an 80 % reduction in emissions of Hg and Hg-compounds since 1995[1].

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

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

For the food web in the North East Atlantic Ocean, positive correlations have been found between concentrations of Hg and dioxins, PCBs, and PBDEs, which accumulate in marine food webs. Concentrations of Hg increased in the food web from North to South in that ocean area (Ho 2021).

There are some evidences of downward long-term trends for Hg. Downward long-term trends were found in blue mussel at eight locations. One significant downward short-term trend was found at Singlekalven in Hvaler. Downward long-term trends were observed in cod fillet at four locations.

When considering the total of 43 possible recent short-term (2011-2020) trends for both cod and blue mussel, no upward trends were found (***Table 9**, **Figure 16***).

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

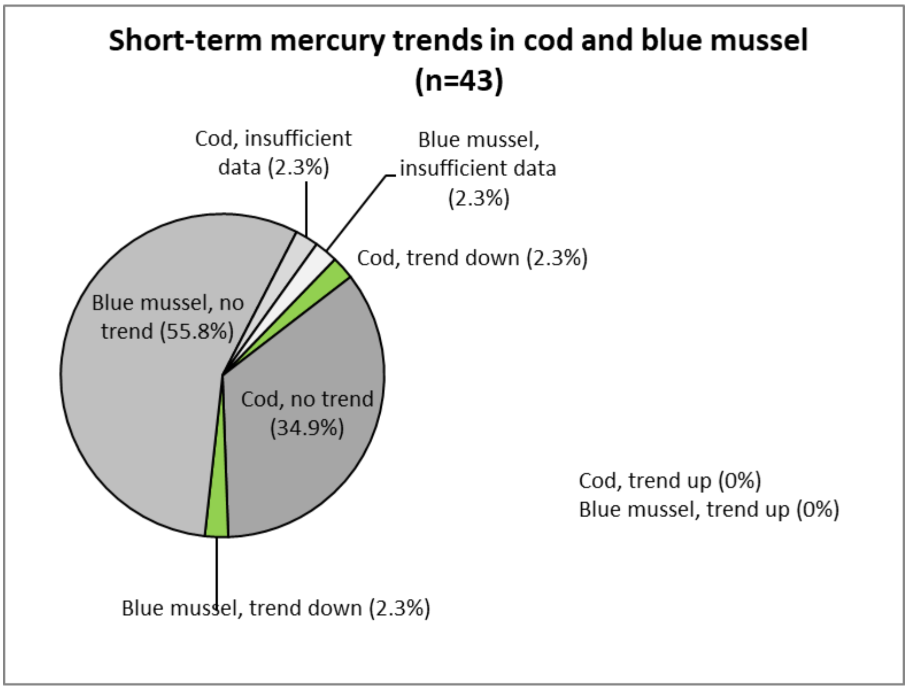


Figure 16. *Frequency of short-term trends (2011-2020) for mercury (Hg) in blue mussel and cod fillet.*

In the present study, there were significant upward long-term trends for Hg in cod fillet from the Inner Oslofjord, Farsund (Skågskjera), Bømlo and Tromsø harbour. Given the overall reduction in national Hg emissions and releases mentioned above and strict regulations of Hg use, the increasing Hg trends are not believed to be related to increased releases from primary sources in Norway, but could be related to factors such as; climate change, more favourable conditions for methyl Hg formation, increased bioavailability of Hg stored in the sediments, increased access of cod to contaminated feeding areas due to improved oxygen levels in deep water, changes in what the cod eat, etc. Present discharge of Hg to the Inner Oslofjord has been calculated to be around 7.3 kg/year (Berge 2013b). Berge et al. (2013b) estimated the discharges of Hg from various sources to the Inner Oslofjord; rivers (2.2 kg Hg/year), atmosphere (1.6 kg Hg/year), impermeable surfaces (2.1 kg Hg/year), wastewater treatment plants (WWTP) (0.9 kg Hg/year) and stormwater runoff (0.5 kg Hg/year). The riverine input to the Inner Oslofjord from Alna river was 0.08 kg Hg in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 0.48 kg Hg in 2020 to the Inner Oslofjord (VEAS 2021).

Another explanation could be atmospheric deposition. Atmospheric deposition is a major source to the seas surrounding Norway and considerably larger than other sources such as riverine discharges, shipping and offshore installations (Green 2013). Bjerkeng et al. (2009) found that more than 60 % of the Hg input to the Bunnefjord was from atmospheric deposition. There was some indication that Norwegian atmospheric deposition in southern Norway is decreasing for the period 1995-2006, but this was not statistically confirmed (Wängberg 2010). Newer data show small downward trends for Hg at Birkenes (19 %) and Zeppelin (10 %), and a larger downward trend is observed in precipitation than in air for Hg at Lista/Birkenes (Nizzetto 2021).

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 82 kg Hg/year in 2020 (***Figure 17***). The emissions to air varied between 104 kg Hg/year in 2009 to 82 kg Hg/year in 2020 for the period

2009-2020. The discharges to water from land-based industries were at a maximum in 2000 (36 kg Hg/year), and at a minimum in 2019 (6.7 kg Hg/year). In 2020, the discharges to water were 7.82 kg Hg/year.

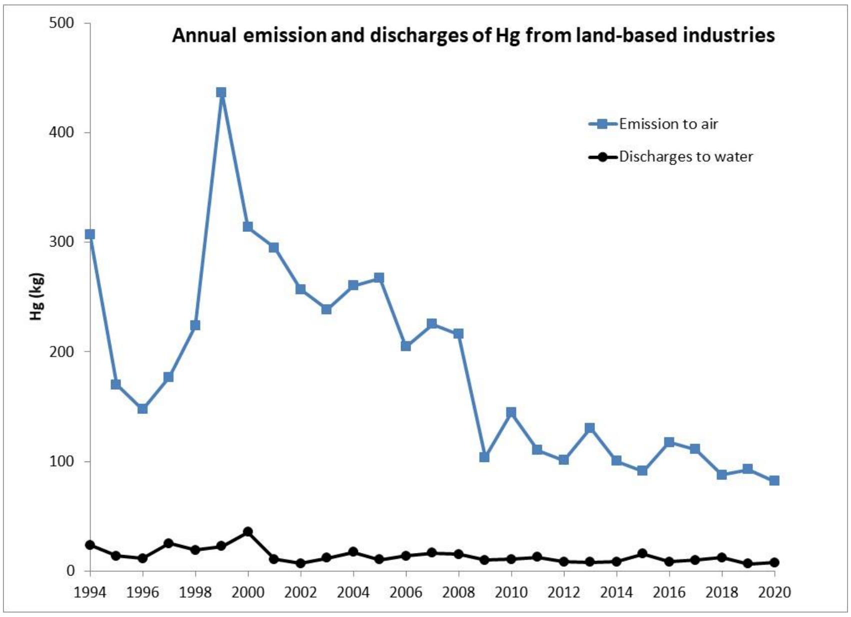


Figure 17. *Annual emissions of Hg to air and discharges to water from land-based industries for the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.3 Cadmium (Cd)

Cadmium (Cd) is a naturally occurring heavy metal. Sources are agricultural and industrial emissions, long-range air pollutants and Cd naturally found in small quantities in the earth's crust. In the present study, Cd was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

Levels exceeding PROREF

Blue mussel at nine stations exceeded the PROREF for Cd by a factor of up to two (***Table 9***). These blue mussel stations were at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, at Kirkøy (st. I024) at Hvaler in the Outer Oslofjord and at Bjørkøya (st. 71A) in the Grenlandfjord. The same result was found at Odderøya (st. I133) in the Kristiansandfjord and at Krossanes (st. 57A) in the Outer Sørfjord. This was also found at Svolvær (st. 98A2) in Lofoten, and at Brashavn (st. 11X) and Skallnes (st. 10A2) in the Varangerfjord.

Cod liver from Hammerfest harbour (st. 45B2) exceeded the PROREF for Cd by a factor up to two.

Increase in PROREF factor since 2019

Blue mussel exceeded PROREF for Cd by a factor up to two in 2020, while there were no exceedances in 2019 at Akershuskaia (st. I301) and Gåsøya (st. I304).

The Cd concentration in cod liver from Hammerfest harbour (st. 45B2) exceeded the PROREF for Cd by a factor of two in 2020, while the level was below the limit in 2019.

Upward trends

There was a significant upward long-term trend for Cd in blue mussel at Gåsøya (st. I304) in the Inner Oslofjord (***Figure 18 A***). There was a significant upward short-term trend for Cd in blue mussel at Brashavn (st. 11X) in the Varangerfjord (***Figure 18 B***).

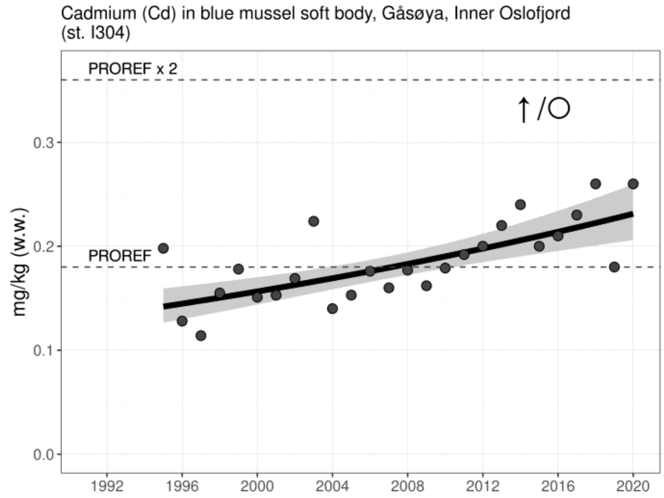
In cod liver from the Inner Oslofjord (st. 30B), a significant upward long-term trend for Cd was found (***Figure 19***).

In flounder at Sande (st. 33F) in the mid Oslofjord, the Cd concentration in liver was 0.240 mg/kg w.w., and a significant upward short-term trend was found.

Decrease in PROREF factor since 2019

Blue mussel at Færder (st. 36A) in the Outer Oslofjord and Utne (st. 64A) in the Outer Sørfjord, had Cd concentrations below PROREF in 2020, while the concentrations exceeded PROREF by a factor of two in 2019.

A



B

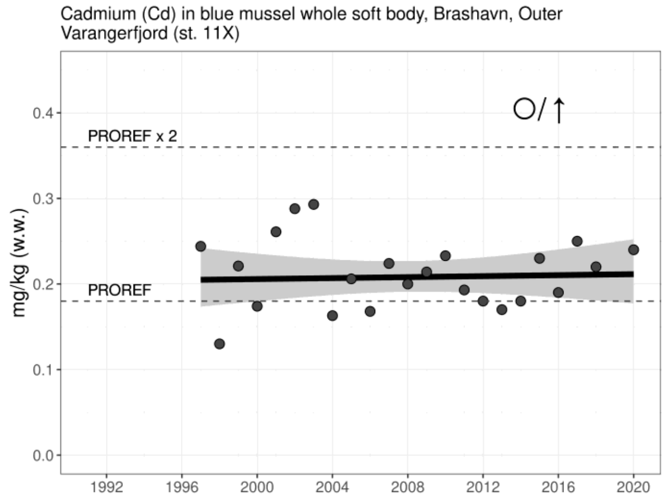


Figure 18. *Median concentrations (mg/kg w.w.) of cadmium (Cd) in blue mussel from Gåsøya (st. I304) in the Inner Oslofjord (A) and from Brashavn (st. 11X) in the Varangerfjord (B) (see* ***Figure 6*** *and* ***Appendix C****).*

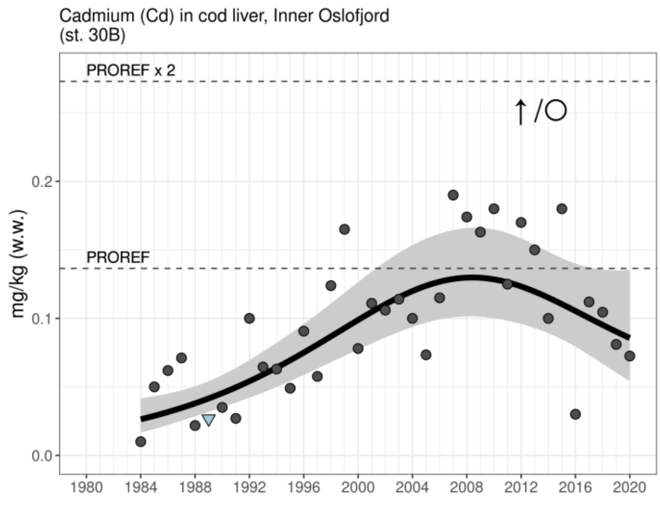


Figure 19. *Median concentrations (mg/kg w.w.) of cadmium (Cd) in cod liver from in the Inner Oslofjord (st. 30B) (see* ***Figure 6*** *and* ***Appendix C****).*

Downward trends
In blue mussel, there were both significant downward long- and short-term trends at Bjørkøya (st. 71A) in the Grenlandfjord. There were significant downward long-term trends at Krossanes (st. 57A) in the Outer Sørfjord, at Vikingneset (st. 65A) in the mid Hardangerfjord and at Nordnes (st. I241) in Bergen harbour.

In cod liver, there were both significant downward long- and short-term trends for Cd in Ålesund harbour (st. 28B). There was a significant downward long-term trend in the Inner Sørfjord (st. 53B). and in the Austnesfjord (st. 98B1) in Lofoten.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cd concentrations were 0.003 mg/kg w.w. in blood and <0.0003 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord had concentration (median 0.073 mg/kg Cd w.w.) in the same range as a comparable study from the Inner Oslofjord in 2020 (mean 0.117 mg/kg Cd w.w.) (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

General, large scale trends
In 2019, one ton of Cd was released in Norway compared with five tons in 1995 and 43 tons in 1985. Today, the metal- and mining industries account for the largest emissions[1].

Discharges of Cd to water from land-based industries showed a decrease from 2000 (1468 kg Cd/year) to 2020 (82 kg Cd/year) (***Figure 20***). The emission of Cd to air showed a gradually decrease from 1999 (560 kg Cd/year) to 2020 (59 kg Cd/year).

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

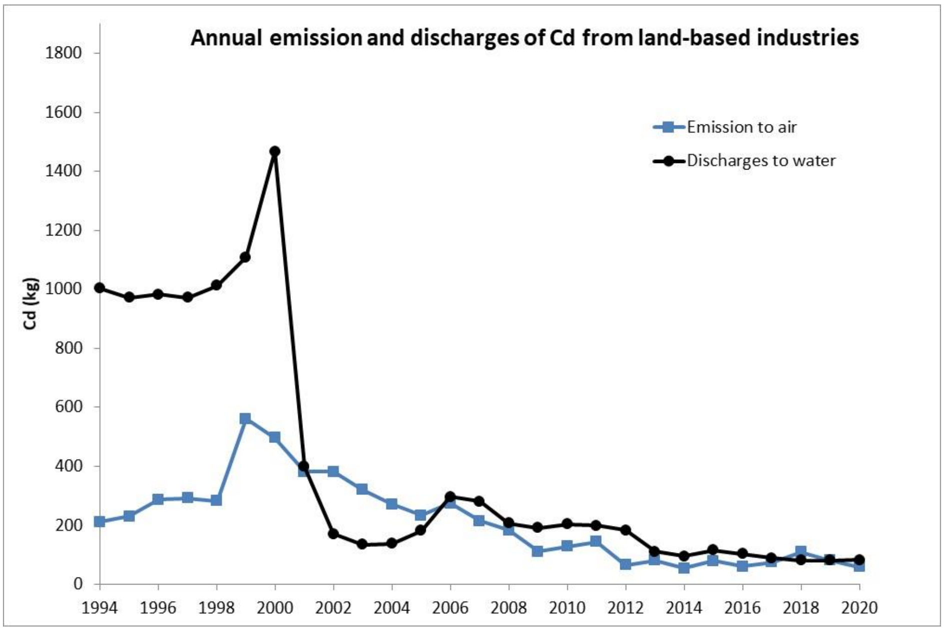


Figure 20. *Annual emissions of Cd to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no,* 04.07.2021*). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 Ullensvang in the Inner Sørfjord decreased from 1316 kg/year in 2000 to 17.13 kg/year in 2020 (www.norskeutslipp.no). There was a significant downward long-term trend in blue mussel at Krossanes in the Outer Sørfjord and at Vikingneset in the mid Hardangerfjord.

Total riverine input of Cd in Norway has been estimated to be 2 tonnes in 2017 (Kaste 2018). The total riverine inputs of Cd in different seawaters were 1 tonne to Skagerrak. The riverine input to the Inner Oslofjord from Alna river was 0.00 tonnes Cd in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 4.3 kg Cd to the Inner Oslofjord in 2020 (VEAS 2021).

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

In the OSPAR monitoring programme, cadmium concentrations in fish and shellfish are above background in nine of 12 assessment areas; the exceptions are the English Channel, Northern Bay of Biscay and Iberian Sea. Concentrations in biota from the Barents Sea and Southern North Sea are 2-5 times higher than the background levels (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/metals-fish-shellfish/).

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 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

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 of 10 to 20. The exceedance was by a factor of five to 10 at Gressholmen (st. 30A) in the Inner Oslofjord. The exceedance was by a factor of two to five at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, Nordnes (st. I241) in the Bergen harbour area, Krossanes (st. 57A) in the Outer Sørfjord, Bodø harbour (st. 97A3) and Mjelle (st. 97A2) in the Bodø area. Blue mussel exceeded PROREF by a factor of up to two at eight stations (***Table 9***). These stations were Kirkøy (st. I024) at Hvaler in the Outer Oslofjord, Bjørkøya (st. 71A) in the Grenlandfjord, Risøy (st. 76A2) at Risør and Gåsøya-Ullerøya (st. 15A) in Farsund. This was also the result at Utne (st. 64A) in the Outer Sørfjord and at Vikingneset (st. 65A) in the mid Hardangerfjord, at Vågsvåg (st. 26A2) in the Outer Nordfjord and Ålesund harbour (st. 28A2).

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Pb by a factor up to two (***Table 9***).

Increase in PROREF factor since 2019

Blue mussel at Odderøya (st. I133) in the Kristiansandfjord exceeded PROREF of Pb by a factor of 10 to 20 in 2020, while the exceedance was between five and 10 times in 2019. The exceedance of Pb was between two and five in 2020, while the exceedance was by a factor up to two at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord and at Mjelle (st. 97A2) in the Bodø area in 2019. At Risøy (st. 76A2) at Risør, Vågsvåg (st. 26A2) in the Outer Nordfjord and Gåsøya-Ullerøya (st. 15A) in Farsund, the concentrations of Pb were below PROREF in 2019, while the exceedances were by a factor up to two in 2020.

Upward trends

There were both significant upward long- and short-term trends in blue mussel from Gressholmen (st. 30A) (***Figure 21 A***) and at Gåsøya (st. I304) (***Figure 21 B***) in the Inner Oslofjord, and at Risøy (st. 76A2) at Risør.

A

B

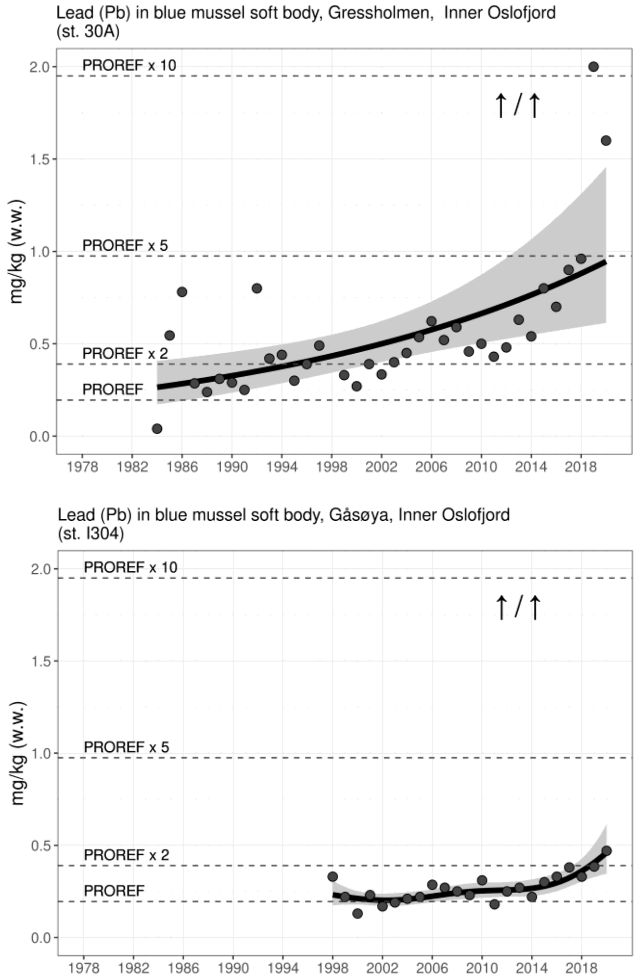


Figure 21. *Median concentrations (mg/kg w.w.) of lead (Pb) in blue mussel from Gressholmen (st. 30A) (**A**) and* Gåsøya *(st. I304) (**B**) in the Inner Oslofjord (see **Figure 6** and **Appendix C**).*

Decrease in PROREF factor since 2019

Blue mussel exceeded PROREF of Pb by a factor between five to 10 in 2020, while the exceedance was between 10 and 20 in 2019. Blue mussel at Kirkøy (st. I024) exceeded PROREF by a factor up to two in 2020, while the concentrations exceeded the PROREF by a factor between two and five in 2019. At Singlekalven (st. I023), the concentrations of Pb were below the PROREF in 2020, while the exceedance was by a factor up to two in 2019.

Downward trends

Of the trend analysis performed for blue mussel, six revealed significant downward long-term trends (***Table 9***). Significant downward long-term trends were found at Akershuskaia (st. I301) in the Inner Oslofjord, at Solbergstrand (st. 31A) in the mid Oslofjord, at Krossanes (st. 57A) in the Sørfjord and Vikingneset (st. 65A) in the mid Hardangerfjord. This was also observed in blue mussel at Espevær (st. 22A) in the Outer Bømlafjord and Nordnes (st. I241).

In cod liver, both significant downward long- and short-term trends were found at Tjøme (st. 36B) in the Outer Oslofjord, at Kirkøy (st. 02B) at Hvaler, in the Kristiansand harbour (st. 13B) and at Bømlo (st. 23B) in the Outer Selbjørnfjord. This was also found in the Trondheim harbour (st. 80B), in the Sandnessjøen area (st. 96B), in the Austnesfjord (st. 98B1) in Lofoten and in Hammerfest harbour (st. 45 B2). Significant downward long-term trends were found at Skågskjera in Farsund (st. 15B) and in the Inner Sørfjord (st. 53B). This was also the case at Kjøfjord (st. 10B) in the Varangerfjord.

In flounder at Sande (st. 33F) in the mid Oslofjord, the Pb concentration in liver was 0.039 mg/kg w.w., and a significant downward long-term trend was found.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Pb concentrations were 0.046 mg/kg w.w. in blood and 0.006 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, concentrations in cod liver from the Inner Oslofjord (median 0.095 mg/kg Pb w.w.) were in the same range as observed in a comparable study (mean 0.064 mg/kg Pb w.w.) from the Inner Oslofjord in 2020 (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

In the present study, Pb concentration (median 0.006 mg/kg w.w.) in eider eggs at Svalbard was almost at the same level as in a comparable study (median 0.005 mg/kg w.w.) (Hill 2018).

General, large scale trends
In 2019, 78 tons of Pb was released in Norway and there has been a 90 % decline since 1995[1]. Lead-free gasoline has significantly reduced the emissions, and now the largest emissions come from ammunition and blowing sand.

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

OSPAR (2010) found 50-80 % reduction in riverine and direct discharges of Pb to the North Sea for the period 1990-2006. While the total riverine input of Pb in Norway was 26 tonnes in 2017, the riverine inputs of Pb in different areas were 14 tonnes to Skagerrak, 8 tonnes to the North Sea, 3 tonnes to the Norwegian Sea and 1 tonnes to the Lofoten/Barents Sea (Kaste 2018) indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from industrial (1 tonnes) effluents amounting about 7 % of the total (28 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.04 tonnes Pb in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 69 kg Pb in 2020 (VEAS 2021).

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

Discharges of Pb to water from land-based industries in Norway showed a decrease from 2010 (6841 kg Pb/year) to 2020 (926 kg Pb/year) (***Figure 22***).

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

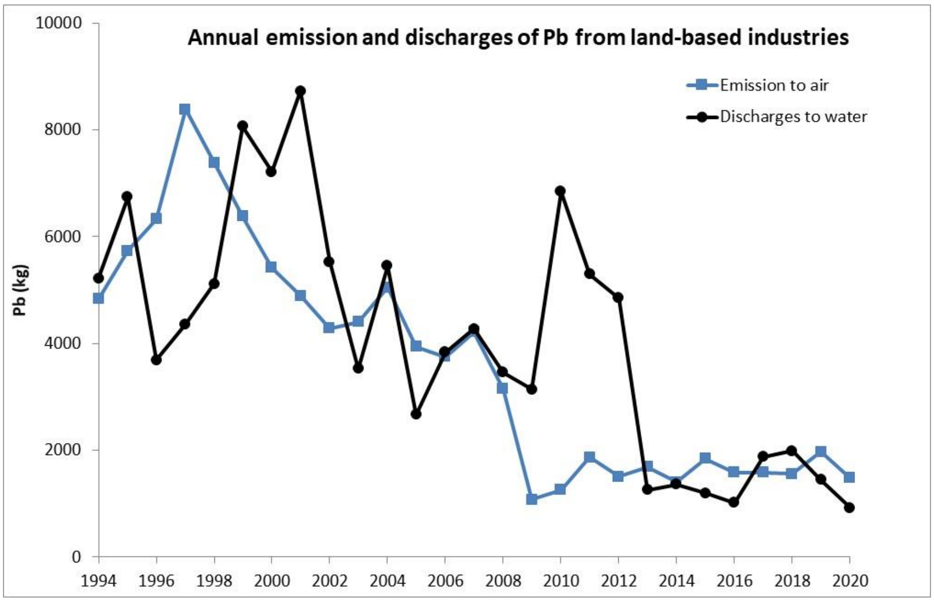


Figure 22. *Annual emissions of Pb to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 04.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

OSPAR has done monitoring of heavy metals in fish and shellfish in several ocean areas. With the exception of the Irish and Scottish West Coast, lead concentrations in biota are above background level. Lead concentrations in biota in the Northern North Sea, Irish Sea and Gulf of Cadiz all are at 2-5 times the background concentration (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/metals-fish-shellfish/).

3.2.5 Copper (Cu)

Copper (Cu) is an element. In the past, wood was often impregnated with Cu. Today such use is prohibited, and the use has been significantly reduced. Under the Biocidal Products Regulation however dicopper oxide and copper thiocyanate is still permitted as active substances in antifouling agents in Norway. When copper from metallic copper, copper thiocyanate or cuprous oxide leaches into marine water in presence of oxygen, the predominant form of the copper is the active substance, the cupric ion, Cu2+[1].

In the present study, Cu was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

Levels exceeding PROREF

In 2020, the Cu concentrations exceeded the PROREF in blue mussel by a factor between two to five in the Bodø harbour (st. 97A3) (***Table 9***). The exceedance of PROREF was by a factor up to two at Gressholmen (st. 30A), Solbergstrand (st. 31A) and Færder (st. 36A) in the Oslofjord, at Kirkøy (st. I024) in the Hvaler area and at Bjørkøya (st. 71A) in the Grenlandfjord. This was also the case at Odderøya (st. I133) in the Kristiansandfjord, Espevær (st. 22A), Nordnes (st. I241) in the Bergen harbour, Ålesund harbour (st. 28A2) and Skallnes (st. 10A2) in the Varangerfjord.

[1] https://echa.europa.eu/documents/10162/7417a7be-8032-c2d1-08d2-f780b50b3751

All Cu concentrations in cod liver were below PROREF.

Upward trends
In blue mussel, a significant upward short-term trend was found at Kirkøy (st. I024) in the Hvaler archipelago and at Nordnes (st. I241) in the Bergen city and harbour area.

In cod liver, a significant upward short-term trend was found at Skågskjera in Farsund (st. 15B) (***Figure 23***).

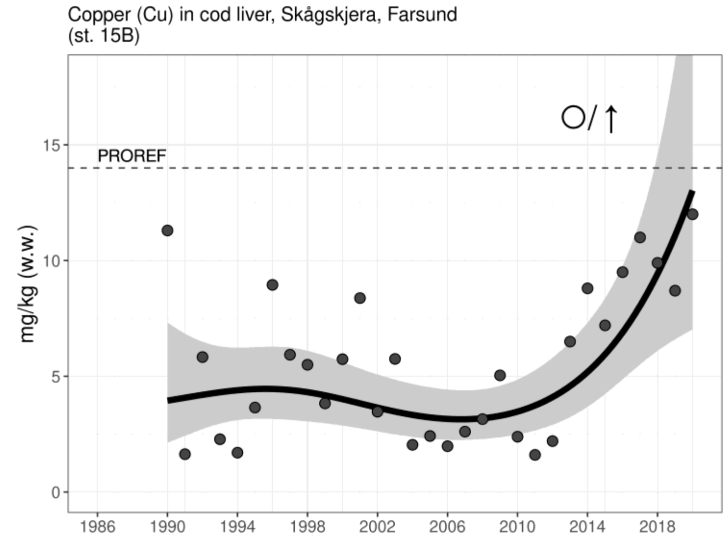


Figure 23. *Median concentrations (mg/kg w.w.) of copper (Cu) in cod liver from Skågskjera in Farsund (st. 15B) (see **Figure 6** and **Appendix C**).*

Downward trends
There were both significant downward long- and short-term trends in mussel from Mjelle in the Bodø area (97A2). A significant downward long-term trend was observed at Gåsøya (st. I304) in the Inner Oslofjord. Significant downward short-term trends were found at Odderøya (st. I133) in the Kristiansand harbour, at Lastad (st. I131A) in Søgne and at Brashavn (st. 11X) in the Varangerfjord.

There were significant downward long-term trends for Cu in cod liver from the Inner Oslofjord (st. 30B) and Tjøme (st. 36B) in the Outer Oslofjord.

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the Cu concentration in liver was 20.0 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cu concentrations were 0.453 mg/kg w.w. in blood and 1.171 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord (median 5.4 mg/kg Cu w.w.) was higher than in a comparable study from the Inner Oslofjord in 2020 (mean 3.72 mg/kg Cu w.w.) (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

General, large scale
In the past, wood was often impregnated with Cu, Cr and As. Today is it prohibited to use, and the use has been significantly reduced. In 2013, 1239 tonnes of Cu were used in the aquaculture industry to prevent overgrowth of the nets, and 80-90 % leaks into the sea[1]. This use is still ongoing. In 2014, 1130 tonnes of copper were sold for use as antifouling agents in Norway, while the corresponding consumption in 2019 was 1698 tonnes (Grefsrud 2021). This corresponds to an increase of 50 % over this period.

Discharges of Cu to water from land-based industries showed a gradually decrease from 1998 (19 385 kg Cu/year) to 2015 (5 560 kg Cu/year) (***Figure 24***). In 2020, the discharges to water were 6551 kg Cu/year.

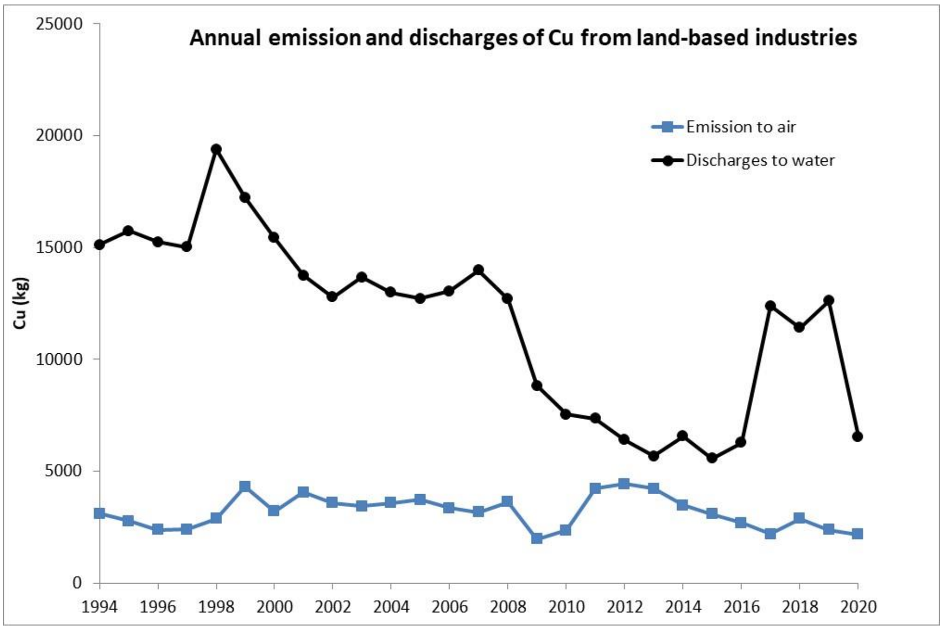


Figure 24. *Annual emissions of Cu to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for 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 to marine- and coastal waters in Norway was 165 tonnes in 2017 (Kaste 2018). The total riverine inputs of Cu were 59 tonnes to Skagerrak, 24 tonnes to the North Sea, 45 tonnes to the Norwegian Sea and 36 tonnes to the Lofoten/Barents Sea. The input of Cu along the coast of the Barent Sea has increased significantly from 1990 to 2018. In addition to riverine inputs, comes the contribution by direct discharges from sewage (5 tonnes) and industrial (5 tonnes) effluents and fish farming (1088 tonnes) amounting to 1099 tonnes (Kaste 2018), or about 87 % of the total (1264 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.20 tonnes Cu

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

in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 0.541 tonnes Cu in 2020 (VEAS 2021).

Berge et al. (2013b) estimated the discharges of Cu from various sources to the Inner Oslofjord; rivers (2.538 tonnes Cu/year), atmosphere (0.100 tonnes Cu/year), impermeable surfaces (1.081 tonnes Cu/year), wastewater treatment plants (WWTP) (2.528 tonnes Cu/year) and overflow (0.229 tonnes Cu/year).

3.2.6 Zinc (Zn)

Zink (Zn) is an element. In the present study, Zn was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

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 9***). These stations were Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, Solbergstrand (st. 31A) in the mid Oslofjord, and Singlekalven (st. I023) and Kirkøy (st. I024) at Hvaler. This was also the result at Odderøya (st. I133) in the Kristiansandfjord and Gåsøya-Ullerøya (st. 15A) in Farsund. This was also the case at Espevær (st. 22A) in the Outer Bømlafjord, at Nordnes (st. I241) in the Bergen harbour area and in Ålesund harbour (st. 28A2). The same result was found at Bodø harbour (st. 97A3), Mjelle (st. 97A2) in the Bodø area and at Skallnes (st. 10A2) in the Varangerfjord.

All Zn concentrations in cod liver were below PROREF.

Increase in PROREF factor since 2019

In 2020, the exceedance in PROREF for Zn was by a factor up to two at six blue mussel stations, while the concentrations were below this level in 2019. These stations were Gåsøya (st. I304), Solbergstrand (st. 31A), Kirkøy (st. I024), Espevær (st. 22A), Ålesund harbour (st. 28A2) and Mjelle (s. 97A2) in Bodø area.

Upward trends

Both significant upward long- and short-term trends were found in blue mussel from Risøy (st. 76A2).

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

Decrease in PROREF factor since 2019

In 2020, the Zn concentrations in blue mussel were below the PROREF while the exceedance was less than two times at Færder (st. 36A), Gåsøya-Ullerøya (st. 15A) in Farsund, at Vikingneset (st. 65A) in the mid Hardangerfjord and at Vågsvåg (st. 26A2) in the Outer Nordfjord.

In cod liver from the Kristiansandfjord (st. 13B), the Zn concentrations was below the PROREF in 2020, compared to an exceedance up to a factor of two in 2019.

Downward trends

In blue mussel, 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, Krossanes (st. 57A) in the Outer Sørfjord, Vikingneset (st. 65A) in the mid Hardangerfjord, Espevær (st. 22A) in the Outer Bømlafjord and at Brashavn (st. 11X) in the Varangerfjord.

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the Zn concentration in liver was 47.0 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Zn concentrations were 5.090 mg/kg w.w. in blood and 16.661 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord (median 28.0 mg/kg Zn w.w.) was higher than a comparable study from the Inner Oslofjord in 2020 (mean 18.2 mg/kg Zn w.w.) (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

General, large scale
Discharges of Zn to water from land-based industries showed a gradually decrease from 1999 (89 290 kg Zn/year) to 2020 (11 367 kg Zn/year) (***Figure 25***).

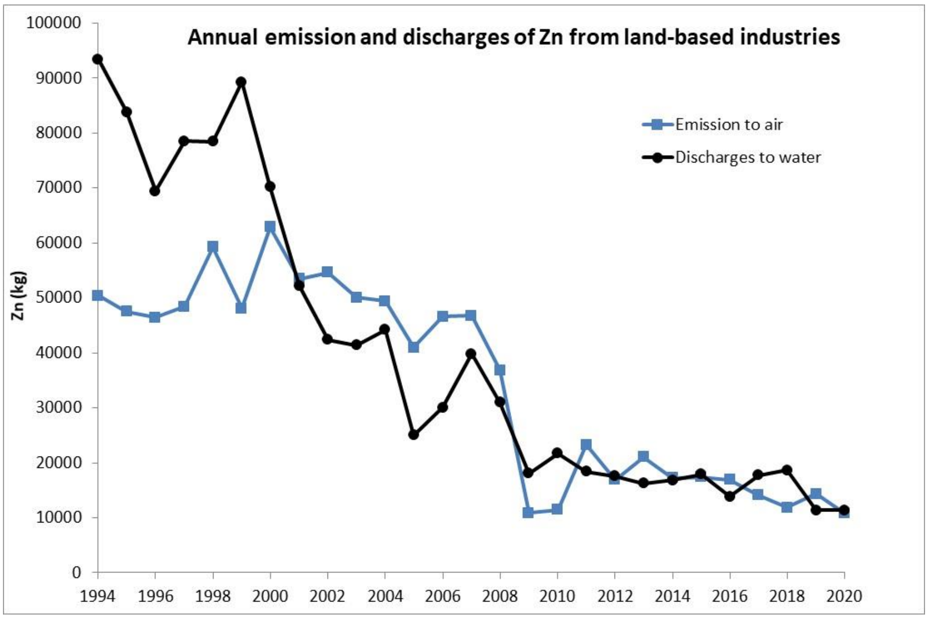


Figure 25. *Annual emissions of Zn to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data*, and this is the reason why this figure for 2019 looked very different than for 2018.

Total riverine input of Zn in Norway has been 407 tonnes in 2017 (Kaste 2018). Total riverine inputs of Zn were 186 tonnes to Skagerrak, 94 tonnes to the North Sea, 92 tonnes to the Norwegian Sea and 36 tonnes to the Lofoten/Barents Sea (Kaste 2018), indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from sewage (20 tonnes) and industrial (16 tonnes) effluents amounting to 36 tonnes or about 8 % of the total (443 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.62 tonnes Zn in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 2202 kg Zn in 2020 (VEAS 2021).

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

3.2.7 Silver (Ag)

Silver (Ag) is an element. Possible sources are the iron and steel industry, cement industry, mining and landfills. Silver is used as active substance in biocidal products and in treated articles. Under the biocidal product regulations all active substances must be authorized to be permitted to be placed on the market. Only silver uses which show acceptable risks, get authorized. Evaluation of silver as an active substance within the biocidal product regulations is ongoing. Pending the outcome of this evaluation, four silver compounds are permitted used as biocides in the EU/ EEA-region. Discharges of wastewater treatment plants (WWTP) and discharges from mine tailings are considered major and important sources for Ag to the aquatic environment (Tappin et al. 2010). The Ag nanoparticles from consumer products is important in terms of inputs to wastewater treatment plants (Nowack 2010). In the present study, Ag was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***)

Levels exceeding PROREF

The concentrations of Ag at all blue mussel stations were <0.050 mg Ag/kg w.w., which exceeded the Norwegian provisional high reference contaminant concentration (PROREF) (0.008565 mg Ag/kg w.w.) by a factor of five to 10 (***Table 9***).

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Ag by a factor of two to five. Cod liver from Tjøme (st. 36B) in the Outer Oslofjord, Stathelle (st. 71B) in the Langesundfjord, Skågskjera (st. 15B) at Farsund, the Inner Sørfjord (st. 53B) and Bergen harbour (st. 24B) exceeded PROREF by a factor up to two.

Increase in PROREF factor since 2019

The Ag concentration in cod liver were below PROREF in 2020, while the exceedance was by a factor up to two in 2019 at Stathelle (st. 71B) in the Langesundfjord, the Inner Sørfjord (st. 53B) and in the Bergen harbour (st. 24B).

Upward trends

In blue mussel, a significant upward short-term trend was found for Ag at Solbergstrand (st. 31A). This is a methodical (artificial) result processing the values below LOQ with random pulling of data between 0.5 LOQ and LOQ, while LOQ increased from 0.004 to 0.05 in 2019 (see details in chapter 2.6).

There were both significant upward long- and short-term trends for Ag in cod liver from Skågskjera (st. 15B) in Farsund (***Figure 26 A***) also when adjusted for length (***Figure 26 B***). A significant upward short-term trend was found in cod liver from Kjøfjord (st. 10B) in the Varangerfjord.

A

B

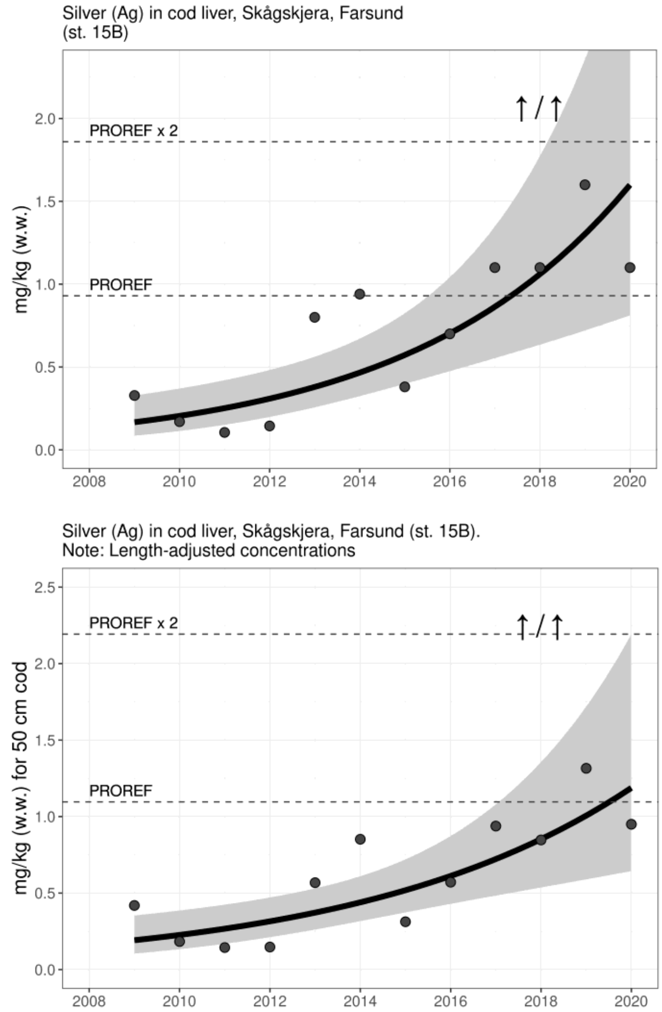


***Figure 26.** Median concentrations (mg/kg w.w.) of silver (Ag) in cod liver from Skågskjera (st. 15B) in Farsund; no adjustment for length (**A**) and adjusted for length (**B**) (see **Figure 6** and **Appendix C**).*

Downward trends

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

Levels in flounder

In flounder at Sande (st. 33F) in the mid Oslofjord, the Ag concentration in liver was 0.060 mg/kg w.w.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Ag concentrations were 0.001 mg/kg w.w. in blood and 0.009 mg/kg w.w. in eggs.

Comparison with other studies

In 2020, the highest Ag concentration in the present study was found in cod liver from the Inner Oslofjord (4.45 mg/kg w.w.), similar levels were observed in 2019 (5.90 mg/kg w.w.), 2018 (2.90 mg/kg w.w.), in 2017 (5.40 mg/kg w.w.), in 2016 (2.40 mg/kg w.w.) and in 2015 (6.85 mg/kg w.w.). Literature is sparse, but in one study equivalent concentrations in the gills of

Atlantic salmon was found to be lethal (Farmen et al. 2012). This indicates the need for a classification system to assess the possible effects in cod.

Cod liver from a comparable study from the Inner Oslofjord in 2019 showed a mean concentration within the range reported for this monitoring programme (3.52 mg/kg Ag w.w. in cod) (Grung et al. 2021). The sampling of cod in the MILKYS programme and the comparable study took place during the autumn.

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 (WWTP) is incorporated into sludge as Ag-sulphide nanoparticles (Ag_2S), although little is known about the Ag-species that occurs in discharged effluent (Kim et al. 2010; Nowack 2010). From a study of eight Norwegian wastewater treatment plants, concentrations of Ag in effluent ranged from 0.01 to 0.49 µg/L, and concentrations in sludge ranged from <0.01 to 9.55 µg/g (Thomas 2011).

General, large scale

Discharges of Ag to water from land-based industries in Norway showed a decrease from 1998 (9.12 kg Ag/year) to 2020 (0.21 kg Ag/year) (***Figure 27***).

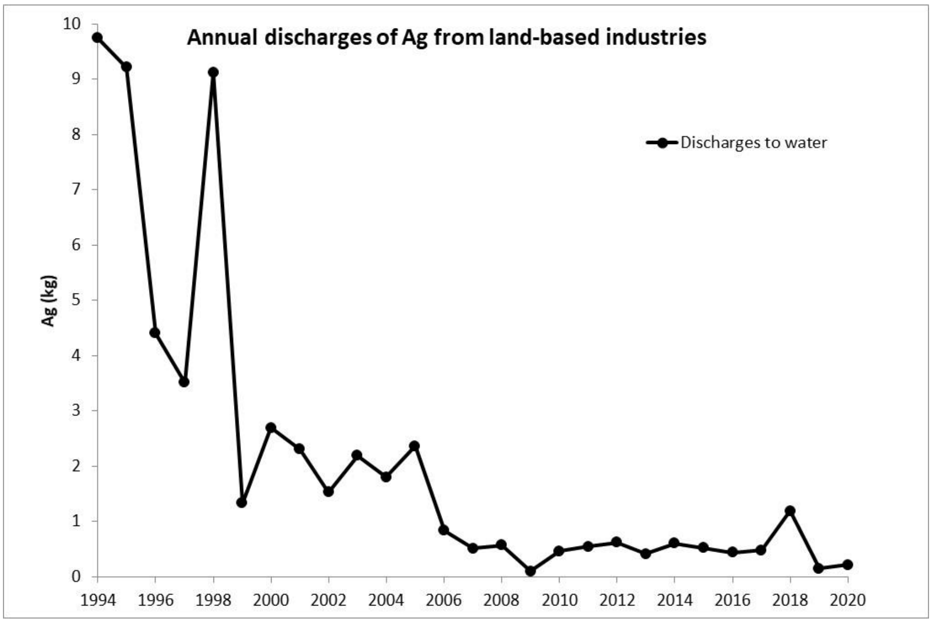


Figure 27. *Annual discharges of Ag to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New 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. The use of arsenic and arsenic compounds to prevent fouling of ships and equipment in water, for the treatment of water in industry, for wood impregnation and sale of treated wood, is prohibited through the REACH Regulation (Annex XVII, item 19). From 2002, it was forbidden to produce and sell CCA-impregnated wood in Norway, but chromium, copper and arsenic continue to leak from old wood. Therefore, it is assumed that impregnated wood is still the largest source of arsenic emissions in Norway. Large quantities are still found in, among other places, wharves, terrace floors and play equipment, and the emissions are therefore still significant. As evidenced from national monitoring activities, atmospheric long-range environmental transport of arsenic to Norway has decreased sharply since the 1970s (State of the Environment Norway[1]).

In the present study, As was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for As by a factor of two to five at Espevær (st. 22A) in the Outer Bømlafjord. The exceedance was by a factor up to two at Gåsøya (st. I304) in the Inner Oslofjord and Gåsøya-Ullerøya (st. 15A) in Farsund. This was also the result at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Hardangerfjord and at Vikingneset (st. 65A) in the mid Hardangerfjord. This was also observed at Nordnes (st. I241) in Bergen, Ålesund harbour (st. 28A2) and at Mjelle (st. 97A2) in Bodø area.

Cod liver exceeded PROREF for As by a factor of up to two at the Inner Oslofjord (st. 30B) and Tjøme (st. 36B) in the Outer Oslofjord.

Increase in PROREF factor since 2019

In 2020, the exceedance of As was between two and five times in blue mussel at Espevær (st. 22A) compared to a factor up to two in 2019. The exceedance was by a factor up to two times in 2020, while the concentrations were below PROREF in 2019 at Gåsøya (st. I304) in the Inner Oslofjord, Gåsøya-Ullerøya (st. 15A) in Farsund, Krossanes (st. 57A) in the Outer Sørfjord and Nordnes (st. I241) in Bergen.

In cod liver from Tjøme (st. 36B) in the Outer Oslofjord, the concentration of As exceeded the PROREF by a factor up to two in 2020 compared to no exceedance in 2019.

Upward trends

In blue mussel, a significant upward short-term trend was observed for As at Akershuskaia (st. I301).

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

Decrease in PROREF factor since 2019

In 2020, the As concentrations in blue mussel were below PROREF, compared to an exceedance by a factor between two and five at Vågsvåg (st. 26A2) and below two at Solbergstrand (st. 31A), Færder (st. 36A) and Ørland (st. 94A2) in 2019.

Downward trends

In blue mussel, both significant downward long- and short-term trends were observed at Bjørkøya (st. 71A) in the Grenlandfjord. A significant downward long-term trend was found at Svolvær airport area (st. 98A2) in Lofoten, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

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

In cod liver, both significant downward long- and short-term trends were found for As at Skågskjera (st. 15B) in Farsund. A significant downward long-term trend was found for As at Bømlo (st. 23B).

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the As concentration in liver was 4.0 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the As concentrations were 0.020 mg/kg w.w. in blood and 0.101 mg/kg w.w. in eggs.

Comparison with other studies
In the present study, cod liver from the Inner Oslofjord revealed median concentration of 15.0 mg/kg w.w. in 2020. Reported concentrations in previous years was 19.0 mg/kg w.w. in 2019, 17.5 mg/kg w.w. in 2018, 11.5 mg/kg As w.w. in 2017 and 4.7 mg/kg As w.w. in 2016. Cod liver from a comparable study from the Inner Oslofjord in 2020 had a mean concentration at the same level (14.0 mg/kg As w.w.) (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

In the present study, As concentration (median 0.101 mg/kg w.w.) in eider eggs at Svalbard was almost at 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 such use is no longer permitted.

Discharges of As to water from land-based industries showed an increase from 2008 (501 kg As/year) to 2010 (2572 kg As/year) (***Figure 28***). Discharges of As to water was 1477 kg in 2020.

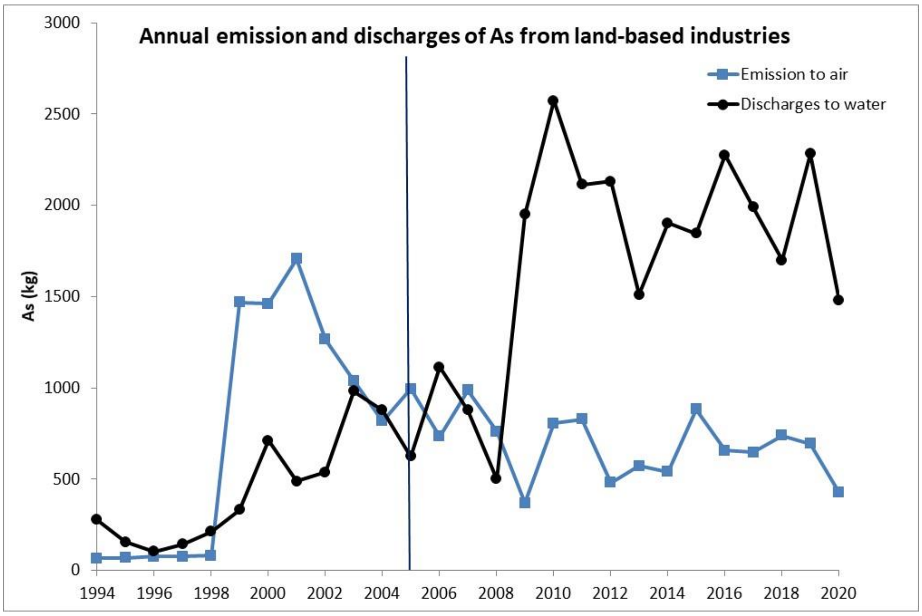


Figure 28. *Annual emissions of As to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). The vertical line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of As in Norway has been 24 tonnes in 2017 (Kaste 2018). Total riverine inputs of As were 11 tonnes to Skagerrak, 4 tonnes to the North Sea, 5 tonnes to the Norwegian Sea and 3 tonnes to the Lofoten/Barents Sea (Kaste 2018), indicating higher input in the southern part of Norway. In addition to riverine inputs, comes the contribution by direct discharges from industrial effluents amounting to 2 tonnes or about 8 % of the total (26 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.02 tonnes As in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 57 kg As in 2020 (VEAS 2021).

3.2.9 Nickel (Ni)

Nickel (Ni) is an element. In the present study, Ni was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

Levels exceeding PROREF

Blue mussel at Odderøya (st. I133) in the Kristiansandfjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Ni by a factor of two to five (***Table 9***). The exceedances were by a factor less than two at Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord and at Singlekalven (st. I023) and Kirkøy (st. I024) at Hvaler in the Outer Oslofjord. This was also the case at Bjørkøya (st. 71A) in the Langesundfjord and at Ørland area (st. 91A2) in the Outer Trondheimfjord.

Increase in PROREF factor since 2019

In 2020, blue mussel at Ørland area (st. 91A2) exceeded the PROREF by a factor less than two, compared to concentrations below PROREF in 2019.

In cod liver, the Ni concentrations at all stations were below the PROREF in 2020.

Upward trends
Both significant upward long- and short-term trends were found in blue mussel at Gressholmen (st. 30A) (***Figure 29***).

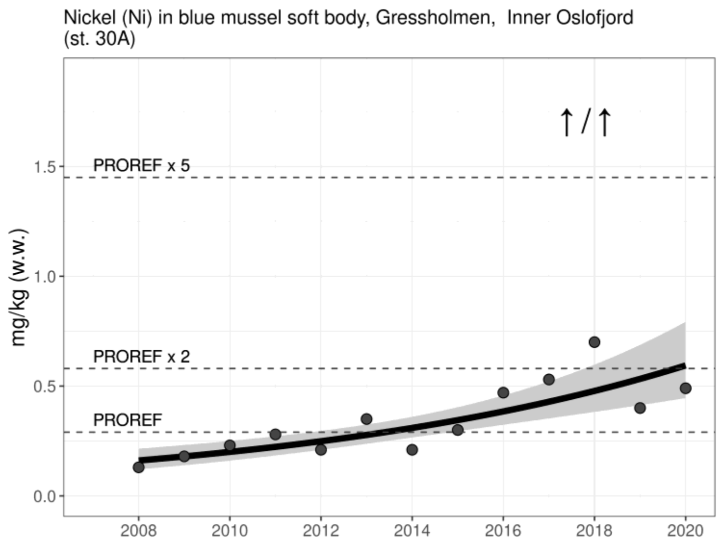


Figure 29. *Median concentrations (mg/kg w.w.) of nickel (Ni) in blue mussel from 2008 to 2020 at Gressholmen (st. 30A) in the Inner Oslofjord (see **Figure 6** and **Appendix C**.)*

Decrease in PROREF factor since 2019
In 2020, the Ni concentrations in blue mussel exceeded the PROREF by a factor less than two, compared to 10 to 20 times at Kirkøy (st. I024) and five to 10 times at Singlekalven (st. I023) at Hvaler in 2019. In 2020, the Ni concentrations were below PROREF, compared to an exceedance by a factor between two and five at the seven mussel stations; Akershuskaia (st. I301) in the Inner Oslofjord, Risøy (st. 76A2) at Risør, Gåsøya-Ullerøya (st. 15A) at Farsund, Krossanes (st. 57A) in the Outer Sørfjord, Vikingneset (st. 65A) in the mid Hardangerfjord, Mjelle (st. 97A2) in the Bodø area and Bodø harbour (st. 97A3). In 2020, the Ni concentrations were below PROREF at Solbergstrand (st. 31A) in the mid Oslofjord, compared to an exceedance less than two in 2019. The higher concentrations of Ni in blue mussel in 2019 indicated contamination during sample preparation.

Downward trends
In cod liver, both significant downward long- and short-term trends were found for Ni at Tjøme (st. 36B) in the Outer Oslofjord and at Ålesund harbour (st. 28B). A significant downward long-term trend was found in the Kristiansand harbour (st. 13B) and at Kjøfjord (st. 10B) in the Outer Varangerfjord.

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the Ni concentration in liver was 0.034 mg/kg w.w.

Levels in eider

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

Comparison with other studies

In the present study, cod liver from the Inner Oslofjord revealed a median concentration of 0.101 mg Ni/kg w.w. Cod liver from a comparable study from the Inner Oslofjord in 2019 showed a concentration of 0.152 mg Ni/kg w.w. (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

General, large scale

Discharges of Ni to water from land-based industries had decreased gradually from 2001 (21 463 kg Ni/year) to 2020 (6 528 kg Ni/year) (***Figure 30***).

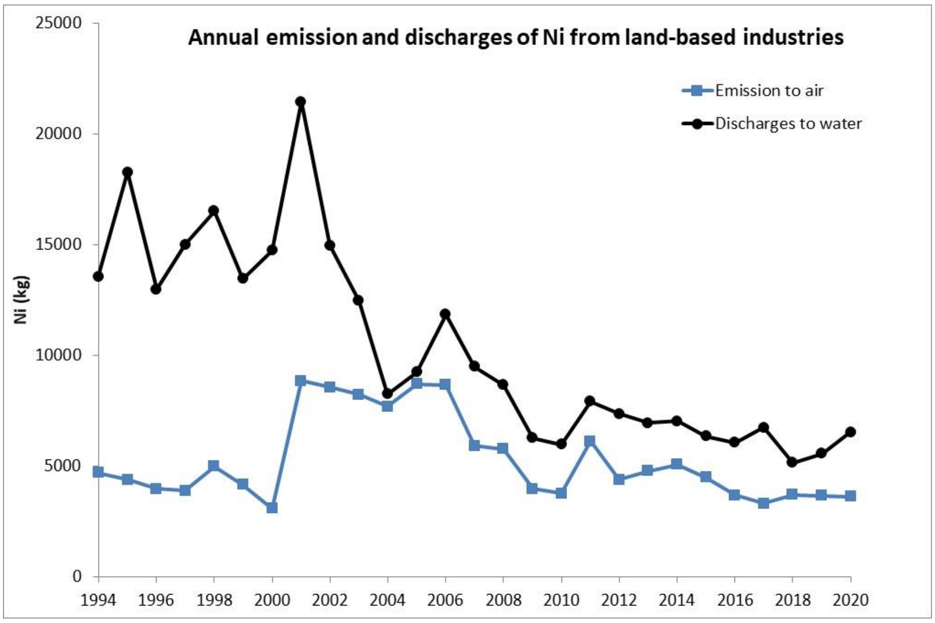


Figure 30. *Annual emissions of Ni to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Ni in Norway was 138 tonnes in 2017 (Kaste 2018). Total riverine inputs of Ni were 34 tonnes to Skagerrak, 13 tonnes to the North Sea, 29 tonnes to the Norwegian Sea and 62 tonnes to the Lofoten/Barents Sea. In addition to riverine inputs, comes the contribution by direct discharges from sewage (3 tonnes) and industrial (6 tonnes) effluents amounting to 9 tonnes or about 6 % of the total (147 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.06 tonnes Ni in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 259 kg Ni in 2020 (VEAS 2021).

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

3.2.10 Chromium (Cr)

Chromium (Cr) is an element found in several forms that have different toxicities. In the past, wood was often impregnated with Cr. From 2002, it was forbidden to produce and sell CCA-impregnated wood in Norway, but Cr, Cu and As continue to leak from old wood. Impregnated wood is therefore still the largest source of Cr emissions in Norway, accounting for around 63 % of emissions in 2019. In the present study, Cr was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

Levels exceeding PROREF

In blue mussel, the exceedances of the Norwegian provisional high reference contaminant concentration (PROREF) of Cr were by a factor between two and five at Gressholmen (st. 30A) in the Inner Oslofjord (***Table 9***). The exceedance of PROREF was by a factor less than two at Gåsøya (st. I304) in the Inner Oslofjord and Kirkøy (st. I024) at Hvaler.

The concentration of Cr in cod liver were below the PROREF at all stations.

Increase in PROREF factor since 2019

In 2020, blue mussel exceeded the PROREF by a factor of two to five at Gressholmen (st. 30A), compared to a factor less than two in 2019. The high concentrations of Cr in blue mussel in 2019 indicated contamination during sample preparation.

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 Varangerfjord. A significant upward long-term trend was observed at Gåsøya (st. I304) in the Inner Oslofjord.

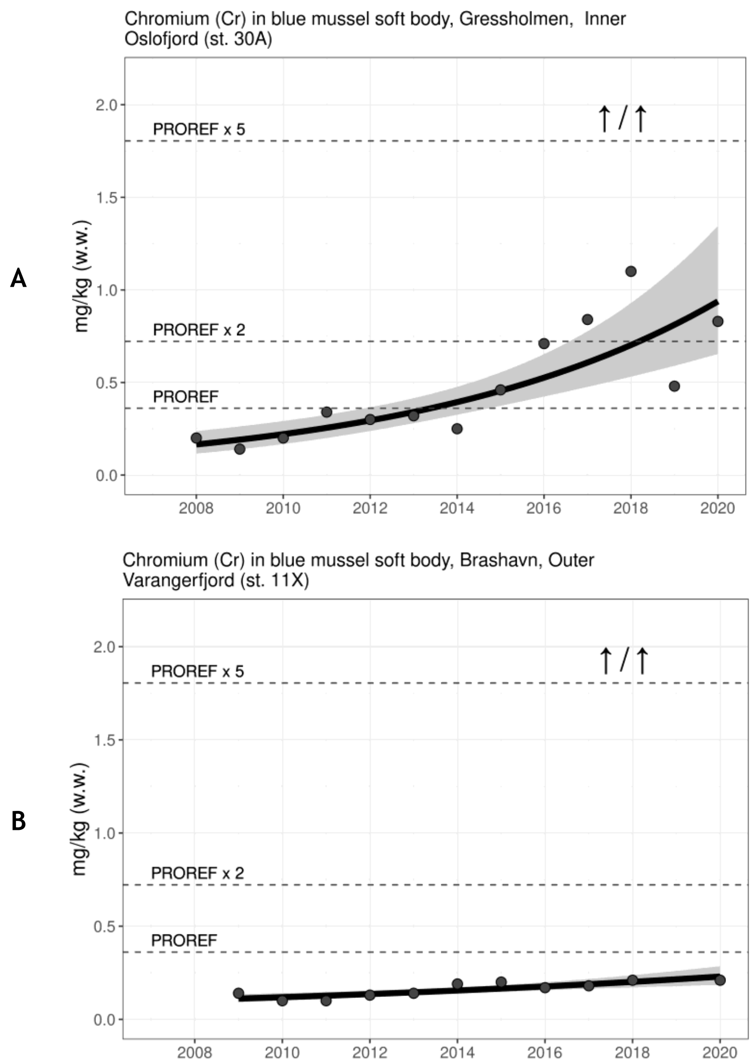


***Figure 31.** Median concentrations (mg/kg w.w.) of chromium (Cr) in blue mussel from 2008 or 2009 to 2020 in Gressholmen in the Inner Oslofjord (st. 30A) (A) and Brashavn (st. 11X) (**B**) (see **Figure 6** and **Appendix C**).*

Decrease in PROREF factor since 2019

In 2020, blue mussel at all stations had PROREF for Cr less than a factor of two, except for at Gressholmen (st. 30A) in the Inner Oslofjord. However, in 2020, mussels from Kirkøy (st. I024) in the Hvaler archipelago exceeded the PROREF for Cr by a factor between one and two, compared to more than 20 in 2019. In 2020, the concentrations of Cr were below the PROREF, compared to an exceedance of 10 to 20 at Singlekalven (st. I023) at Hvaler and an exceedance between five to 10 at Akershuskaia (st. I301) in the Inner Oslofjord and at Mjelle (st. 97A2) in the Bodø area in 2019. In 2020, the Cr concentrations were below the PROREF, compared to an exceedance between two and five at the seven stations in 2019; Solbergstrand (st. 31A) in the mid Oslofjord, Risøy (st. 76A2) at Risør, Odderøya (st. I133) in the Kristiansandfjord, Gåsøya-Ullerøya (st. 15A) in Farsund, Krossanes (st. 57A) in the Outer Sørfjord, Vikingneset (st. 65A) in the mid Hardangerfjord and Bodø harbour (st. 97A3).

In 2020, the concentration of Cr in cod liver was below PROREF at Skågskjera (st. 15B) in Farsund, but the exceedance was by a factor up to two in 2019.

Downward trends
A significant downward short-term trend was found for Cr at Espevær (st. 22A) in the Outer Bømlafjord.

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

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the Cr concentration in liver was 0.052 mg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cr concentrations were <0.003 mg/kg w.w. in blood and 0.006 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 0.075 mg Cr/kg w.w. Cod liver from a comparable study from the Inner Oslofjord in 2020 had mean concentration of 0.082 mg Cr/kg w.w. (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

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

Emissions of Cr to air and discharges to water from land-based industries had maintained stable levels the last years and are shown in ***Figure 32***. The discharges to water in 2020 was 1654 kg Cr/years.

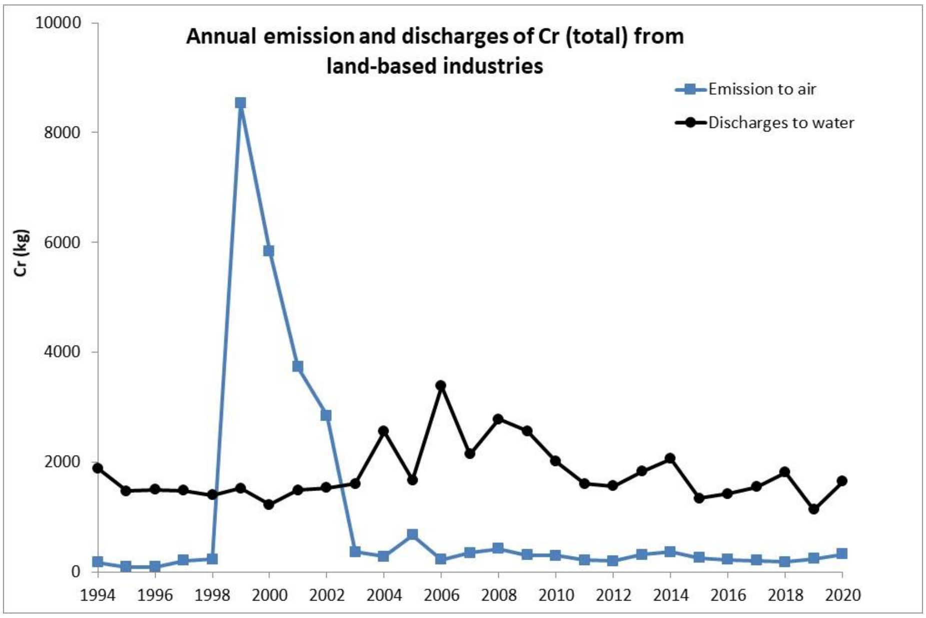


Figure 32*. Annual emissions of Cr to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Cr in Norway has been 31 tonnes in 2017 (Kaste 2018). The ranges of total riverine inputs of Cr were 11 tonnes to Skagerrak, 4 tonnes to the North Sea, 10 tonnes to the Norwegian Sea and 6 tonnes to the Lofoten/Barents Sea. In addition to riverine inputs, comes the contribution by direct discharges from sewage (1 tonnes) and industrial (1 tonnes) effluents amounting to 3 tonnes (Kaste 2018), or about 9 % of the total (34 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.02 tonnes Cr in 2019 (Kaste 2021). VEAS sewage treatment plant reported a discharge of 56 kg Cr in 2020 (VEAS 2021).

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

3.2.11 Cobalt (Co)

In the present study, cobalt (Co) was analysed in blue mussel at 25 stations, in cod liver at 17 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

Levels exceeding PROREF

Blue mussel from Kirkøy (st. I024) at Hvaler in the Outer Oslofjord and Odderøya (st. I133) in the Kristiansandfjord exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for Co by a factor of two to five (***Table 9***). Blue mussel at six stations exceeded PROREF for Co by a factor of up to two. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, Risøy (st. 76A2) at Risør, Ørland area (st. 91A2) in the Outer Trondheimfjord and at Bodø harbour (st. 97A3).

Cod liver from the Inner Oslofjord (st. 30B) exceeded the PROREF for Co by a factor less than two.

Increase in PROREF factor since 2019

In 2020, the Co concentration in blue mussel at Odderøya (st. I133) in the Kristiansandfjord exceeded the PROREF by a factor of two to five, compared to less than two in 2019. In 2020, there were an exceedance of the PROREF by a factor less than two, compared to levels below this limit in 2019 at Akershuskaia (st. I301), Gåsøya (st. I304) and Ørland area (st. 91A2).

In 2020, the Co concentration in cod liver from the Inner Oslofjord exceeded the PROREF by a factor less than two, compared to levels below this limit in 2019.

Upward trends

Both significant upward long- and short-term trends were observed in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord. A significant upward short-term trend was seen at Kirkøy (st. I024) at Hvaler.

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

Decrease in PROREF factor since 2019

In 2020, there were no exceedance of the PROREF of Co in blue mussel, compared to an exceedance less than two at Solbergstrand (st. 31A) in the mid Oslofjord, Singlekalven (st. I023) at Hvaler, Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord and at Mjelle (st. 97A2) in the Bodø area in 2019.

Downward trends

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

Levels in flounder

In flounder at Sande (st. 33F) in the mid Oslofjord, the Co concentration in liver was 0.120 mg/kg w.w.

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Co concentrations were 0.003 mg/kg w.w. in blood and 0.007 mg/kg w.w. in eggs.

General, large scale trends

Discharges of Co to water from land-based industries showed decreasing values from 2019 (701 kg Co/year) to 2020 (454 kg Co/year) (***Figure 33***).

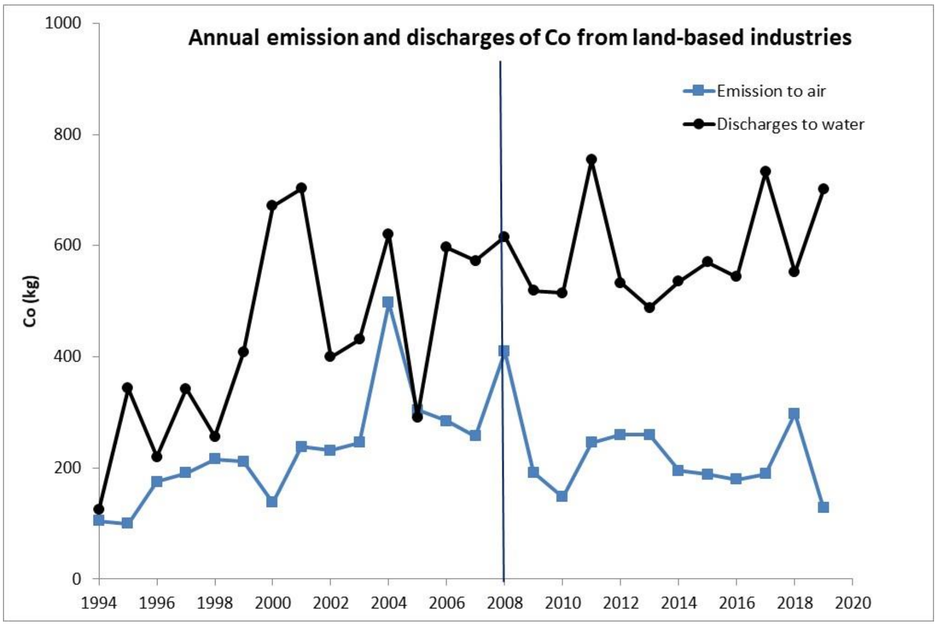


Figure 33. *Annual emissions of Co to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). The vertical grey line at 2008 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, 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 that was used as a biocide especially in marine antifouling paints until 2008, when it was banned globally. TBT is toxic to marine life and was first known to be used in the 1960s. Masculinized female marine snails was first described in the late sixties (Blaber 1970). TBT induces male sex characters onto females, such as imposex in dogwhelk and intersex in common periwinkle. In female dogwhelk, the TBT effect causes a vas deference and a pseudopenis that are superimposed onto female genital structures. Sterility and even death of individuals occur in the most advanced stages. In female common periwinkle, the TBT effect causes a pathological alteration in the oviduct, development of spermatocytes in ovary or oocytes in the testis and/or penis. Sterility occurs in the most advanced stages. Common periwinkle is less sensitive to TBT than dogwhelk and may act as an alternative sentinel when dogwhelk is not found.

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 and intersex (ISI) in common periwinkle (***Table 1***).

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 (< 3.1 µg/kg w.w.) and common periwinkle (< 0.680 µg/kg w.w.), all TBT-concentrations were below EQS in 2020 (***Table 8***), as in 2019.

Environmental Quality Standards (EQS) for river basin specific pollutants
When applying the EQS for triphenyltin (TPhT) (150 µg/kg w.w.) in biota on blue mussel (<1.8 µg/kg w.w.), dogwhelk (<2.4 µg/kg w.w.) and common periwinkle (<0.490 µg/kg w.w.), all TPhT-concentrations were below EQS in 2020, as in 2019 (***Table 8***).

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 two to five at Gressholmen (st. 30A) and up to two times at Akershuskaia (st. I301) (***Table 9***).

Increase in PROREF factor since 2019
Blue mussel at Gressholmen (st. 30A) exceeded PROREF for TBT by a factor of two to five in 2020, compared to up to two times in 2019. Mussels at Akershuskaia (st. I301) exceeded PROREF by a factor up two times in 2020, but did not exceeded this limit in 2019.

Decrease in PROREF factor since 2019
The concentrations of TBT in blue mussel at Odderøya (st. I133) in the Kristiansandfjord were below the PROREF in 2020, while the exceedance was up to two in 2019.

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

Dogwhelk
Levels of TBT
The TBT levels in dogwhelk were low (<3.1 µg/kg w.w.) at all eight stations.

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

Biological effects of TBT (imposex/VDSI) in dogwhelk
The effects of TBT measured by the imposex parameter VDSI, were zero at all eight stations. All results were below the OSPARs Background Assessment Criteria (BAC=0.3) (OSPAR 2009) and the OSPARs Ecotoxicological Assessment Criteria (EAC=2) (OSPAR 2013) in 2020, as in 2019.

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

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

Common periwinkle

Levels of TBT

The TBT concentration in common periwinkle at Fugløyskjær (st. 71G) in the Outer Langesundfjord was 0.68 µg/kg w.w.

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

The effect of TBT in common periwinkle, the intersex parameter ISI, was zero in 2020 at Fugløyskjær (st. 71G), as in 2019. ISI in common periwinkle is too sensitive for application of BAC and EAC (OSPAR 2013).

Trends of ISI

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

Comparison with other studies

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

General, large scale trends

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

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

The international convention that was initiated by the International Maritime Organization (IMO) did not only ban application of organotin on ships after 2003 but also stated that organotin after 2008 could not be part of the system for preventing fouling on ships. VDSI in dogwhelk was around level 4 in all dogwhelk stations before the ban in 2003, except for the Varangerfjord where the VDSI had been low (<0.3) in the whole monitoring period. It was a clear decline in VDSI as well as TBT at all stations between 2003 and the total ban in 2008 (***Figure 34***, ***Figure 35***). In the post-ban period since 2008, the VDSI levels have been below PROREF (3.68) at all stations, and the levels have gradually become zero. A typical example of a decreasing trend is shown for Færder in the Outer Oslofjord in ***Figure 36***.

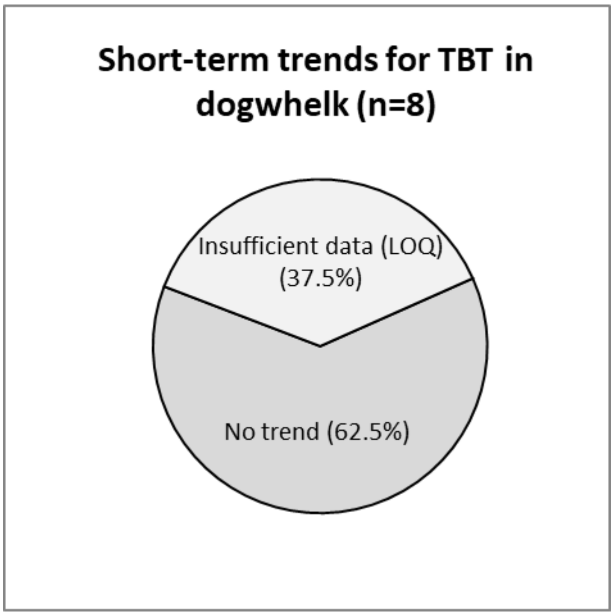


Figure 34. *Frequency of short-term trends for the concentration of TBT in dogwhelk (2011-2020). No trends were detected. Concerns about LOQ prevented some trend analyses.*

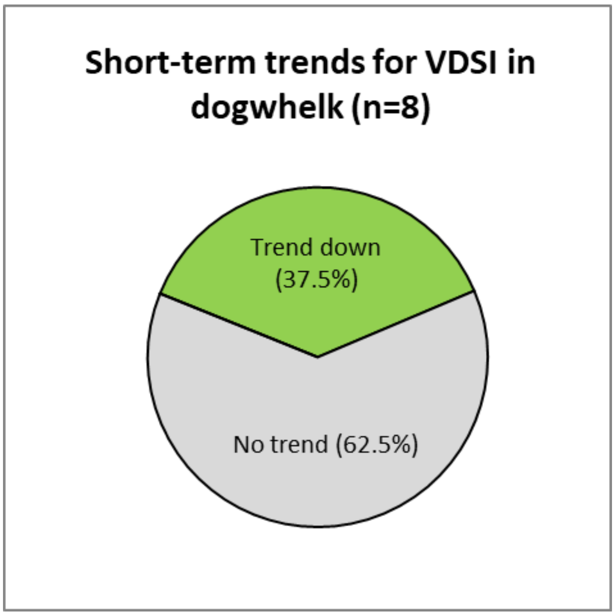


Figure 35. *Frequency of short-term trends for VDSI in dogwhelk (2011-2020). No upward trends were detected.*

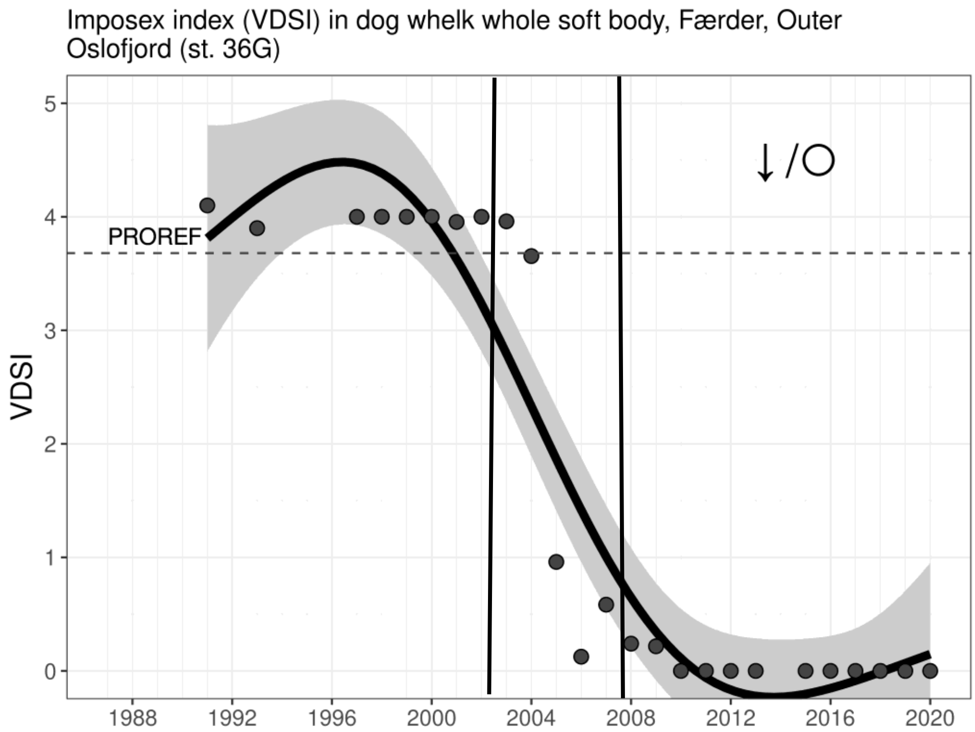


Figure 36. *Changes in VDSI for dogwhelk from Færder (st. 36G) (1991-2020). The vertical black lines indicate the ban of TBT in 2003 and total ban in 2008 (see* ***Figure 6*** *and* ***Appendix C****.)*

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 TPhT to water from land-based industries from 1997 to 2020 is shown in ***Figure 37***, 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 TPhT/year) and 2009 (504 g TBT and TPhT/year), and these peaks were related to discharges to water from industry in Vestfold in the Outer Oslofjord. The annual discharges were 3.9 g TBT and TPhT in 2020.

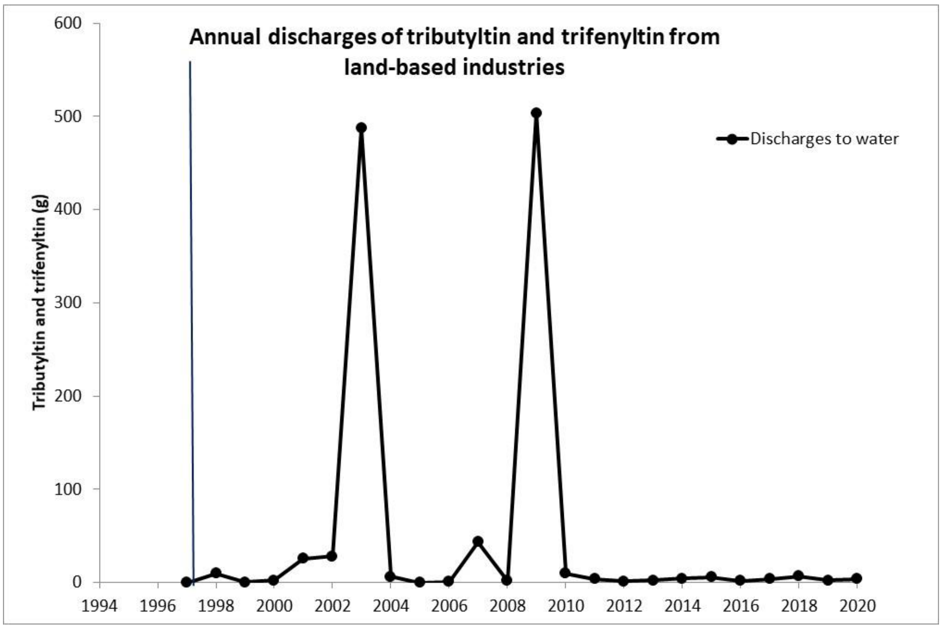


Figure 37*. Annual discharges of TBT and TPhT to water from land-based industries in the period 1997-2020 (data from www.norskeutslipp.no, 05.07.2021). No data are reported for 1994-1996. The vertical grey line at 1997 marks when the MILKYS-measurements of TBT started. The MILKYS-measurements of VDSI 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) are a group of chlorinated organic compounds that previously had a broad industrial and commercial application. There are more than 200 different PCBs. It is estimated that 1300 tons of PCBs were used in products and buildings in Norway, and that 100 tons remains in products and buildings today[1]. In the present study, PCB-7 was analysed in blue mussel at 24 stations, in cod liver at 16 stations, in flounder liver at one station and in eider blood and eggs at one station (***Table 1***).

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 4***), the concentrations at all stations exceeded the limit (***Table 8***).

When applying the EQS for PCB-7 (0.6 µg/kg w.w.) on cod liver (see ***Table 4***), all stations exceed this value (***Table 8***).

Applying this EQS for flounder liver, the concentration of PCB-7 would have exceeded the EQS (***Table 8***).

Applying this EQS for eider blood and eggs, the concentrations of PCB-7 would have exceeded the EQS for eggs but not for blood (0.270 µg/kg w.w.) (***Table 8***).

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

Levels exceeding PROREF

Blue mussel exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for PCB-7 at all stations (***Table 9***). The mussels exceeded the limit by a factor of 10 to 20 at Gressholmen (st. 30A) in the Inner Oslofjord and a factor of five to 10 at Akershuskaia (st. I301) and Ålesund harbour (st. 28A2). The mussels exceeded the limit by a factor of two to five at Gåsøya (st. I304) in the Inner Oslofjord, Kirkøy (st. I024) at Hvaler, Nordnes (st. I241) in Bergen harbour and at Bodø harbour (st. 97A3). 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 of two to five in the Inner Oslofjord (st. 30B) and at Bergen harbour (st. 24B). The exceedance in cod liver was by a factor up to two at Ålesund harbour (st. 28B). There were no exceedances at the remaining 13 cod stations.

Increase in PROREF factor since 2019

In blue mussel, the PROREF for PCB-7 was exceeded by a factor of 10 to 20 in 2020, compared to between five to 10 in 2019 at Gressholmen (st. 30A). The PROREF was exceeded by a factor of five to 10 in 2020, compared to between two and five in 2019 at Akershuskaia (st. I301). At Gåsøya (st. I304) in the Inner Oslofjord and Kirkøy (st. I024) at Hvaler, the PROREF was exceeded by a factor of two to five in 2020, compared to less than two in 2019.

In 2020, the PROREF for PCB-7 in cod liver from Ålesund harbour (st. 28B) was exceeded by a factor less than two, compared to levels below PROREF in 2019.

Upward trends

In 2020, two new long-term trends and seven new short-term trends were found for PCB-7 in blue mussel compared to 2019. For the total of 24 stations, there were upward long-term trends for three and upward short-term trends for 12 (**Table 9**). For 10 short-term trends, this is caused by a methodical (artificial) result processing the values below LOQ with random pulling of data between 0.5 LOQ and LOQ, while LOQ increased from 0.05 to 0.3 µg/kg in 2017 (see chap. 2.6). These stations are Singlekalven (st. I023), Risøy (st. 76A2), Kvalnes (st. 56A), Krossanes (st. 57A), Utne (st. 64A), Vikingneset (st. 65A), Espevær (st. 22A), Svolvær (st. 98A2), Skallnes (st. 10A2) and Brashavn (st. 11X).

There were both upward long- and short-term trends at Risøy (st. 76A2) at Risør, Utne (st. 64A) in the Outer Sørfjord and Vågsvåg (st. 26A2) in the Outer Nordfjord. A significant upward short-term trend was found at Gressholmen (st. 30A) (***Figure 38 B***) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler, Kvalnes (st. 56A) in the mid Sørfjord, Krossanes (st. 57A) in the Outer Sørfjord and at Vikingneset (st. 65A) in the mid Hardangerfjord. This result was also seen at Espevær (st. 22A) in the Outer Bømlafjord, Svolvær (st. 98A2) in Lofoten, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord.

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

Decrease in PROREF factor since 2019

The PROREF of PCB-7 was exceeded by a factor of two to five in 2020, compared to between 5 to 10 in 2019 at Nordnes (st. I241) in Bergen harbour. In 2020, the PROREF was exceeded by a factor less than two, compared to an exceedance between two and five at the Ørland area (st. 91A2) in the Outer Trondheimfjord in 2019.

In 2020, the PROREF for PCB-7 in cod liver from Ålesund harbour (st. 28B) was less than a factor of two, compared to no exceedance in 2019.

Downward trends
For blue mussel, there were downward long-term trends at seven out of the total 24 stations (***Table 9***). These stations were Akershuskaia (st. I301) (***Figure 38 A***) and Gåsøya (st. I304) (***Figure 39 A***) in the Inner Oslofjord and Solbergstrand (st. 31A) (***Figure 39 B***) in the mid Oslofjord. This was also the result at Kirkøy (st. I024) at Hvaler and Odderøya (st. I133) in the Kristiansandfjord. This was also the case at Kvalnes (st. 56A) in the mid Sørfjord 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 Kirkøy (st. 02B) at Hvaler and Hammerfest harbour (st. 45B2). There were significant downward long-term trends at Tjøme (st. 36B) in the Outer Oslofjord, Bømlo (st. 23B) in the Outer Selbjørnfjord, Trondheim harbour (st. 80B) and Kjøfjord (st. 10B) in the Outer Varangerfjord. A significant downward short-term trend was observed in Kristiansand harbour (st. 13B).

The Inner Oslofjord
Blue mussel at Gressholmen (st. 30A) exceeded PROREF by a factor of 10 to 20 in 2020. Mussels at Akershuskaia (st. I301) exceeded PROREF by a factor of five to 10, while the exceedance was between two to five at Gåsøya (st. I304). Significant downward long-term trends were detected in 2020 at Akershuskaia and Gåsøya.

Liver from cod caught at 100 m depth in the Inner Oslofjord (st. 30B) exceeded PROREF by a factor of two to five in 2020.

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the concentration of PCB-7 in liver was 57.194 µg/kg w.w.

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PCB-7 were 0.270 µg/kg w.w. in blood and 7.221 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 2 265.9 µg PCB-7/kg w.w. Cod liver from a comparable study from the Inner Oslofjord in 2020 had lower mean concentration (1 554 µg PCB-7/kg w.w.) (Grung et al. 2021). The collection of cod in both studies took place during the autumn.

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

In the present study, the concentration of PCB-153 (median 0.099 µg/kg w.w.) in eider blood at Svalbard was lower than in a comparable study from Svalbard (mean 0.187±0.023.8 µg/kg w.w.)

(Bustnes et al. 2010). A study of eider from the Inner Oslofjord in 2017, found mean values of 4.697 µg PCB-153/kg w.w. in blood (Ruus 2018).

In the present study, the median concentrations were 0.270 µg PCB-7/kg w.w. in blood and 7.221 µg PCB-7/kg w.w. in eider eggs from Svalbard. A comparable study of eider from the Inner Oslofjord in 2017, found mean values of 10.519 µg PCB-7/kg w.w. in blood and 138.312 µg PCB-7/kg w.w. in eggs (Ruus 2018), which was 19-39 times higher concentrations in the Inner Oslofjord compared to results from Svalbard.

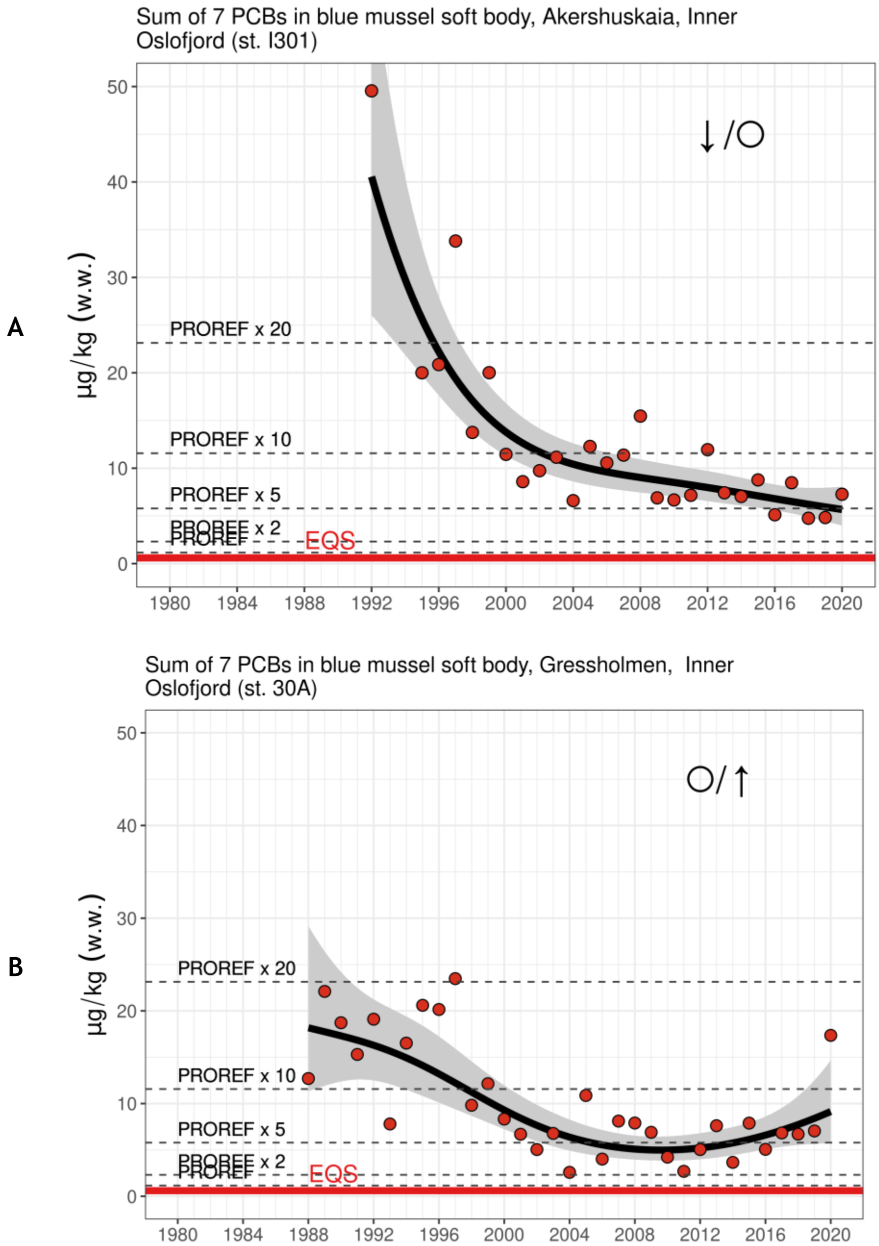
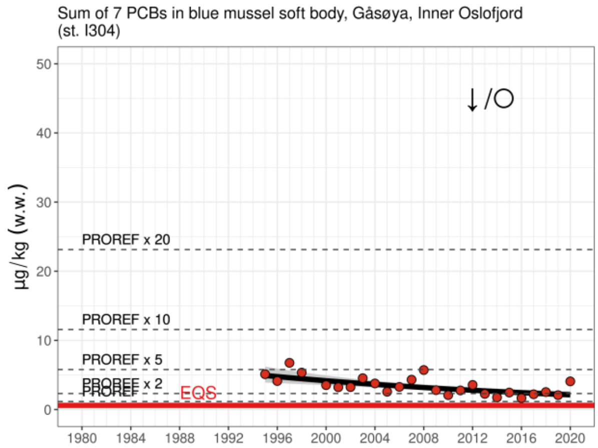


Figure 38. *Median concentrations (mg/kg w.w.) of PCB-7 in blue mussel in the Inner Oslofjord at Akershuskaia (st. I301 (**A**), Gressholmen (st. 30A) (**B**) (see **Figure 6** and **Appendix C**).*

A



B

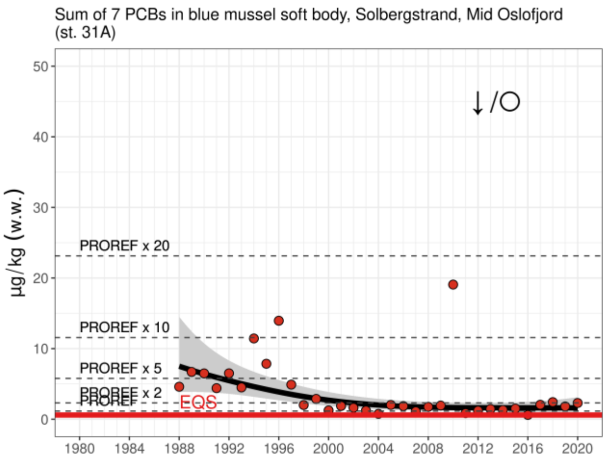


Figure 39. *Median concentrations (mg/kg w.w.) of PCB-7 in blue mussel in the Inner Oslofjord at Gåsøya (st. I304) (***A***) and Solbergstrand (st. 31A) (***B***) (see* ***Figure 6*** *and* ***Appendix C****).*

General, large scale trends

In Norway, the use of PCB-7 has been prohibited since 1980, but leakage from old products as well as landfills and natural deposits and contaminated sediments may still be a source of contamination. Production and use of PCB-7 are prohibited regionally- and globally through the Convention on Long-range Transboundary Air Pollution (LRTAP) and the Stockholm Convention.

Emissions of PCB-7 to air and discharges to water from land-based industries are shown in ***Figure 40***. In 2020, the discharges to water were 5.63 g PCBs/year. High emission to air was reported in 2008 (140 g PCBs/year), while the emission was 8.78 g PCBs/year in 2020. Investigations by Schuster et al. (2010) indicate that emissions in the northern Europe have declined during the period 1994-2008 by about 50 %.

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

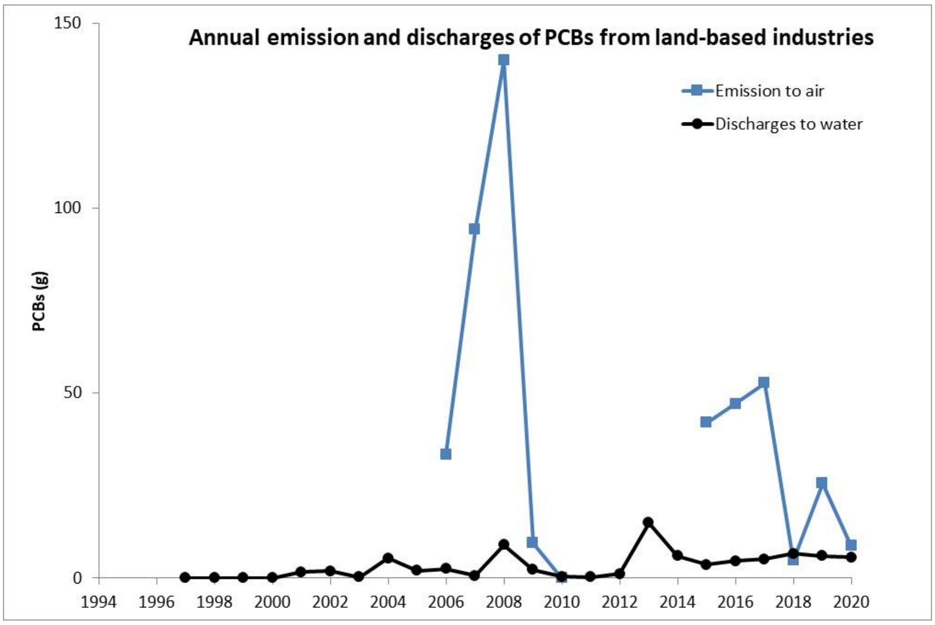


Figure 40. *Annual emissions of PCBs to air and discharges to water from land-based industries in the period 1997-2020 (data from www.norskeutslipp.no, 05.07.2021). No data for emissions to air are reported for 1994-2005 and 2011-2014. No data for discharges to water are reported for 1994-1996. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.14 Dichlorodiphenyldichloroethylene (DDE)

DDT (dichloro-diphenyl-trichloroethane) is the first modern synthetic pesticides developed in the 1940s. Dichlorodiphenyldichloroethylene (DDE) is a chemical compound formed by the loss of hydrogen chloride (dehydrohalogenation) from DDT, and DDE is one of the more common breakdown products. The compounds are used for insects and weed control. Production and use of DTT is prohibited regionally- and globally through the Convention on Long-range Transboundary Air Pollution (LRTAP) and the Stockholm Convention, but use of DDT in disease vector control is still permitted and occurs in several countries (in Africa, South America and India) (http://chm.pops.int/Implementation/Exemptions/AcceptablePurposes/AcceptablePurposesDDT/tabid/456/Default.aspx). 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, agriculture, forestry and orchards can still be a problem and the possibility of some long-range transport cannot be excluded. In the present study, dichlorodiphenyldichloroethylene (p,p'-DDE, referred to herein as DDE) was analysed in blue mussel at 15 stations and in cod liver at seven stations and in flounder at one station (***Table 1***).

Environmental Quality Standards (EQS) for priority substances

EQS for total DDT is 610 µg/kg w.w., but for the present study we apply the same limit to DDE in biota (see ***Table 4***). Applying this EQS for blue mussel and liver in cod and flounder, all concentrations were below EQS. In the present study DDE has been used as a proxy for the priority substance DDT.

Levels exceeding PROREF

Concentrations of DDE exceeded the Norwegian provisional high reference contaminant concentration (PROREF) at 10 blue mussel stations (***Table 9***). The highest concentrations were found in the Sørfjord and Hardangerfjord. Blue mussel exceeded PROREF by a factor over 20 at Kvalnes (st. 56A) in the mid Sørfjord and at Utne (st. 64A) in the Outer Sørfjord. Mussels exceeded PROREF by a factor of 10 to 20 at Krossanes (st. 57A) in the Outer Sørfjord. Mussel exceeded PROREF by a factor of five to 10 at Vikingneset (st. 65A) in the mid Hardangerfjord. Mussels at Gressholmen (st. 30A) in the Inner Oslofjord and at Solbergstrand (st. 31A) in the mid Oslofjord exceeded PROREF by a factor of two to five. The exceedance was by a factor of up to two at Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, at Odderøya (st. I133) in the Kristiansandfjord and at Espevær (st. 22A) in the Outer Bømlafjord.

Concentrations of DDE exceeded PROREF by a factor of two to five in cod liver from the Inner Sørfjord (st. 53B). The exceedance was less than two in cod liver from the Inner Oslofjord (st. 30B).

Increase in PROREF factor since 2019
In 2020, blue mussel at Gressholmen (st. 30A) and Solbergstrand (st. 31A) exceeded the PROREF of DDE by a factor between two and five, compared to a factor less than two in 2019. The mussel at Akershuskaia (st. I301) and Odderøya (st. I133) exceeded the PROREF for DDE by a factor less than two in 2020, while there was no exceedance in 2019.

In 2020, the concentration of DDE in cod liver from the Inner Oslofjord (st. 30B) exceeded the PROREF by a factor up to two, compared to no exceedance in 2019.

Upward trends
There was a significant upward long-term trend in blue mussel at Kvalnes (st. 56A) in the mid Sørfjord. There was a significant upward short-term trend in mussel at Espevær (st. 22A) (***Figure 41***) in the Outer Bømlafjord.

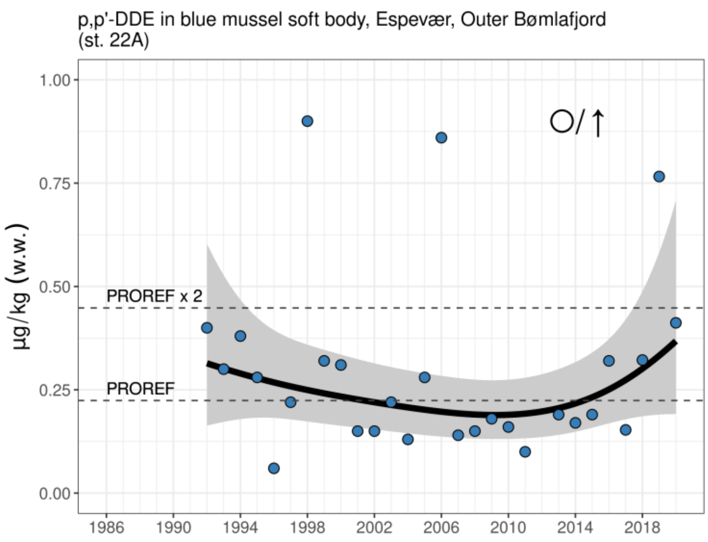


Figure 41. *Median concentrations (mg/kg w.w.) of DDE (p,p'-DDE) in blue mussel from 1992 to* 2020 at Espevær (st. 22A) on the West coast *(see **Figure 6** and **Appendix C**).*

Decrease in PROREF factor since 2019
In 2020, there was an exceedance of PROREF of DDE by less than two in mussel at Espevær (st. 22A), compared to an exceedance by a factor of two to five in 2019.

Downward trends
Significant downward long-term trends were found in blue mussel at four stations. These stations were Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, Færder (st. 36 A) in the Outer Oslofjord and Brashavn (st. 11X) in the Varangerfjord.

Significant downward long-term trends were found for DDE in cod liver from the Inner Oslofjord (st. 30B), Tjøme (st. 36B) in the Outer Oslofjord, Skågskjera (st. 15B) in Farsund, Bømlo (st. 23B) in the Outer Selbjørnfjord and Kjøfjord (st. 10B) in the Outer Varangerfjord.

Levels in flounder
In flounder at Sande (st. 33F) in the mid Oslofjord, the concentration of DDE in liver was 26.6 µg/kg w.w.

Comparison with other studies, Sørfjord
In the present study, blue mussel from Krossanes had concentration of 4.0 µg/kg DDE w.w. and mussels from Utne, on the opposite side of the fjord, had concentration of 7.7 µg/kg DDE w.w. Mussels from a comparable study in the Sørfjord in 2015 had concentrations of 11 µg DDT/kg w.w. at Krossanes and 27 µg DDT/kg w.w. at Grimo, on the opposite side of the fjord (Ruus 2016a).

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

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

Increased ΣDDT-concentrations in blue mussel from the Sørfjord were discussed (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
Global use, long-distance transport, effects of climate change and the importance of leaching from contaminated soil are relevant for large scale trends.

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

Hexachlorobenzene (HCB) was for many years used as a fungicide, and was also used in the production of rubber, aluminium, dyes and in wood preservation. HCB is formed as a by-product during the manufacture of other chemicals (mainly solvents) and pesticides. It is an animal carcinogen and is classified as a probable human carcinogen. After its introduction as a fungicide in 1945, for crop seeds, this toxic chemical was found in all types of food. HCB is very toxic to aquatic organisms and is very persistent. HCB is included in the Convention on Long-range Transboundary Air Pollution (LRTAP) and Stockholm Convention and has been banned globally since 2004.

Pentachlorobenzene (QCB, quintochlorobenzene) was used as an intermediate in the manufacture of pesticides, particularly the fungicide pentachloronitrobenzene. QCB was a component of a mixture of chlorobenzenes added to products containing PCBs in order to reduce viscosity. QCB has also been used as a fire retardant. QCB is very toxic to aquatic organisms, it is persistent and accumulates in the food chain. QCB was banned in the EU in 2002 and globally since 2009 by the Stockholm Convention on Persistent Organic Pollution. It is also included in the Convention on Long-range Transboundary Air Pollution (LRTAP).

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

HCB, OCS and QCB were analysed in blue mussel from 14 stations, cod from seven stations, flounder from one station and in eider (only HCB) from one station (***Table 11***).

All concentrations of HCB, OCS and QCB were low, and all median concentrations in blue mussel were below the limit of quantification (LOQ) (***Table 11***). Cod from the Austnesfjord in Lofoten (st. 98B1) had highest concentration of HCB, with 14.8 µg/kg w.w. (***Figure 44***). That same station also had highest concentration of OCS, with 1.1 µg/kg w.w. No median concentrations of QCB in cod were above the LOQ.

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

Levels exceeding PROREF
The median concentration of HCB in cod liver from the Austnesfjord in Lofoten (st. 98B1) was slightly higher than the PROREF for this substance (14 µg/kg w.w.).

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

Downward trends

Long-term downward trends were found for median concentration of HCB in liver of cod from the Inner Oslofjord (st. 30A, ***Figure 42***), Tjøme in the Outer Oslofjord (st. 36B) and Skågskjera at Farsund (st. 15B, ***Figure 42***). Long-term downward trends were also found for HCB in blue mussel from Bjørkøya in the Grenlandfjord (st. 71A), Færder in the Outer Oslofjord (st. 36A[1]) and Odderøya in Kristiansand (st. I133, ***Figure 42***). Long-term downward trends were also found for HCB in flounder from Sande in the mid Oslofjord (st. 33F).

A downward tendency in concentration of QCB in cod from the Inner Sørfjord was observed, but no significant trend (***Figure 43***).

Levels in eider

Median concentration of HCB in blood of eider was 0.201 µg/kg w.w., and median concentration of HCB in eider eggs was 5.50 µg/kg w.w. The concentration of HCB in blood and eggs of eider has a downward tendency for the four-year monitoring period.

Levels in flounder

No median concentrations of OCS and QCB in flounder liver were above the limit of quantification (LOQ). The concentration of HCB in flounder liver was lower than in cod liver. Median concentration of HCB in flounder liver from Sande in the mid Oslofjord was 1.2 µg/kg w.w.

Comparison with other studies

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

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

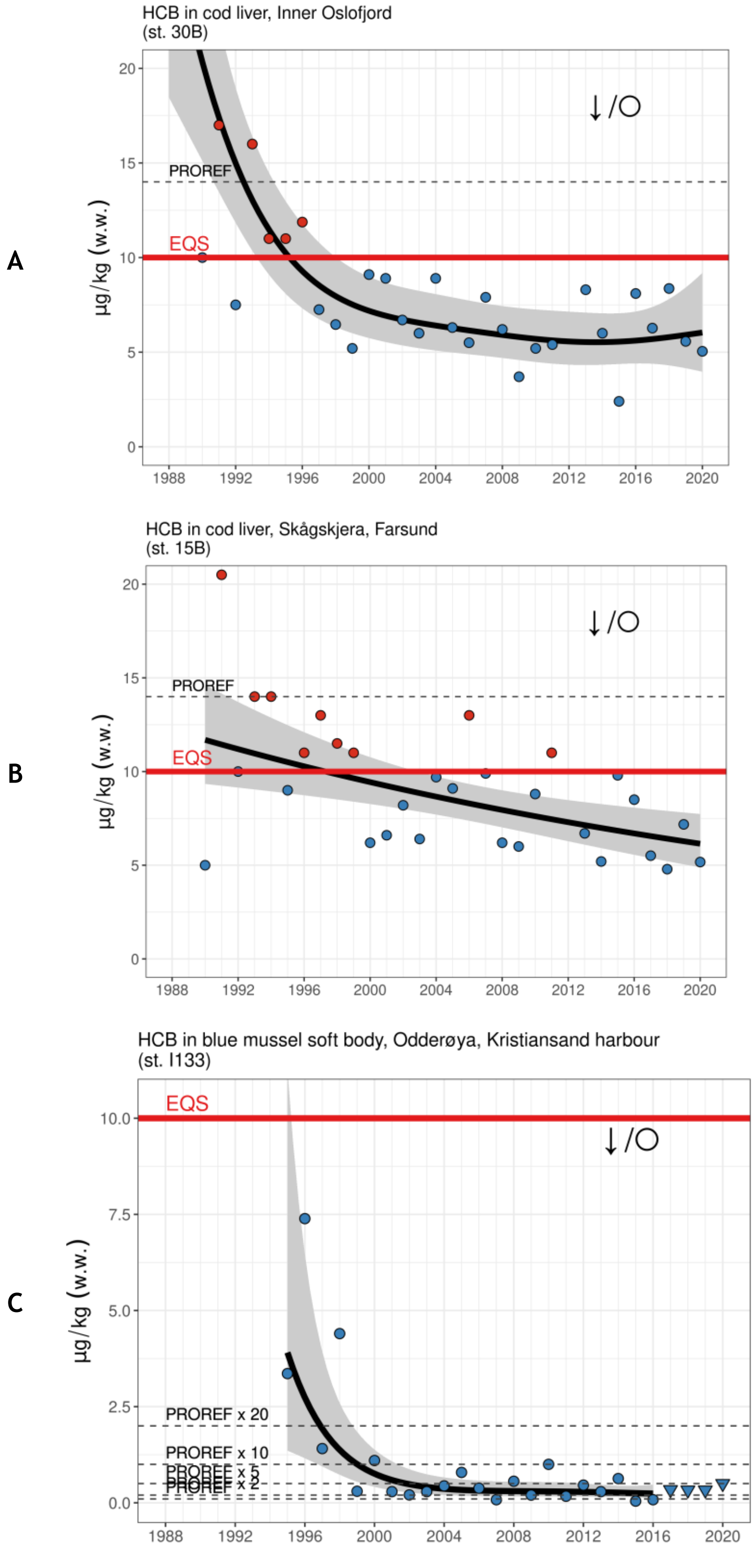


***Figure 42.** Median concentrations (µg/kg w.w.) of HCB in cod liver from the Inner Oslofjord (st. 30B) (**A**), Skågskjera in Farsund (st. 15B) (**B**) and HCB in blue mussel from Odderøya in Kristiansand harbour (st. 13B) (**C**) (see **Figure 6** and **Appendix C**).*

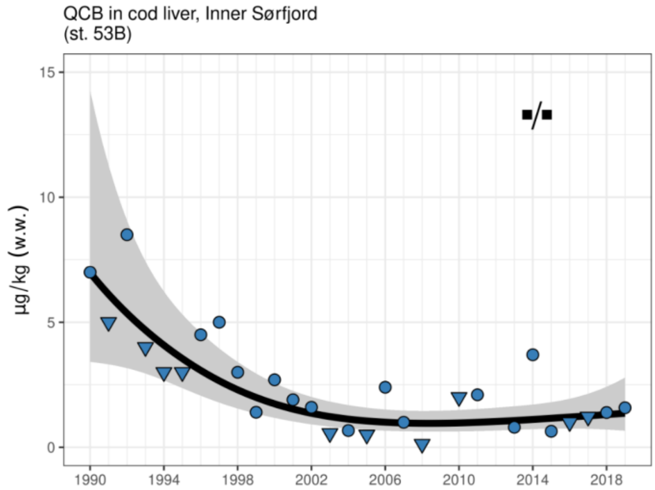


***Figure 43**. Median concentrations (µg/kg w.w.) of QCB in cod liver from the Inner Sørfjord (st. 53B) (see **Figure 6** and **Appendix C**).*

***Table 11**. Median concentrations (µg/kg w.w.) of HCB, OCS and QCB in blue mussel, cod liver, flounder liver and eider blood and egg (only HCB) in 2020. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is the LOQ. 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.*

Component	Count	HCB			OCS			QCB		
Species and sampling locality	2020	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)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Gåsøya, Inner Oslofjord (st. I304)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Risøya, Risør (st. 76A2)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Brashavn, Outer Varangerfjord (st. 11X)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Skallnes, Outer Varangerfjord (st. 10A2)	3 (3-50)	0.50	0.00	0 [n.a.]	0.10	0.00	0 [n.a.]	0.50	0.00	0 [n.a.]
Cod, liver										
Inner Oslofjord (st. 30B)	12 (7-6)	5.05	2.76	12 [2.9-10.4]	0.88	0.38	12 [0.6-1.86]	1.14	0.00	3 [1.03-1.36]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	5.51	2.11	15 [1.99-8.8]	0.33	0.55	12 [0.22-2.2]	1.22	0.00	0 [n.a.]
Skågskjera, Farsund (st. 15B)	15 (0-1)	5.17	1.34	15 [3.4-8.4]	0.56	0.14	15 [0.26-0.72]	1.19	0.00	0 [n.a.]
Inner Sørfjord (st. 53B)	15 (4-3)	5.40	2.74	15 [2.7-12.3]	0.50	0.49	15 [0.23-2]	1.11	0.00	2 [1.09-1.24]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	6.56	3.04	15 [4.1-14.5]	0.30	0.28	11 [0.21-1.01]	1.16	0.00	2 [1.23-1.33]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	14.80	4.84	14 [9.2-20]	1.10	0.71	14 [0.38-2.5]	1.14	0.00	4 [1.23-1.39]
Kjøfjord, Outer Varangerfjord (st. 10B)	15 (5-2)	10.20	3.28	15 [6.4-18.4]	0.85	0.36	15 [0.39-1.65]	1.14	0.00	4 [1.13-1.36]
Flounder, liver										
Sande, Mid Oslofjord (st. 33F)	3 (3-5)	1.20	0.22	2 [1.2-1.53]	0.12	0.01	0 [n.a.]	1.19	0.00	0 [n.a.]
Eider, blood										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.20	0.13	15 [0.13-0.54]						
Eider, egg										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	5.50	2.32	15 [4.2-11.1]						

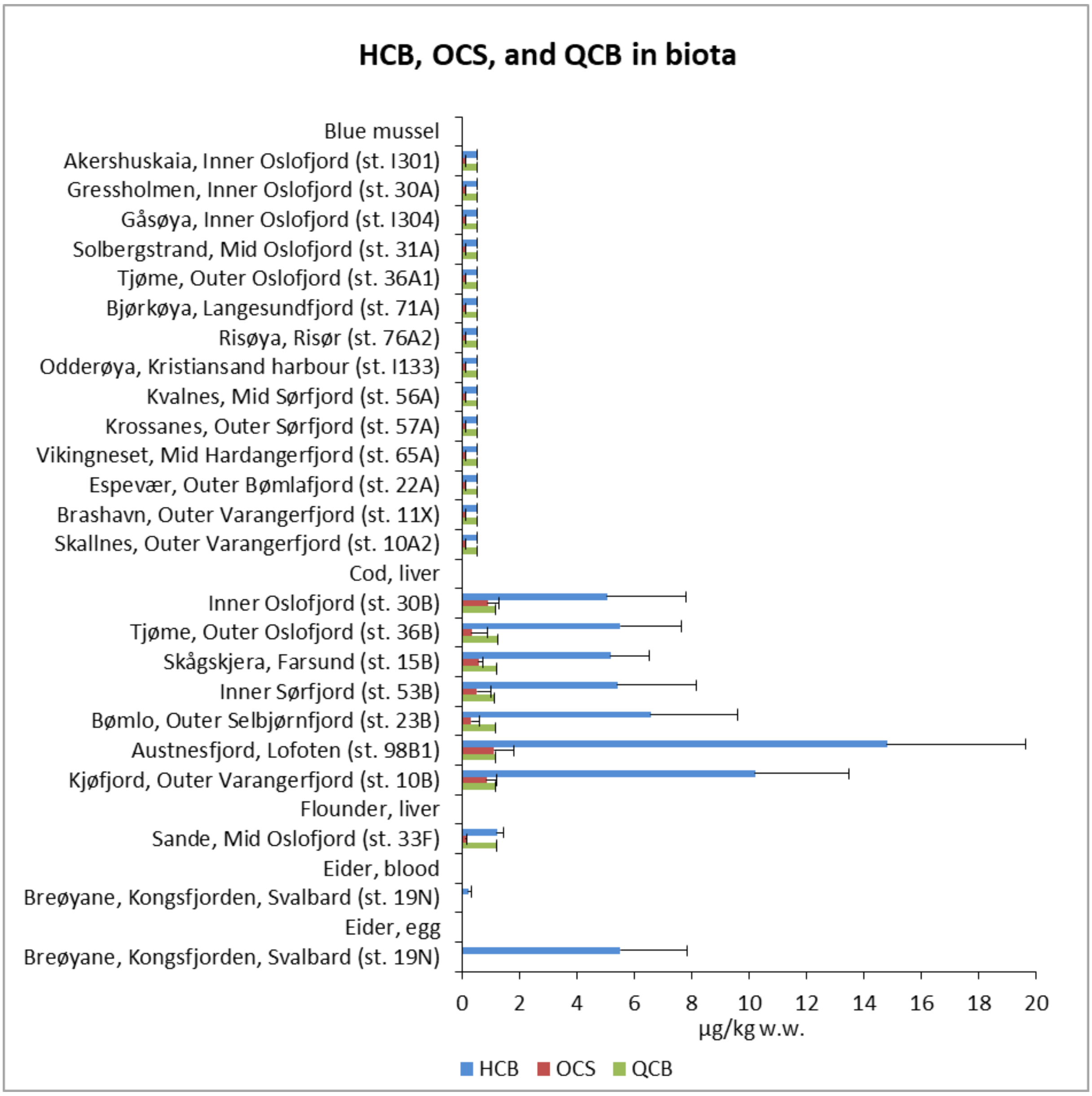


***Figure 44**. Median concentration (µg/kg w.w.) of HCB, OCS and QCB in blue mussel, cod liver, flounder liver, and eider blood and eggs in 2020. The error bar indicates one standard deviation above the median.*

3.2.16 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds produced by incomplete combustion or high-pressure processes. PAHs form when complex organic substances are exposed to high temperatures or pressures. The main sources of PAH in coastal waters include discharges from smelting industry and waste incinerators. Creosote impregnated wood is also an important source. In 2017, 77 tons of PAH was released in Norway, and there has been an 70 % reduction in discharges of PAH since 1995 (https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/polysykliske-aromatiske-hydrokarboner-pah/). The Convention on Long-range Transboundary Air Pollution (LRTAP) impose parties to introduce measures to control emissions of PAH to air from major stationary sources. However, emissions and releases continue in Norway and other countries. High PAH levels are therefore reported in air in Norway, with three to four times higher concentrations in Southern Norway than in the Arctic, at Svalbard (Nizzetto 2020).

In the present study, PAH[1] were analysed in blue mussel at seven stations (***Table 1***).

PROREF

Blue mussel at two stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for PAH-16 (***Table 9***) by a factor less than two; Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord.

Increase in PROREF factor since 2019

In 2020, blue mussel at Akershuskaia (st. I301) and Gressholmen (st. 30A) exceeded the PROREF by a factor up to two, while the levels were below this limit in 2019.

Downward trends

A significant downward long-term trend was observed at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord.

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries can be seen in ***Figure 45***. In 2020, the emission to air was 43 161 kg PAHs, and 25 749 kg PAHs originated from Agder, according to www.norskeutslipp.no. The discharges to water were 4 177 kg PAHs in 2020, and 893 kg PAHs were from Agder, according to www.norskeutslipp.

[1] For this report the total is the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic)-totalling 15 compounds (see ***Appendix B***).

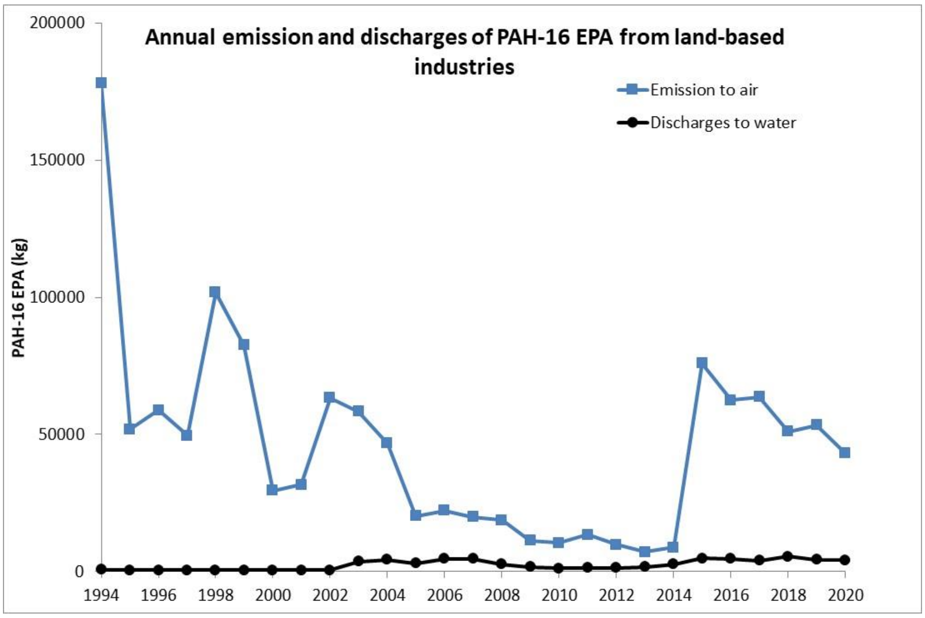


***Figure 45.** Annual emissions of PAHs (PAH-16 EPA) to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

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

OSPAR has monitored PAH in shellfish in several coastal areas in Europe. Four of the assessment areas (Northern North Sea, Skagerrak and Kattegat, Irish Sea and Northern Bay of Biscay) show no statistically significant change in PAH concentrations. Declining PAH concentrations are observed in four assessment areas (Southern North Sea, English Channel, Irish and Scottish West Coast and the Iberian Sea), with mean annual decreases in concentrations of between 6.5 % and 3.2 %. PAH concentrations were below the EAC (European Assessment Criteria), but above the BAC (the OSPAR Background Assessment Concentration) in all 10 assessment areas. As PAH concentrations in shellfish were below the EAC, they are unlikely to cause any adverse effects (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/status-and-trends-concentrations-polycyclic-aromatic-hydrocarbon/).

3.2.17 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

In the present study, sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs, see ***Appendix B***) was analysed in blue mussel at seven stations (***Table 1***).

Levels exceeding PROREF

Blue mussel at all seven stations exceeded the Norwegian provisional high reference contaminant concentration (PROREF) for KPAHs (***Table 9***). The exceedances were by a factor of 10 to 20 at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, and by a factor of five to 10 at Bjørkøya (st. 71A) in the Langesundfjord and at Lastad (st. I131A) at Søgne. The exceedances were by a factor of two to five at Gåsøya (st. I304) in the Inner Oslofjord, at Singlekalven (st. I023) at Hvaler and at Svolvær airport area (st. 98A2) in Lofoten.

Increase in PROREF since 2019
In 2020, blue mussel at Akershuskaia (st. I301) and Gressholmen (st. 30A) exceeded the PROREF by a factor of 10 to 20, compared to a factor of five to 10 in 2019.

Downward trends
There were both significant downward long- and short-term trends in blue mussel from Akershuskaia (st. I301) in the Oslo harbour area, Singlekalven (st. I023) at Hvaler and at Svolvær airport (st. 98A2) in Lofoten. A significant downward long-term trend was found in mussel at Gressholmen (st. 30A) in the Inner Oslofjord, while significant downward short-term trends were found at Gåsøya (st. I304) in the Inner Oslofjord and at Lastad (st. I131A) in Søgne.

3.2.18 Anthracene (ANT)

Anthracene is a PAH-compound and is *inter alia* used as an intermediate in industrial processes and is formed during combustion. In the present study, anthracene was analysed in blue mussel at seven stations (***Table 1***).

Environmental Quality Standards (EQS) for priority substances
The EQS for anthracene is 2400 µg/kg w.w. in biota (relate to crustaceans and molluscs, see 2013/39/EU). Applying this EQS for blue mussel, all stations were below EQS in 2019 (***Table 8***), as in previous years.

Levels exceeding PROREF
Blue mussel at three stations had concentrations above the Norwegian provisional high reference contaminant concentration (PROREF) for anthracene. The exceedance was by a factor of two to five at Akershuskaia (st. I301), and by a factor less than two at Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord.

Increase in PROREF since 2019
In 2020, the PROREF was exceeded by a factor of two to five at Akershuskaia (st. I301), and by a factor less than two at Gressholmen (st. 30A) and Gåsøya (st. I304), compared to all levels below PROREF in 2019.

General, large scale trends
Emissions of anthracene to air and discharges to water from land-based industries can be seen in ***Figure 46***. In 2020, the emission to air was 1 021 kg anthracene. The discharges to water were 39.9 kg anthracene in 2020.

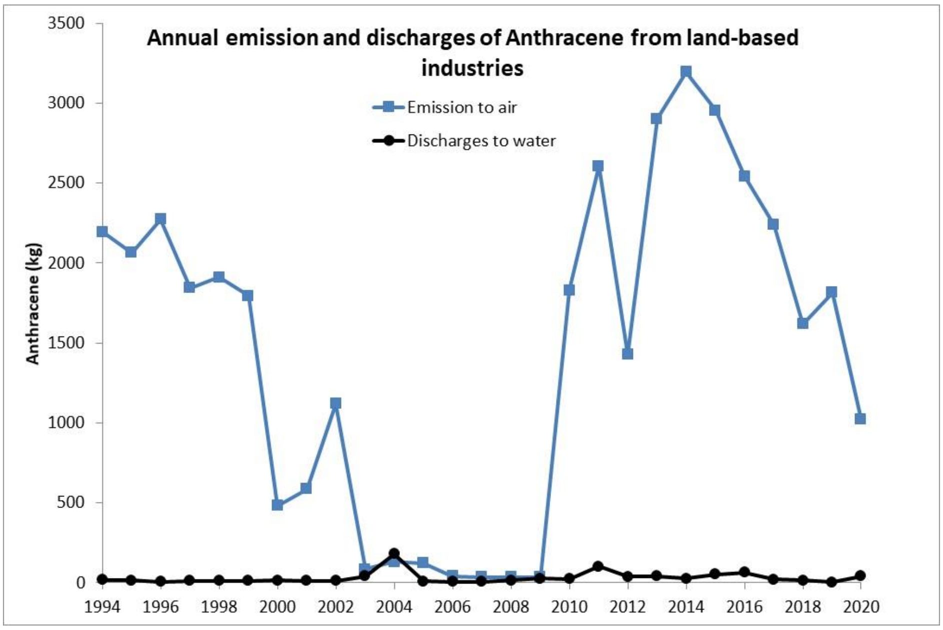


Figure 46. *Annual emissions of anthracene to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.19 Fluoranthene (FLU)

Fluoranthene is a PAH-compound. In the present study, fluoranthene was analysed in blue mussel at seven stations (***Table 1***).

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 8***).

Levels exceeding PROREF

Blue mussel at two stations had concentrations above the Norwegian provisional high reference contaminant concentration (PROREF) for fluoranthene. The exceedance was by a factor of two to five at Akershuskaia (st. I301), and by a factor less than two at Gressholmen (st. 30A) in the Inner Oslofjord (***Table 9***).

Increase in PROREF since 2019

In 2020, the PROREF was exceeded by a factor of two to five at Akershuskaia (st. I301) and by a factor less than two at Gressholmen (st. 30A), compared to levels below PROREF in 2019.

Downward trends

There were both significant downward long- and short-term trends at Singlekalven (st. I023) at Hvaler. A significant downward long-term trend was seen at Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord.

General, large scale trends
Emissions of fluoranthene to air and discharges to water from land-based industries can be seen in ***Figure 47***. In 2020, the emission to air was 1 995 kg fluoranthene. The discharges to water were 378 kg fluoranthene in 2020.

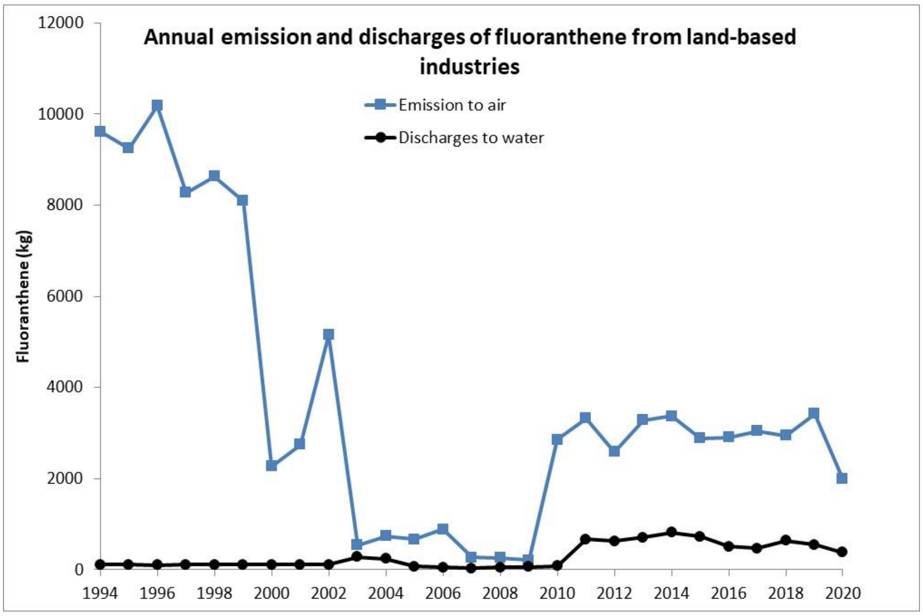


Figure 47. *Annual emissions of fluoranthene to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

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

Benzo(a)anthracene is a PAH-compound, and the substance is used in industry. In the present study, benzo(a)anthracene was analysed in blue mussel at seven stations (***Table 1***).

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 8***).

Levels exceeding PROREF
In 2020, blue mussel had concentrations of benzo(a)anthracene exceeding the Norwegian provisional high reference contaminant concentration (PROREF) by a factor below two at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord (***Table 9***).

Increase in PROREF factor since 2019
In 2020, blue mussel at Akershuskaia (st. I301) and Gressholmen exceeded PROREF of benzo(a)anthracene by a factor up to two, compared to levels below PROREF in 2019.

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

3.2.21 Benzo[a]pyrene (B[a]P)

Benzo[a]pyrene (B[a]P) is a PAH-compound, and it is used as raw materials in industry. In the present study, B[a]P was analysed in blue mussel at seven stations (***Table 1***).

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 8***).

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

General, large scale trends
Emissions of B[a]P to air and discharges to water from land-based industries can be seen in ***Figure 48***. In 2020, the emission to air was 366 405 kg B[a]P, while it was 645 870 kg B[a]P in 2019. In 2020, the discharges to water were 47 222 kg B[a]P, while they were 62 484 kg B[a]P in 2019.

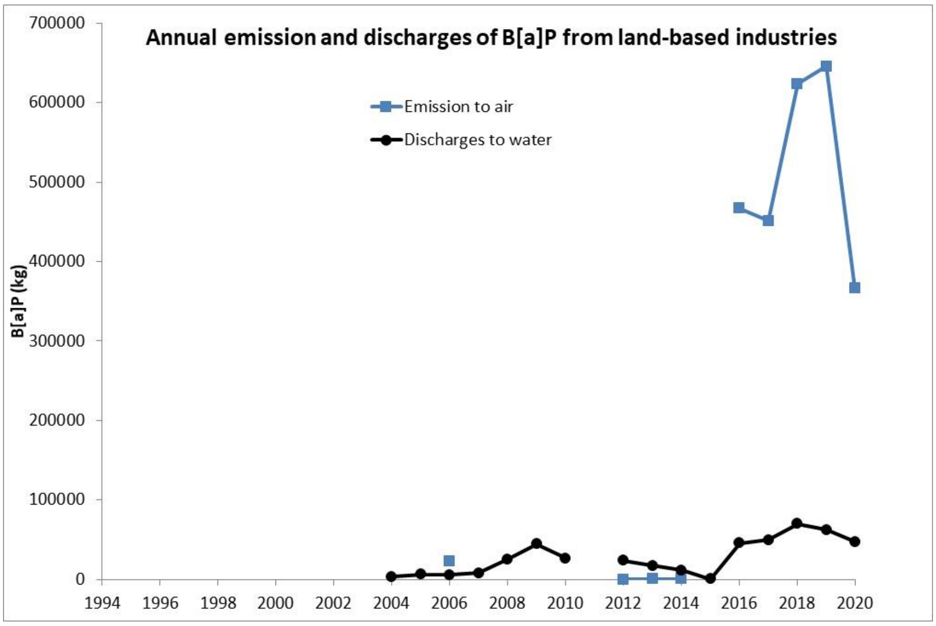


Figure 48. *Annual emissions of B[a]P to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.22 Naphthalene (NAP)

Naphthalene is a PAH-compound. Naphthalene was analysed in blue mussel at seven stations (***Table 1***).

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 8***).

In 2020, all concentrations of naphthalene at all blue mussel stations were <50.00 µg/kg w.w.

Decrease in PROREF factor since 2019

In 2020, the levels of naphthalene exceeded PROREF by a factor of two to five, compared to more than 20 at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, at Singlekalven (st. I023) at Hvaler and at Svolvær airport area (st. 98A2) in Lofoten, due to high detection limits in 2019. In 2020, the levels exceeded the PROREF by a factor of two to five, compared to levels below PROREF at Gåsøya (st. I304) in the Inner Oslofjord and at Lastad at Søgne (st. I131A) in 2019. Changes in PROREF from 2019 to 2020 are due to changes in detection limits, considerably higher in 2019.

General, large scale trends

Emissions of naphthalene to air and discharges to water from land-based industries can be seen in ***Figure 49***. In 2020, the emission to air was 11 576 kg naphthalene. The discharges to water were 1 930 kg naphthalene in 2020.

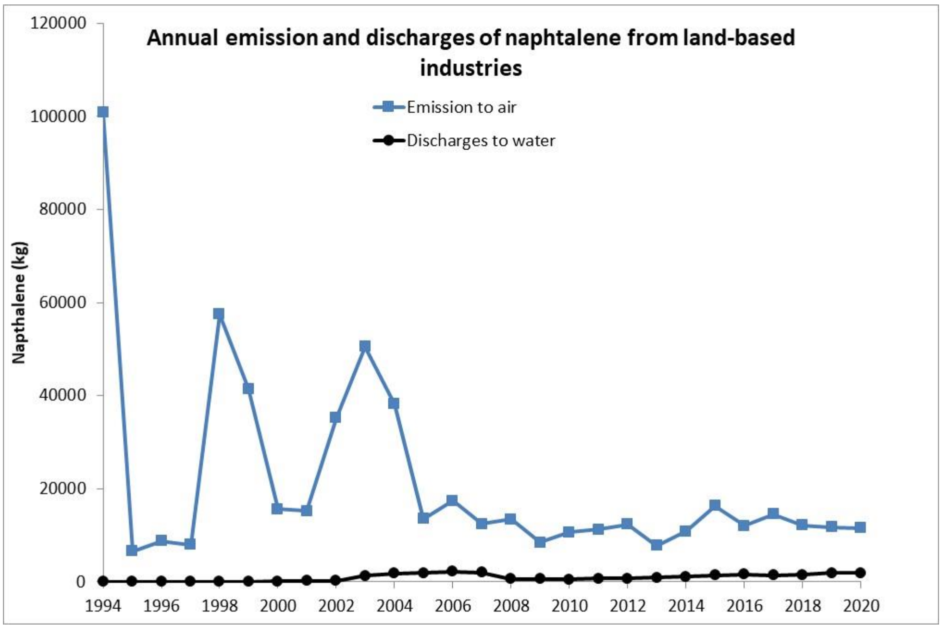


Figure 49*. Annual emissions of naphthalene to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.23 Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (BDEs) are a group of brominated flame retardants used in a variety of consumer products. They are used in electrical and electronic products, textiles and cars. In 2013, the consumption of brominated flame retardants in Norway was estimated to 280 tons[1]. The most important commercial PBDE mixtures are banned globally by their listing in the Stockholm Convention. In Norway, production, imports, placing on the market and use of PBDEs is banned. Regulations are also in place to ensure proper management of PBDE containing wastes and stockpiles. 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 1***).

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 8***).

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 8***). These results, when one congener alone exceeds the EQS for the sum of six congeners, indicate that the EQS might not be a useful criterion to judge the condition of the environment with respect to this contaminant in biota. In the present study, additional assessments of the environmental quality were therefore conducted using BDE47 as a proxy for the PBDEs (included on the Norwegian List of Priority Substances[2]).

Levels exceeding PROREF

Except for blue mussel at st. 97A3 Bodø harbour, the concentrations 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 Bergen harbour (st. 24B) exceeded PROREF of sum BDEs (28, 47, 99, 100, 153 and 154) by a factor less than two (***Table 9***, ***Table 12***, ***Figure 52***).

Decrease in PROREF factor for sum BDEs since 2019

In 2020, blue mussel at Bodø harbour (st. 97A3) exceeded the PROREF by a factor less than two, compared to no exceedance in 2019.

Downward trends for sum BDEs

Both significant downward short- and long-term trends were found for sum BDEs (28, 47, 99, 100, 153 and 154) in blue mussel from Nordnes (st. I241) in Bergen harbour. A significant downward long-term trend was found for sum BDE levels in mussel from Gressholmen (st. 30A) in the Inner Oslofjord, at Færder (st. 36A) in the Outer Oslofjord and at Svolvær (st. 98A2) in Lofoten.

Both significant downward long- and short-term trends were found in cod liver for sum BDE levels (28, 47, 99, 100, 153 and 154) from the Inner Oslofjord (st. 30B) (***Figure 50 A***), the Kristiansand harbour (st. 13B), the Inner Sørfjord (st. 53B), Bømlo (st. 23B) (***Figure 50 B***), Trondheim harbour (st. 80B) (***Figure 51 A***) and Tromsø harbour (st. 43B2) (***Figure 51 B***).

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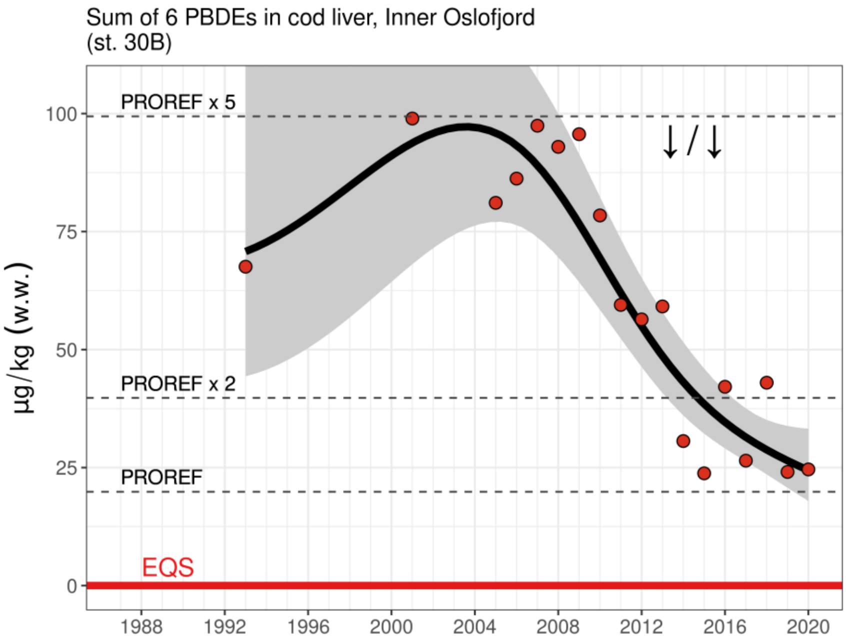
[1] https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/bromerte-flammehemmere/

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

A



B

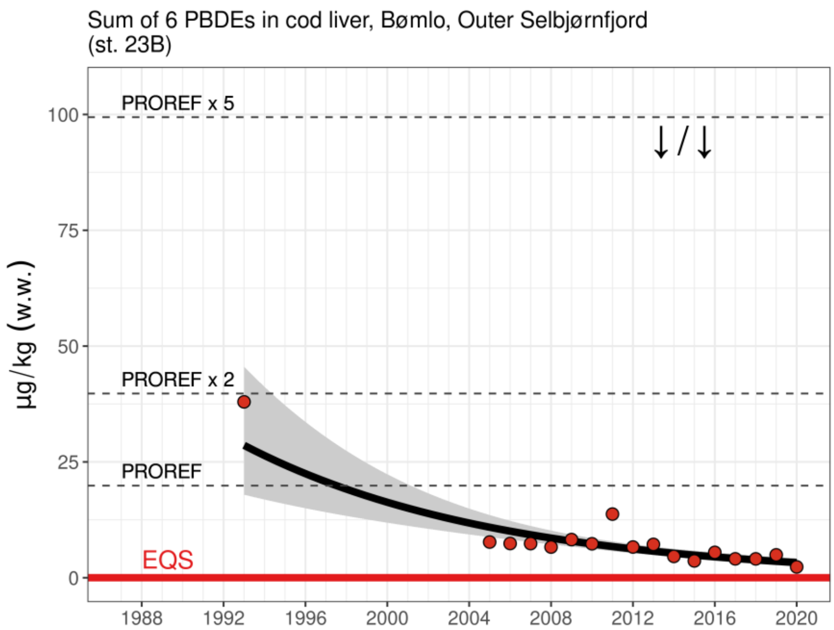


Figure 50. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 1993 to 2020 in Inner Oslofjord (st. 30B) (**A**) and at Bømlo (st. 23B) (**B**) (see **Figure 6** and **Appendix C**).*

A

B

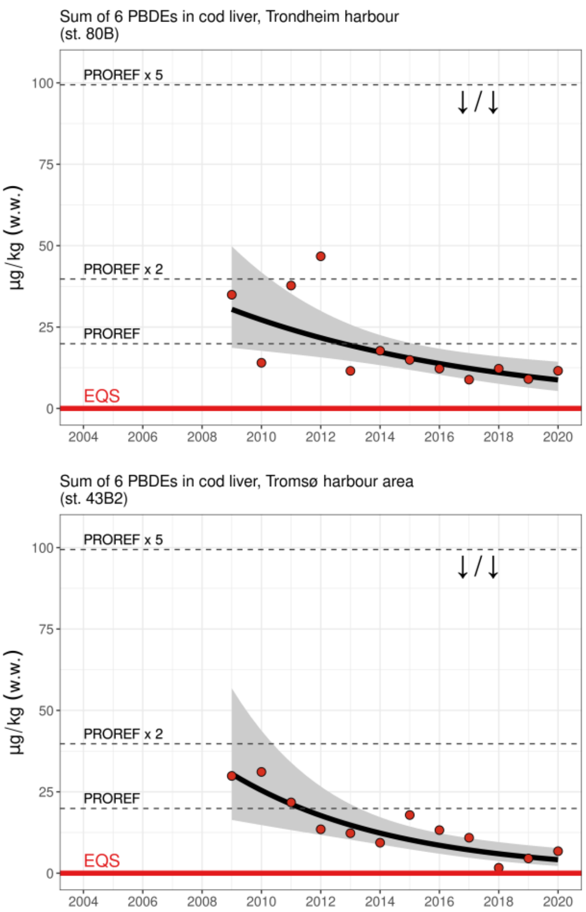


Figure 51*. Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 2009 to 2020 at Trondheim harbour (st. 80B) (****A****) and Tromsø harbour* (st. 43B2) *(****B****) (see* ***Figure 6*** *and* ***Appendix C****).*

Levels in blue mussel

In 2020, the most dominant congener in mussel was BDE47. BDE47 is a main constituent of the commercial flame retardant mixture pentabromocyclododecane or pentaBDE. It was detected in all blue mussel sampled in 2020. The 2020 findings are similar to the finding's earlier years which found BDE47 in all samples and showed it to be the predominant congener. The highest median concentrations of BDE47 were found in mussels from Bodø harbour (st. 97A3) (0.322 µg BDE47/kg w.w.).

The congeners BDE47, 99 and 100 showed concentrations above the LOQ for half or more of the samples at all stations (***Table 9***, ***Table 12***, ***Figure 53***). Concentrations of BDE209 in mussels were all below LOQ.

The most dominant congener in 2020 was BDE47, which was also the case in 2019. BDE47 was detected at all stations in 2020, as in 2019. The highest median concentration was found in mussels from Bodø harbour (st. 97A3) (0.322 µg BDE47/kg w.w.).

Blue mussel from Bodø harbour (st. 97A3) showed significantly higher concentrations of BDE47 than mussels from all the other stations (Tukey-Kramer HSD test, see also ***Figure 53***).

Levels in cod liver

In 2020, the most dominant congener in cod liver was BDE47, as for blue mussel. It was detected at all cod stations sampled in 2020. The 2020 findings are similar to the findings from earlier years which found BDE47 in all samples and showed it to be the predominant congener. The highest median concentration of BDE47 was found in cod liver from Bergen harbour (22.4 µg BDE47/kg w.w.).

The standard deviation varied considerably among stations, also for other PBDEs. The highest standard deviation was found in cod liver from Bergen harbour (st. 24B) for BDE47 (***Table 12***) in 2020. It seems like variation was highest in affected areas.

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

PBDEs have been investigated annually in cod liver since 2005. In the Inner Oslofjord (st. 30B), cod have also been analysed for PBDEs in 1993, 1996 and 2001 (***Figure 54***). 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 2020, PBDEs were analysed in cod from 11 stations (***Table 12***). Of the PBDEs, congeners BDE28, 47, 99, 100, 126 and 154 were above the limit of quantification (LOQ) in cod liver in at least half of the samples from each station.

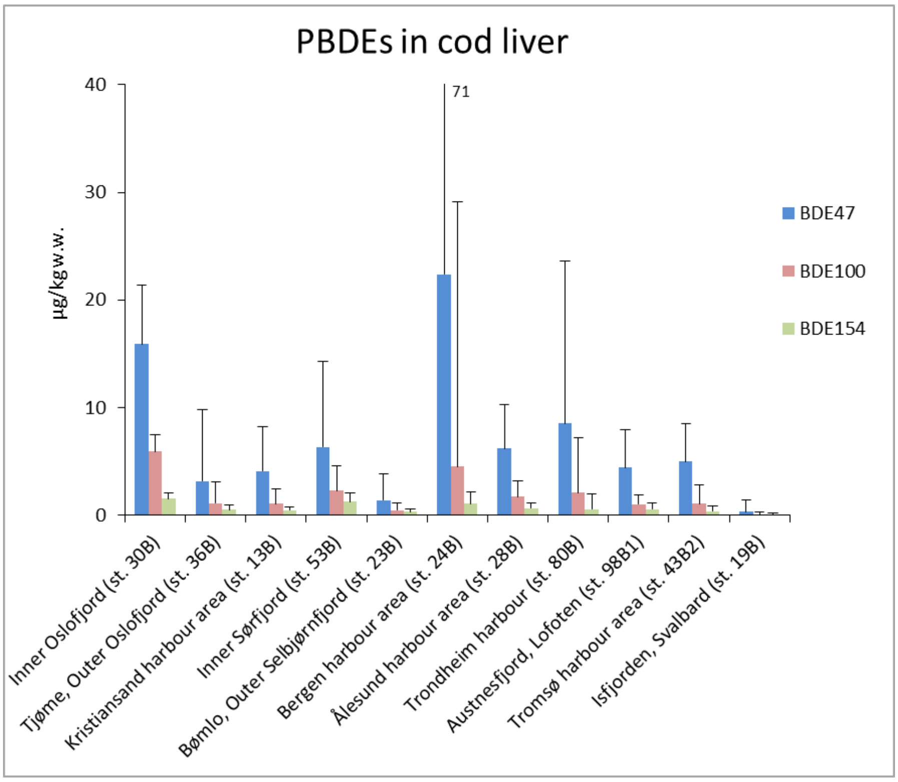
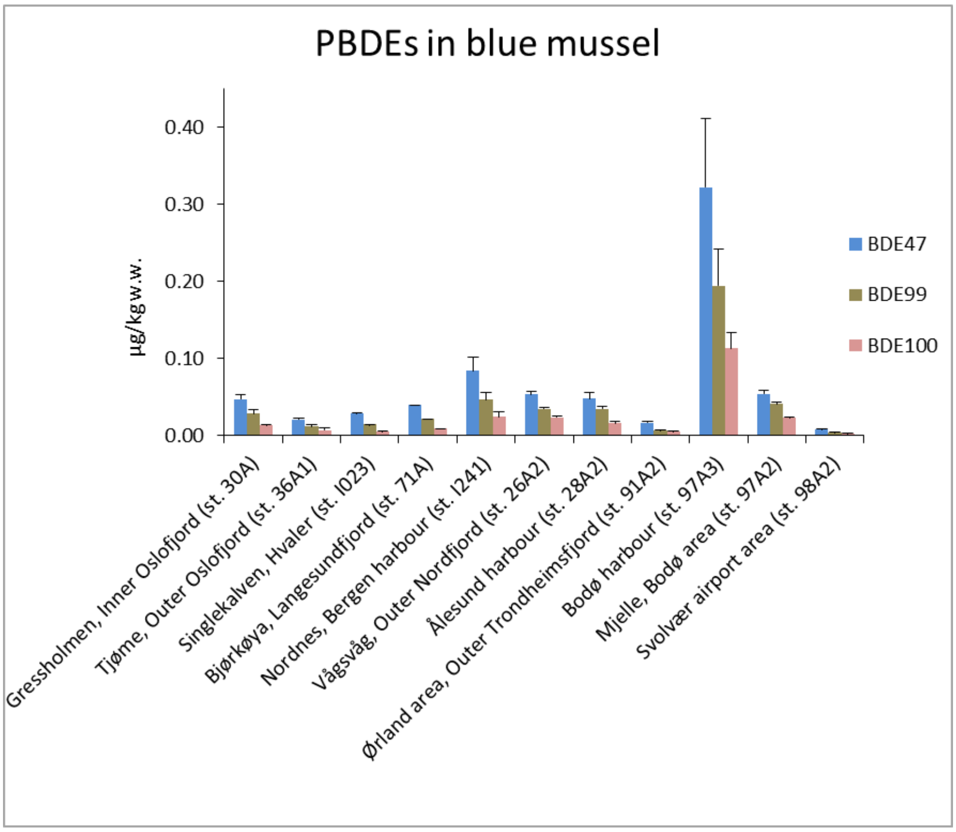


Figure 52. *Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2020. The error bar indicates one standard deviation above the median.*

A



B

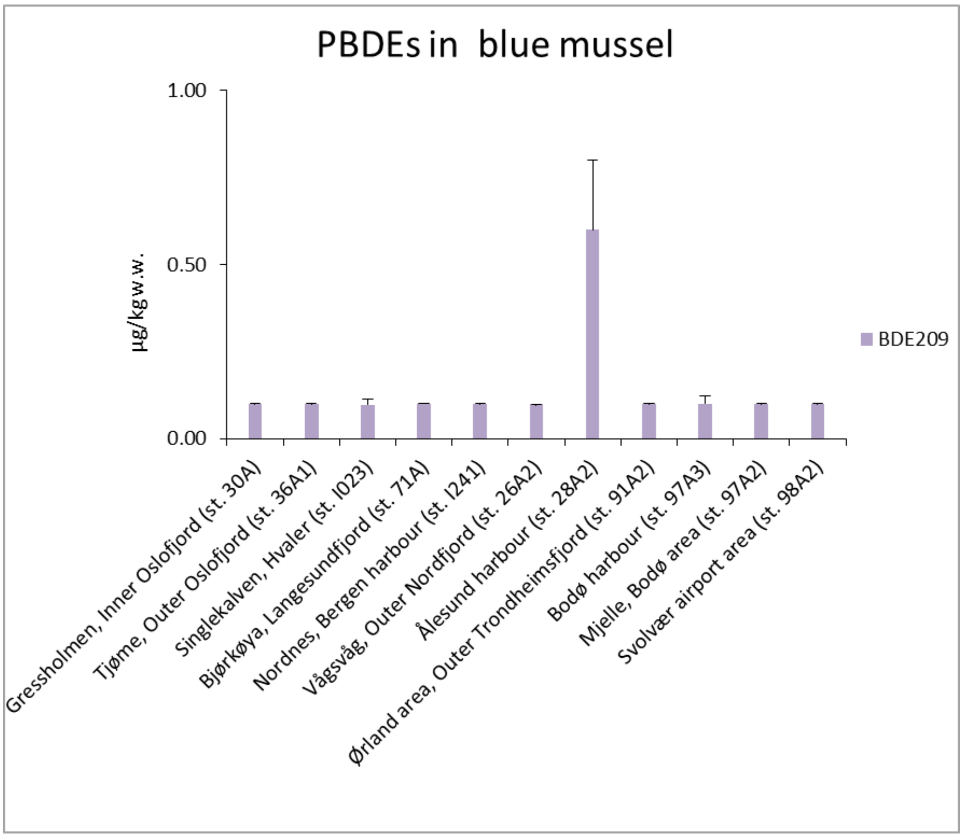


***Figure 53**. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2020; BDE47, BDE99 and BDE100 (A) and BDE209 (all results below LOQ) (**B**). The error bar indicates one standard deviation above the median.*

Table 12*. Median concentrations (µg/kg w.w.) and standard deviations (S.d.) for PBDE congeners in blue mussel, cod liver, and eider blood and eggs in 2020. 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 the value shown in these cells is the LOQ. The standard deviation is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. BDE6 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 4****, 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	2020	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																			
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.001	0.000	2 [0.001-0.001]	0.047	0.006	3 [0.04-0.05]	0.028	0.006	3 [0.02-0.03]	0.013	0.001	3 [0.01-0.01]	0.002	0.000	0 [n.a.]	0.003	0.001	1 [0.004]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.001	0.000	1 [0.001]	0.020	0.002	3 [0.02-0.02]	0.012	0.002	3 [0.01-0.01]	0.007	0.003	2 [0.006-0.007]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.001	0.000	1 [0.001]	0.028	0.001	3 [0.03-0.03]	0.014	0.000	3 [0.01-0.01]	0.005	0.000	3 [0.005-0.005]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.001	0.000	0 [n.a.]	0.039	0.000	1 [0.04]	0.021	0.000	1 [0.02]	0.009	0.000	1 [0.009]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.003	0.001	3 [0.003-0.004]	0.084	0.018	3 [0.08-0.11]	0.046	0.009	3 [0.05-0.06]	0.024	0.007	3 [0.02-0.03]	0.002	0.000	1 [0.002]	0.005	0.002	3 [0.005-0.009]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.002	0.001	3 [0.001-0.002]	0.053	0.004	3 [0.05-0.06]	0.034	0.001	3 [0.03-0.04]	0.023	0.002	3 [0.02-0.02]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Ålesund harbour (st. 28A2)	3 (3-50)	0.001	0.000	2 [0.001-0.001]	0.047	0.008	3 [0.04-0.06]	0.034	0.003	3 [0.03-0.04]	0.015	0.003	3 [0.01-0.02]	0.002	0.000	3 [0.002-0.002]	0.003	0.001	2 [0.003-0.004]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.001	0.000	0 [n.a.]	0.016	0.002	3 [0.01-0.02]	0.006	0.001	3 [0.005-0.007]	0.004	0.001	3 [0.004-0.005]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Bodø harbour (st. 97A3)	3 (3-50)	0.005	0.001	3 [0.004-0.007]	0.322	0.089	3 [0.28-0.45]	0.194	0.047	3 [0.15-0.25]	0.113	0.020	3 [0.09-0.13]	0.002	0.000	0 [n.a.]	0.010	0.002	3 [0.007-0.01]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.001	0.000	0 [n.a.]	0.054	0.004	3 [0.05-0.06]	0.041	0.002	3 [0.04-0.04]	0.023	0.001	3 [0.02-0.02]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Svolvær airport area (st. 98A2)	3 (3-50)	0.001	0.000	0 [n.a.]	0.007	0.001	3 [0.006-0.008]	0.003	0.001	2 [0.003-0.004]	0.002	0.000	3 [0.002-0.003]	0.002	0.000	0 [n.a.]	0.003	0.000	0 [n.a.]
Cod, liver																			
Inner Oslofjord (st. 30B)	12 (7-6)	0.298	0.135	12 [0.11-0.6]	15.900	5.472	12 [6.3-24]	0.207	0.258	12 [0.08-1.01]	5.920	1.593	12 [2.9-8.7]	0.234	0.139	12 [0.13-0.63]	0.046	0.033	8 [0.04-0.12]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	0.198	0.209	15 [0.01-0.74]	3.180	6.639	15 [0.51-28]	0.030	0.032	9 [0.02-0.13]	1.120	1.956	15 [0.54-8.3]	0.115	0.073	15 [0.05-0.3]	0.030	0.005	1 [0.05]
Kristiansand harbour area (st. 13B)	8 (6-2)	0.164	0.143	8 [0.08-0.52]	4.115	4.092	8 [1.36-12.2]	0.166	0.110	8 [0.1-0.44]	1.072	1.367	8 [0.2-3.8]	0.065	0.070	7 [0.02-0.21]	0.047	0.024	7 [0.03-0.11]
Inner Sørfjord (st. 53B)	15 (4-3)	0.238	0.191	15 [0.08-0.63]	6.350	7.925	15 [1.99-24]	0.149	0.113	15 [0.04-0.47]	2.280	2.289	15 [0.24-6.9]	0.165	0.161	14 [0.02-0.6]	0.030	0.031	7 [0.04-0.12]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	0.066	0.101	14 [0.02-0.35]	1.410	2.452	15 [0.25-9.9]	0.025	0.051	10 [0.02-0.22]	0.490	0.649	15 [0.07-2.6]	0.057	0.053	13 [0.04-0.22]	0.038	0.019	9 [0.04-0.09]
Bergen harbour area (st. 24B)	14 (6-2)	0.570	1.549	14 [0.13-6]	22.400	70.992	14 [3.1-275]	0.329	0.742	14 [0.03-2.5]	4.545	24.556	14 [0.85-96]	0.074	0.066	14 [0.03-0.24]	0.059	0.073	10 [0.03-0.24]
Ålesund harbour area (st. 28B)	14 (2-2)	0.218	0.180	14 [0.08-0.66]	6.195	4.059	14 [1.56-16.1]	0.236	0.239	14 [0.09-1.07]	1.745	1.416	14 [0.44-5.4]	0.134	0.112	14 [0.03-0.39]	0.048	0.034	12 [0.04-0.14]
Trondheim harbour (st. 80B)	14 (0-1)	0.332	0.286	14 [0.06-0.94]	8.540	15.065	14 [1.52-50]	0.198	0.641	13 [0.04-2.3]	2.120	5.053	14 [0.36-15.8]	0.082	0.119	13 [0.03-0.36]	0.030	0.099	5 [0.04-0.36]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	0.228	0.223	15 [0.03-0.82]	4.420	3.560	15 [0.55-14.1]	0.038	0.124	13 [0.02-0.51]	1.040	0.899	15 [0.12-3.5]	0.097	0.128	14 [0.03-0.53]	0.030	0.010	1 [0.07]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.093	0.083	15 [0.04-0.33]	4.990	3.486	15 [1.54-15.3]	0.076	0.060	15 [0.03-0.27]	1.090	1.724	15 [0.44-7.4]	0.063	0.069	15 [0.04-0.29]	0.030	0.002	1 [0.04]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.023	0.035	15 [0.01-0.13]	0.347	1.081	15 [0.24-3.6]	0.020	0.004	1 [0.04]	0.074	0.229	15 [0.05-0.73]	0.020	0.038	3 [0.03-0.15]	0.030	0.000	0 [n.a.]
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.006	0.015	0 [n.a.]	0.027	0.062	3 [0.03-0.04]	0.011	0.026	1 [0.02]	0.006	0.013	1 [0.006]	0.003	0.007	0 [n.a.]	0.010	0.024	0 [n.a.]
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.006	0.002	1 [0.01]	0.037	0.030	13 [0.03-0.14]	0.013	0.006	9 [0.01-0.03]	0.029	0.016	15 [0.009-0.05]	0.003	0.000	0 [n.a.]	0.010	0.004	4 [0.01-0.02]

***Table 12**. (cont.)*

Component	Count	BDE154			BDE183			BDE196			BDE209			BDE6S			BDESS		
Species and sampling locality	**2020**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**
Blue mussel																			
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.100	0.001	0 [n.a.]	0.095	0.013	0 [n.a.]	0.292	0.015	3 [0.07-0.1]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	0.045	0.006	0 [n.a.]	0.237	0.007	3 [0.04-0.05]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.003	0.000	1 [0.004]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.098	0.015	0 [n.a.]	0.055	0.001	0 [n.a.]	0.247	0.016	3 [0.05-0.06]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.101	0.000	0 [n.a.]	0.076	0.000	0 [n.a.]	0.272	0.000	1 [0.08]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.012	0.003	3 [0.01-0.02]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	0.171	0.039	0 [n.a.]	0.377	0.042	3 [0.17-0.24]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.099	0.000	0 [n.a.]	0.118	0.005	0 [n.a.]	0.314	0.006	3 [0.11-0.12]
Ålesund harbour (st. 28A2)	3 (3-50)	0.009	0.002	3 [0.008-0.01]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.600	0.200	0 [n.a.]	0.110	0.017	0 [n.a.]	0.900	0.199	3 [0.1-0.13]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.099	0.000	0 [n.a.]	0.033	0.003	0 [n.a.]	0.226	0.002	3 [0.03-0.04]
Bodø harbour (st. 97A3)	3 (3-50)	0.015	0.003	3 [0.01-0.01]	0.005	0.000	1 [0.006]	0.010	0.000	0 [n.a.]	0.100	0.022	0 [n.a.]	0.659	0.160	0 [n.a.]	0.906	0.200	3 [0.54-0.86]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.004	0.000	3 [0.004-0.004]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.098	0.002	0 [n.a.]	0.125	0.007	0 [n.a.]	0.317	0.010	3 [0.12-0.14]
Svolvær airport area (st. 98A2)	3 (3-50)	0.003	0.000	0 [n.a.]	0.005	0.000	0 [n.a.]	0.010	0.000	0 [n.a.]	0.100	0.001	0 [n.a.]	0.019	0.002	0 [n.a.]	0.210	0.003	3 [0.02-0.02]
Cod, liver																			
Inner Oslofjord (st. 30B)	12 (7-6)	1.535	0.535	12 [1.09-3.1]	0.050	0.010	1 [0.08]	0.100	0.000	0 [n.a.]	1.000	0.004	0 [n.a.]	24.615	7.129	0 [n.a.]	28.921	8.974	12 [14.1-35]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	0.511	0.477	15 [0.26-1.84]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.000	0 [n.a.]	5.092	9.175	0 [n.a.]	8.128	10.433	15 [1.48-39]
Kristiansand harbour area (st. 13B)	8 (6-2)	0.490	0.318	8 [0.2-1.17]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.071	0 [n.a.]	6.206	5.889	0 [n.a.]	9.065	6.602	8 [2.1-16.6]
Inner Sørfjord (st. 53B)	15 (4-3)	1.270	0.852	15 [0.3-3.2]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.136	0 [n.a.]	10.704	10.698	0 [n.a.]	14.406	11.820	15 [3.2-32]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	0.328	0.265	15 [0.12-1.22]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.000	0 [n.a.]	2.344	3.406	0 [n.a.]	4.531	3.952	15 [0.55-13.6]
Bergen harbour area (st. 24B)	14 (6-2)	1.090	1.111	14 [0.25-4.3]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.274	0 [n.a.]	30.298	97.731	0 [n.a.]	36.002	99.439	14 [4.9-382]
Ålesund harbour area (st. 28B)	14 (2-2)	0.675	0.458	14 [0.42-1.85]	0.050	0.007	1 [0.08]	0.100	0.000	0 [n.a.]	1.000	0.003	0 [n.a.]	8.569	5.899	0 [n.a.]	11.780	6.321	14 [2.9-24]
Trondheim harbour (st. 80B)	14 (0-1)	0.575	1.425	14 [0.12-4.4]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.003	0 [n.a.]	11.569	22.308	0 [n.a.]	16.632	24.470	14 [2.1-74]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	0.579	0.530	15 [0.06-2]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.103	0 [n.a.]	6.420	5.242	0 [n.a.]	9.749	6.507	15 [0.81-21]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.379	0.455	15 [0.23-1.78]	0.050	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]	1.000	0.000	0 [n.a.]	6.757	5.610	0 [n.a.]	10.391	5.885	15 [2.4-25]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.067	0.179	15 [0.03-0.68]	0.050	0.001	1 [0.05]	0.100	0.000	0 [n.a.]	1.000	0.000	0 [n.a.]	0.560	1.519	0 [n.a.]	2.563	1.715	15 [0.38-4.9]
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.009	0.020	0 [n.a.]	0.007	0.017	0 [n.a.]	0.013	0.032	0 [n.a.]	0.366	0.851	0 [n.a.]	0.069	0.159	0 [n.a.]	0.613	1.419	3 [0.07-0.12]
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.019	0.013	15 [0.01-0.06]	0.007	0.000	0 [n.a.]	0.015	0.003	0 [n.a.]	0.366	0.046	0 [n.a.]	0.143	0.060	0 [n.a.]	0.718	0.123	15 [0.08-0.31]

The Inner Oslofjord

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

In the present study, cod liver from the Inner Oslofjord showed a median concentration of 15.9 µg BDE47/kg w.w., and the mean concentration in a comparable study in 2020 (Grung et al. 2021) was 17.5 µg BDE47/kg w.w. The median concentration of BDE100 was 5.9 µg /kg w.w. in the present study, while the mean concentration was 5.6 µg/kg w.w. in the comparable study (Grung et al. 2021). The median concentration of BDE154 was 1.5 µg/kg w.w. in the present study, while the mean concentration was 1.2 µg/kg w.w. in the comparable study (Grung et al. 2021). 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 <0.069 µg/kg w.w. in blood and 0.143 µg/kg w.w. in eggs. The concentrations of BDE47 in eider were <0.027 µg/kg w.w. in blood and 0.037 µg/kg w.w. in eggs.

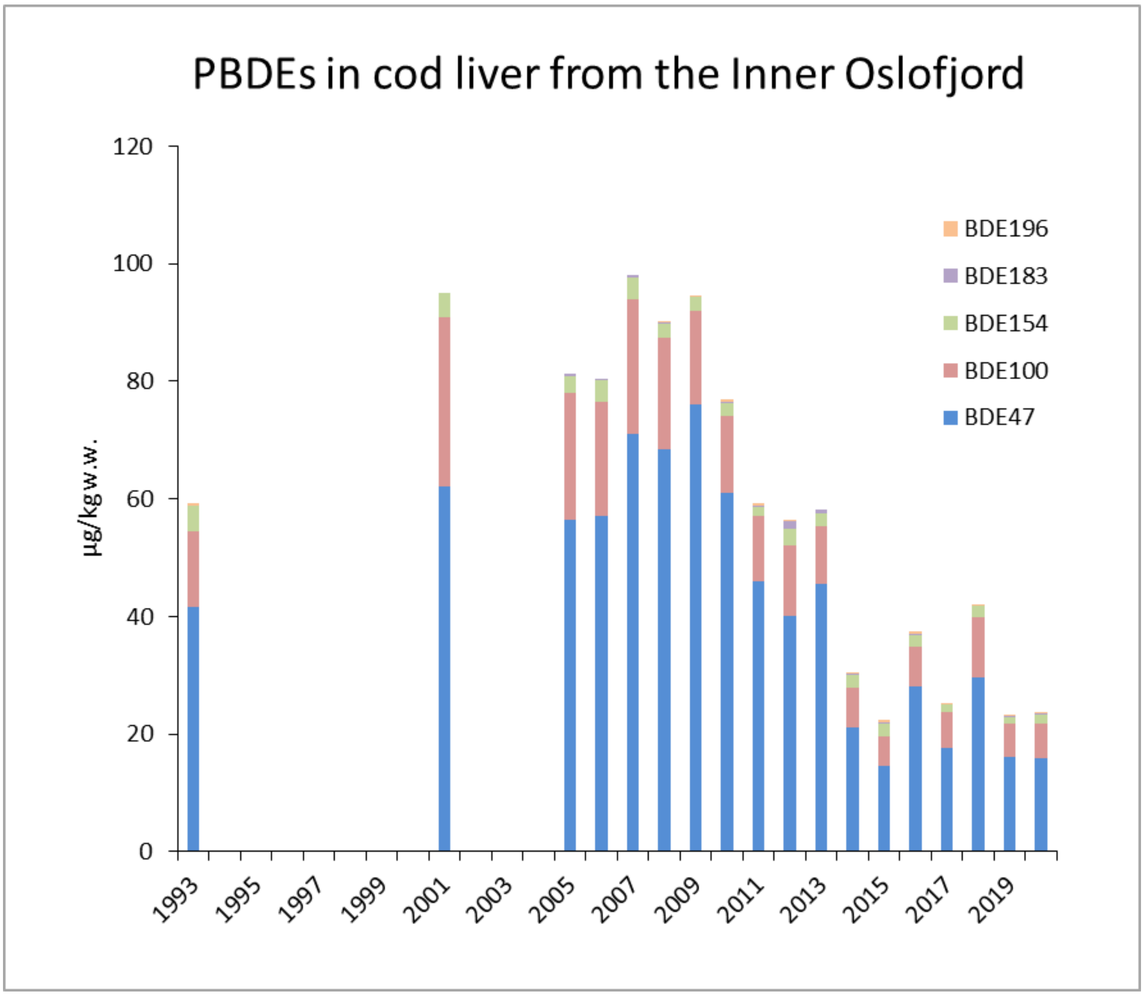


***Figure 54.** Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 1993, 2001 and from the period 2005 to 2020 in the Inner Oslofjord (st. 30B). When median was below the limit of quantification (LOQ), the LOQ is used.*

Comparison with other studies

Median concentrations for the sum BDEs (BDE28, 47, 66, 49+71, 77, 99, 100, 119, 153, 154, 183 and 209) found at presumed reference stations like Lofoten (8.49 µg/kg w.w.), Færder (9.61 µg/kg w.w.), Lista (12.9 µg/kg w.w.) and Bømlo-Sotra (23.8 µg/kg w.w.) indicate background levels in diffusely contaminated areas for cod liver (Fjeld 2005). This is lower than the sum BDEs (28, 47, 99, 100, 153 and 154) of 24.6 µg/kg w.w. found at MILKYS cod stations in the Inner Oslofjord (st. 30B) in 2020 (cf. ***Figure 52***).

The congeners BDE47 and 100 were the most dominant in 2020, as in previous years. The low concentrations of BDE99 could be due to the debromination to BDE47, because BDE99 is more prone to biotransformation than other common PBDE such as BDE47 (Streets et al. 2006). Furthermore, BDE47 is also reported to be a more stable congener than BDE99 (Benedict et al. 2007). Investigations of brown trout (*Salmo trutta*), smelt (*Osmerus eperlanus*) and vendace (*Coregonus albula*) in lake Mjøsa showed that the decrease was greatest for BDE99, which probably is due to a biotransformation (debromination) to BDE47 (Fjeld 2012). Since the early 2000s, there has been a clear reduction of PBDE concentrations in freshwater fish from Mjøsa (Jartun 2021).

In the present study, the median concentration of PBDE47 (0.037 µg/kg w.w.) in eider eggs from Svalbard was lower than in another study of eider from three stations in northern Norway and one at Svalbard (mean 0.12 ± 0.06 µg/kg w.w.) (Harju 2013). A comparable study of eider from the Inner Oslofjord in 2017, found mean values of 0.385 µg PBDE47/kg w.w. in eggs (Ruus 2018), which was 10 times higher than at Svalbard (0.037 µg PBDE47/kg w.w.).

General, large scale trends

A few time-trend analyses showed upward trends in concentration of PBDE congeners in blue mussel; significant upward short-term trends were found for both BDE99 and BDE100 in blue mussel from the Vågsvåg (st. 26A2) in the Outer Nordfjord. BDE99 is a main constituent of the penta-BDE flame retardant mixtures.

For PBDEs in cod liver, the only significant upward short-term trend was for BDE154 in cod liver from the Austnesfjord in Lofoten (st. 98B1). BDE154 is a main component of commercial octa-BDE flame retardant mixtures.

There was a total of 34 significant downward long-term trends (sum BDE not included), 12 were found in blue mussel and 22 in cod liver. Of 16 significant downward short-term trends, three were found in blue mussel and 13 in cod liver.

Overall, there were more downward trends (50) for PBDEs than increasing trends for PBDEs (3). These results of dominating downward trends likely reflect how the restrictions on penta- and octa-BDE that entered into force for most countries globally in 2010 have resulted in reductions in emissions and releases. The findings are in line with findings reported in other studies; the general decreasing trends for the commercial penta-BDE mixture (that includes BDE100) (Law et al. 2014), declining European emissions of PBDE (Schuster et al. 2010) and lower concentrations of PBDEs in marine mammals in the Arctic and North Atlantic since 2000 (Rotander et al. 2012). It can be noted that after 2002 a sharp decline in concentrations of PBDEs (as well as PFASs) was observed in blood from newborns in New York state (Ma et al. 2013). Furthermore, both the penta- and octa PBDE mixtures were listed in the Stockholm Convention and has been regulated globally through since 2010.

Emissions of PBDEs to air and discharges to water from land-based industries can be seen in ***Figure 55***. In 2016, the emission to air was 0.03 kg brominated diphenyl ethers. The discharges to water were 1.7 kg brominated diphenyl ethers in 2017 and 0 kg in both 2019 and 2020.

OSPAR has monitored PBDE concentrations in fish, mussels and oysters in several ocean areas. The results indicate that the mean concentrations of PBDEs are decreasing in the majority of assessed areas. The Skagerrak and Kattegat is the exception, where concentrations in biota show no statistically significant change. The highest mean concentrations of PBDEs in biota were found in biota in the English Channel and Irish Sea. The lowest concentrations are found in the Iberian Sea (https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/pbde-fish-shellfish/).

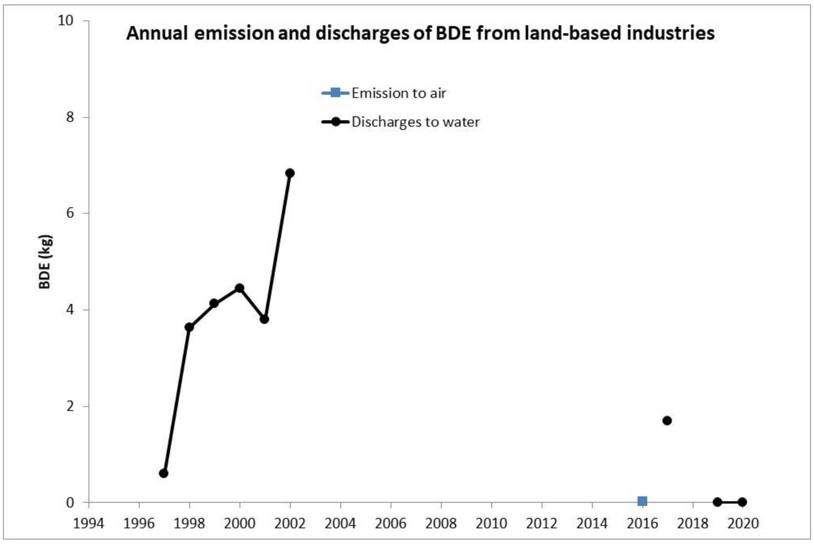


Figure 55. *Annual emissions* of *PBDEs to air and discharges to water from land-based industries in the period 1994-2020 (data from www.norskeutslipp.no, 05.07.2021). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.24 Perfluorinated alkylated substances (PFAS)

Perfluorinated alkylated substances (PFAS) are organofluorine compounds used as oil-, stain- and water-repellent surfactants and in several other applications. There are approximately 6330 PFASs on the marked globally, and firefighting foam was the largest source to PFOS in the Norwegian environment until the ban in 2007[1]. In Norway, PFOA in consumer products has been regulated since June 2014.

In the present study, PFAS were analysed in blue mussel at six stations, cod liver at 10 stations, and in eider blood and eggs at one station (***Table 1***, ***Table 9***, ***Figure 57***). 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 is 9.1 µg/kg w.w. and applies to whole fish (Directive 2013/39/EU on priority substances in the field of water policy). Applying this for blue mussel, all stations were below the EQS (***Table 8***). 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 5.5 µg/kg w.w. in the Inner Oslofjord (st. 30B)) (***Table 8***). Applying this EQS for eider blood and eggs, the PFOS concentrations were below the EQS (***Table 8***).

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

The EQS for perfluorooctanoic acid (PFOA) is 91.3 µg/kg w.w. in biota (2013/39/EU). Applying this for blue mussel, cod liver, and eider blood and eggs, all concentrations of PFOA were below EQS (***Table 8***).

Levels exceeding PROREF

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of PFOSA by a factor less than two.

Downward trends in cod liver

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

Levels in blue mussel

Most data for PFAS in blue mussel are not sufficient to analyse trends or PROREF. In blue mussel, the concentration of PFOS at all stations were below LOQ (<0.100 µg/kg w.w.) except for at Svolvær airport area (st. 98A2, 0.100 µg/kg w.w.). The concentrations of PFOSA were 0.500 µg/kg w.w. at Gressholmen (st. 30A), 0.200 µg/kg w.w. at Færder (st. 36A) and 0.100 µg/kg w.w. at Ålesund harbour (st. 28A2). In blue mussel, all concentrations of PFNA **(**perfluorononanoic acid) were below LOQ (<0.500 µg/kg w.w.). The median concentrations of the remaining PFASs were mostly below LOQ (***Table 13***).

Levels in cod

In cod liver, the highest median concentration of PFOS was found in the Inner Oslofjord (st. 30B) (5.5 µg/kg w.w.) and the lowest level was observed at Svalbard (st. 19B, 0.300 µg/kg w.w.) (***Figure 57, Figure 58***, ***Table 13***). At Tjøme (st. 36B) the PFOS concentrations had decreased from 7.4 µg/kg w.w. in 2018 to 1.4 µg/kg w.w. in 2020. Maximum median concentration of PFOSA was 8.1 µg/kg w.w. in cod liver from the Inner Oslofjord (st. 30B), and a minimum level was found at Svalbard (st. 19B, <0.100 µg/kg w.w.) (***Figure 57, Figure 58)***. In 2020, the concentration of PFOSA was higher than PFOS in the Inner Oslofjord (st. 30B) and at Tjøme (st. 36B). PFOSA was significantly higher in cod liver from the Inner Oslofjord (st. 30B) than any other station (Tukey-Kramer HSD test). In cod liver, all concentrations of PFNA **(**perfluorononanoic acid) were below LOQ (<0.500 µg/kg w.w.) except for in the Inner Oslofjord (0.500 µg/kg w.w.). The median concentrations of PFOA were below LOQ (***Table 13***).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PFOS were 0.400 µg/kg w.w. in blood and 1.1 µg/kg w.w. in eggs. The concentrations of PFOA were <0.500 µg/kg w.w. in blood and <0.500 µg/kg w.w. in eggs.

Comparison with other studies - The Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities including presence of PFOSA in certain products such as fire-fighting foam and consumer products (Herzke 2009). PFOSA was detected in sewage sludge as a minor constituent (Grung et al. 2021) . 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 sources, as well as reduced water exchange with the Outer Oslofjord.

In the present study, cod liver from the Inner Oslofjord had median concentrations of 5.5 µg PFOS/kg w.w. and 8.1 µg PFOSA/kg w.w. in 2020. Cod liver from a comparable study from the Inner Oslofjord in 2020 had mean concentrations of PFOS (4.0 µg/kg w.w.) and PFOSA (9.2 µg/kg w.w.) (Grung et al. 2021) within the same range. 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. 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 for liver in the MILKYS programme in 2009 from the Inner Oslofjord (Green et al. 2010). They found that PFOSA was the most dominant PFAS-compound with a median level six times higher than for PFOS. The median level of PFOSA in cod blood was about five times higher than in liver while the median level of PFOS in cod liver was about 1.5 times higher than in blood. Further, PFNA was also detected in cod blood. Rundberget et al. (2014) investigated cod from Inner Oslofjord (st. 30B) in the period 2009 to 2013 and found that blood was the preferred matrix for analysing PFAS. The levels of PFOS were roughly the same in blood as in liver and bile, but levels of other PFAS were higher in blood and therefore easier to detect. A study of cod liver from the Inner Oslofjord in 2012 showed higher median concentration of PFOS, than the median concentration of PFOSA which was lower in cod from 2012 (Ruus 2014) as opposed to what was observed in the present study.

Comparison with other studies - The Outer Oslofjord

There were high levels in cod liver at Tjøme in the Outer Oslofjord in 2018 (7.4 µg PFOS/kg w.w. and 44 µg PFOSA/kg w.w.) compared to 2020 (1.4 µg PFOS/kg w.w. and 2.2 µg PFOSA/kg w.w.). In 2017, Ruus et al. (2018) reported that several PFAS compounds (e. g. PFOS) was found in high concentrations in the seagulls of the Outer Oslofjord (both blood and eggs), possibly related to contamination in the area because of an earlier airport in proximity of the colony. Use of firefighting foam with PFOS at former Rygge Airport at Vansjø has caused contamination of surrounding terrestrial and aquatic environment (Fjeld 2017). Another study has also related PFAS concentrations in blue mussel to earlier use of firefighting foam in the area of Mossesundet (Øxnevad, Brkljacic, and Borgersen 2016).

Comparison with other studies

Valdersnes et al. (2017) found that the levels of PFAS in cod liver along the Norwegian coast were 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 (Tønsberg/Vrengen, Sandefjord, Kragerø, Tvedestrand and Lillesand) of Norway. Valdernes et al. (2017) found geographical differences, with highest PFOS concentrations in the eastern part compared to the western (Farsund, Flekkefjord, Egersund, Sandnes, Stavanger and Karmsundet) and northern part (Svolvær, Narvik, Hammerfest and Honningsvåg). 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-Norway 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 present study, the median concentrations of PFOS (1.1 µg/kg w.w.) and PFOSA (<0.1 µg/kg w.w.) in eider eggs from Svalbard were almost within the same range as in another study of eider from three stations in northern Norway and one at Svalbard (mean 3.7±2.3 µg PFOS/kg w.w. and 0.26±0.14 µg PFOSA/kg w.w.) (Harju 2013).

In the present study, the median concentrations were 0.400 µg PFOS/kg w.w. in blood and 1.1 µg PFOS/kg w.w. in eider eggs from Svalbard. A study of eider from the Inner Oslofjord in 2019, found mean values of 9.97 µg PFOS/kg w.w. in blood and 23.21 µg PFOS/kg w.w. in eggs (Ruus 2019). The PFOS concentrations in eider blood and eggs were 21-25 times higher in the Inner Oslofjord than at Svalbard.

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

PFAS compounds in freshwater fish in Norway have been regularly monitored (Jartun 2021). 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. The national monitoring programme "Monitoring of environmental contaminants in freshwater ecosystems 2020" (Jartun 2021) showed downward trends for PFOS for all fish in Lake Mjøsa in 2020 compared to levels in 2013/2014, but the concentrations have seemed to stabilize the last four years.

General, large scale trends

Five of the 10 cod liver stations had significant downward long-term trends for PFOS. 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[1]) to water from land-based industries are shown in ***Figure 56***. The discharges to water had increased from 330 g PFAS in 2013 to 4 171 g PFAS in 2017, and then decreased to 1 430 g PFAS in 2020.

[1] Includes: 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**.)

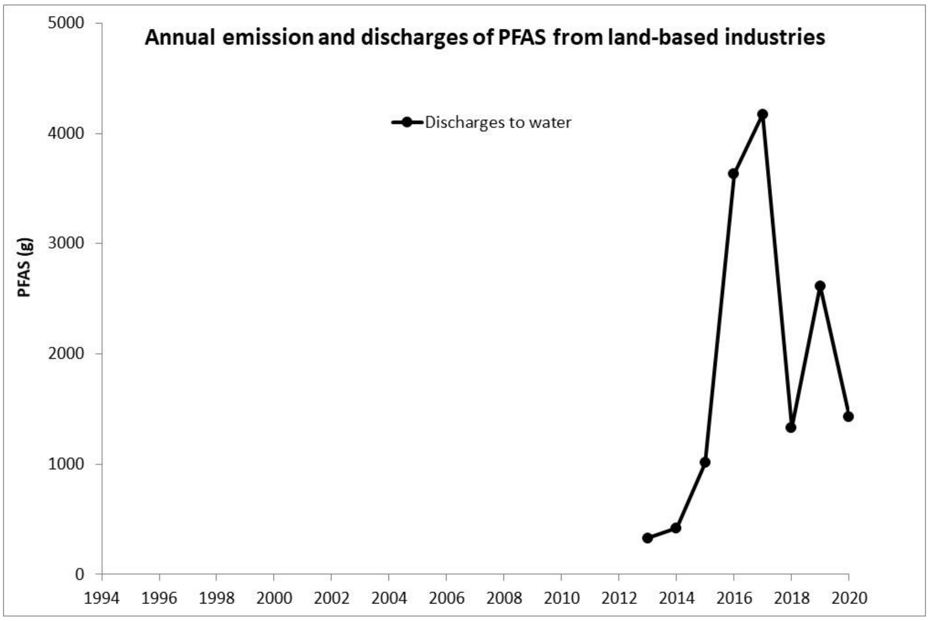


Figure 56*. Annual discharges of PFAS to water from land-based industries for 2013 to 2020 (data from www.norskeutslipp.no, 05.07.2021). No data for emissions to air are reported, and no data for discharges to water are reported for 1994-2012. Note that emissions and discharges from municipal treatment 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.*

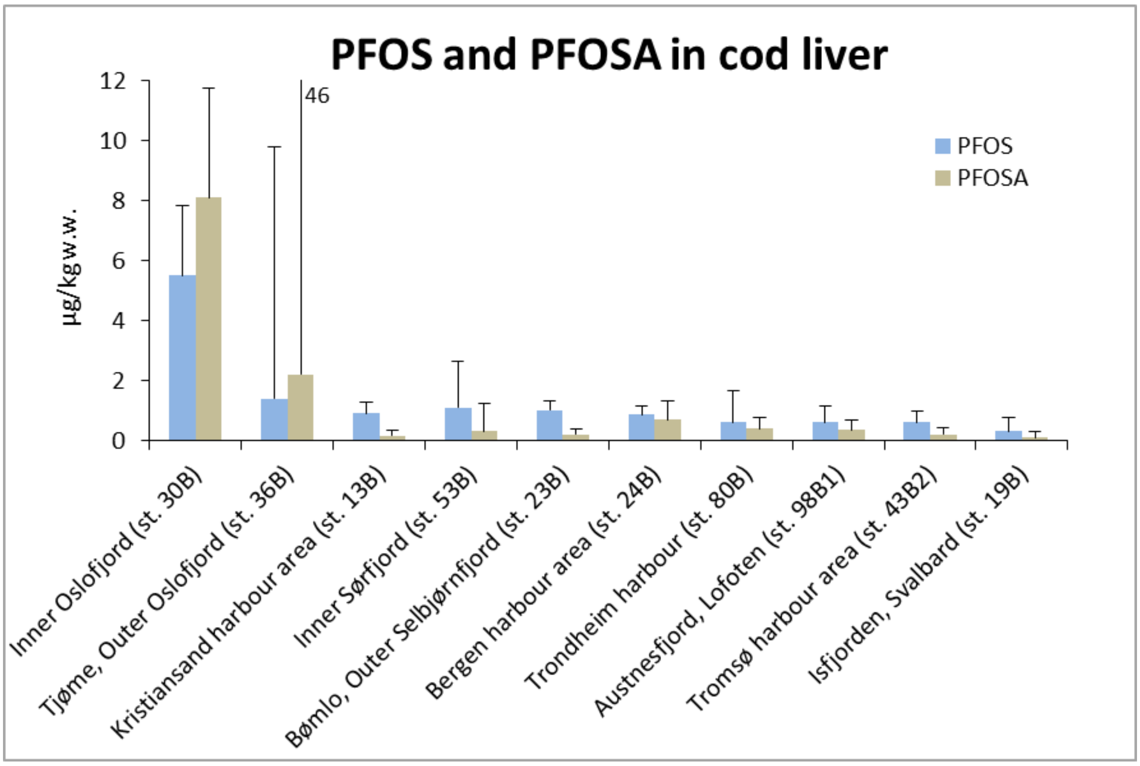


Figure 57*. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver in 2020. The error bar indicates one standard deviation above the median (see also* ***Table 13****).*

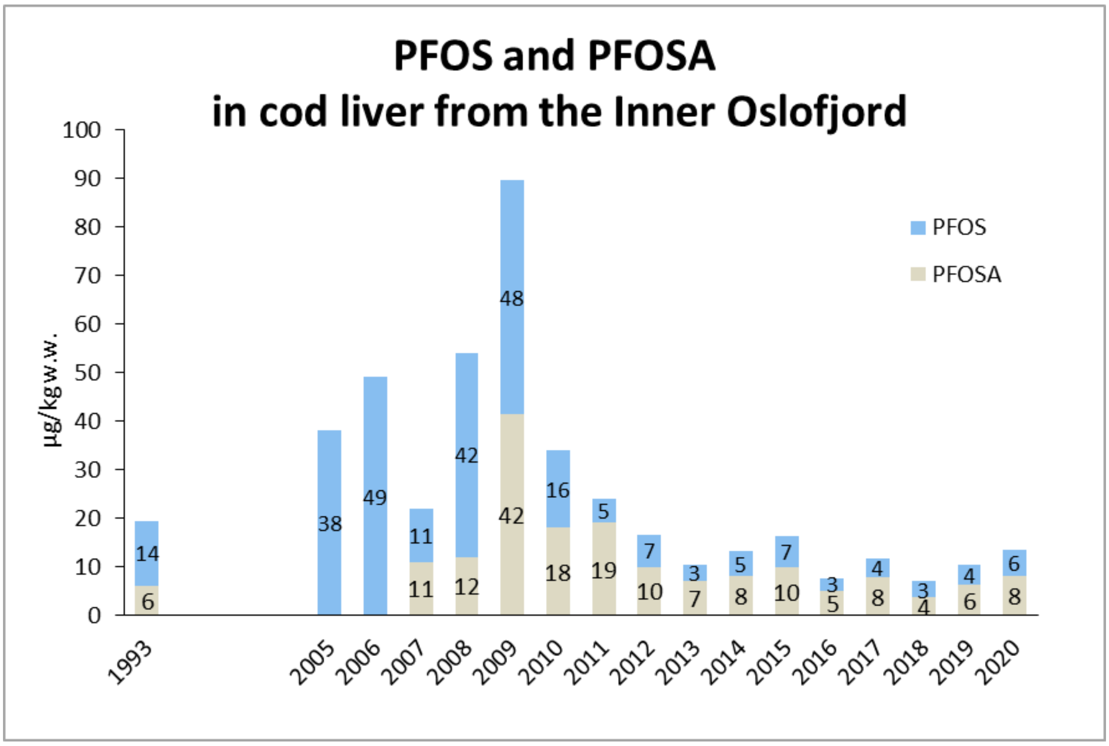


Figure 58. *Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 and 2005 to 2020 in the Inner Oslofjord (st. 30B).*

Table 13*. Median concentrations (µg/kg w.w.) and standard deviations (S.d.) of the PFAS-compounds analysed in blue mussel, cod liver, and eider blood and eggs in 2020. 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 the value shown in these cells is the LOQ. The standard deviation is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See* ***Chapter 2.10*** *for more details and* ***Appendix B*** *for description of chemical codes).*

Component	Count	PFNA			PFOA			PFOS			PFOSA			PFUdA		
Species and sampling locality	**2020**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**	**Med.**	**S.d.**	**D.d.i.**
Blue mussel																
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.5	0.058	3 [0.4-0.5]	0.4	0	0 [n.a.]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.2	0.058	3 [0.1-0.2]	0.4	0	0 [n.a.]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.1	0	0 [n.a.]	0.4	0	0 [n.a.]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.1	0	1 [0.1]	0.4	0	0 [n.a.]
Ålesund harbour (st. 28A2)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0	0 [n.a.]	0.1	0	3 [0.1-0.1]	0.4	0	0 [n.a.]
Svolvær airport area (st. 98A2)	3 (3-50)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.1	0.058	3 [0.1-0.2]	0.1	0	0 [n.a.]	0.4	0	0 [n.a.]
Cod, liver																
Inner Oslofjord (st. 30B)	12 (7-6)	0.5	0.116	6 [0.5-0.8]	0.5	0	0 [n.a.]	5.5	2.34	12 [1.4-7.7]	8.1	3.632	12 [3.6-16]	2.05	0.815	12 [0.6-2.6]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.4	8.407	15 [0.8-34]	2.2	45.76	15 [0.5-180]	0.7	0.312	14 [0.5-1.7]
Kristiansand harbour area (st. 13B)	8 (6-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.9	0.394	8 [0.7-1.9]	0.15	0.173	4 [0.2-0.6]	0.5	0.139	6 [0.4-0.8]
Inner Sørfjord (st. 53B)	15 (4-3)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.1	1.523	15 [0.3-5]	0.3	0.933	11 [0.1-3.8]	1	0.446	13 [0.5-1.7]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1	0.338	15 [0.5-1.6]	0.2	0.181	10 [0.1-0.6]	0.4	0.056	5 [0.4-0.6]
Bergen harbour area (st. 24B)	14 (6-2)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.85	0.284	14 [0.4-1.4]	0.7	0.598	14 [0.1-2.4]	0.45	0.291	9 [0.4-1.3]
Trondheim harbour (st. 80B)	15 (0-1)	0.5	0.232	1 [1.4]	0.5	0	0 [n.a.]	0.6	1.045	15 [0.2-4.3]	0.4	0.379	15 [0.1-1.3]	0.4	0.188	9 [0.4-0.9]
Austnesfjord, Lofoten (st. 98B1)	14 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.6	0.552	14 [0.3-2.2]	0.35	0.308	14 [0.1-1]	0.4	0.354	7 [0.4-1.6]
Tromsø harbour area (st. 43B2)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.6	0.361	15 [0.1-1.3]	0.2	0.205	10 [0.1-0.6]	0.4	0.091	3 [0.5-0.7]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.3	0.474	15 [0.2-1.9]	0.1	0.18	3 [0.1-0.7]	0.4	0.27	3 [0.4-1.3]
Eider, blood																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	0.4	0.145	15 [0.1-0.6]	0.1	0	0 [n.a.]	0.4	0	0 [n.a.]
Eider, egg																
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.5	0	0 [n.a.]	0.5	0	0 [n.a.]	1.1	0.755	15 [0.5-2.8]	0.1	0	0 [n.a.]	0.5	0.129	13 [0.4-0.8]

3.2.25 Hexabromocyclododecanes (HBCD)

Hexabromocyclododecanes (HBCD) is a persistent organic pollutant; it is toxic, persistent, bioaccumulates and undergo long-range environmental transport. 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 11 stations, and in blood and eggs of eider from one station (***Table 1***).

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 2020 (***Table 8***). In the present study α–HBCD (coded HBCDA in the present study) has been used as a proxy for the priority substance sum of the α–, β–, and γ–HBCD diastereomers (coded HBCDD in the present study).

Levels exceeding PROREF

The median concentration of HBCD in blue mussel from Bodø harbour (st. 97A3) exceeded the Norwegian provisional high reference contaminant concentration (PROREF) by a factor of two to five. The median concentration of HBCD has increased at this station since 2018. There were also median concentrations of HBCD in blue mussel from three other stations that exceeded the PROREF by a factor of up to two. These stations were Gressholmen, Inner Oslofjord (st. 30A), Nordnes, Bergen harbour (st. I241) and Ålesund harbour (st. 28A2).

Upward trends

There were no upward trends for HBCD in cod or blue mussel in 2020.

Downward trends

There were significant downward long- and short-term trends for HBCD in cod liver from Stathelle area, Langesundfjord (st. 71B) (***Figure 60 A***), Kirkøy, Hvaler (st. 02B), Kristiansand harbour (st. 13B), Inner Sørfjord (st. 53B) 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- and short-term trends were found for HBCD in blue mussel from Færder, Outer Oslofjord (st. 36A[1]), Nordnes, Bergen harbour (st. I241), Ørland area, Outer Trondheimfjord (st. 91A2), Mjelle, Bodø area (st. 97A2) and Svolvær airport (st. 98A2).

Levels in eider

The concentration of HBCD in eider egg increased from below LOQ in 2019 to 0.057 µg/kg in 2020. The concentration of HBCD in eider blood was below the LOQ.

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 59***, ***Table 14***). Median concentration of HBCD in cod liver from the Inner Oslofjord was 5.045 µg/kg w.w.

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

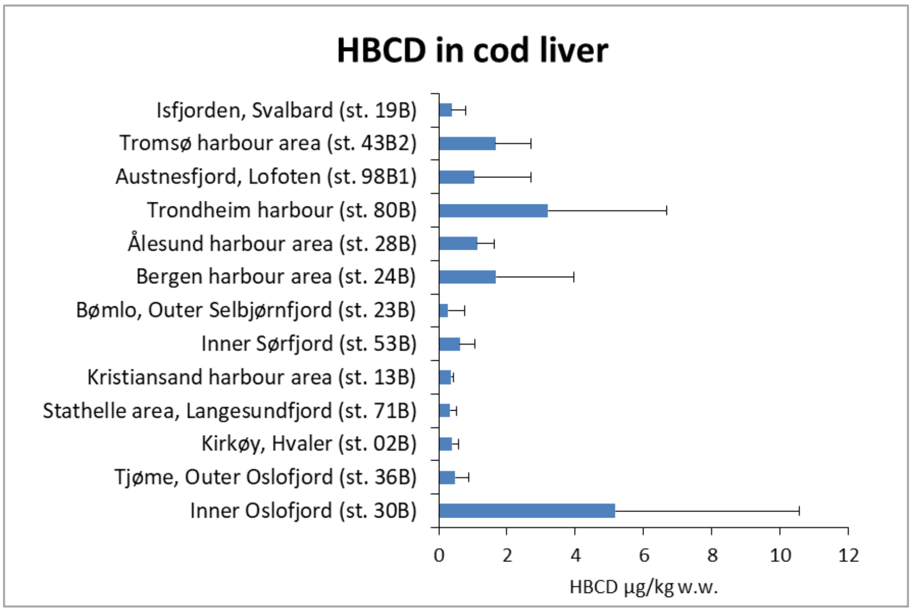


***Figure 59**. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver in 2020. The error bar indicates one standard deviation above the median.*

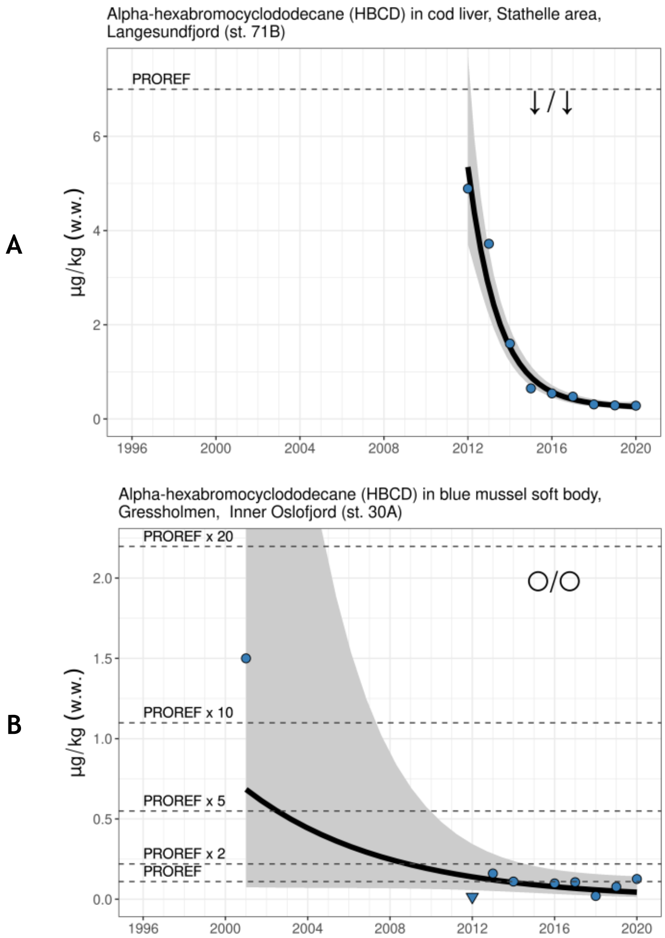


***Figure 60**. Median concentrations (mg/kg w.w.) of α–HBCD (HBCDA) in cod liver from 2012 to 2020 in Stathelle area (st. 71B) in the Langesundfjord (**A**) and in blue mussel from Gressholmen (st. 30A) in the Inner Oslofjord (**B**) (see **Figure 6** and **Appendix C**).*

Table 14. Median concentration (µg/kg w.w.) with standard deviation (S.d.) of α-HBCD, γ-HBCD, β-HBCD and HBCD (sum of α-, γ- and β-diastereomers) in cod liver, blue mussel and eider blood and eggs in 2020. 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 the value shown in these cells is the LOQ. The standard deviation is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.11 for more details and **Appendix B** for description of chemical codes).

Component	Count	a-HBCD			g-HBCD			b-HBCD			HBCD		
Species and sampling locality	2020	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)	0.126	0.007	3 [0.12-0.13]	0.018	0.006	0 [n.a.]	0.006	0.001	0 [n.a.]	0.150	0.013	3 [0.14-0.16]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	0.019	0.008	1 [0.03]	0.009	0.002	0 [n.a.]	0.006	0.000	0 [n.a.]	0.033	0.010	1 [0.05]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.035	0.004	3 [0.03-0.04]	0.006	0.000	0 [n.a.]	0.006	0.000	0 [n.a.]	0.047	0.004	3 [0.04-0.05]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.023		1 [0.02]	0.007		0 [n.a.]	0.006		0 [n.a.]	0.036		1 [0.04]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.130	0.008	3 [0.12-0.14]	0.018	0.003	0 [n.a.]	0.011	0.001	0 [n.a.]	0.158	0.011	3 [0.15-0.17]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.052	0.007	3 [0.05-0.06]	0.008	0.001	0 [n.a.]	0.006	0.000	0 [n.a.]	0.067	0.007	3 [0.07-0.08]
Ålesund harbour (st. 28A2)	3 (3-50)	0.117	0.011	3 [0.11-0.13]	0.051	0.002	3 [0.05-0.05]	0.013	0.003	3 [0.009-0.01]	0.179	0.012	3 [0.17-0.2]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.020	0.010	3 [0.02-0.04]	0.006	0.000	0 [n.a.]	0.006	0.000	0 [n.a.]	0.032	0.010	3 [0.03-0.05]
Bodø harbour (st. 97A3)	3 (3-50)	0.440	0.017	3 [0.44-0.47]	0.363	0.027	3 [0.36-0.41]	0.109	0.006	3 [0.1-0.12]	0.936	0.027	3 [0.91-0.96]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.025	0.007	3 [0.02-0.03]	0.006	0.000	0 [n.a.]	0.006	0.000	0 [n.a.]	0.037	0.007	3 [0.03-0.04]
Svolvær airport area (st. 98A2)	3 (3-50)	0.011	0.003	0 [n.a.]	0.006	0.001	0 [n.a.]	0.006	0.000	0 [n.a.]	0.024	0.003	0 [n.a.]
Cod, liver													
Inner Oslofjord (st. 30B)	12 (7-6)	5.045	5.286	12 [2.3-18.4]	0.062	0.107	6 [0.08-0.33]	0.030	0.022	2 [0.08-0.1]	5.173	5.397	12 [2.4-18.8]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	0.421	0.392	13 [0.05-1.6]	0.029	0.002	0 [n.a.]	0.029	0.002	0 [n.a.]	0.480	0.393	13 [0.1-1.66]
Kirkøy, Hvaler (st. 02B)	8 (6-2)	0.338	0.198	8 [0.07-0.63]	0.029	0.001	0 [n.a.]	0.029	0.001	0 [n.a.]	0.398	0.197	8 [0.13-0.68]
Stathelle area, Langesundfjord (st. 71B)	10 (5-5)	0.282	0.168	10 [0.06-0.67]	0.028	0.002	0 [n.a.]	0.028	0.002	0 [n.a.]	0.338	0.169	10 [0.11-0.73]
Kristiansand harbour area (st. 13B)	8 (6-2)	0.319	0.056	8 [0.25-0.41]	0.028	0.007	1 [0.05]	0.028	0.003	0 [n.a.]	0.367	0.061	8 [0.31-0.49]
Inner Sørfjord (st. 53B)	15 (4-3)	0.553	0.446	15 [0.19-1.64]	0.029	0.002	0 [n.a.]	0.029	0.002	0 [n.a.]	0.612	0.447	15 [0.25-1.7]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	0.221	0.473	14 [0.11-1.96]	0.029	0.013	0 [n.a.]	0.029	0.001	0 [n.a.]	0.278	0.484	14 [0.16-2.1]
Bergen harbour area (st. 24B)	14 (6-2)	1.620	2.252	14 [0.06-7.6]	0.030	0.033	3 [0.06-0.12]	0.028	0.001	0 [n.a.]	1.683	2.274	14 [0.12-7.7]
Ålesund harbour area (st. 28B)	14 (2-2)	0.987	0.479	14 [0.46-2.1]	0.045	0.055	5 [0.12-0.19]	0.029	0.001	0 [n.a.]	1.122	0.501	14 [0.54-2.2]
Trondheim harbour (st. 80B)	15 (0-1)	3.070	3.473	15 [0.05-13.1]	0.066	0.040	11 [0.03-0.16]	0.027	0.002	0 [n.a.]	3.196	3.485	15 [0.11-13.2]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	0.978	1.660	14 [0.58-6]	0.028	0.007	1 [0.05]	0.028	0.006	1 [0.05]	1.036	1.669	14 [0.64-6.1]
Tromsø harbour area (st. 43B2)	15 (0-1)	1.600	1.019	15 [0.36-3.9]	0.030	0.009	0 [n.a.]	0.029	0.001	0 [n.a.]	1.670	1.020	15 [0.42-3.9]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	0.315	0.420	15 [0.2-1.86]	0.030	0.001	0 [n.a.]	0.030	0.001	0 [n.a.]	0.375	0.420	15 [0.25-1.92]
Eider, blood													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.030	0.000	0 [n.a.]	0.031	0.000	0 [n.a.]	0.023	0.000	0 [n.a.]	0.084	0.000	0 [n.a.]
Eider, egg													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	0.057	0.119	15 [0.03-0.5]	0.031	0.000	15 [0.03-0.03]	0.023	0.008	15 [0.02-0.05]	0.111	0.120	15 [0.08-0.56]

Analysis of cod liver showed that α–HBCD was about 100 times higher than in blue mussel on a wet weight basis (compare ***Figure 61*** and ***Figure 62***). 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 all stations except for Trondheim harbour (st. 80B) (Tukey-Kramer HSD test, see also ***Figure 61***).

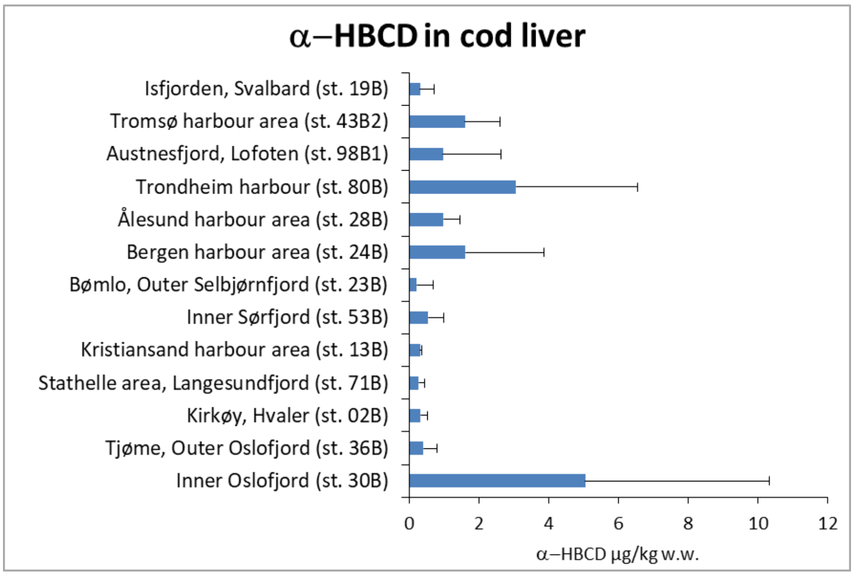


Figure 61*. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2020. The error bar indicates one standard deviation above the mean.*

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 62***).

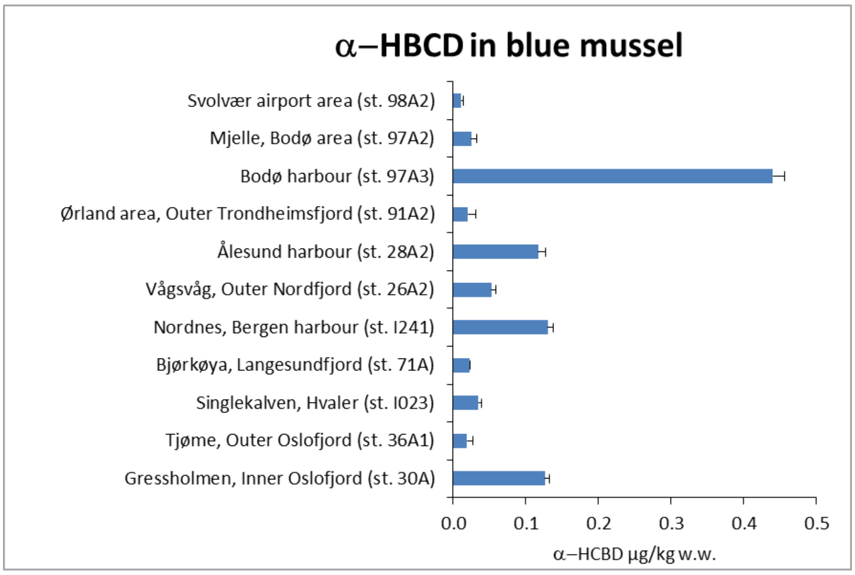


Figure 62*. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2020. The error bar indicates one standard deviation above the mean.*

General, large scale trends

The discharges of HBCD to water from land-based industries showed a decrease from 2004 (12.90 kg HBCD/year) to 2005 (1.50 kg HBCD/year) (***Figure 63***). In 2006, the discharge to water was 0.51 kg and during the following years the discharges have gradually decreased to 0 kg[1] in 2016. The emissions to air have been reported as zero since 2016. Data for discharges of HBCD to water have not been reported for the years 2017 to 2020. HBCDs in air have been measured at Birkenes in Southern Norway and at Zeppelin at Svalbard. The measurements taken in 2020 showed very low concentrations at Birkenes (only α-HBCD was detected). In contrast, at Zeppelin at Svalbard all HBCD diastereomers were detected in >50 % of the samples in 2020 (Nizzetto 2021).

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).

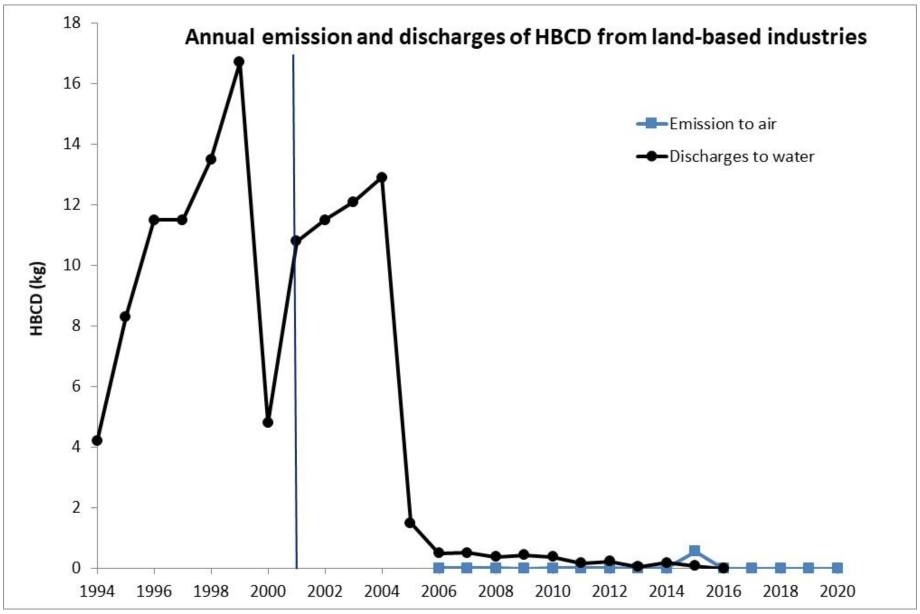


Figure 63*. Annual emissions of HBCD* to air and discharges to water from land-based industries in the period 1994-2020 (data from *www.norskeutslipp.no*, 05.07.2021). HBCD has been monitored in this project since 2001 (indicated with a vertical line). No data for emissions to air are reported for 2002-2005. Discharges to water in 2017-2019 is not reported. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.

Comparison with other studies

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

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

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

3.2.26 Chlorinated paraffins (SCCP and MCCP)

Chlorinated paraffins are complex mixtures of polychlorinated organic compounds. They are mainly used in metal working fluids, sealants, as flame-retardants in rubbers and textiles, in leather processing and in paints and coatings. Their persistence, bioaccumulation, potential for long-ranged environmental transport and toxicity imply that they may have harmful environmental effects at a global level. A global regulation of SCCP has been in place since the end of 2019 through the Stockholm Convention. In 2020, a proposal was made by the UK to list MCCP as a persistent organic pollutant in Annex A, B or C to 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 1***).

Chlorinated paraffins are subdivided according to their carbon chain length into short chain chlorinated paraffins (SCCPs, C_{10-13}) and medium chain chlorinated paraffins (MCCPs, C_{14-17}). The EQS for SCCP and MCCP in biota are 6000 and 170 µg/kg w.w., respectively (Norwegian_Environment_Agency 2016). SCCPs and MCCPs are persistent in the environment and has a high potential for bioaccumulation and they are toxic to aquatic organisms (Tomy et al. 1998), they also undergo long-range environmental transport (Nizzetto 2021). 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 8***). Cod from Svalbard (st. 19B) had the highest concentration of SCCP, with a median concentration of 59 µg/kg w.w., and high individual variation. The highest concentration of SCCP in blue mussels were found in Bodø harbour, with a median concentration of 23 µg/kg w.w.

Environmental Quality Standards (EQS) for river basin specific pollutants

When applying the EQS for MCCP (170 µg/kg w.w.) in biota, all median concentrations of MCCP in cod liver were below the EQS. Cod from the Inner Oslofjord (st. 30B) had the highest concentration of MCCPs with a median concentration of 155 µg/kg w.w. High individual variation was observed (***Figure 68***, ***Table 15***). There were lower concentrations of MCCP in cod liver in 2020 than in 2019. No median concentrations of MCCPs in blue mussel or eider were above the EQS.

Levels exceeding PROREF

No median concentrations of SCCPs and MCCPs in cod liver and eider exceeded the PROREF. The median concentration of SCCPs and MCCPs in blue mussel from Bodø harbour (st. 97A3) exceeded PROREF by a factor up to two. The median concentration of SCCPs in blue mussel from this station increased from 12 µg/kg w.w. in 2019 to 23 µg/kg w.w. in 2020, and for MCCPs there was an increase from 62 µg/kg w.w. in 2019 to 95 µg/kg w.w. in 2020.

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

Upward trends
There were significant short- and long-term upward trends for SCCP in blue mussel from Singlekalven, Hvaler (st. I023) (***Figure 64***). However, the concentrations of SCCPs on this station were low.

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

Downward trends
There was a significant long-term downward trend for SCCPs in blue mussel from Færder, Outer Oslofjord (st. 36A[1]). There were significant short- and long-term downward trends for SCCPs in liver of cod from Bergen harbour area (st. 24B) (***Figure 65 A***), and there was a significant long-term downward trend for SCCPs in liver of cod from the Inner Sørfjord (st. 53B) (***Figure 65 B***).

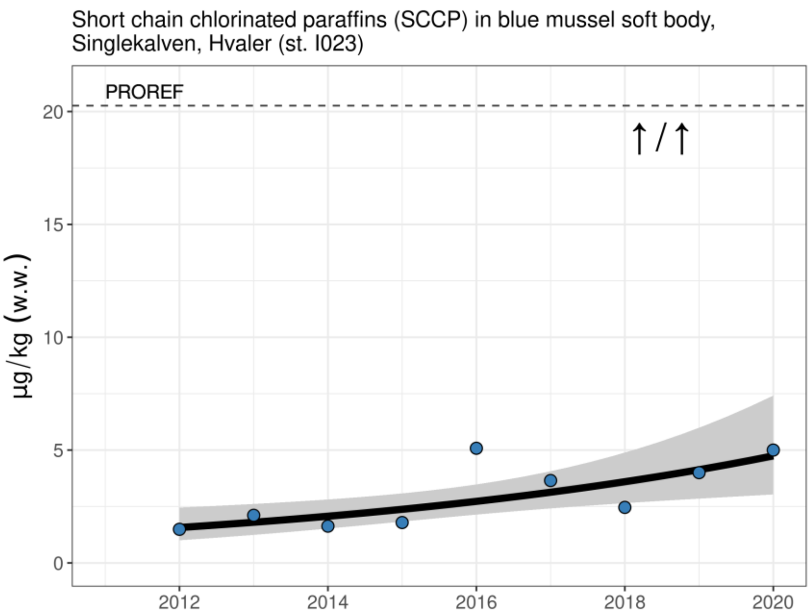
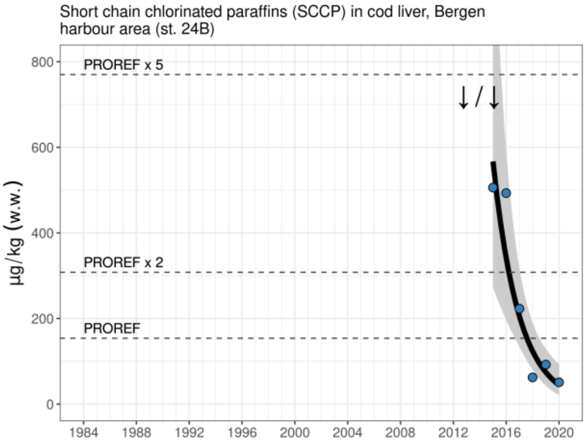


Figure 64. *Median concentrations (μg/kg w.w.) of SCCP in blue mussel from Singlekalven, Hvaler (st. I023) (see* ***Figure 6*** *and* ***Appendix C****.)*

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

A



B

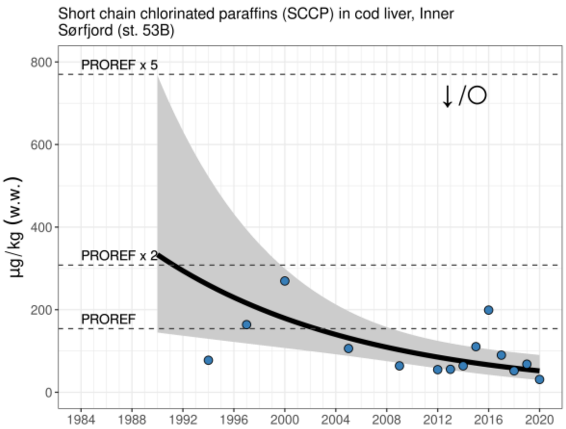


Figure 65*. Median concentration of SCCPs in cod liver from Bergen harbour area (st. 24B) (A) and the Inner Sørfjord (st. 53B) (****B****)* (see ***Figure 6*** *and* ***Appendix C****.)*

Levels in eider

Median concentration of SCCP was 13.0 µg/kg w.w. in eider blood, and 26.0 µg/kg w.w. in eider egg from Kongsfjord, Svalbard (st. 19N). Median concentration of MCCP was 22.0 µg/kg w.w. in eider blood and 35.0 µg/kg w.w. in eider egg from the same station. For both SCCPs and MCCPS there were higher concentrations in eider eggs compared to 2019.

General, large scale trends

Cod from Svalbard (st. 19B) had the highest concentration of SCCPs, with a median concentration of 59 µg/kg w.w., and high individual variation (***Figure 66***). However, MCCPs and SCCPs have been quantified in air at Zeppelin at Svalbard. In 2020 annual mean concentration of SCCPs at Zeppelin was 510 pg/m^3, and for MCCPs 750 pg/m^3. These concentrations are one to three orders of magnitude higher than the concentrations of most of the other POPs (Nizzetto 2021). Cod from Bergen harbour had also high median concentration of SCCPs (51.0 µg/kg w.w.). The median concentration of SCCP in blue mussel ranged from 4.0 to 23.0 µg/kg w.w. in the present study and the highest concentration was found in the samples from Bodø harbour (st. 97A3) (***Figure 67***).

Cod from the Inner Oslofjord (st. 30B) had highest concentrations of MCCPs, with median concentration of 155 µg/kg w.w., and cod from Austnesfjord, Lofoten (st. 98B1) had median concentration of 140 µg/kg w.w. (***Figure 68***). The concentrations of MCCPs in blue mussel were lower than in cod, and ranged from 15.0 to 95.0 µg/kg w.w. Blue mussel from Bodø harbour (st. 97A3) had the highest concentrations of MCCPs (***Figure 69***).

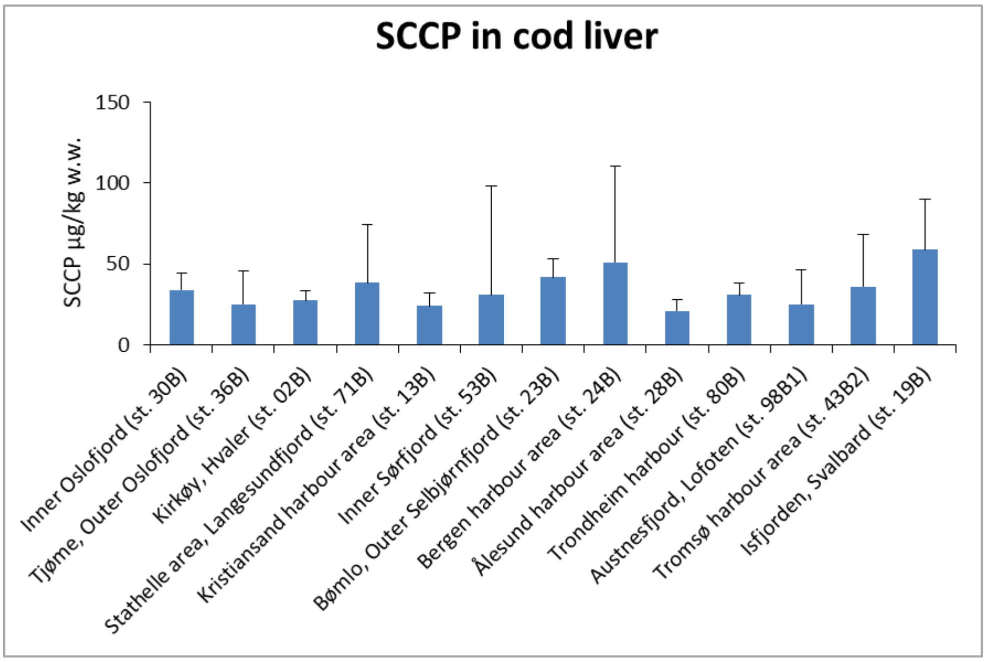


Figure 66. *Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in cod liver in 2020. The error bar indicates one standard deviation above the median.*

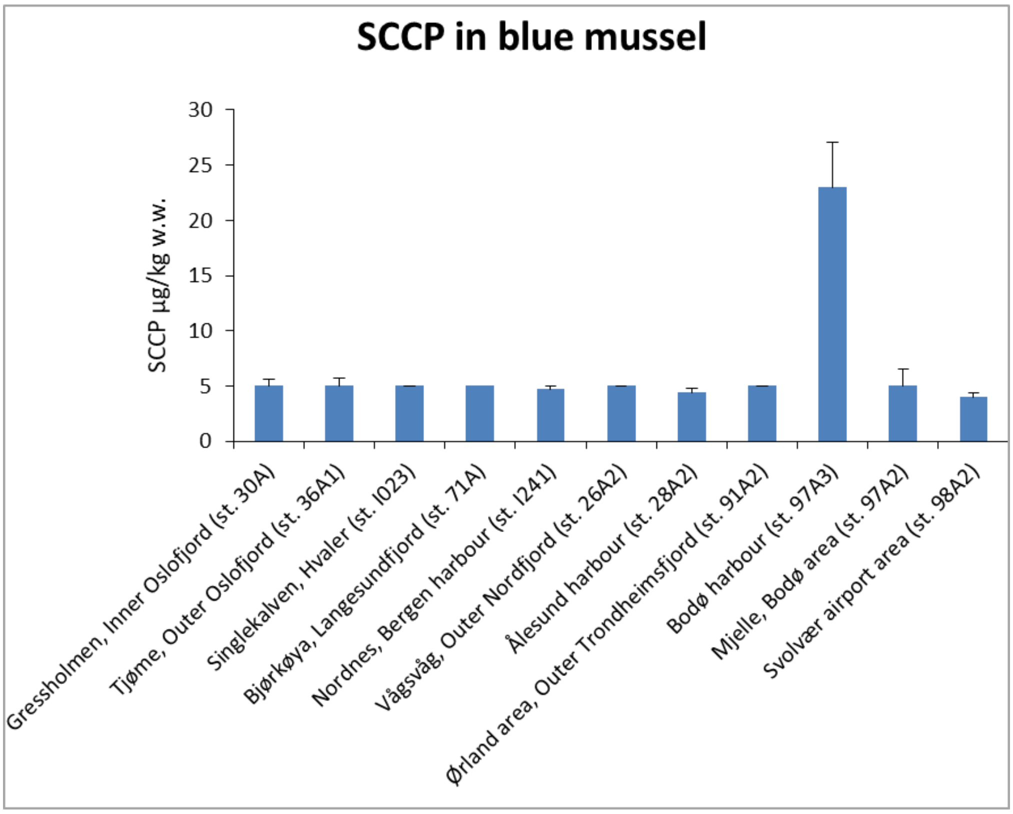


Figure 67. *Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in blue mussel in 2020. The error bar indicates one standard deviation above the median.*

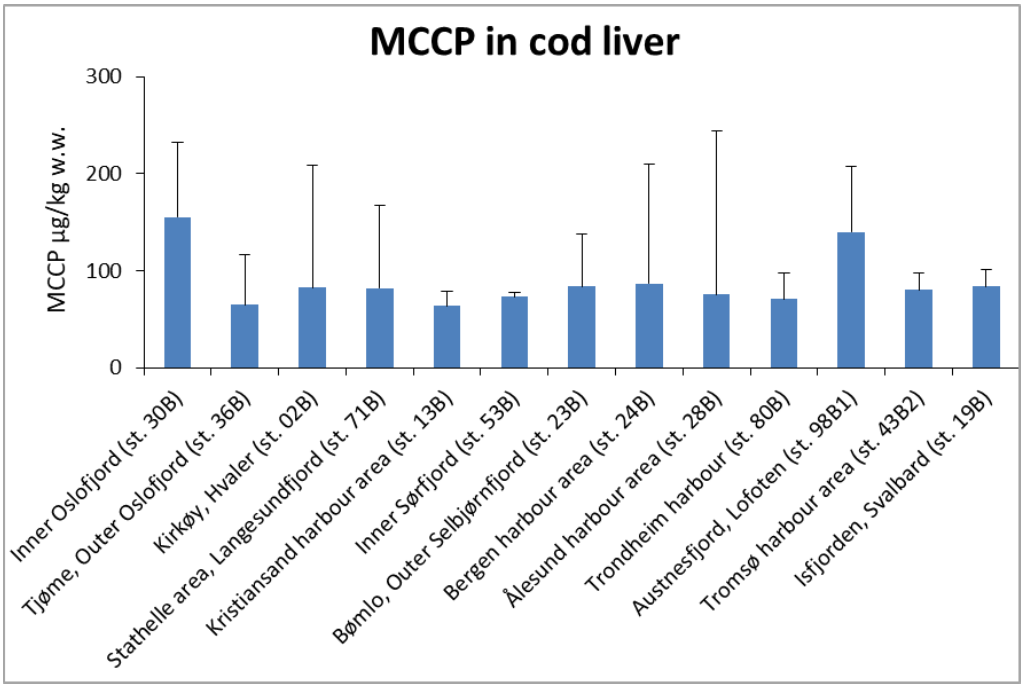


__Figure 68__. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in cod liver in 2020. The error bar indicates one standard deviation above the median.

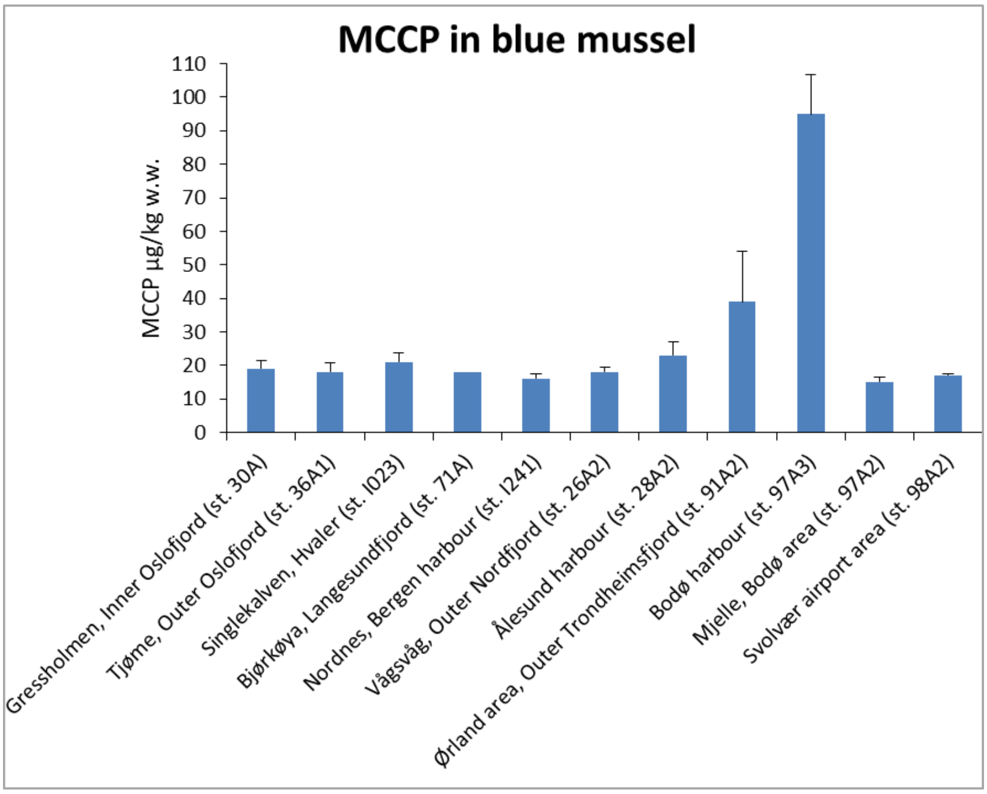


__Figure 69__. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in blue mussel in 2020. The error bar indicates one standard deviation above the median.

Comparison with other studies

Cod from the Inner Oslofjord had median concentration of SCCP in liver of 34.0 µg/kg w.w. and ranging between 28 to 63 µg/kg w.w. Median concentration of MCCP in cod liver from the Inner Oslofjord was 135 µg/kg w.w. , and ranged between 40 to 310 µg/kg w.w. Ruus et al. (2020a) found higher levels of SCCP in cod from the Inner Oslofjord (268.7 to 1100.4 µg/kg w.w.).

***Table 15**. 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 2020. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. The standard deviation (S.d.) is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter** 2.10 for more details*).

Component	Count	SCCP			MCCP		
Species and sampling locality	2020	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel							
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	5.00	0.64	3 [4-5.2]	19.00	2.31	3 [15-19]
Tjøme, Outer Oslofjord (st. 36A1)	3 (3-50)	5.00	0.70	3 [4.8-6.1]	18.00	2.89	3 [18-23]
Singlekalven, Hvaler (st. I023)	3 (3-50)	5.00	0.00	3 [5-5]	21.00	2.89	3 [16-21]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	5.00		1 [5]	18.00		1 [18]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	4.70	0.26	3 [4.3-4.8]	16.00	1.53	3 [15-18]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	5.00	0.00	3 [5-5]	18.00	1.53	3 [16-19]
Ålesund harbour (st. 28A2)	3 (3-50)	4.40	0.40	3 [4-4.8]	23.00	4.16	3 [17-25]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	5.00	0.00	3 [5-5]	39.00	15.00	3 [24-54]
Bodø harbour (st. 97A3)	3 (3-50)	23.00	4.04	3 [23-30]	95.00	11.68	3 [87-110]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	5.00	1.53	3 [4-7]	15.00	1.53	3 [14-17]
Svolvær airport area (st. 98A2)	3 (3-50)	4.00	0.40	3 [4-4.7]	17.00	0.58	3 [16-17]
Cod, liver							
Inner Oslofjord (st. 30B)	12 (7-6)	34.00	10.49	12 [28-63]	155.00	77.58	12 [40-310]
Tjøme, Outer Oslofjord (st. 36B)	15 (4-2)	25.00	20.76	15 [16-95]	65.00	52.02	15 [44-250]
Kirkøy, Hvaler (st. 02B)	8 (6-2)	27.50	5.90	8 [25-39]	82.50	126.07	8 [80-440]
Stathelle area, Langesundfjord (st. 71B)	10 (5-5)	38.50	36.17	10 [25-130]	82.00	85.60	10 [67-270]
Kristiansand harbour area (st. 13B)	7 (5-2)	24.00	8.12	7 [19-44]	64.00	14.42	7 [57-100]
Inner Sørfjord (st. 53B)	15 (4-3)	31.00	66.87	15 [24-290]	73.00	4.44	15 [66-83]
Bømlo, Outer Selbjørnfjord (st. 23B)	15 (6-2)	42.00	10.95	15 [35-82]	84.00	54.09	15 [70-290]
Bergen harbour area (st. 24B)	13 (5-2)	51.00	59.44	13 [31-210]	87.00	123.15	13 [55-400]
Ålesund harbour area (st. 28B)	14 (2-2)	21.00	7.20	14 [16-44]	75.50	168.02	14 [50-700]
Trondheim harbour (st. 80B)	15 (0-1)	31.00	7.34	15 [21-54]	71.00	27.04	15 [48-150]
Austnesfjord, Lofoten (st. 98B1)	15 (0-1)	25.00	21.45	15 [20-100]	140.00	67.76	15 [41-270]
Tromsø harbour area (st. 43B2)	15 (0-1)	36.00	32.47	15 [26-160]	80.00	17.07	15 [70-140]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	59.00	31.24	15 [27-140]	84.00	16.65	15 [54-100]
Eider, blood							
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	13.00	13.23	9 [12-50]	22.00	1024.37	13 [11-4004]
Eider, egg							
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	26.00	9.06	15 [11-49]	35.00	23	12 [10-97]

Comments about the results for MCCPs and SCCPs in cod liver in 2020

Most of the concentrations of MCCPS and SCCPs in cod liver were much lower in 2020 than in 2019. Cod liver is a difficult matrix for analysis of SCCPs and MCCPS, and SCCP and MCCP are also challenging groups to analyse since they are sums of almost 8000 theoretical congeners (SCCP) and almost 124 000 theoretical congeners (MCCP). Therefore, they are analysed with a few numbers of standards and different labs can have different cut-offs for which retention times to include. Another problem is that in the mass spectrometer, high concentrations of PCBs in cod liver cause interferences with signals from SCCPs and MCCPs. For these analyses it can be difficult to tell if the observed signals are caused by high levels of PCBs or from the chlorinated paraffines. Chlorinated paraffines are also present in many substances in the surroundings, and this can also affect the analyses. In sum, there are some challenges concerning the analysis of SCCPs and MCCPs, and therefore quite high uncertainty with regard to the levels of quantification (LOQ).

3.2.27 Siloxanes (D4, D5 and D6)

Siloxanes are chemical compounds consisting of silicon and oxygen substituted with various organic side chains, and they exist both as linear and cyclic substances. Siloxanes are chemicals used as synthetic intermediates in silicone polymer productions and can be ingredients in cosmetic and personal care products. Siloxanes have properties that affect the consistency of personal care products such as deodorants, skin and hair products to facilitate their use. The chemicals are also used in mechanical fluids and lubricants, biomedical products, cleaning and surface treatment agents, paint, insulation materials and cement. Since 1. February 2020, there are restrictions for D4 and D5 for wash-off cosmetic products in concentrations above 0.1 %[1] in the EU/EEA.

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 1***); in the Inner Oslofjord (st. 30B), Bergen harbour (st. 24B), Tromsø harbour (st. 43B2), Kjøfjord (st. 10B) in the Outer Varangerfjord and in the Isfjord (st. 19B) at Svalbard (***Table 16***, ***Figure 70***). 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 8***). The EQS for D5 in biota is provided for fish and are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in the present study only measured 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 2020-samples (***Table 8***). No individual D5-concentration exceeded EQS (***Table 16***).

Levels in cod liver

Data for D4, D5 or D6 in cod liver are not sufficient to analyse trends or PROREF. D5 was the most dominant cVMS in the Inner Oslofjord (st. 30B) (968.1 µg/kg w.w.). Median D5-concentrations in cod liver were lowest at Svalbard (6.5 µg/kg w.w.). The same pattern was found for D6 in the Inner Oslofjord (92.4 µg/kg w.w.) and at Svalbard (3.1 µg/kg w.w.). For D4, the highest concentrations were also found in the Inner Oslofjord (63.8 µg/kg w.w.) while the lowest concentrations were found in Kjøfjord (st. 10B) in the Outer Varangerfjord (2.9 µg/kg w.w.)

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of D4, D5 and D6 in blood were 0.8, 0.7 and <1.7 µg/kg w.w., respectively. The concentrations of D4, D5 and D6 in eggs were 1.9, 3.0 and 1.9 µg/kg w.w., respectively.

Comparison with other studies

The Inner Oslofjord

D5 was the dominating compound in all studies of cod from the Inner Oslofjord including this study and the publications of Powell (2009), Powell et al. (2010; 2018), Ruus et al. (2016b; 2017; 2018, 2019), Schlabach et al. (2008) and Schøyen et al. (2016).

In 2020, median D5 concentration in cod liver from the Inner Oslofjord was 968.1 µg/kg w.w., while the mean D5 concentration was 1012 µg/kg w.w. in a comparable study (Grung et al. 2021). In the current study, median concentrations of D4 and D6 in cod liver from the Inner Oslofjord

[1] https://www.miljodirektoratet.no/aktuelt/nyheter/2020/februar-2020/nytt-forbud-mot-bruk-av-miljogifter/

were 63.7 and 92.4 µg/kg w.w., respectively, while the mean concentrations were 45.8 and 87.2 µg/kg w.w., respectively, in the comparable study. The collection of cod in both studies took place during the autumn, in August for the Urban fjord programme and in November for this MILKYS programme. 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 2016b).

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. 30) (Schøyen 2016). There was a positive correlation between lipid content and lipid-normalized concentrations of D4, D5 and D6 in cod, but a negative correlation in herring. Lipid-normalized concentrations of D4, D5 and D6 in cod, herring and shrimp were lowest in 2014 compared to the period 2011 to 2013.

In 2008, the mean concentrations of D4, D5 and D6 in cod (whole fish) from the Inner Oslofjord (st. 30B) were 2.6, 61.7 and 4.2 µg/kg w.w., respectively (Powell 2010). In 2006, the concentration ranges of D4, D5 and D6 in cod liver from the Inner Oslofjord (st. 30B) were 81.2-134.4, 1490.8-1978.5 and 109.1-151.5 µg/kg w.w., respectively (Schlabach 2008). In 2005, the concentrations of D4, D5 and D6 in cod liver from the Inner Oslofjord (st. 30B) were 70, 2200 and 74 µg/kg w.w., respectively (Kaj 2005).

A literature overview and possible EQS derivation for D5 in biota (fish) is estimated to 833 µg/kg w.w. to protect the environment from secondary poisoning via the food chain (Sahlin 2018).

Siloxanes have been included in the environmental monitoring in Mjøsa since 2010 (Borgå 2012). D5 was detected in highest concentrations in 2020 (Jartun 2021). The mean concentrations were highest in brown trout (*Salmo trutta*) (39 µg/kg w.w.), vendace (*Coregonus albula*) (23 µg/kg w.w.), European smelt (*Osmerus eperlanus*) (17 µg/kg w.w.), Mysis (*Mysis relicta*) (7.5 µg/kg w.w.) and zooplankton (0.30 µg/kg w.w.) (Jartun 2021). There was a slight decline in D5 concentration in brown trout from 2010 to 2020, and the concentrations have stabilized between 2017 and 2020 (Jartun 2021).

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 (968.1 µg/kg w.w.) from the Inner Oslofjord was higher than the mean concentration in trout liver from Lake Mjøsa in 2020 (39 µg/kg w.w.) (Jartun 2021).

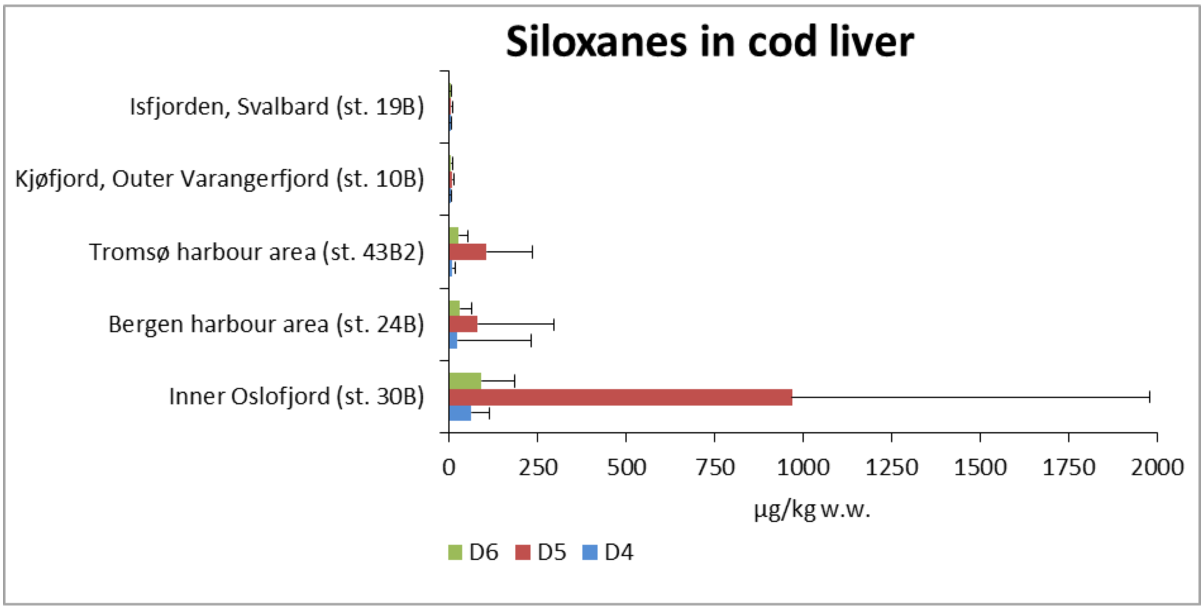


***Figure 70**. Median concentration (µg/kg w.w.) of siloxanes D4, D5 and D6 in cod liver in 2020. The error bar indicates one standard deviation above the median.*

***Table 16**. Median concentrations (µg/kg w.w.) with standard deviation of siloxanes (D4, D5 and D6) in cod liver and eider blood and eggs in 2020. Count indicates number of samples (replicates) analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See **Chapter** 2.10 for more details*).

Component	Count	D4			D5			D6		
Species and sampling locality	2020	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Cod, liver										
Inner Oslofjord (st. 30B)	14 (0-1)	63.76	50.67	14 [20-216]	968.14	1008.92	14 [162-3963]	92.44	92.44	14 [32-239]
Bergen harbour area (st. 24B)	15 (0-1)	24.53	206.79	15 [3.3-722]	81.54	215.96	15 [5.6-775]	31.42	31.42	15 [2.1-224]
Tromsø harbour area (st. 43B2)	15 (0-1)	9.35	7.46	15 [4.3-34]	105.85	129.58	15 [24-508]	27.06	27.06	15 [7.1-114]
Kjøfjord, Outer Varangerfjord (st. 10B)	15 (0-1)	2.89	1.01	15 [1.66-5.2]	9.02	6.33	15 [2.3-25]	5.70	5.70	15 [3.5-11.9]
Isfjorden, Svalbard (st. 19B)	15 (0-1)	3.16	1.14	15 [1.91-6.9]	6.51	2.08	15 [2.7-10.7]	3.11	3.11	13 [2.4-8.5]
Eider, blood										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	17 (0-1)	0.82	0.26	17 [0.61-1.47]	0.75	0.44	17 [0.37-2.3]	1.68	0.13	6 [1.7-2.1]
Eider, egg										
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15 (0-1)	1.92	0.48	15 [1.42-3.4]	3.01	0.80	15 [2.2-4.8]	1.89	0.59	15 [1.59-3.1]

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 (https://miljostatus.miljodirektoratet.no/siloksaner). Estimated discharges of siloxanes (D4 and D5) have increased gradually from 200 tons in 2000, to 387 tons in 2015 and 365 tonnes in 2019 (**Figure 71**). In 2017, the discharges were 6.25 tonnes.

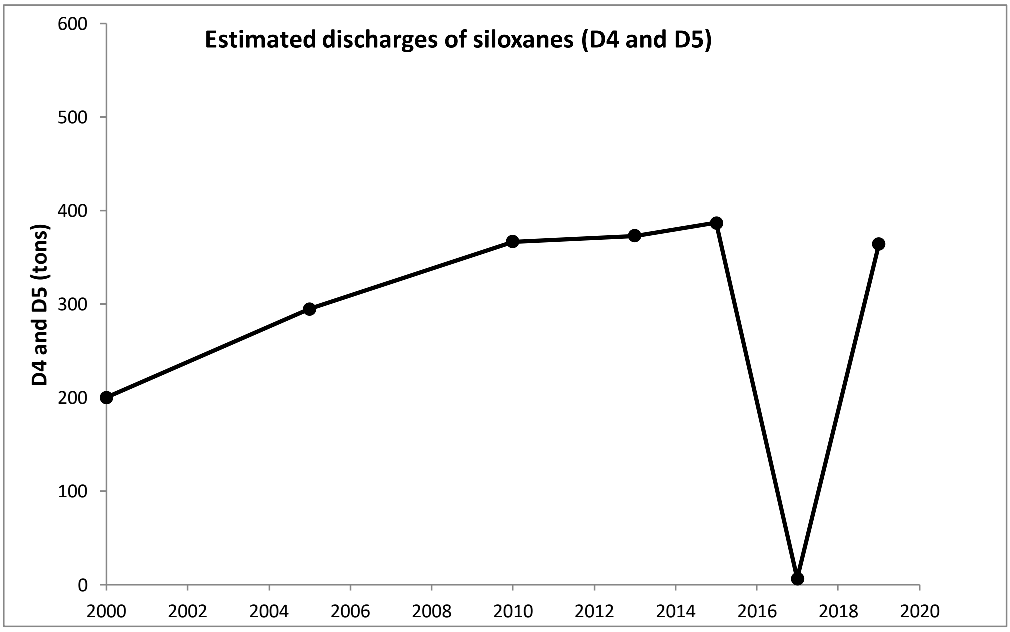


Figure 71. Estimated discharges of D4 and D5 from 2000 to 2019 (*data from* https://miljostatus.miljodirektoratet.no/tema/miljogifter/prioriterte-miljogifter/siloksaner/*)*.

3.3 Biological effects methods for cod

Biological effect methods (BEM) are included in the monitoring programme to assess the potential pollution effects on organisms. This can hardly be done solely on the basis of tissue concentrations of chemicals. There are three BEM methods used on cod liver samples (including analyses of degradation products of PAH in bile). Each method is in theory specific for individual or groups of chemicals. One of the advantages of these methods used at the individual level is the ability to integrate biological and chemical endpoints, since both approaches are performed on the same individuals. The results can be seen in relation to established reference values (OSPAR 2013).

3.3.1 OH-pyrene metabolites in bile

Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs and is thus a marker of exposure. Quantification methods for OH-pyrene have been improved two times since the initiation of these analyses in the CEMP/MILKYS programme. In 1998, the support/normalisation parameter was changed from biliverdin 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 2020 the median (non-normalized) concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) was similar to those in 2019 and resembled the concentrations most recent years. The absorbance at 380 nm, however, was generally higher in bile from 2020, for unknown reasons, probably associated with methodological issues (higher dilution). Thus, all normalized OH-pyrene concentrations are reduced. Median OH-pyrene bile concentration in 2020 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 at Farsund (st. 15B). At Bømlo (st. 23B, reference station), median OH-pyrene bile concentrations did not exceed the ICES/OSPAR assessment criterion in 2020. Note that the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380 nm. In the Inner Sørfjord (st. 53B), the median concentration of OH-pyrene metabolites in bile from cod appeared substantially lower (a factor of >10 on a non-normalized basis) than in 2019. Among the four stations, OH-pyrene concentrations were highest in the Inner Oslofjord (st. 30B) and lowest in the Bømlo area (st. 23B) (Tukey-Kramer HSD) (***Appendix F***). Pyrene-concentrations in blue mussels were highest in the Oslofjord (Akershuskaia), compared to all stations where PAHs were analysed.

3.3.2 ALA-D in blood cells

Inhibited activity of ALA-D indicates exposure to lead. Although ALA-D inhibition is lead-specific, it is not possible to rule out interference by other metals or organic contaminants. Note that the protocol for ALA-D analysis was slightly altered (to avoid Hg-containing reagents) in 2017.

The median ALA-D activity at the reference station (Bømlo area; 23B) appeared similar as, or even slightly higher as, most previous years (since 2013).

As previously noted, most years up to 2011 the activity of ALA-D in cod was somewhat inhibited in the Inner Oslofjord (st. 30B), compared to reference stations, i.e. Outer Oslofjord (st. 36B; only data to 2001), Bømlo (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Green et al. 2016). The median ALA-D activity in the Inner Oslofjord (st. 30B) in 2020 was lower (Tukey-Kramer HSD) than in Bømlo (st. 23B, reference station, ***Appendix F***). Also, in the Inner Sørfjord (st. 53B), the median activity of ALA-D appeared slightly lower than at the reference station (st. 23B) (however not significantly different from neither st. 30B, nor st. 23B; Tukey-Kramer HSD). The frequent lower activities of ALA-D in cod from the Inner Oslofjord and Inner Sørfjord compared to the reference station (basis for comparison prior to 2007, 2009-2011 and 2013-2019) indicate the contamination of lead. Higher concentrations of lead in cod liver have generally been observed in the Inner Oslofjord and Inner Sørfjord compared to Bømlo, though with a relatively large individual variation, as was also the case in 2020. Median concentrations of lead in cod liver from the Inner Oslofjord (st. 30B) and the Sørfjord (st. 53B) were 0.095 mg/kg and 0.014 mg/kg, respectively, in 2020. In the Bømlo area (st. 23B) the median concentration was 0.006 mg/kg. In cod liver, significant downward long-term trends were found for Pb in cod liver at st. 23B and st. 53B. A significant downward short-term trend was also observed at st. 23B (***Table 9***).

3.3.3 EROD-activity

High activity of hepatic cytochrome P450 1A-activity (EROD-activity) normally occurs as a response to the contaminants indicated in ***Table 3***. It was expected that higher activity would be found at the stations that were presumed to be most impacted by planar PCBs, PCNs, PAHs or dioxins such as the Inner Oslofjord (st. 30B). Since 2000, the median EROD-activity has generally been higher in the Inner Oslofjord compared to the reference station on the west coast (Bømlo, st. 23B). In 2018, EROD activities in neither the Inner Oslofjord (st. 30B), nor the Inner Sørfjord (st. 53B) were higher than at the reference station (st. 23B). In 2019, the median EROD activity appeared slightly higher in the Inner Oslofjord (st. 30B) and slightly lower in the Inner Sørfjord (st. 53B), compared to Bømlo (st. 23B), but these differences were not statistically different. In 2020, the median EROD activity was lower in the Inner Sørfjord (st. 53B) than in the Inner Oslofjord (st. 30B) and the Bømlo area (st. 23B; Tukey-Kramer HSD), while st. 23B and st. 30B were not significantly different. Statistically significant downward trends in EROD activity were observed on both a long-term basis (whole data series) and a short-term basis (last 10 years) at Bømlo (st. 23B), on a long-term basis in the Inner Oslofjord (st. 30B), and on a short-term basis in the Inner Sørfjord (st. 53B) (***Figure 72***). Median EROD-activities were below the ICES/OSPAR assessment criterion (background assessment criteria, BAC). Concentrations over BAC would indicate possible impact by planar PCBs, PCNs, PAHs or dioxins. No concentrations of PAHs in blue mussel exceeded the EQS.

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

B

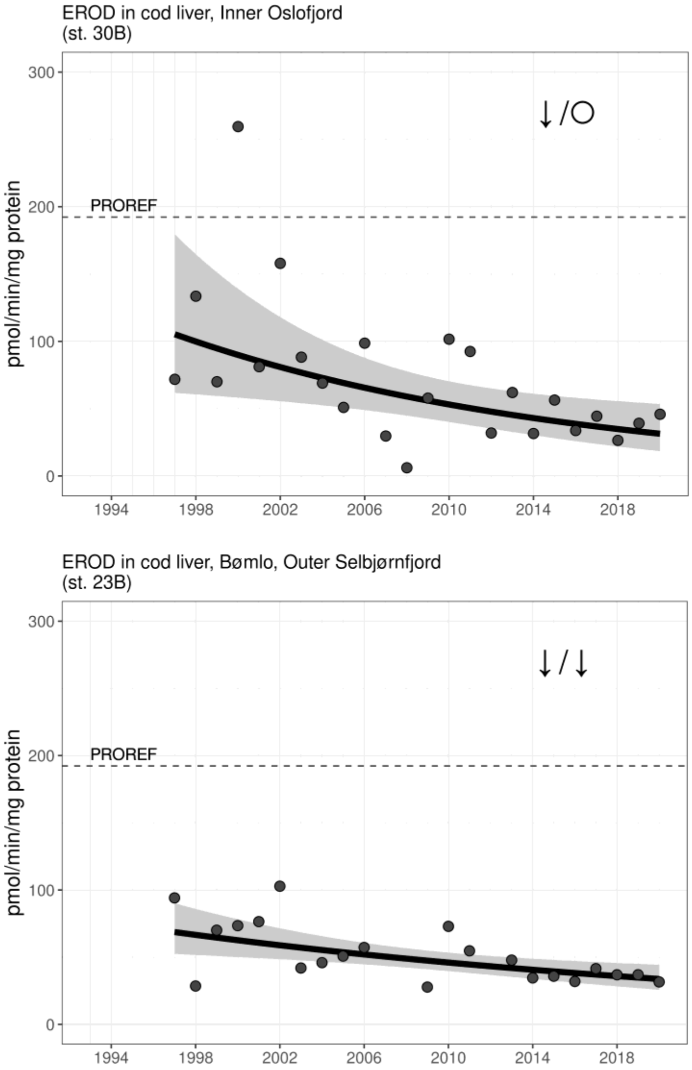


Figure 72. *Median activity (pmol/min/mg-protein) of EROD in cod liver from 1990 to 2020 in the Inner Oslofjord (st. 30B) (***A***) and from 1997 to 2020 in Bømlo (st. 23B) (***B***). The Norwegian provisional high reference contaminant concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* ***Figure 6*** *and* ***Appendix C****.)*

3.4 Analysis of stable isotopes

3.4.1 General description of method

Stable isotopes of carbon and nitrogen are useful indicators of food origin and trophic levels. $\delta^{13}C$ gives an indication of carbon source in the diet of a food web. For instance, it is in principle possible to detect differences in the importance of autochthonous (native marine) and allochthonous (watershed/origin on land) carbon sources in the food web, since the $\delta^{13}C$ signature of the land-based energy sources is lower (greater negative number) than the autochthonous. Also $\delta^{15}N$ (although to a lesser extent than $\delta^{13}C$) may be lower in allochthonous as compared to autochthonous organic matter (Helland, Åberg, and Skei 2002), but more important, it increases in organisms with higher trophic level because of a greater retention of the heavier isotope (^{15}N). The relative increase of ^{15}N over ^{14}N ($\delta^{15}N$) is 3-5 ‰ per trophic level (Layman et al. 2012; Post 2002). It thus offers a continuous descriptor of trophic position. As such, it is also the basis for Trophic Magnification Factors (TMFs). TMFs give the factor of increase in concentrations of contaminants per trophic level. If the concentration increase per trophic level can be expressed as:

Log Concentration = *a* + *b* * (Trophic Level)

Then:

TMF = 10^b

TMFs has recently been amended to Annex XIII of the European Community Regulation on chemicals and their safe use (REACH) for possible use in weight of evidence assessments of the bioaccumulative potential of chemicals as contaminants of concern.

In the present report, the stable isotope data have been applied to elucidate if spatial differences in contaminant concentrations may partially be attributed to different energy sources between stations, or that the same species (cod) may inhabit different trophic levels on different stations (***Table 17***). Analysis of stable isotopes was included in the programme in 2012, thus the database now includes nine years. So far for the period 2012-2019 (Green et al. 2020) the results of the stable isotope analysis (of both blue mussel and cod) have shown a continual geographical pattern, suggesting a spatial trend persistent in time, and the isotopic signatures in mussels thus provide valuable information about the isotopic baselines along the Norwegian coast. This information has e.g. earlier been used to normalize trophic positions of herring gulls, when geographic comparisons have been made (Keilen 2017). Last year, The $\delta^{15}N$ data were scrutinized further by deducing the trophic position of the cod, based on a known baseline in the area, given by the isotopic profile of blue mussel, inhabiting trophic position 2 (primary consumer, feeding on particulate matter; see (Green et al. 2020)). This study showed that baseline adjusted trophic position of cod differed between stations along the Norwegian coast, suggesting that parts of the spatial differences in contaminant concentrations may be attributed to different trophic positions of the cod at the different stations, and not merely differences in environmental concentrations between stations.

3.4.2 Results and discussion

The results of the stable isotope analysis in 2020 generally show the same pattern as observed in 2012-2019 (Green et al. 2020) i.e. a continual geographical pattern, suggesting a spatial trend persistent in time (***Figure 73***).

As previously, it can be noted that individual cod from the Sørfjord (st. 53B) and Bergen harbour (station 24B; both in former Hordaland County, now Vestland) stand out with particularly low $\delta^{15}N$ signature (**Figure 73**); Bergen harbour, station 24B, was introduced in 2015. The same is shown for mussels from the Sørfjord (stations 56A and 57A), indicating that the $\delta^{15}N$ -baseline of the food web in the Sørfjord is lower. The reason for this is unknown, but a higher influence of allochthonous nitrogen is possible. Likewise, isotope signatures of both fish (30B) and mussels (30A and I304) from the Oslofjord are among the highest observed (**Figure 73**) indicating a high baseline. These geographic differences were also observed 2012-2019 (Green et al. 2020). Interestingly, cod from stations from the North of Norway (Lofoten, 98B1) and Svalbard (19B) show intermediate $\delta^{15}N$ values and low $\delta^{13}C$ values (***Figure 73***). The same can be observed in mussels from Northern Norway (98A2). As previously pointed out, the stations generally show very similar patterns from year to year in terms of isotopic signatures, indicating a geographical trend, persistent in time.

Table 17. Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ in blue mussel, cod and eider in 2020. Statistics shown are count (n), mean and standard deviation. Vienna Pee Dee Belemnite (VPDB) and atmospheric air (AIR) are standards.

Station ID		$\delta^{13}C_{VPDB}$ n	$\delta^{13}C_{VPDB}$ mean	$\delta^{13}C_{VPDB}$ s.d.	$\delta^{15}N_{AIR}$ n	$\delta^{15}N_{AIR}$ mean	$\delta^{15}N_{AIR}$ s.d.
Presumed less impacted:							
Blue mussel (Mytilus edulis)	**statistics >>**	**3**	**-21.12**	**0.14**	**3**	**5.75**	**0.18**
Tjøme, Outer Oslofjord (st. 36A1)		3	-20.12	0.06	3	7.41	0.18
Singlekalven, Hvaler (st. I023)		3	-20.52	0.25	3	7.24	0.37
Bjørkøya, Langesundfjord (st. 71A)		1	-20.15		1	5.04	
Gåsøya-Ullerøya, Farsund (st. 15A)		3	-21.31	0.07	3	7.15	0.24
Krossanes, Outer Sørfjord (st. 57A)		3	-20.04	0.27	3	2.50	0.14
Espevær, Outer Bømlafjord (st. 22A)		3	-21.44	0.02	3	5.66	0.14
Vågsvåg, Outer Nordfjord (st. 26A2)		3	-20.66	0.02	3	4.85	0.15
Ørland area, Outer Trondheimsfjord (st. 91A2)		3	-21.11	0.28	3	5.54	0.16
Mjelle, Bodø area (st. 97A2)		3	-21.77	0.17	3	6.37	0.22
Svolvær airport area (st. 98A2)		3	-22.53	0.09	3	5.55	0.12
Brashavn, Outer Varangerfjord (st. 11X)		3	-22.64	0.13	3	5.94	0.12
Atlantic cod (*Gadus morhua*)	**statistics >>**	**15**	**-19.67**	**0.67**	**15**	**14.25**	**0.61**
Tjøme, Outer Oslofjord (st. 36B)		15	-18.88	0.43	15	15.86	0.97
Kirkøy, Hvaler (st. 02B)		15	-18.30	2.07	15	14.73	0.48
Skågskjera, Farsund (st. 15B)		15	-19.64	0.64	15	14.97	0.62
Bømlo, Outer Selbjørnfjord (st. 23B)		15	-18.98	0.46	15	13.82	0.46
Sandnessjøen area (st. 96B)		15	-19.60	0.37	15	14.19	0.43
Austnesfjord, Lofoten (st. 98B1)		15	-20.37	0.35	15	14.11	0.71
Kjøfjord, Outer Varangerfjord (st. 10B)		15	-20.44	0.63	15	13.58	0.55
Isfjorden, Svalbard (st. 19B)		15	-21.17	0.37	15	12.77	0.67
Common eider (*Somateria mollissima*), blood	**statistics >>**	**15**	**-20.31**	**0.58**	**15**	**10.50**	**0.77**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-20.31	0.58	15	10.50	0.77
Common eider (*Somateria mollissima*), egg	**statistics >>**	**15**	**-23.21**	**0.32**	**15**	**9.87**	**0.50**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-23.21	0.32	15	9.87	0.50
Presumed more impacted:							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**3**	**-20.56**	**0.16**	**3**	**6.06**	**0.19**
Gressholmen, Inner Oslofjord (st. 30A)		3	-19.59	0.25	3	7.41	0.10
Gåsøya, Inner Oslofjord (st. I304)		3	-19.15	0.30	3	7.90	0.11
Kirkøy, Hvaler (st. I024)		3	-20.24	0.15	3	7.46	0.46
Odderøya, Kristiansand harbour (st. I133)		3	-21.31	0.04	3	6.26	0.06
Kvalnes, Mid Sørfjord (st. 56A)		3	-20.43	0.04	3	2.65	0.44
Nordnes, Bergen harbour (st. I241)		3	-20.68	0.06	3	4.19	0.08
Ålesund harbour (st. 28A2)		3	-20.65	0.22	3	6.08	0.08
Bodø harbour (st. 97A3)		3	-22.40	0.20	3	6.52	0.23
Atlantic cod (*Gadus morhua*)	**statistics >>**	**15**	**-19.09**	**0.77**	**15**	**13.39**	**0.79**
Inner Oslofjord (st. 30B)		15	-18.90	0.90	15	15.74	0.73
Stathelle area, Langesundfjord (st. 71B)		15	-18.05	1.00	15	13.59	0.64
Kristiansand harbour area (st. 13B)		15	-18.98	0.76	15	14.13	0.41
Inner Sørfjord (st. 53B)		15	-18.05	0.76	15	11.45	0.95
Bergen harbour area (st. 24B)		15	-19.66	1.23	15	11.00	1.59
Ålesund harbour area (st. 28B)		15	-20.06	0.38	15	13.28	0.55
Trondheim harbour (st. 80B)		15	-18.52	0.86	15	14.05	0.88
Tromsø harbour area (st. 43B2)		15	-19.19	0.76	15	13.95	0.90
Hammerfest harbour area (st. 45B2)		15	-20.41	0.31	15	13.33	0.43
Mean of all blue mussel	**statistics >>**	**3**	**-20.88**	**0.14**	**3**	**5.88**	**0.19**
Mean of all Atlantic cod	**statistics >>**	**15**	**-19.37**	**0.72**	**15**	**13.80**	**0.70**

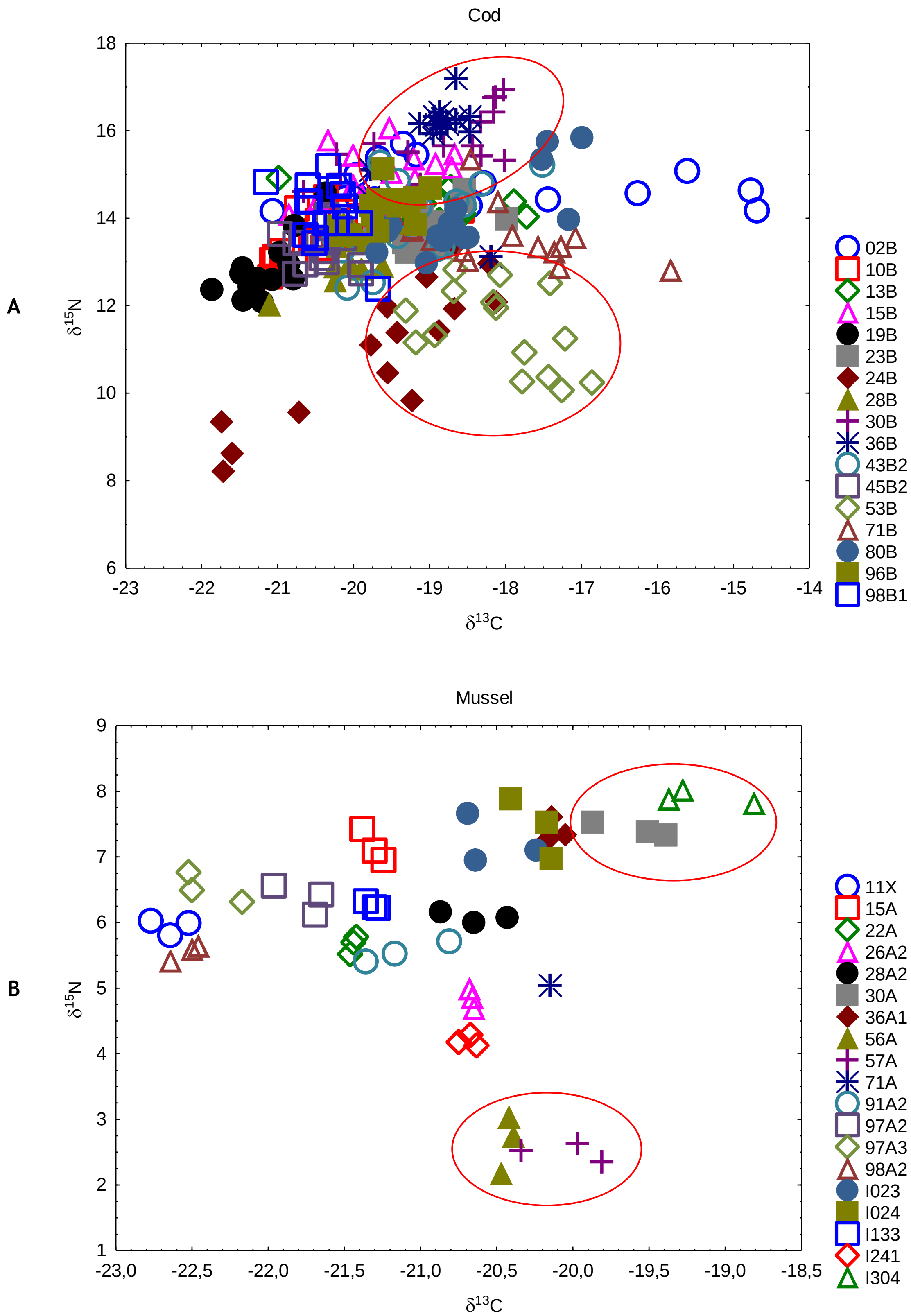


***Figure 73**. $\delta^{13}C$ plotted against $\delta^{15}N$ in for cod (**A**) and blue mussel (**B**). Red ellipses indicate the position of the majority of the samples of cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively. See station names and codes in **Table 17**.*

The biomagnifying properties of mercury are well known. A 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=0.0023 R^2=0.0362; **Figure 74**). This may partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations. However, as mentioned, it was previously shown that baseline adjusted trophic position of cod differed between stations along the Norwegian coast, suggesting that parts of the spatial differences in contaminant concentrations may be attributed to different trophic positions of the cod at the different stations. Furthermore, linear regressions isolated for each station produced significant positive linear relationships between δ^{15}N and Log[Hg] for the stations at Hvaler (st. 02B), Farsund (st. 15B), Svalbard (st.19B), Bømlo (st. 23B), Bergen (st. 24B), Inner Oslofjord (st. 30B), Hammerfest harbour (st. 45B2) and Trondheim harbour (st.80B).

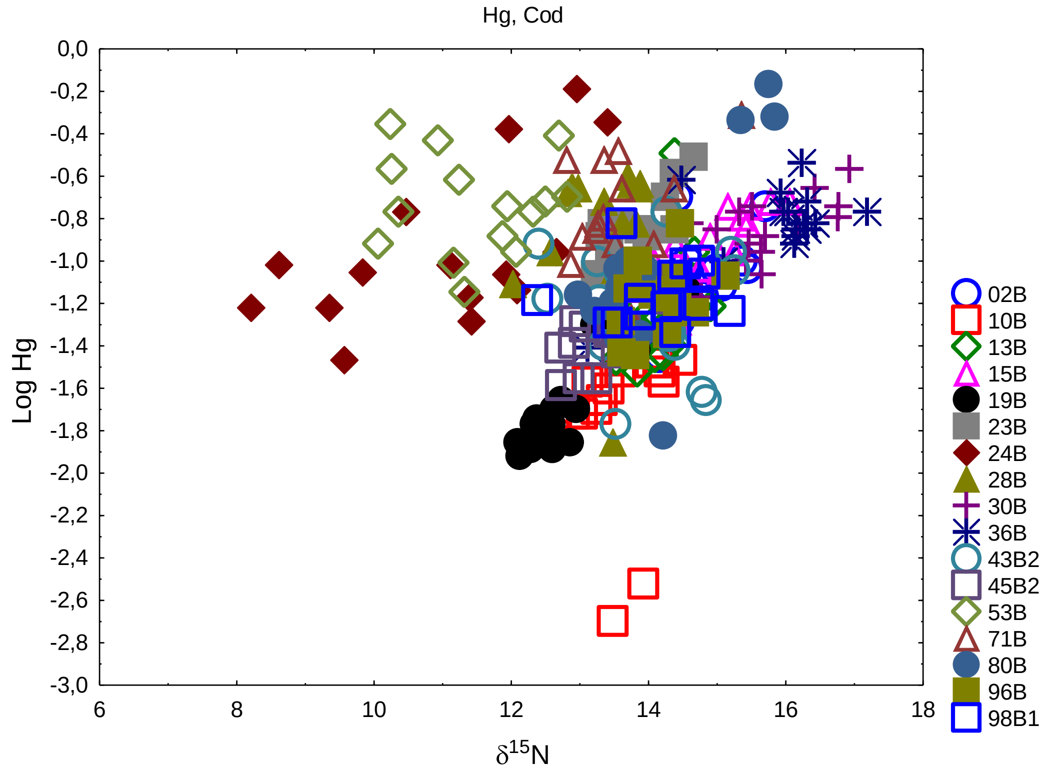


Figure 74. *δ^{15}N plotted against the log-transformed concentration of Hg in cod. See station names and codes in **Table 17**.*

δ^{15}N ratio in eiders from Svalbard (blood and egg) sampled in 2020 resembled those in 2018-2019 (***Figure 75***). 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 75***) 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 median C:N ratio was 3.70 in blood and 9.77 in egg, and a C:N ratio of >3.5 implies the presence of lipids, which may somewhat confound δ^{13}C interpretation, since lipids are δ^{13}C-depleted relative to proteins (Sweeting, Polunin, and Jennings 2006). The δ^{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).

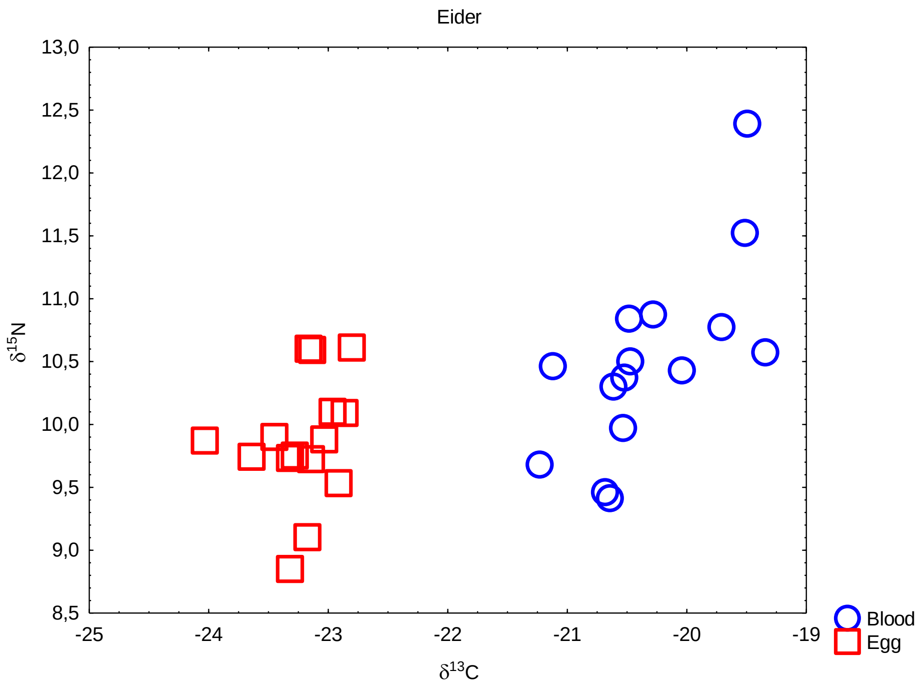


***Figure 75**. δ^{15}C plotted against δ^{15}N in blood (blue circles) and egg (red squares) of eider from Svalbard (st. 19N) in 2018 and 2019.*

3.5 Summary of results from Svalbard

Investigation of contaminants in samples of cod and eider from Svalbard was included in the MILKYS programme in 2017. Contaminant levels are monitored in two species from two different locations; fillet and liver from cod caught in the Isfjord (st. 19B) and blood and eggs from the eider found in the Kongsfjord (st. 19N) (***Table 18***). The results are reported in the preceding sections (see **Chapters 3.2** and **0**) and summarized here. Where possible, concentrations in cod are compared to the EQS and PROREF. However, for the eider samples, comparison to the EQS was not considered justified, and values for PROREF have not yet been established.

Levels in cod

As for cod from most of the other stations, the median concentrations in cod liver at Svalbard exceeded the EQS for PCB-7, BDE6 and BDE47, but were below the EQS for Hg (in fillet), PFOA, PFOS, D5, α–HBCD, SCCP and MCCP (***Table 8***). Median concentrations of contaminants in cod liver and cod fillet were generally low (below PROREF), the exception being for Cd which exceeded PROREF by a factor below two. (***Table 9***).

Siloxanes, i.e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5) and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver for the fourth time at the four stations, including Svalbard. D5, the most dominant cVMS, as well as D6 were lowest at Svalbard compared to the other sampling stations included in the study (***Figure 70***).

The correlation between δ^{15}N and contaminant concentration in cod could suggest higher concentrations in individuals with higher δ^{15}N.

Levels in eider

The median concentrations in eider blood and eggs from Svalbard exceeded the EQS for Hg, PCB-7 (in eggs), BDE6 and BDE47 (in eggs), but were below the EQS for PCB-7 (in blood), α–HBCD (in eggs), SCCP, MCCP, PFOA, PFOS, D5 and HCB (***Table 8***).

Median concentrations of Hg, Pb and As in eider eggs from Svalbard was almost at the same levels as observed in a comparable study (Hill 2018). The median concentration of PCB-153 (0.099 µg/kg w.w.) in eider blood at Svalbard was lower than in another study from Svalbard (mean 0.187±0.023.8 µg/kg w.w. after five days of incubation) (Bustnes et al. 2010). The Hg concentrations in eider blood and eggs at Svalbard in 2020 was almost within the same range as a study in the Inner Oslofjord in 2017 (Ruus 2018) (see ***Chapter 3.2.2***).

In the present study, the median concentration of PBDE47 was lower, and the concentrations of PFOS and PFOSA was almost within the same ranges as average concentrations found in another study of eider from three stations in northern Norway and one at Svalbard (Harju 2013). The PFOS concentrations in eider eggs and blood were 21 and 25 times higher, respectively, in the Inner Oslofjord study in 2019 (Ruus 2019) than in this study at Svalbard in 2020 (see ***Chapter 3.2.24***).

The $\delta^{15}N$ ratios in eider (blood and eggs) from Svalbard were fairly similar to that observed in 2007 (Evenset et al. 2016).

Table 18*. Median concentrations (µg/kg w.w.) and standard deviations for contaminant levels in cod livers (unless otherwise specified) from the Isfjord (st. 19B) and eider blood and eggs from Breøyane in Kongsfjord (st. 19N) in 2020. Units are: percent for dry and lipid weight, permille for stabile isotopes, mg/kg (w.w.) for metals and µg/kg (w.w.) for the remaining substances. Shaded cells indicate that the median was below the limit of quantification (LOQ) and the value shown in these cells is the LOQ. The standard deviation (S.d.) is based on all values and values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See* ***Chapter 2.10*** *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.	D.d.i.
DRYWT%	60.000	8.614	15 [38-66]						
Fett	55.100	12.649	15 [25-63]	0.260	0.582	8 [0.08-1.8]	16.985	1.412	15 [15-19.7]
AG	0.130	0.334	12 [0.06-1.2]	0.001	0.001	15 [4e-04-0.002]	0.009	0.010	15 [0.004-0.04]
AS	2.400	1.311	15 [1.8-6.3]	0.020	0.022	15 [0.01-0.09]	0.101	0.052	15 [0.06-0.25]
CD	0.110	0.256	15 [0.07-1.1]	0.003	0.002	15 [0.001-0.007]	0.0002	0.0001	7 [3e-04-4e-04]
CO	0.012	0.006	15 [0.005-0.03]	0.003	0.001	15 [0.002-0.005]	0.007	0.002	15 [0.004-0.01]
CR	0.033	0.015	15 [0.02-0.07]	0.003	0.055	4 [0.003-0.22]	0.006	0.013	13 [0.003-0.05]
CU	1.600	1.045	15 [0.55-5]	0.453	0.081	15 [0.33-0.66]	1.171	0.161	15 [0.93-1.41]
HG (in muscle)	0.017	0.017	15 [0.01-0.07]	0.111	0.040	15 [0.07-0.19]	0.111	0.034	15 [0.08-0.19]
NI	0.042	0.013	15 [0.02-0.07]	0.003	0.030	4 [0.004-0.12]	0.005	0.007	15 [0.004-0.03]
PB	0.009	0.003	14 [0.008-0.02]	0.046	0.061	15 [0.02-0.21]	0.006	0.003	15 [0.002-0.01]
SN	0.022	3.351	15 [0.01-13]	0.002	0.000	2 [0.003-0.003]	0.002	0.002	2 [0.002-0.009]
ZN	13.000	4.108	15 [8.1-24]	5.090	0.503	15 [4.1-6]	16.661	1.825	15 [14.1-20]
CB_S7	12.398	37.296	15 [6.9-140]	0.270	0.080	15 [0.19-0.42]	7.221	4.696	15 [5.5-22]
CB18				0.017	0.006	2 [0.02-0.04]	0.017	0.002	0 [n.a.]
CB28	0.370	0.135	10 [0.34-0.69]	0.013	0.008	10 [0.01-0.04]	0.169	0.131	15 [0.08-0.49]
CB31				0.011	0.006	5 [0.01-0.03]	0.019	0.004	15 [0.02-0.03]
CB33				0.010	0.003	5 [0.01-0.02]	0.010	0.000	0 [n.a.]
CB37				0.010	0.001	2 [0.01-0.01]	0.010	0.000	3 [0.008-0.01]
CB47				0.011	0.004	5 [0.01-0.03]	0.063	0.048	15 [0.03-0.19]
CB52	1.470	2.184	15 [0.76-9.6]	0.012	0.006	4 [0.01-0.03]	0.030	0.006	15 [0.02-0.04]
CB66				0.010	0.004	8 [0.01-0.02]	0.157	0.112	15 [0.05-0.43]
CB74				0.009	0.004	14 [0.007-0.02]	0.200	0.127	15 [0.09-0.56]
CB99				0.018	0.007	15 [0.01-0.03]	0.738	0.418	15 [0.29-1.89]
CB101	2.050	3.983	15 [1.08-16]	0.027	0.002	1 [0.03]	0.055	0.016	15 [0.03-0.09]
CB105				0.014	0.005	15 [0.009-0.03]	0.356	0.279	15 [0.19-1.27]
CB114				0.004	0.003	9 [0.004-0.01]	0.023	0.017	15 [0.01-0.08]
CB118	1.810	5.180	15 [1.01-18.1]	0.029	0.012	9 [0.03-0.06]	1.130	0.822	15 [0.66-3.7]
CB122				0.004	0.002	5 [0.004-0.01]	0.004	0.051	3 [0.06-0.19]
CB123				0.004	0.003	8 [0.004-0.01]	0.019	0.012	15 [0.01-0.06]
CB128				0.012	0.005	15 [0.007-0.03]	0.262	0.212	15 [0.18-0.96]
CB138	2.460	9.157	15 [1.4-33]	0.052	0.018	15 [0.03-0.09]	1.730	1.206	15 [1.19-5.4]
CB141				0.005	0.004	8 [0.005-0.02]	0.010	0.010	13 [0.006-0.04]
CB149				0.028	0.001	1 [0.03]	0.210	0.113	15 [0.06-0.54]
CB153	3.370	13.534	15 [1.89-50]	0.099	0.039	15 [0.06-0.19]	3.820	2.202	15 [2.9-10.1]
CB156				0.006	0.004	15 [0.004-0.02]	0.098	0.089	15 [0.08-0.41]
CB157				0.004	0.004	11 [0.003-0.02]	0.031	0.021	15 [0.02-0.1]
CB167				0.005	0.004	15 [0.004-0.02]	0.093	0.063	15 [0.07-0.29]
CB170				0.008	0.003	14 [0.007-0.01]	0.141	0.138	15 [0.02-0.6]
CB180	0.785	3.403	15 [0.43-12.2]	0.020	0.008	12 [0.02-0.04]	0.596	0.424	15 [0.4-1.96]
CB183				0.010	0.005	13 [0.008-0.02]	0.194	0.159	15 [0.11-0.62]
CB187				0.025	0.008	15 [0.01-0.04]	0.645	0.392	15 [0.37-1.77]
CB189				0.005	0.003	5 [0.006-0.01]	0.011	0.007	15 [0.008-0.03]
CB194				0.008	0.005	5 [0.009-0.02]	0.041	0.030	15 [0.02-0.14]
CB206				0.005	0.003	5 [0.006-0.02]	0.015	0.011	15 [0.007-0.05]
CB209				0.004	0.004	12 [0.002-0.02]	0.011	0.006	15 [0.006-0.03]
Sum-HepCB				0.072	0.024	15 [0.04-0.13]	1.660	1.168	15 [1.28-4.6]
Sum-HexCB				0.133	0.044	13 [0.1-0.22]	4.520	2.565	15 [3.3-11.5]
Sum-PenCB				0.118	0.034	10 [0.07-0.19]	2.540	1.695	15 [1.26-7.7]
Sum-TetCB				0.070	0.027	7 [0.05-0.12]	0.460	0.312	15 [0.19-1.24]
Sum-TriCB				0.075	0.036	8 [0.04-0.14]	0.202	0.136	15 [0.1-0.53]
HCB				0.201	0.129	15 [0.13-0.54]	5.500	2.319	15 [4.2-11.1]
PECB				0.036	0.012	14 [0.02-0.06]	0.578	0.170	15 [0.4-1]

Table 18. *(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.
HBCDA	0.315	0.420	15 [0.2-1.86]	0.030	0.000	0 [n.a.]	0.057	0.119	15 [0.03-0.5]
HBCDG	0.030	0.001	0 [n.a.]	0.031	0.000	0 [n.a.]	0.031	0.000	15 [0.03-0.03]
HBCDB	0.030	0.001	0 [n.a.]	0.023	0.000	0 [n.a.]	0.023	0.008	15 [0.02-0.05]
HBCDD	0.375	0.420	15 [0.25-1.92]	0.084	0.000	0 [n.a.]	0.111	0.120	15 [0.08-0.56]
BDESS	2.563	1.715	15 [2.4-7.5]	0.613	1.419	3 [0.62-1.04]	0.718	0.123	15 [0.63-0.99]
BDE6S	0.560	1.519	15 [0.38-4.9]	0.069	0.159	3 [0.07-0.12]	0.143	0.060	15 [0.08-0.31]
BDE17	0.010	0.000	1 [0.01]	0.006	0.013	0 [n.a.]	0.006	0.003	1 [0.02]
BDE28	0.023	0.035	15 [0.01-0.13]	0.006	0.015	0 [n.a.]	0.006	0.002	1 [0.01]
BDE47	0.347	1.081	15 [0.24-3.6]	0.027	0.062	3 [0.03-0.04]	0.037	0.030	13 [0.03-0.14]
BDE49	0.116	0.152	15 [0.06-0.57]	0.005	0.011	0 [n.a.]	0.005	0.011	3 [0.007-0.05]
BDE66	0.010	0.002	2 [0.01-0.02]	0.004	0.010	0 [n.a.]	0.004	0.012	1 [0.05]
BDE71	0.010	0.000	0 [n.a.]	0.003	0.008	0 [n.a.]	0.003	0.010	1 [0.04]
BDE77	0.010	0.000	0 [n.a.]	0.003	0.008	0 [n.a.]	0.003	0.000	0 [n.a.]
BDE85	0.020	0.000	0 [n.a.]	0.004	0.009	0 [n.a.]	0.004	0.000	0 [n.a.]
BDE99	0.020	0.004	1 [0.04]	0.011	0.026	1 [0.02]	0.013	0.006	9 [0.01-0.03]
BDE100	0.074	0.229	15 [0.05-0.73]	0.006	0.013	1 [0.006]	0.029	0.016	15 [0.009-0.05]
BDE119	0.020	0.010	3 [0.02-0.05]	0.004	0.009	0 [n.a.]	0.004	0.007	4 [0.006-0.03]
BDE126	0.020	0.038	3 [0.03-0.15]	0.003	0.007	0 [n.a.]	0.003	0.000	0 [n.a.]
BDE138	0.030	0.000	0 [n.a.]	0.011	0.026	0 [n.a.]	0.011	0.001	0 [n.a.]
BDE153	0.030	0.000	0 [n.a.]	0.010	0.024	0 [n.a.]	0.010	0.004	4 [0.01-0.02]
BDE154	0.067	0.179	15 [0.03-0.68]	0.009	0.020	0 [n.a.]	0.019	0.013	15 [0.01-0.06]
BDE156	0.030	0.000	0 [n.a.]	0.017	0.039	0 [n.a.]	0.017	0.001	0 [n.a.]
BDE183	0.050	0.001	1 [0.05]	0.007	0.017	0 [n.a.]	0.007	0.000	0 [n.a.]
BDE184	0.050	0.000	0 [n.a.]	0.007	0.016	0 [n.a.]	0.007	0.000	0 [n.a.]
BDE191	0.050	0.000	0 [n.a.]	0.010	0.023	0 [n.a.]	0.010	0.002	0 [n.a.]
BDE196	0.100	0.000	0 [n.a.]	0.013	0.032	0 [n.a.]	0.015	0.003	0 [n.a.]
BDE197	0.100	0.000	0 [n.a.]	0.010	0.025	0 [n.a.]	0.012	0.002	0 [n.a.]
BDE202				0.016	0.038	0 [n.a.]	0.016	0.003	0 [n.a.]
BDE206	0.200	0.000	0 [n.a.]	0.043	0.101	0 [n.a.]	0.055	0.016	0 [n.a.]
BDE207	0.200	0.000	0 [n.a.]	0.027	0.065	0 [n.a.]	0.048	0.017	0 [n.a.]
BDE209	1.000	0.000	0 [n.a.]	0.366	0.851	0 [n.a.]	0.366	0.046	0 [n.a.]
SCCP	59.000	31.240	15 [27-140]	13.000	13.233	9 [12-50]	26.000	9.059	15 [11-49]
SCCP eksl. LOQ	51.500	25.246	8 [30-110]						
MCCP	84.000	16.645	15 [54-100]	22.000	1024.365	13 [11-4004]	35.000	22.638	12 [10-97]
MCCP eksl. LOQ	43.500	17.138	8 [29-77]						
PFAS	0.400	0.639	15 [0.3-2.4]	0.500	0.145	15 [0.2-0.7]	1.200	0.755	15 [0.6-2.9]
PFDcA	0.500	0.000	0 [n.a.]	0.400	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFHpA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFHxA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFHxS	0.100	0.000	0 [n.a.]	0.200	0.074	15 [0-0.3]	0.100	0.000	0 [n.a.]
PFNA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFOA	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]	0.500	0.000	0 [n.a.]
PFOS	0.300	0.474	15 [0.2-1.9]	0.400	0.145	15 [0.1-0.6]	1.100	0.755	15 [0.5-2.8]
PFOSA	0.100	0.180	3 [0.1-0.7]	0.100	0.000	0 [n.a.]	0.100	0.000	0 [n.a.]
PFUdA	0.400	0.270	3 [0.4-1.3]	0.400	0.000	0 [n.a.]	0.500	0.129	13 [0.4-0.8]
TBA				0.011	0.026	0 [n.a.]	0.284	0.181	15 [0.12-0.81]
D4	3.164	1.140	15 [1.91-6.9]	0.816	0.262	17 [0.61-1.47]	1.921	0.481	15 [1.42-3.4]
D5	6.506	2.082	15 [2.7-10.7]	0.749	0.435	17 [0.37-2.3]	3.014	0.796	15 [2.2-4.8]
D6	3.113	1.551	13 [2.4-8.5]	1.684	0.134	6 [1.7-2.1]	1.895	0.588	15 [1.59-3.1]
Delta13C (in muscle)	-21.26	0.370	15 [-21.86--20.37]	-20.48	0.578	15 [-21.23--19.34]	-23.16	0.320	15 [-24.03--22.8]
Delta15N (in muscle)	12.60	0.668	15 [12.1-14.6]	10.46	0.767	15 [9.4-12.4]	9.87	0.502	15 [8.8-10.6]
C/N (in muscle)	3.32	0.066	15 [3.2-3.5]	3.70	0.171	15 [3.5-4.1]	9.77	0.745	15 [8.4-11]

4. Conclusions

The main conclusions from the 2020 investigations were (based on wet weight basis) that:

The environmental quality in Norwegian coastal waters is generally good, with some exceptions

- The majority (68 %) of the median concentrations that could be assessed against the EQS were below the EQS.
- The majority (69 %) of the median concentrations that could be assessed against the PROREF were below the PROREF.
- Statistical analyses showed that downward short-term trends were primarily associated with metals, α–HBCD and BDEs. Upward short-term trends were mainly associated with metals for cod and blue mussel, while many upward short-term trends for PCB-7 in blue mussel were caused by methodical (artificial) results due to higher limits of quantifications (LOQ).
- In cod fillet, significant upward long-term trends for Hg were found in the Inner Oslofjord, Farsund (Skågskjera), Bømlo and Tromsø. While Hg concentration is strongly linked to fish length, these trends were significant also after adjusting for cod length for the Inner Oslofjord, Kristiansand harbour and Farsund.
- The Inner Oslofjord had many of the highest concentrations;
    - The second highest concentrations of Pb in blue mussel at Gressholmen.
    - The highest concentrations of PBDEs, predominantly BDE47 in cod liver.
    - The highest PCB-7 concentrations in in cod liver, and in blue mussel from Gressholmen.
    - The highest α–HBCD (dominant HBCD isomer) concentrations in cod liver.
    - The highest MCCP concentrations in cod liver.
- Blue mussel from two stations in the Sørfjord had concentrations of DDE exceeding PROREF by a factor greater than 20, presumably related to the earlier use of DDT as pesticide in this orchard district.
- Cod liver from the Outer Oslofjord had highest concentrations of PFOSA.
- In cod liver, the highest concentration of SCCP was found in cod from Svalbard. Blue mussel samples indicated highest SCCP and MCCP concentrations in Bodø harbour. A significant upward short-term trend was found for SCCP in blue mussel from Singlekalven, and a significant upward long-term trend for MCCP was found in cod liver from Bømlo in the Outer Selbjørnfjord.
- The median concentration of HCB in cod liver from the Austnesfjord in Lofoten, exceeded the EQS for this substance. Significant long-term downward trends were found for median concentration of HCB in liver of cod from the Inner Oslofjord, Tjøme in the Outer Oslofjord and from Farsund.
- In liver of flounder caught at Sande in the mid Oslofjord, significant upward short-term trends were found for Cd and Hg, and significant downward long-term trends were found for Pb and HCB.

Contaminant levels at Svalbard are generally low, but Hg levels in common eider is of potential concern

- Median concentrations of contaminants in cod liver and cod fillet from Svalbard were generally low.
- Cod liver from Svalbard had highest concentrations of SCCPs. The high concentrations of SCCPs is might be caused by long-range transported pollution. High concentrations of these substances have been measured in air at Svalbard.
- D5 was the most dominant siloxane found in cod liver, and the concentrations were highest in the Inner Oslofjord and lowest in the Isfjord at Svalbard. The same patterns were found for D6.

- Contaminants were analyzed in the blood and eggs (homogenate of yolk and albumin) of the eider from Svalbard since 2017. Concentrations of Hg, Pb, As, PFOS and PFOSA in eggs were in the range as found in comparable studies from the Svalbard region. The Hg concentrations in eider blood and eggs at Svalbard in 2020 was almost within the same range as reported in a comparable study in the Inner Oslofjord in 2017. The concentrations of PCB-7, BDE47 (eggs) and PFOS were higher in eider blood and eggs in the Inner Oslofjord in 2017 than at Svalbard in 2020. There is a downward tendency for concentration of HCB in blood and eggs of eider for the monitoring period 2017 to 2020.

Biological effect parameters (biomarker analysis) found no effects of TBT but confirm exposure of PAH, lead and planar halogenated hydrocarbons and other structurally similar compounds

- No observable biological effects of TBT were found in this study; the effects of TBT on dogwhelk as measured by the imposex parameter VDSI, were zero at all eight stations where dogwhelk was sampled. The less sensitive intersex parameter ISI was assessed in common periwinkle at only one station and was found to be zero, indicating no effect of TBT also at this station.
- The ICES/OSPAR Background Assessment Criteria (BAC) for OH-pyrene in cod bile was exceeded at all stations investigated, except at the reference station at Bømlo.
- Inhibited ALA-D activity in cod liver from the Inner Oslofjord indicated exposure to Pb and were in line with observations of high Pb levels in blue mussel at Gressholmen in the Inner Oslofjord.
- Median EROD-activities were below the ICES/OSPAR assessment criterion at all stations investigated, and downward trends in EROD activities could be observed at all stations.

Elevated levels in coastal waters near urban centres suggests that these hot-spots are of concern

- The Inner Oslofjord, and to a lesser degree the harbour areas of Bergen, Kristiansand, Trondheim and Bodø seem on the whole to be an area where contaminant concentrations tend to be higher. This is probably due to high population in the relevant watershed areas, a multitude of urban activities, and former and present use of products containing contaminants. The Oslofjord has contaminated sediments from previous industry, the densest population and the highest shipping traffic (number of people per day). A reduced water exchange in the Inner Oslofjord with the outer fjord will also contribute to higher contaminant concentrations in water and biota.
- High concentrations of PCB-7 and Hg in cod are reasons for concern, particularly in the Inner Oslofjord. There is some evidence that elevated concentrations may result from increased fish length due to poor recruitment of cod in recent years in this area. In the Inner Oslofjord, a significant upward long-term trend and a significant downward short-term trend were observed for Hg in cod fillet. When adjusted for fish length, also a significant upward long-term trend for Hg was found in the Inner Oslofjord.
- Results from stable isotopes of C and N indicate that the stations show very similar patterns from 2012 to 2020 in terms of isotopic signatures, indicating a geographical difference consistent over time.
- Some legacy contaminants are still present in elevated levels in Norwegian coastal waters and give reason for concern.

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Appendix A
Quality assurance programme

Information on Quality Assurance

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, BIPEA), international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, round 2020-1 apply to the 2020-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 2019 samples (cf. Green et al. 2020 – M-1894|2020).

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.

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. Processing and measurement in CRM are comparable to sample matrices even though in certain cases the matrices differ. 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. However, the PFC analysis is not accredited according to this ISO-standard.

Summary of quality control results

Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly. Apple juice was used as an in-house reference material for the quality control of the determination of metals. The reference material for determination of BDEs, HBCDDs, PCBs and PAHs in blue mussel, as well as BDEs, PCBs and PAHs in liver, was an internal reference (fish oil). For tin organic compounds the reference material ZRM 81 was used as SRM in mussel tissue. For the determination of dieldrin, trans-nonachlor and DDTs in blue mussel, internal reference materials provided by EF GfA Lab services were used, these consisted of fish meal and feedingstuff. For the quality assurance of chlorinated paraffines spiked fish was used as an in-house reference material, and spiked fish liver was used for quality control of PFCs.

Summary of the quality control of results for the 2020 biota samples analysed in 2020-2021. The Standard Reference Material (SRM) used was ZRM 81 (for mussel tissue). The in-house reference materials were apple juice, spiked fish oil, spiked fish meal and spiked fish liver. The SRM 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 (in w.w.): metals (µg/kg), BDE (pg/g), PCB (ng/kg), DDTs (ng/kg), SCCPs and MCCPs (ng/sample), HBCDDs (ng/g), PAH (pg/g), tin organic compounds (mg/kg), PFCs (% recovery), and trans-nonachlor (ng/kg). Tissue types were: mussel soft body (SB), fish liver (LI) and fish fillet (MU).

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
Ag	Silver	-	-	-	-	-	-	-
As	Arsenic	SB/MU/LI	Apple juice	109 ± 23	45	8	109	4,9
Cd	Cadmium	SB/MU/LI	Apple juice	106 ± 32	45	8	106,40	4,00
Cr	Chromium	SB/MU/LI	Apple juice	102 ± 17	45	8	104,90	5,70
Co	Cobalt	-	-	-	-	-	-	-
Cu	Copper	SB/MU/LI	Apple juice	6147 ± 1229	45	8	6365	224
Hg	Mercury	SB/MU/LI	Apple juice	19,4 ± 3,8	45	8	19,20	0,970
Ni	Nickel	SB/MU/LI	Apple juice	111± 26	45	8	113	6,25
Pb	Lead	SB/MU/LI	Apple juice	105 ± 32	45	8	107	3,60
Zn	Zinc	SB/MU/LI	Apple juice	1315 ± 334	45	8	1296	80,0
Sn	Tin	-	-	-	-	-	-	-
BDE-28	2,2,4' Tribromodiphenylether	SB	Internal RM (fish oil)	85.7 ± 25.7	20	10	81,2	4,89
BDE-47	2,2',4,4',-Tetrabromodiphenylether	SB	Internal RM (fish oil)	1590 ± 477	20	10	1645,6	56,02
BDE-100	2,2',4,4',6-Pentabromodiphenylether	SB	Internal RM (fish oil)	324 ± 97.2	20	10	339,3	13,9
BDE-99	2,2',4,4',5-Pentabromodiphenylether	SB	Internal RM (fish oil)	248 ± 74.4	20	10	259,8	9,85
BDE-154	2,2',4,4',5,6'-Hexabromodiphenylether	SB	Internal RM (fish oil)	223.5 ± 67.1	20	10	254,1	11,01
BDE-153	2,2',4,4'5,5'-Hexabromodiphenylether	SB	Internal RM (fish oil)	58.5 ± 17.6	20	10	67,7	7,32
BDE-49	2,2',4,5'-tetrabromodiphenyleter	SB	Internal RM (fish oil)	431 ± 129.3	20	10	463,4	16,5
BDE-66	2,3',4,4'-Tetrabromodiphenyleter	-	-	-	-	-	-	-
BDE-119	2,3',4,4',6-Pentabromodiphenyl ether	SB	Internal RM (fish oil)	30.8 ± 9.24	20	10	33,1	2,21
PCB 52	PCB congener CB-52	SB/MU/LI	Internal RM (fish oil)	444,4 +- 133,3	33	12	464,07	25,64
PCB 28	PCB congener CB-28	SB/MU/LI	Internal RM (fish oil)	269,7 +- 80,90	33	12	292,34	21,68
PCB 180	PCB congener CB-180	SB/MU/LI	Internal RM (fish oil)	4590 +- 1377	33	12	4859,36	322,10
PCB 153	PCB congener CB-153	SB/MU/LI	Internal RM (fish oil)	5289 +- 1587	33	12	5116,23	307,78
PCB 138	PCB congener CB-138	SB/MU/LI	Internal RM (fish oil)	3605 +- 1082	33	12	3902,88	238,71
PCB 118	PCB congener CB-118	SB/MU/LI	Internal RM (fish oil)	883,1 +- 264,9	33	12	927,87	51,53
PCB 101	PCB congener CB-101	SB/MU/LI	Internal RM (fish oil)	1647 +- 494,1	33	12	1776,19	322,10
DDEOP	o,p'-DDE	SB/MU/LI	Internal RM (feed)	0.11±0.03	14	10	0,08	0,015
TDEOP	o,p'-DDD	SB/MU/LI	Internal RM (feed)	0.267±0.08	14	10	0,23	0,015
DDTOP	o,p'-DDT	SB/MU/LI	Internal RM (feed)	0.259±0.08	14	10	0,21	0,034
DDEPP	p,p'-DDE	SB/MU/LI	Internal RM (feed)	5.01±1.5	13	10	4,47	0,290
TDEPP	p,p'-DDD	SB/MU/LI	Internal RM (feed)	1.73±0.5	14	10	1,50	0,271
DDTPP	p,p'-DDT	SB/MU/LI	Internal RM (feed)	0.613±0.2	14	10	0,56	0,038
SCCP	Short-chain chlorinated Paraffins (C10-C13)	SB/MU/LI	Internal RM (spiked fish)	10000	17	13	10540	1062
MCCP	Medium-chain chlorinated Paraffins (C14-C17)	SB/MU/LI	Internal RM (spiked fish)	10000	17	13	10140	1453
α-HBCDD	α-Hexabromocyclododecane	SB/MU/LI	Internal RM (fish oil)	1.21 ± 0.363	14	11	1,26	0,085
ß-HBCDD	ß- Hexabromocyclododecane	SB/MU/LI	Internal RM (fish oil)	0.08 ± 0.024	14	11	0,067	0,013
γ-HBCDD	γ- Hexabromocyclododecane	SB/MU/LI	Internal RM (fish oil)	0.32 ± 0.096	14	11	0,38	0,038
BGHIP	Benzo[ghi]perylene	-	-	-	-	-	-	-
ICDP	Indeno[1,2,3-cd]pyrene	-	-	-	-	-	-	-
BBJF	Benzo[b+j]fluoranthene	SB	Internal RM (fish oil)	513 ± 154	6	6	551,5	73,5

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
DBA3A	**Dibenzo[ac,ah]anthracene**	-	-	-	-	-	-	-
BKF	**Benzo[k]fluoranthene**	SB	Internal RM (fish oil)	127 ± 62	6	6	153	29
ACNLE	**Acenaphthylene**	SB	Internal RM (fish oil)	1210 ± 363	6	6	1232,3	239,4
ANT	**Anthracene**	SB	Internal RM (fish oil)	1040 ± 312	6	6	1187,6	79,6
BAA	**Benzo[a]anthracene**	SB	Internal RM (fish oil)	511 ± 153	6	6	531,4	109,4
BAP	**Benzo[a]pyrene**	SB	Internal RM (fish oil)	236 ± 71	6	6	276,1	26,5
CHR	**Chrysene**	SB	Internal RM (fish oil)	502 ± 151	6	6	598,2	34,7
FLU	**Fluoranthene**	SB	Internal RM (fish oil)	3230 ± 969	6	6	3629,1	323,3
FLE	**Fluorene**	SB	Internal RM (fish oil)	4490 ± 1347	6	6	4873,4	377,2
NAP	**Naphthalene**	-	-	-	-	-	-	-
PA	**Phenanthrene**	SB	Internal RM (fish oil)	9110 ± 2733	6	6	9695,5	408,5
PYR	**Pyrene**	SB	Internal RM (fish oil)	2080 ± 624	6	6	2239,8	309,1
ACNE	**Acenaphthene**	SB	Internal RM (fish oil)	2140 ± 642	6	6	2071,7	219,3
TBBPA	**Tetrabromobisphenol-A**	-	-	-	-	-	-	-
BPA	**Bisphenol-A**	-	-	-	-	-	-	-
APO	**4-tert-oktylfenol**	-	-	-	-	-	-	-
APO	**4-n-oktylfenol**	-	-	-	-	-	-	-
APO	**4-n-nonylfenol**	-	-	-	-	-	-	-
MBT	**Monobutyltinn (MBT)**	SB	ZRM 81 (mussel)	1.5 ± 0.5	5	6	1,96	0,083
DBT	**Dibutyltinn (DBT)**	-	-	-	-	-	-	-
TBT	**Tributyltinn (TBT)**	SB	ZRM 81 (mussel)	2.2 ± 0.7	6	5	1,74	0,034
TPhT	**Trifenyltinn (TPhT)**	SB	ZRM 81 (mussel)	1.4 ± 0.4	6	6	1,40	0,038
PFBS	**Perfluorobutane sulphonate**	LI*	In-house spiked liver*	100%[1)]	5	14	97	3,3
PFHxA	**Perfluorohexane acid**	LI*	In-house spiked liver*	100%[1)]	5	14	97	3,3
PFHpA	**Perfluoroheptane acid**	LI*	In-house spiked liver*	100%[1)]	5	14	104	2,7
PFOA	**Perfluorooctane acid**	LI*	In-house spiked liver*	100%[1)]	5	14	99	3,3
PFNA	**Perfluorononane acid**	LI*	In-house spiked liver*	100%[1)]	5	14	99	3,7
PFOS	**Perfluorooctane sulphonate**	LI*	In-house spiked liver*	100%[1)]	5	14	99	2,9
PFOSA	**Perfluorooctane sulphone amide**	LI*	In-house spiked liver*	100%[1)]	5	14	101	3,1
PFHxS	**Perfluorohexane sulphonate**	LI*	In-house spiked liver*	100%[1)]	5	14	90	2,3
PFDA	**Perfluorodecanoic acid**	LI*	In-house spiked liver*	100%[1)]	5	14	99	3,7
PFUDA	**Perfluoroundecanoic acid**	LI*	In-house spiked liver*	100%[1)]	5	14	100	2,0
PFDS	**Perfluorodecanesulphonate**	LI*	In-house spiked liver*	100%[1)]	5	14	91	5,2
	Dieldrin	-	-	-	-	-	-	-
	Trans-Nonachlor	SB/MU/LI	Internal RM (feed)	1.39±0.4	14	10	1,35	0,239

* For some PFCs the tissue type also contained blue mussel, sea gull egg and blood

1) Recovery of spiked control sample

Appendix B
Abbreviations

(Includes all abbreviations used in MILKYS and forerunner programmes,
and not just those used in the present study.)

Abbreviation[1]	English	*Norwegian*	Param. group
ELEMENTS			
Al	aluminium	*aluminium*	I-MET
Ag	silver	*sølv*	I-MET
As	arsenic	*arsen*	I-MET
Ba	barium	*barium*	I-MET
Cd	cadmium	*kadmium*	I-MET
Ce	cerium	*serium*	I-MET
Co	cobalt	*kobolt*	I-MET
Cr	chromium	*krom*	I-MET
Cu	copper	*kobber*	I-MET
Fe	iron	*jern*	I-MET
Hg	mercury	*kvikksølv*	I-MET
La	lanthanum	*lantan*	I-MET
Li	lithium	*litium*	I-MET
Mn	manganese	*mangan*	I-MET
Mo	molybdenum	*molybden*	I-MET
Nd	neodymium	*neodym*	I-MET
Ni	nickel	*nikkel*	I-MET
Pb	lead	*bly*	I-MET
Pb210	lead-210	*bly-210*	I-RNC
Pr	praseodymium	*praseodym*	I-MET
Se	selenium	*selen*	I-MET
Sn	tin	*tinn*	I-MET
Ti	titanium	*titan*	I-MET
V	vanadium	*vanadium*	I-MET
Zn	zinc	*sink*	I-MET
METAL COMPOUNDS			
TBT	tributyltin (formulation basis =TBTIN*2.44)	*tributyltinn (formula basis =TBTIN*2.44)*	O-MET
MBTIN (MBT)	Monobutyltin	*monobutyltinn*	O-MET
MBTIN (MBT)	Monobutyltin	*monobutyltinn*	O-MET
MOT	Monooctyltin	*monooktyltinn*	O-MET
MPTIN	Monophenyltin	*monofenyltinn*	O-MET
DBT	dibutyltin (di-n-butyltin)	*dibutyltinn (di-n-butyltinn)*	O-MET
DBTIN	dibutyltin (di-n-butyltin)	*dibutyltinn (di-n-butyltinn)*	O-MET
DOT	dioctyltin	*dioktyltinn*	O-MET
DPTIN	diphenyltin	*difenyltinn*	O-MET
TBTIN	tributyltin (=TBT*0.40984)	*tributyltinn (=TBT*0.40984)*	O-MET
TCHT	tricyclohexyl-stannylium	*tricyclohexyl-stannylium*	O-MET
TPhT-Sn	Triphenyltin tin weight (=TPhT/3)	*Trifenyltinn tinn-vekt (=TPhT/3)*	O-MET
TPhT	Triphenyltin ion weight (=TPhT-Sn*3)	*Trifenyltinn ion-vekt (=TPhT-Sn*3)*	O-MET
TTBT	tetrabutyltin	*tetrabutyltinn*	O-MET
PAHs			

Abbreviation[1]	English	*Norwegian*	Param. group
PAH	polycyclic aromatic hydrocarbons	*polysykliske aromatiske hydrokarboner*	
ACNE [3]	acenaphthene	*acenaften*	PAH
ACNLE [3]	acenaphthylene	*acenaftylen*	PAH
ANT [3]	anthracene	*antracen*	PAH
BAA [3, 4]	benzo[*a*]anthracene	*benzo[a]antracen*	PAH
BAP [3, 4]	benzo[*a*]pyrene	*benzo[a]pyren*	PAH
BBF [3, 4]	benzo[*b*]fluoranthene	*benzo[b]fluoranten*	PAH
BKF [3, 4]	benzo[*k*]fluoranthene	*benzo[k]fluoranten*	PAH
BJF [3, 4]	benzo[*j*]fluoranthene	*benzo[j]fluoranten*	PAH
BBJKF [3, 4]	benzo[*b,j,k*]fluoranthene	*benzo[b,j,k]fluoranten*	PAH
BBJKF [3, 4]	benzo[b+j,k]fluoranthene	*benzo[b+j,k]fluoranten*	PAH
BBKF [3, 4]	benzo[*b*+*k*]fluoranthene	*benzo[b+k]fluoranten*	PAH
BEP	benzo[*e*]pyrene	*benzo[e]pyren*	PAH
BGHIP [3]	benzo[*ghi*]perylene	*benzo[ghi]perylen*	PAH
BIPN [2]	biphenyl	*bifenyl*	PAH
BJKF [3, 4]	benzo[*j,k*]fluoranthene	*benzo[j,k]fluorantren*	PAH
BKF [3, 4]	benzo[*k*]fluoranthene	*benzo[k]fluorantren*	PAH
CHR [3, 4]	chrysene	*chrysen*	PAH
CHRTR [3, 4]	chrysene+triphenylene	*chrysen+trifenylen*	PAH
COR	coronene	*coronen*	PAH
DBAHA [3, 4]	dibenz[*a,h*]anthracene	*dibenz[a,h]anthracen*	PAH
DBA3A [3, 4]	dibenz[*a,c/a,h*]anthracene	*dibenz[a,c/a,h]antracen*	PAH
DBP [4, 6]	dibenzopyrenes	*dibenzopyren*	PAH
DBT	dibenzothiophene	*dibenzothiofen*	PAH
DBTC1	C_1-dibenzothiophenes	*C_1-dibenzotiofen*	PAH
DBTC2	C_2-dibenzothiophenes	*C_2-dibenzotiofen*	PAH
DBTC3	C_3-dibenzothiophenes	*C_3-dibenzotiofen*	PAH
FLE [3]	fluorene	*fluoren*	PAH
FLU [3]	fluoranthene	*fluoranten*	PAH
ICDP [3, 4]	indeno[*1,2,3-cd*]pyrene	*indeno[1,2,3-cd]pyren*	PAH
NAP [2, 4]	naphthalene	*naftalen*	PAH
NAPC1 [2]	C_1-naphthalenes	*C_1-naftalen*	PAH
NAPC2 [2]	C_2-naphthalenes	*C_2-naftalen*	PAH
NAPC3 [2]	C_3-naphthalenes	*C_3-naftalen*	PAH
NAP1M [2]	1-methylnaphthalene	*1-metylnaftalen*	PAH
NAP2M [2]	2-methylnaphthalene	*2-metylnaftalen*	PAH
NAPD2 [2]	1,6-dimethylnaphthalene	*1,6-dimetylnaftalen*	PAH
NAPD3 [2]	1,5-dimethylnaphthalene	*1,5-dimetylnaftalen*	PAH
NAPDI [2]	2,6-dimethylnaphthalene	*2,6-dimetylnaftalen*	PAH
NAPT2 [2]	2,3,6-trimethylnaphthalene	*2,3,6-trimetylnaftalen*	PAH
NAPT3 [2]	1,2,4-trimethylnaphthalene	*1,2,4-trimetylnaftalen*	PAH
NAPT4 [2]	1,2,3-trimethylnaphthalene	*1,2,3-trimetylnaftalen*	PAH
NAPTM [2]	2,3,5-trimethylnaphthalene	*2,3,5-trimetylnaftalen*	PAH

Abbreviation[1]	English	*Norwegian*	Param. group
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
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/PAH/PAH-15	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)*	
PAH-16	Sum EPA PAH16	*Sum EPA PAH16*	
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

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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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

Abbreviation[1]	English	*Norwegian*	Param. group
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
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/BDE6	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

Abbreviation[1]	English	*Norwegian*	Param. group
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, $C_{10\text{-}13}$	*kortkjedete klorerte parafiner, $C_{10\text{-}13}$*	
MCCP	medium chain chlorinated, $C_{14\text{-}17}$ paraffins	*mediumkjedete klorerte parafiner, $C_{14\text{-}17}$*	
Alkylphenols	**phenols/chlorophenols**	***fenoler/klorfenoler***	
4-n-NP	4-n-nonylphenol	*4-n-nonylfenol*	
4-n-OP	4-n-octylphenol	*4-n-oktylfenol*	
4-t-NP	4-tert-nonylphenol	*4-tert-nonylfenol*	
4-t-OP	4-tert-octylphenol	*4-tert-oktylfenol*	
	stable isotopes	***stabile isotoper***	
C/N	$\delta^{13}C$ /$\delta^{15}N$	*$\delta^{13}C$ /$\delta^{15}N$*	
Delta15N	$\delta^{15}N$	*$\delta^{15}N$*	
Delta13C	$\delta^{13}C$	*$\delta^{13}C$*	
	phthalates/organic esters	***phtalater/organiske estere***	
BBP	benzylbutylphthalate	*benzylbutylftalat*	
DBP[6]	dibutylphthalate	*dibutylftalat*	
DBPA	dibutyladipat	*dibutyladipat*	
DEHA	diethylhexcyladipate	*dietylheksyladipat*	
DEHP	di(2-ethylhexyl)-phthalate	*di(2-etylhexyl)-ftalat*	
DEP	dietylphthale	*dietylftalat*	
DEPA	diethyladipat	*dietyladipat*	
DIBP	diisobutylphthalate	*diisobutylftalat*	
DIDP	diisodectylyphthalate	*diisodekylftalat*	
DIHP	diisoheptylphthalate	*diisoheptylftalat*	
DINCH	1,2-Cyclohexane dicarboxylic acid diisononyl ester	*1,2-sykloheksan dikarboksyl syre diisononyl ester*	
DIPA	diisobutyl adipate	*diisobutyladipat*	
DMP	dimethylphthalate	*dimetylftalat*	
DNOP	di-n-octylphthalte	*di-n-oktylftalt*	
DPF	diphenylphthalate	*difenylftalat*	
SDD	dinonylphthalte+diisononylphthalate	*dinonylftalat+diisononylftalat*	
TBP	tributylphosphate	*tributylfosfat*	
TOA	tributyl-o-acetylcitrate	*tributyl-o-acetylcitrate*	
Triclosan	triclosan	*triklosan*	
Dodecylphenol	dodecylphenol	*dodecylfenol*	
Diuron	Duiron	*Durion*	
Irgarol	Irgarol	*Irgarol*	

Abbreviation[1]	English	*Norwegian*	Param. group
Siloxanes			
D4	octamethylcyclotetrasiloxane		
D5	decamethylcyclopentasiloxane		
D6	dodecamethylcyclohexasiloxane		
Dechlorane Plus			
DBALD	dibromoaldrin	*Dibromoaldrin*	
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
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 P450 1A-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]*	
EFM	Eurofins [N, Moss]	*Eurofins [N, Moss]*	
GFA	Eurofins [DE, GFA]	*Eurofins [DE, GFA]*	
EFSofia	Eurofins [DE, Sofia]	*Eurofins [DE, Sofia]*	
WEJ	Eurofins WEJ	*Eurofins WEJ*	
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]*	
IFE	Institute for Energy Technology	*Institutt for energiteknikk*	
IMR	Institute of Marine Research (IMR)	*Havforskningsinstituttet*	
NACE	Nordic Analytical Center	*Nordisk Analyse Center*	

Abbreviation[1]	English	*Norwegian*	Param. group
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	Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology-SINTEF (a division, previously: Center for Industrial Research SI)	*Stiftelsen for industriell og teknisk forskning ved Norges tekniske høgskole- SINTEF (en avdeling, tidligere: Senter for industriforskning SI)*	
VETN	Norwegian Veterinary Institute	*Veterinærinstituttet*	
VKID	Water Quality Institute [DK]	*Vannkvalitetsintitutt [DK]*	

1) After: ICES Environmental Data Reporting Formats. International Council for the Exploration of the Sea. July 1996 and supplementary codes related to non-ortho and mono-ortho PCBs and "dioxins" (ICES pers. comm.)

2) Indicates "PAH" compounds that are dicyclic and not truly PAHs typically identified during the analyses of PAH, include naphthalenes and "biphenyls".

3) Indicates the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 (often called PAH-16) minus naphthalene (dicyclic).

4) Indicates PAH compounds potentially cancerogenic for humans according to IARC (1987), updated 14 August 2007), i.e., categories 1, 2A, and 2B (are, possibly and probably carcinogenic). NB.: the update includes Chrysene as cancerogenic.

5) Indicates non ortho- co-planer PCB compounds i.e., those that lack Cl in positions 1, 1', 5, and 5'

6) DBP is ambiguous; a code for both a PAH and an phthalate. DBP as a PAH was only measured in 1992 whereas DBP as an phthalate has been measure in 2012 and 2013. A correction in the data base is needed in this regard.

*) The Pesticide Index, second edition. The Royal Society of Chemistry, 1991.

Other abbreviations *andre forkortelser*

	English	*Norwegian*
TEQ	"Toxicity equivalency factors" for the most toxic compounds within the following groups: • polychlorinated dibenzo-p-dioxins and dibenzofurans (**PCDD/PCDFs**). Equivalents calculated after Nordic model (Ahlborg 1989) [1] or international model (Int./EPA, cf. Van_den_Berg *et al.* (1998) [2] • non-ortho and mono-ortho substituted chlorobiphenyls after WHO model (Ahlborg et al. 1994) [3] or Safe (1994, cf. NILU pers. comm.)	*"Toxisitetsekvivalentfaktorer" for de giftigste forbindelsene innen følgende grupper.* • *polyklorerte dibenzo-p-dioksiner og dibenzofuraner (**PCDD/PCDF**). Ekvivalentberegning etter nordisk modell (Ahlborg 1989) [1] eller etter internasjonal modell (Int./EPA, cf. Van_den_Berg et al.* (1998) [2] • *non-orto og mono-orto substituerte klorobifenyler etter WHO modell (Ahlborg et al. 1994) [3] eller Safe (1994, cf. NILU pers. medd.)*

ppm	parts per million, mg/kg	*deler pr. milliondeler, mg/kg*
ppb	parts per billion, µg/kg	*deler pr. milliarddeler, µg/kg*
ppp	parts per trillion, ng/kg	*deler pr. tusen-milliarddeler, ng/kg*
d.w.	dry weight basis	*tørrvekt basis*
w.w.	wet weight or fresh weight basis	*våtvekt eller friskvekt basis*

[1]) Ahlborg, U.G., 1989. Nordic risk assessment of PCDDs and PCDFs. Chemosphere 19:603-608.

[2]) Van den Berg, Birnbaum, L, Bosveld, A. T. C. and co-workers, 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Hlth. Perspect. 106:775-792.

[3]) Ahlborg, U.G., Becking G.B., Birnbaum, L.S., Brouwer, A, Derks, H.J.G.M., Feely, M., Golor, G., Hanberg, A., Larsen, J.C., Liem, A.K.G., Safe, S.H., Schlatter, C., Wärn, F., Younes, M., Yrjänheikki, E., 1994. Toxic equivalency factors for dioxin-like PCBs. Report on a WHO-ECEH and IPSC consultation, December 1993. Chemosphere 28:1049-1067.

Appendix C
Norwegian provisional high reference contaminant concentrations (PROREF) revised 2019

*Norwegian provisional high reference contaminant concentrations (PROREF) for contaminants in blue mussel (Mytilus edulis), perwinkle (Littorina littorea), dogwhelk (Nucella lapillus) and Atlantic cod (Gadus morhua) for whole soft body, liver and fillet based on MILYKYS data (see **Chapter 2.7**). All values are on a wet weight (w.w.) basis. The stations, count and total number of values used to determine PROREF are indicated. Also indicated for comparison to PROREF used previously in MILKYS reports, e.g. Green et al. (2018), and the risk-based standards (e.g. EU EQS and Water Region Specific Substances) used in this report (Norwegian_Environment_Agency 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-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
AG	Mytilus edulis	**soft body**	26A2,22A,I241,I023,I712,I131A,63A,97A2	**8**	162	mg/kg	0.009	0.0080	0.9340		
AS	Mytilus edulis	**soft body**	31A,I301,I023,30A,I712	**5**	116	mg/kg	2.503	3.3150	1.3247		
CD	Mytilus edulis	**soft body**	I241,26A2,I969	**3**	106	mg/kg	0.180	0.1800	1.0000		
CO	Mytilus edulis	**soft body**	26A2,I241	**2**	34	mg/kg	0.080	0.0791	0.9890		
CR	Mytilus edulis	**soft body**	52A,15A,26A2,I131A,64A	**5**	100	mg/kg	0.361	0.3610	1.0000		
CU	Mytilus edulis	**soft body**	I307,I712,63A,I306,I304,57A,51A,64A,I023	**9**	353	mg/kg	1.400	1.4200	1.0143		
HG	Mytilus edulis	**soft body**	36A,46A,10A2	**3**	137	mg/kg	0.012	0.0100	0.8197	0.020	1.6393
MO	Mytilus edulis	**soft body**	B7,B11,B2,B3,B6,B10,35A,B5	**8**	207	mg/kg	0.220				
NI	Mytilus edulis	**soft body**	I241,I131A,52A,57A,26A2	**5**	101	mg/kg	0.290	0.2900	1.0000		
PB	Mytilus edulis	**soft body**	11X,48A	**2**	75	mg/kg	0.195	0.1950	1.0000		
SN	Mytilus edulis	**soft body**	10A2,11X,15A,22A,26A2,30A,31A,35A,57A,63A,64A,65A,69A,71A,91A2,97A2,98A2,I023,I131A,I133,I301,I304,I306,I965,I969,I241,52A,I307,I712	**29**	625	mg/kg	0.300	0.3000	1.0000		
ZN	Mytilus edulis	**soft body**	43A,I712,48A	**3**	49	mg/kg	17.660	17.6600	1.0000		
PCB-7	Mytilus edulis	**soft body**	10A2,41A,11X,98A2,64A,97A2	**6**	194	µg/kg	1.157	0.4891	0.4228	0.600	0.5187
CB28	Mytilus edulis	**soft body**	10A2,11X,15A,22A,36A,41A,43A,44A,46A,48A,56A,57A,63A,65A,69A,84A,91A2,92A1,98A2	**19**	910	µg/kg	0.120	0.1200	1.0000		
CB52	Mytilus edulis	**soft body**	10A2,11X,15A,26A2,41A,43A,64A,65A,69A,84A,97A2,98A2	**12**	480	µg/kg	0.200	0.2000	1.0000		
CB77	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg	0.010	0.0111	1.1054		
CB81	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg		0.0005			
CB101	Mytilus edulis	**soft body**	43A,48A,98A2,97A2,10A2,64A,26A2,11X,41A	**9**	245	µg/kg	0.200	0.2000	1.0000		
CB105	Mytilus edulis	**soft body**	10A2,11X,15A,41A,43A,46A,48A	**7**	208	µg/kg	0.150	0.1500	1.0000		
CB118	Mytilus edulis	**soft body**	43A	**1**	15	µg/kg	0.070	0.0730	1.0429		
CB126	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg		0.0010			
CB138	Mytilus edulis	**soft body**	43A,10A2,11X,41A	**4**	153	µg/kg	0.200	0.2040	1.0200		
CB153	Mytilus edulis	**soft body**	43A,11X,10A2,41A	**4**	153	µg/kg	0.260	0.2600	1.0000		
CB156	Mytilus edulis	**soft body**	10A2,11X,15A,22A,35A,36A,41A,43A,44A,46A,48A	**11**	399	µg/kg	0.150	0.1500	1.0000		
CB169	Mytilus edulis	**soft body**	76A	**1**	18	µg/kg		0.0001			
CB180	Mytilus edulis	**soft body**	10A2,11X,15A,22A,26A2	**5**	282	µg/kg	0.100	0.1000	1.0000		
DDEPP	Mytilus edulis	**soft body**	43A,41A,10A2,11X	**4**	147	µg/kg	0.224	0.2240	1.0000	610.000	2 723.2143
DDTEP	Mytilus edulis	**soft body**	84A,36A,71A,31A	**4**	107	µg/kg	3.000				
DDTPP	Mytilus edulis	**soft body**	10A2,11X,15A,22A,30A,31A,36A,71A,76A,98A2,I022,I023,I024,I131A,I132,I133,I304,I306,I307,I712	**20**	644	µg/kg	0.600	0.6000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
TDEPP	Mytilus edulis	**soft body**	41A,43A,44A,46A,48A,92A1	**6**	93	µg/kg	0.100	0.1000	1.0000		
HCB	Mytilus edulis	**soft body**	48A,43A,15A,22A,46A,41A,98A2,11X,30A,10A2,36A	**11**	473	µg/kg	0.100	0.1000	1.0000	10.000	100.0000
HBCDA	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.110	0.1099	1.0000	167.000	1 520.2549
HBCDG	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.030	0.0317	1.0577		
HBCDB	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.020	0.0199	0.9925		
HBCDD	Mytilus edulis	**soft body**	I023,97A2,91A2	**3**	44	µg/kg	0.147	0.1396	0.9513		
BDESS	Mytilus edulis	**soft body**	98A2	**1**	16	µg/kg	0.193	0.193	1.0000		
BDE6	Mytilus edulis	**soft body**	98A2,26A2,91A2,71A,I023,97A2,30A	**7**	109	µg/kg	0.408	0.1900	0.4657	0.009	0.0208
BDE47	Mytilus edulis	**soft body**	98A2,26A2,71A,I023,91A2,30A	**6**	94	µg/kg	0.171	0.1410	0.8270	0.009	0.0499
BDE99	Mytilus edulis	**soft body**	98A2,91A2,26A2,I023	**4**	61	µg/kg	0.060	0.0600	1.0000		
BDE100	Mytilus edulis	**soft body**	98A2,26A2,I023,91A2,71A	**5**	79	µg/kg	0.050	0.0510	1.0200		
BDE126	Mytilus edulis	**soft body**	71A,97A2,26A2,I023,91A2	**5**	75	µg/kg	0.050	0.0500	1.0000		
BDE153	Mytilus edulis	**soft body**	97A2,26A2,I023,91A2,71A,98A2,30A	**7**	109	µg/kg	0.050	0.0500	1.0000		
BDE154	Mytilus edulis	**soft body**	97A2,26A2,I023,91A2,71A,98A2,30A	**7**	109	µg/kg	0.050	0.0500	1.0000		
BDE183	Mytilus edulis	**soft body**	71A,97A2,26A2,I023,91A2,98A2	**6**	92	µg/kg	0.300	0.3000	1.0000		
BDE196	Mytilus edulis	**soft body**	71A,97A2,26A2,I023,91A2	**5**	75	µg/kg	0.300	0.3000	1.0000		
BDE209	Mytilus edulis	**soft body**	71A,97A2,91A2,I023,26A2	**5**	75	µg/kg	1.290	1.2920	1.0016		
SCCP	Mytilus edulis	**soft body**	I023,71A,91A2,97A2,26A2,30A	**6**	90	µg/kg	20.260	20.2600	1.0000	6 000.000	296.1500
MCCP	Mytilus edulis	**soft body**	I023,26A2,71A,91A2,97A2,30A	**6**	89	µg/kg	87.600	87.6000	1.0000	170.000	1.9406
PAH16	Mytilus edulis	**soft body**	98A2,I023	**2**	32	µg/kg	33.828	33.8280	1.0000		
PAH-sum	Mytilus edulis	**soft body**	98A2,I023	**2**	32	µg/kg	30.050				
KPAH	Mytilus edulis	**soft body**	98A2	**1**	17	µg/kg	0.622				
ACNE	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A	**5**	177	µg/kg	0.800	0.8000	1.0000		
ACNLE	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A,I132,I133	**7**	266	µg/kg	1.000	1.0000	1.0000		
ANT	Mytilus edulis	**soft body**	98A2,I131A,I307,I915,I913,71A	**6**	208	µg/kg	0.800	1.1000	1.3750	2 400.000	3 000.0000
BAA	Mytilus edulis	**soft body**	I023,98A2	**2**	32	µg/kg	1.490	1.4900	1.0000	300.000	201.3423
BAP	Mytilus edulis	**soft body**	98A2,I307,I131A,I306,I304,30A,I913	**7**	354	µg/kg	1.200	1.3000	1.0833	5.000	4.1667
BBJF	Mytilus edulis	**soft body**	98A2,I023,I304,I306,I307	**5**	107	µg/kg	6.240	6.2400	1.0000		
BBJKF	Mytilus edulis	**soft body**	I304,I306,I307,30A	**4**	96	µg/kg	3.925				
BGHIP	Mytilus edulis	**soft body**	98A2,I023,I304,I306,I307,I913,71A	**7**	254	µg/kg	2.070	2.0700	1.0000		
BKF	Mytilus edulis	**soft body**	30A,98A2,I023,I304,I306,I307,I913	**7**	167	µg/kg	1.500	1.5000	1.0000		
CHR	Mytilus edulis	**soft body**	98A2	**1**	17	µg/kg	0.520	0.5180	0.9962		
DBA3A	Mytilus edulis	**soft body**	30A,I131A	**2**	117	µg/kg	0.500	0.5000	1.0000		
FLE	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A,I304,I306,I307,I915	**9**	364	µg/kg	1.600	1.6000	1.0000		
FLU	Mytilus edulis	**soft body**	98A2,I023	**2**	32	µg/kg	5.350	5.3500	1.0000	30.000	5.6075
ICDP	Mytilus edulis	**soft body**	30A,71A,98A2,I023,I131A	**5**	176	µg/kg	1.730	1.7250	0.9971		
NAP	Mytilus edulis	**soft body**	I023,98A2,71A	**3**	47	µg/kg	17.300	17.3000	1.0000	2 400.000	138.7283
PA	Mytilus edulis	**soft body**	98A2,I023,71A	**3**	47	µg/kg	2.280	2.2800	1.0000		
PYR	Mytilus edulis	**soft body**	98A2	**1**	17	µg/kg	1.020	1.0200	1.0000		
TBT	Mytilus edulis	**soft body**	11X	**1**	20	µg/kg	7.107	7.1065	1.0000	150.000	21.1074
TCHT	Mytilus edulis	**soft body**	I301,I133,22A,30A	**4**	65	µg/kg	2.000	2.0000	1.0000		

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
MBTIN	Mytilus edulis	**soft body**	22A	**1**	14	µg/kg	0.860	0.8638	1.0044		
DBTIN	Mytilus edulis	**soft body**	30A,I131A,I201,I205,I304,I306,I307	**7**	317	µg/kg	4.770	4.7680	0.9996		
TBEP	Mytilus edulis	**soft body**	26A2,I023,91A2,97A2,30A	**5**	71	µg/kg	11.300	11.3000	1.0000		
TBP	Mytilus edulis	**soft body**	30A,I023,97A2,26A2,91A2	**5**	71	µg/kg	5.960	5.9550	0.9992		
TCEP	Mytilus edulis	**soft body**	26A2,I023,91A2,97A2,30A	**5**	71	µg/kg	55.500	55.5000	1.0000		
TCPP	Mytilus edulis	**soft body**	30A,26A2,97A2,91A2	**4**	56	µg/kg	40.250	40.2500	1.0000		
TDCP	Mytilus edulis	**soft body**	26A2,91A2,97A2,I023,30A	**5**	71	µg/kg	8.930	8.9250	0.9994		
TEHP	Mytilus edulis	**soft body**	26A2,I023,91A2,97A2,30A	**5**	71	µg/kg	23.950	23.9500	1.0000		
TIBP	Mytilus edulis	**soft body**	30A,I023,26A2,97A2,91A2	**5**	71	µg/kg	9.900	9.9000	1.0000		
EHDPP	Mytilus edulis	**soft body**	30A,26A2,I023,91A2,97A2	**5**	71	µg/kg	11.050	11.0500	1.0000		
BPA	Mytilus edulis	**soft body**	30A,97A2,I023	**3**	45	µg/kg	7.450	7.4460	0.9995		
TBBPA	Mytilus edulis	**soft body**	30A,97A2,26A2,I023,71A,91A2	**6**	87	µg/kg	0.270	0.2669	0.9885		
Delta13C	Mytilus edulis	**soft body**	97A2,22A,26A2,15A	**4**	60	‰	20.450	-20.4470	-0.9999		
Delta15N	Mytilus edulis	**soft body**	56A,51A	**2**	30	‰	3.770	3.7743	1.0011		
C/N	Mytilus edulis	**soft body**	15A,71A,I304,22A,30A,I023,97A2,56A	**8**	120	%	4.980	4.9810	1.0002		
DOT	Mytilus edulis	**soft body**	I301,I133,22A,30A	**4**	65	µg/kg	0.990	0.9900	1.0000		
MOT	Mytilus edulis	**soft body**	I301,I133,22A,30A	**4**	65	µg/kg	0.990	0.9900	1.0000		
MBT	Littorina littorea	**soft body**	71G	**1**	5	µg/kg	1.344				
DBT	Littorina littorea	**soft body**	71G	**1**	5	µg/kg	1.964				
TTBT	Nucella lapillus	**soft body**	15G,76G,22G,131G,36G,11G,227G	**7**	35	µg/kg	1.015				
TBT	Nucella lapillus	**soft body**	11G,131G,15G,98G	**4**	66	µg/kg	23.540	23.5350	0.9998	150.000	6.3721
TCHT	Nucella lapillus	**soft body**	76G,22G,131G,11G,36G,15G,98G,227G1	**8**	55	µg/kg	2.330	2.3300	1.0000		
MBTIN	Nucella lapillus	**soft body**	22G,98G,36G,11G,15G,76G,131G,227G1	**8**	47	µg/kg	2.180	2.1770	0.9986		
DBTIN	Nucella lapillus	**soft body**	11G,131G,15G,98G,36G,22G,76G	**7**	42	µg/kg	1.200	1.2000	1.0000		
MPTIN	Nucella lapillus	**soft body**	71G	**1**	5	µg/kg	2.624				
DPTIN	Nucella lapillus	**soft body**	71G	**1**	5	µg/kg	1.940				
TPhT	Nucella lapillus	**soft body**	71G	**1**	6	µg/kg	1.650	1.6463	0.9977		
VDSI	Nucella lapillus	**soft body**	11G,15G,131G,76G	**4**	63	Index	3.680	3.6832	1.0009		
DOT	Nucella lapillus	**soft body**	76G,22G,131G,36G,15G,11G,98G,227G1	**8**	55	µg/kg	1.200	1.2000	1.0000		
MOT	Nucella lapillus	**soft body**	76G,22G,131G,36G,15G,11G,98G,227G1	**8**	55	µg/kg	1.200	1.2000	1.0000		
AG	Gadus morhua	**Liver**	80B,10B	**2**	229	mg/kg	0.930	0.9256	0.9953		
AS	Gadus morhua	**Liver**	10B,13B,80B,43B2,71B,15B	**6**	721	mg/kg	12.800	12.8000	1.0000		
CD	Gadus morhua	**Liver**	80B,67B,15B,23B	**4**	1655	mg/kg	0.137	0.1365	1.0000		
CO	Gadus morhua	**Liver**	43B2	**1**	145	mg/kg	0.060	0.0584	0.9733		
CR	Gadus morhua	**Liver**	10B,15B,71B,43B2,80B,13B,36B,30B,98B1	**9**	1176	mg/kg	0.400	0.4025	1.0063		
CU	Gadus morhua	**Liver**	10B,15B,80B	**3**	1101	mg/kg	14.000	14.0000	1.0000		
NI	Gadus morhua	**Liver**	15B,23B,43B2,10B,71B,80B,53B,36B	**8**	973	mg/kg	0.650	0.6500	1.0000		
PB	Gadus morhua	**Liver**	92B,36B,67B,43B,15B,43B2,98B1,10B,23B,80B	**10**	3588	mg/kg	0.050	0.0500	1.0000		
SN	Gadus morhua	**Liver**	10B,15B,23B,36B,43B2,53B,71B,80B,13B,98B1,30B	**11**	1381	mg/kg	0.300	0.3000	1.0000		
ZN	Gadus morhua	**Liver**	98B1,10B,92B,43B2,80B	**5**	1351	mg/kg	35.000	35.0000	1.0000		
PCB-7	Gadus morhua	**Liver**	98B1,10B,92B,43B	**4**	1229	µg/kg	614.000	614.0000	1.0000	0.600	0.0010

Parame-ter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
CB28	Gadus morhua	**Liver**	80B,98B1,23B,67B,10B,43B,92B,53B,43B2	**9**	3039	µg/kg	8.000	8.0000	1.0000		
CB52	Gadus morhua	**Liver**	67B,23B,98B1	**3**	1385	µg/kg	16.000	16.0000	1.0000		
CB101	Gadus morhua	**Liver**	23B	**1**	554	µg/kg	32.350	32.3500	1.0000		
CB118	Gadus morhua	**Liver**	98B1,23B,10B,92B,43B,67B,80B	**7**	2359	µg/kg	100.000	100.0000	1.0000		
CB138	Gadus morhua	**Liver**	98B1,10B,43B,92B	**4**	1282	µg/kg	157.950	157.9500	1.0000		
CB153	Gadus morhua	**Liver**	98B1,10B,92B,43B	**4**	1282	µg/kg	189.950	189.9500	1.0000		
CB180	Gadus morhua	**Liver**	98B1,10B,92B	**3**	1165	µg/kg	45.800	45.8000	1.0000		
DDEPP	Gadus morhua	**Liver**	23B,10B,98B1	**3**	1498	µg/kg	160.750	160.7500	1.0000	610.000	3.7947
DDTPP	Gadus morhua	**Liver**	10B,23B,36B,98B1	**4**	885	µg/kg	13.000	13.0000	1.0000		
TDEPP	Gadus morhua	**Liver**	23B,92B,36B	**3**	1303	µg/kg	32.000	32.0000	1.0000		
HCHA	Gadus morhua	**Liver**	53B,15B,36B,10B,23B,30B,67B,92B,43B,98B1	**10**	4071	µg/kg	8.000	8.0000	1.0000		
HCHG	Gadus morhua	**Liver**	53B,10B,92B,36B	**4**	1602	µg/kg	11.000	12.0000	1.0909	61.000	5.5455
HCB	Gadus morhua	**Liver**	36B,53B	**2**	1079	µg/kg	14.000	14.0000	1.0000	10.000	0.7143
4-N-NP	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	131.000	131.0000	1.0000	3 000.000	22.9008
4-N-OP	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	23.500	23.5000	1.0000	0.004	0.0002
4-T-NP	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	240.900	240.9000	1.0000	3 000.000	12.4533
4-T-OP	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	20.000	20.0000	1.0000	0.004	0.0002
CYP1A	Gadus morhua	**Liver**	23B,53B	**2**	487		2.070	2.0669	0.9985		
EROD	Gadus morhua	**Liver**	23B,53B,36B,30B	**4**	1303	pmol/min/mg protein	192.290	192.2861	1.0000		
HBCDA	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	7.000	7.0000	1.0000	167.000	23.8571
HBCDG	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	0.890	0.8948	1.0054		
HBCDB	Gadus morhua	**Liver**	43B2,80B	**2**	135	µg/kg	0.400	0.4030	1.0075		
HBCDD	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	7.180	7.1960	1.0022		
BDESS	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	21.420	21.4200	1.0000		
BDE6	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	19.882	19.8800	1.0000	0.009	0.0004
BDE28	Gadus morhua	**Liver**	36B,13B,98B1,23B,43B2	**5**	701	µg/kg	1.400	1.4000	1.0000		
BDE47	Gadus morhua	**Liver**	98B1,36B,23B	**3**	557	µg/kg	16.000	16.0000	1.0000	0.009	0.0005
BDE49	Gadus morhua	**Liver**	23B,98B1	**2**	266	µg/kg	3.950				
BDE66	Gadus morhua	**Liver**	23B,98B1	**2**	266	µg/kg	0.595				
BDE71	Gadus morhua	**Liver**	98B1,23B,53B,30B	**4**	553	µg/kg	0.400				
BDE77	Gadus morhua	**Liver**	30B	**1**	122	µg/kg	1.690				
BDE85	Gadus morhua	**Liver**	98B1,53B,23B,30B	**4**	536	µg/kg	1.725				
BDE99	Gadus morhua	**Liver**	13B,23B	**2**	363	µg/kg	0.750	0.7540	1.0053		
BDE100	Gadus morhua	**Liver**	98B1	**1**	173	µg/kg	2.600	2.6000	1.0000		
BDE126	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,80B	**6**	419	µg/kg	0.100	0.1000	1.0000		
BDE138	Gadus morhua	**Liver**	30B,23B,53B,98B1	**4**	561	µg/kg	0.300				
BDE153	Gadus morhua	**Liver**	13B,23B	**2**	363	µg/kg	0.150	0.1490	0.9933		
BDE154	Gadus morhua	**Liver**	98B1,36B	**2**	323	µg/kg	1.500	1.5000	1.0000		
BDE183	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,53B,80B,98B1	**8**	1360	µg/kg	0.600	0.6005	1.0008		
BDE196	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,53B,80B,98B1	**8**	1142	µg/kg	1.000	1.0000	1.0000		

Parameter code	Species	Tissue	Reference stations	Station count	Value count	Unit on wet wt. Basis	PROREF-2019	PROREF-2017	PROREF-2017 / PROREF-2019	EQS	EQS/ PROREF-2019
BDE205	Gadus morhua	**Liver**	23B,30B,98B1,53B	**4**	559	µg/kg	1.500				
BDE209	Gadus morhua	**Liver**	13B	**1**	131	µg/kg	2.000	2.0000	1.0000		
SCCP	Gadus morhua	**Liver**	23B,43B2,80B	**3**	245	µg/kg	154.000	154.0000	1.0000	6 000.000	38.9610
MCCP	Gadus morhua	**Liver**	23B,43B2	**2**	174	µg/kg	392.800	392.8000	1.0000	170.000	0.4328
PFAS	Gadus morhua	**Liver**	43B2,80B	**2**	251	µg/kg	11.000	20.0000	1.8182		
PFNA	Gadus morhua	**Liver**	13B,23B,30B,36B,43B2,80B,98B1,53B	**8**	1315	µg/kg	5.000	5.0000	1.0000		
PFOA	Gadus morhua	**Liver**	43B2,13B,80B,53B,36B,98B1,23B,30B	**8**	1289	µg/kg	10.000	10.0000	1.0000	91.000	9.1000
PFOS	Gadus morhua	**Liver**	43B2,80B	**2**	251	µg/kg	10.250	10.2500	1.0000	9.100	0.8878
PFOSA	Gadus morhua	**Liver**	43B2,98B1,53B,80B,23B	**5**	718	µg/kg	6.245	6.2450	1.0000		
PFBS	Gadus morhua	**Liver**	13B,36B,43B2,53B,80B,23B,30B,98B1	**8**	1316	µg/kg	8.000	8.0000	1.0000		
TBEP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
TBP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
TCEP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	477.200	477.2000	1.0000		
TCPP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	67.600	67.6000	1.0000		
TDCP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	71.120	71.1200	1.0000		
TEHP	Gadus morhua	**Liver**	43B2	**1**	64	µg/kg	334.150	334.1500	1.0000		
TIBP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	135.000	135.0000	1.0000		
EHDPP	Gadus morhua	**Liver**	43B2	**1**	65	µg/kg	66.420	66.4200	1.0000		
BPA	Gadus morhua	**Liver**	43B2,80B	**2**	134	µg/kg	2.000	2.0000	1.0000		
TBBPA	Gadus morhua	**Liver**	80B,43B2	**2**	135	µg/kg	0.570	0.5675	0.9956		
HG	Gadus morhua	**Fillet**	10B	**1**	504	mg/kg	0.056	0.0600	1.0714	0.020	0.3571
ALAD	Gadus morhua	**Blood**	53B	**1**	395	ng/min/mg protein	34.940	34.9390	1.0000		
BAP3O	Gadus morhua	**Bile**	30B,15B	**2**	305	µg/kg	2.780	2.7828	1.0010		
PA1O	Gadus morhua	**Bile**	23B,15B,30B,53B	**4**	800	µg/kg	6.150	6.1542	1.0007		
PYR1O	Gadus morhua	**Bile**	23B	**1**	398	µg/kg	15.840	15.8370	0.9998		
TBT	Littorina/Nucella	**soft body**	11G,15G,131G,98G	**4**	66	µg/kg	23.535				

Appendix D
Maps of stations

Nominal station positions 1981-2020
(cf. Appendix E)

Appendix D (cont.) Map of stations

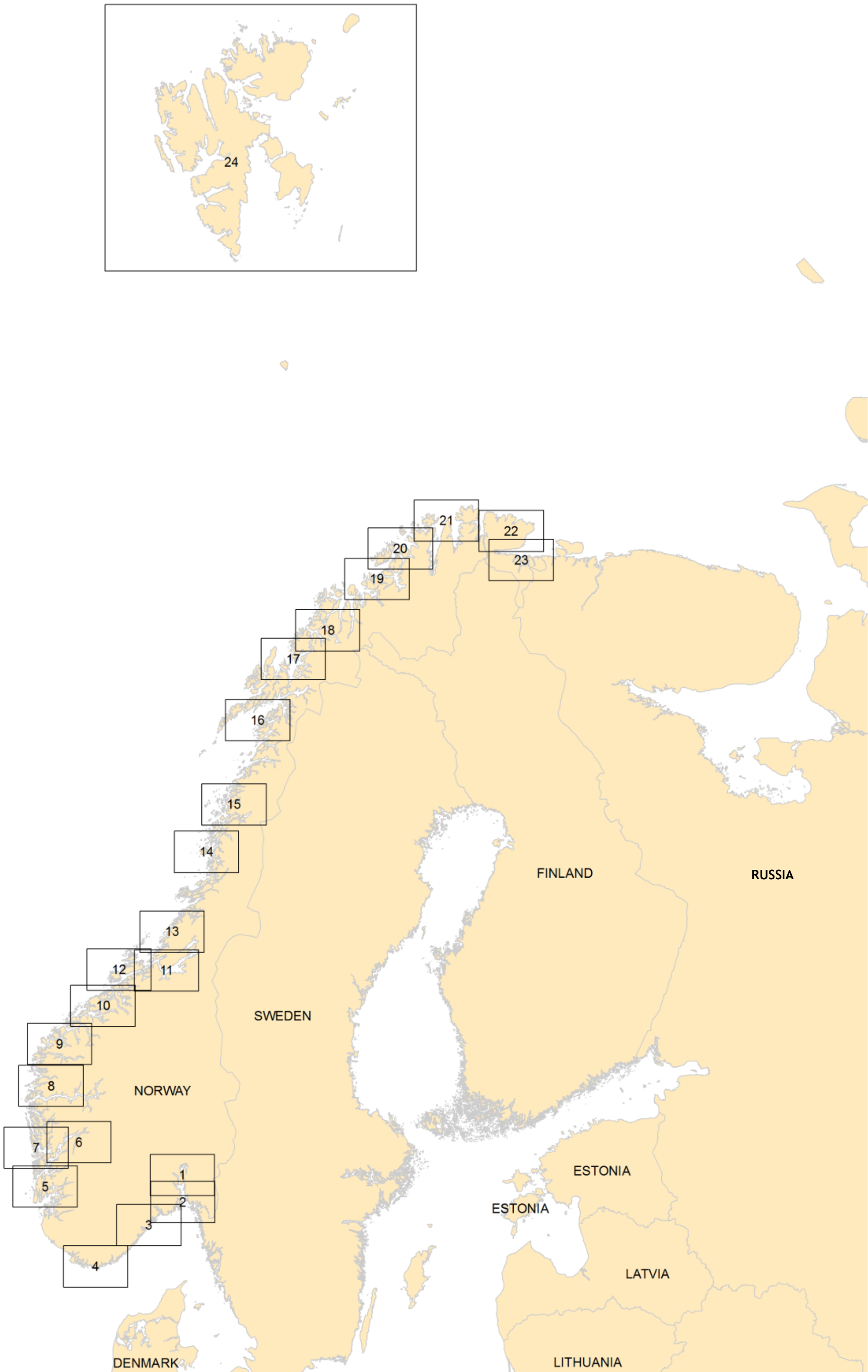
NOTES

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 ESRI ArcGIS version 10.4.

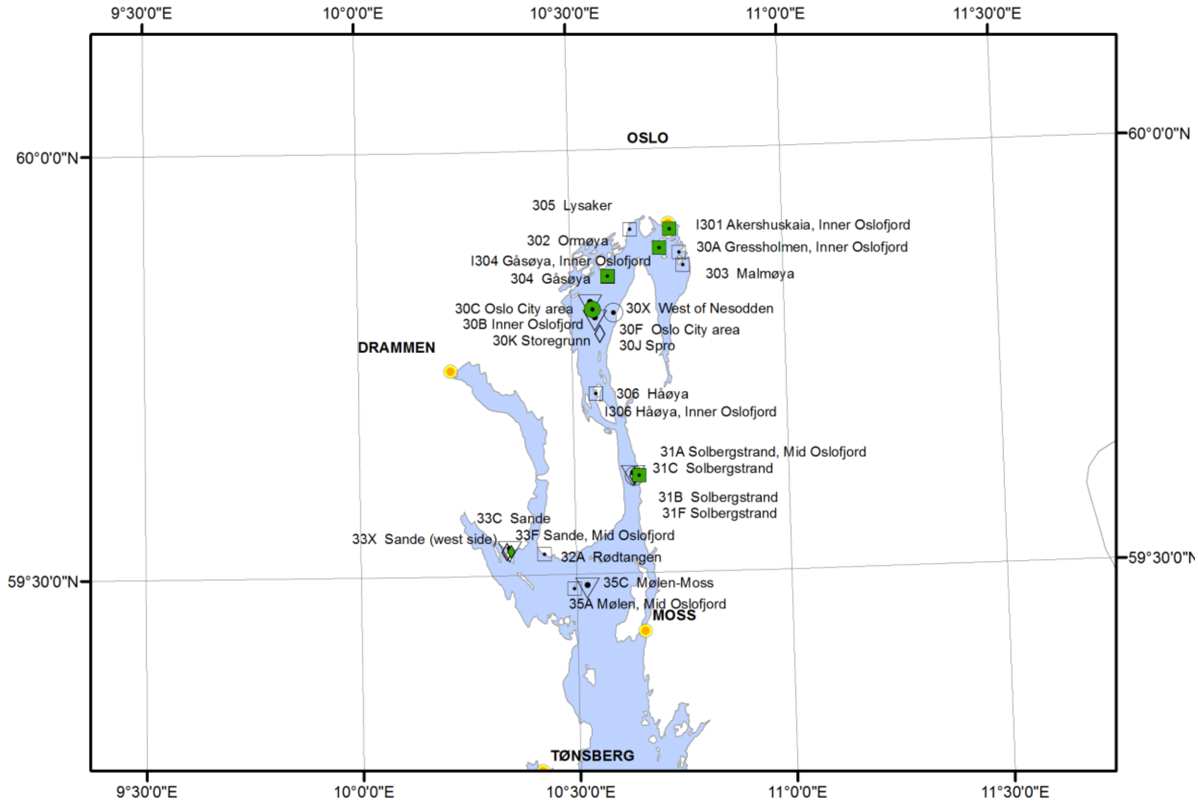
The following symbols and codes apply:

All years	2020	Explanation	Station code
		Sediment	<number>S
		Blue mussel	<number>A
		Blue mussel	I<number/letter> [1)]
		Blue mussel	R<number/letter> [1)]
		Dogwhelk/Periwinkle	<number>G
		Prawn	<number>C
		Atlantic cod	<number>B
		Flatfish	<number>F
		Other round fish	
		Common eider duck	<number>N
		Town or city	

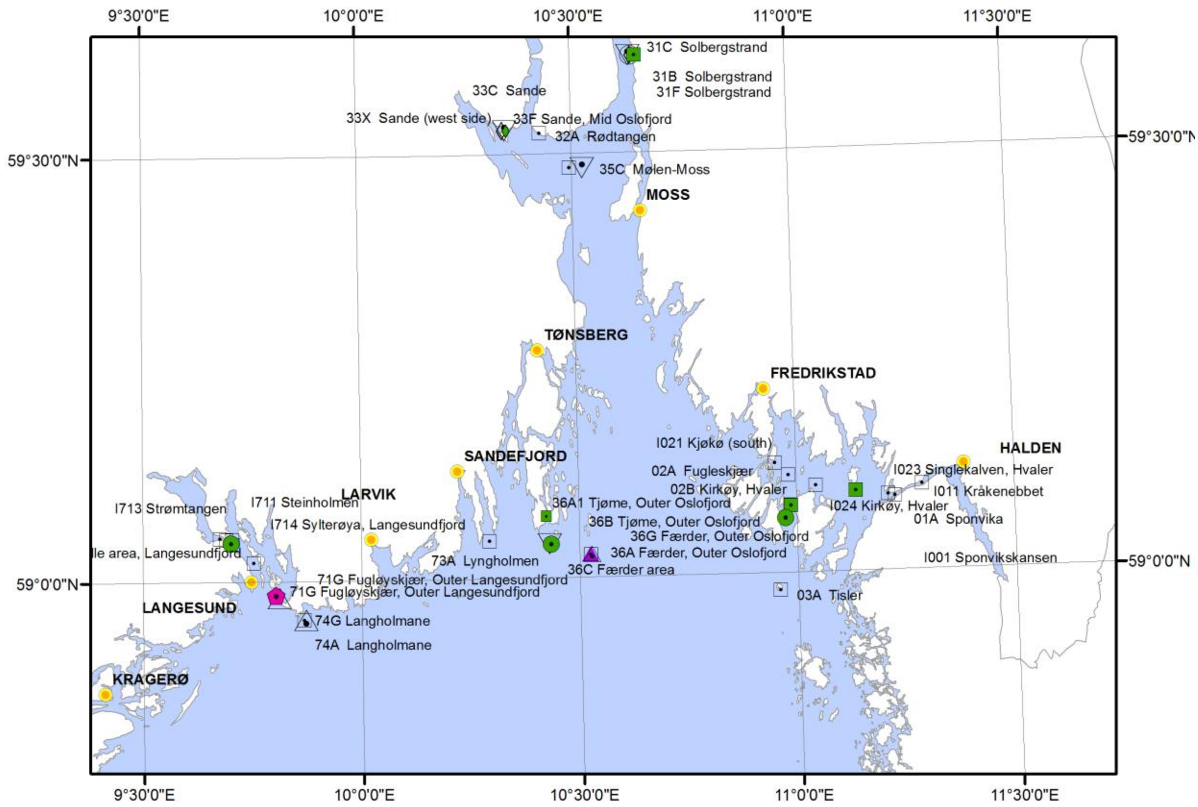
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (Green et al. 2011).



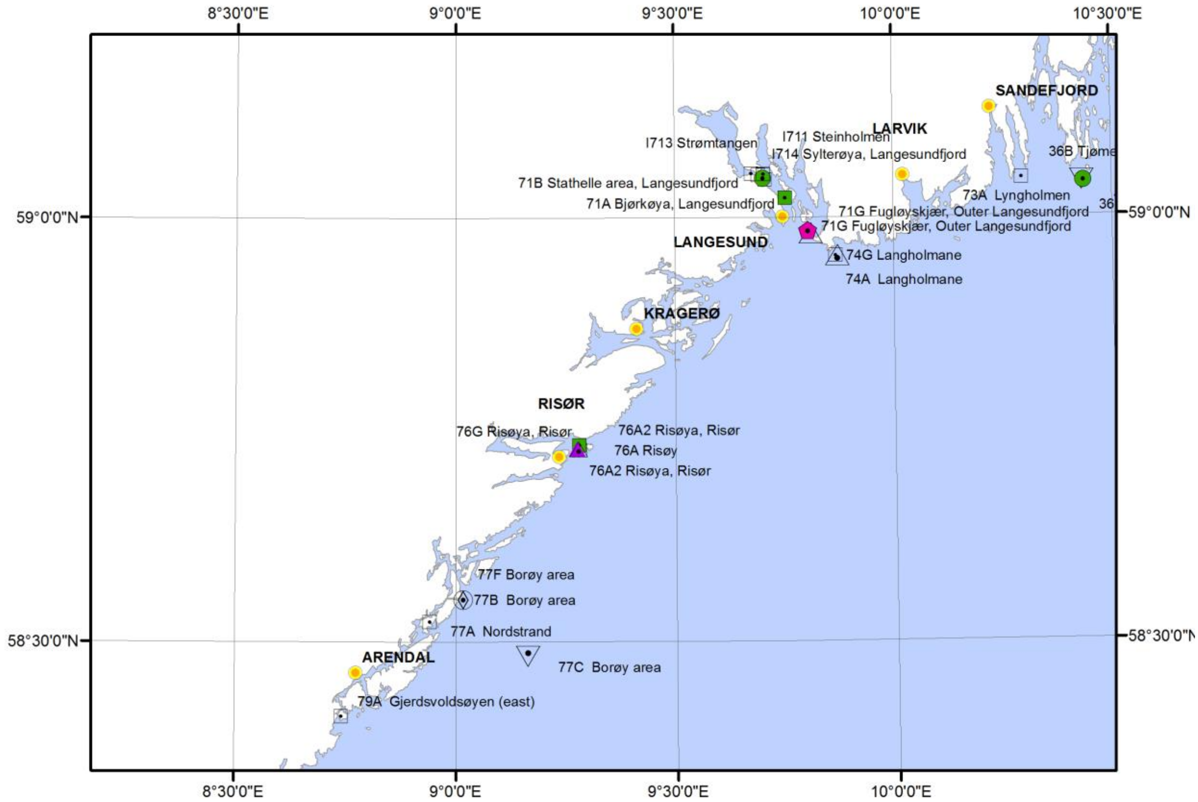
Maps presenting MILKYS stations in Norway. Numbers refer to map references that follow.


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
60°0'0"N
59°30'0"N
OSLO
DRAMMEN
MOSS
TØNSBERG
305 Lysaker
302 Ormøya
I304 Gåsøya, Inner Oslofjord
304 Gåsøya
I301 Akershuskaia, Inner Oslofjord
30A Gressholmen, Inner Oslofjord
303 Malmøya
30C Oslo City area
30B Inner Oslofjord
30K Storegrunn
30X West of Nesodden
30F Oslo City area
30J Spro
306 Håøya
I306 Håøya, Inner Oslofjord
31A Solbergstrand, Mid Oslofjord
31C Solbergstrand
31B Solbergstrand
31F Solbergstrand
33C Sande
33X Sande (west side)
33F Sande, Mid Oslofjord
32A Rødtangen
35C Mølen-Moss
35A Mølen, Mid Oslofjord

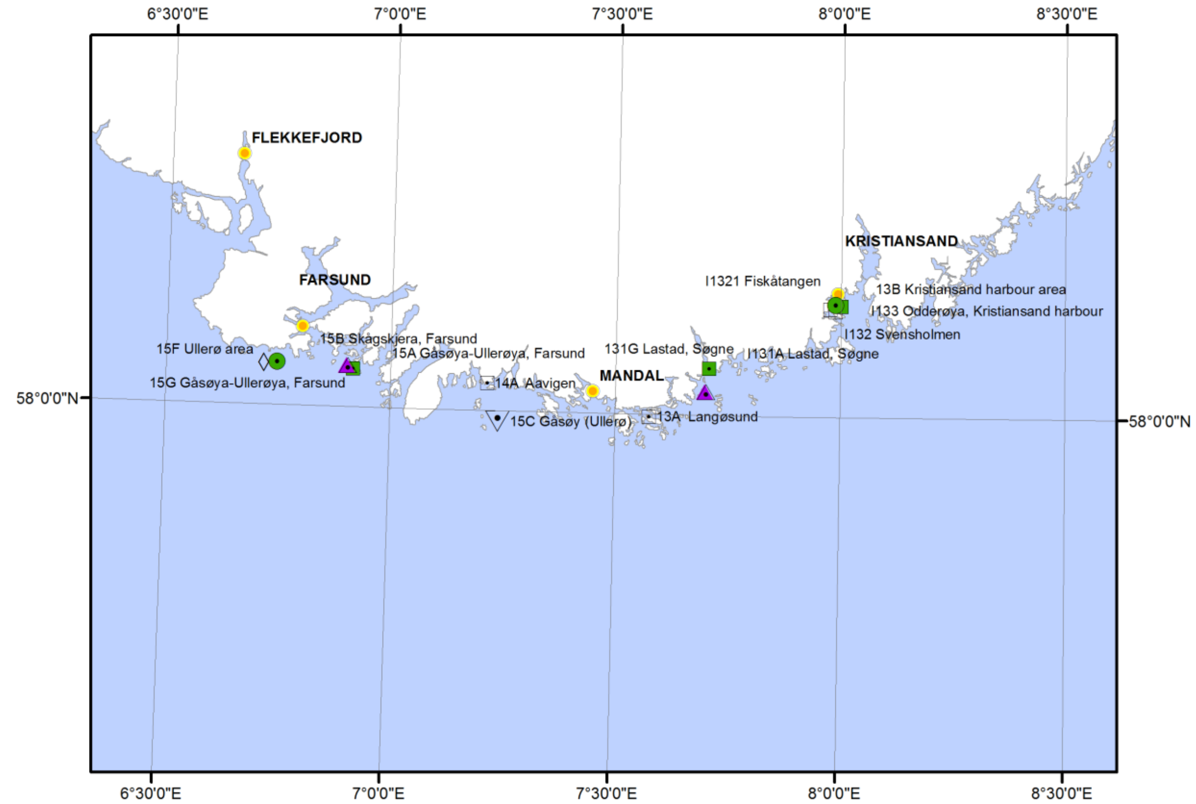
MAP 1


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
59°30'0"N
59°0'0"N
31C Solbergstrand
31B Solbergstrand
31F Solbergstrand
33C Sande
33X Sande (west side)
33F Sande, Mid Oslofjord
32A Rødtangen
35C Mølen-Moss
MOSS
TØNSBERG
FREDRIKSTAD
HALDEN
SANDEFJORD
LARVIK
LANGESUND
KRAGERØ
I021 Kjøkø (south)
02A Fugleskjær
02B Kirkøy, Hvaler
I023 Singlekalven, Hvaler
I011 Kråkenebbet
I024 Kirkøy, Hvaler
01A Sponvika
I001 Sponvikskansen
03A Tisler
36A1 Tjøme, Outer Oslofjord
36B Tjøme, Outer Oslofjord
36G Færder, Outer Oslofjord
36A Færder, Outer Oslofjord
36C Færder area
73A Lyngholmen
I713 Strømtangen
I711 Steinholmen
I714 Sylterøya, Langesundfjord
lle area, Langesundfjord
71G Fugløyskjær, Outer Langesundfjord
71G Fugløyskjær, Outer Langesundfjord
74G Langholmane
74A Langholmane

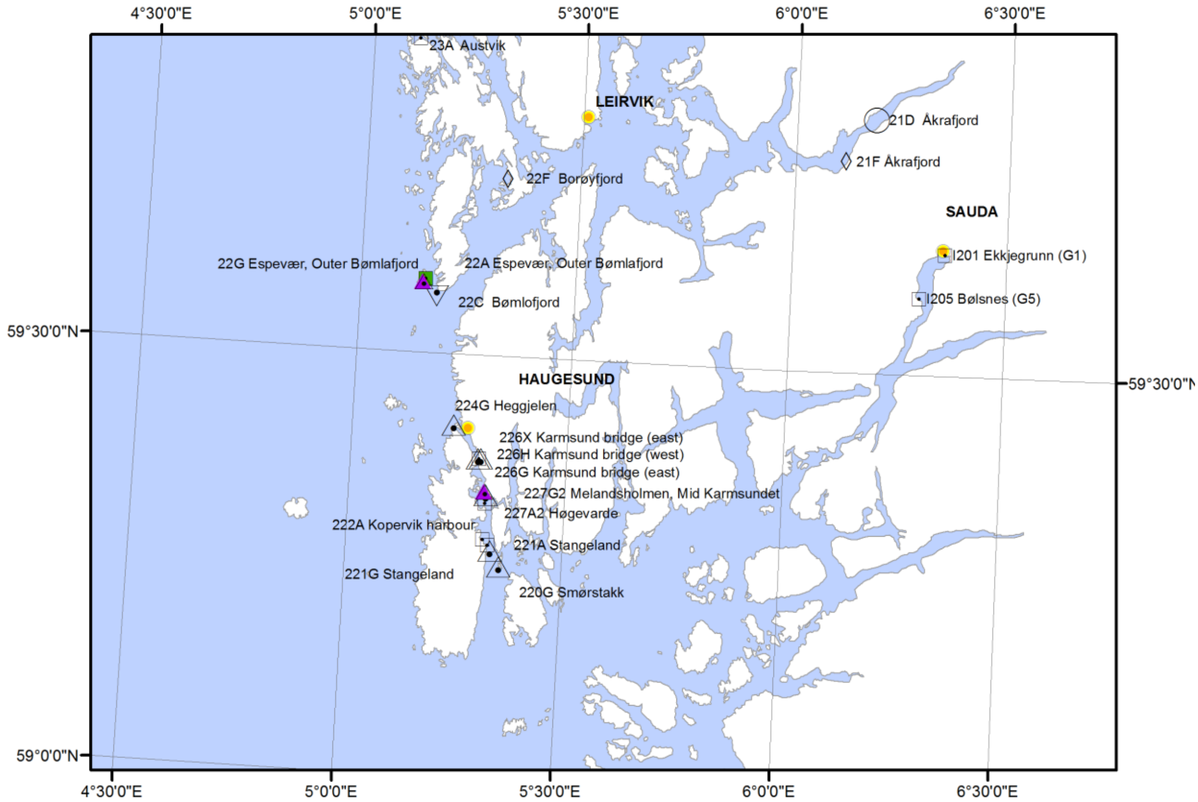
MAP 2


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
I711 Steinholmen
I713 Strømtangen
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)

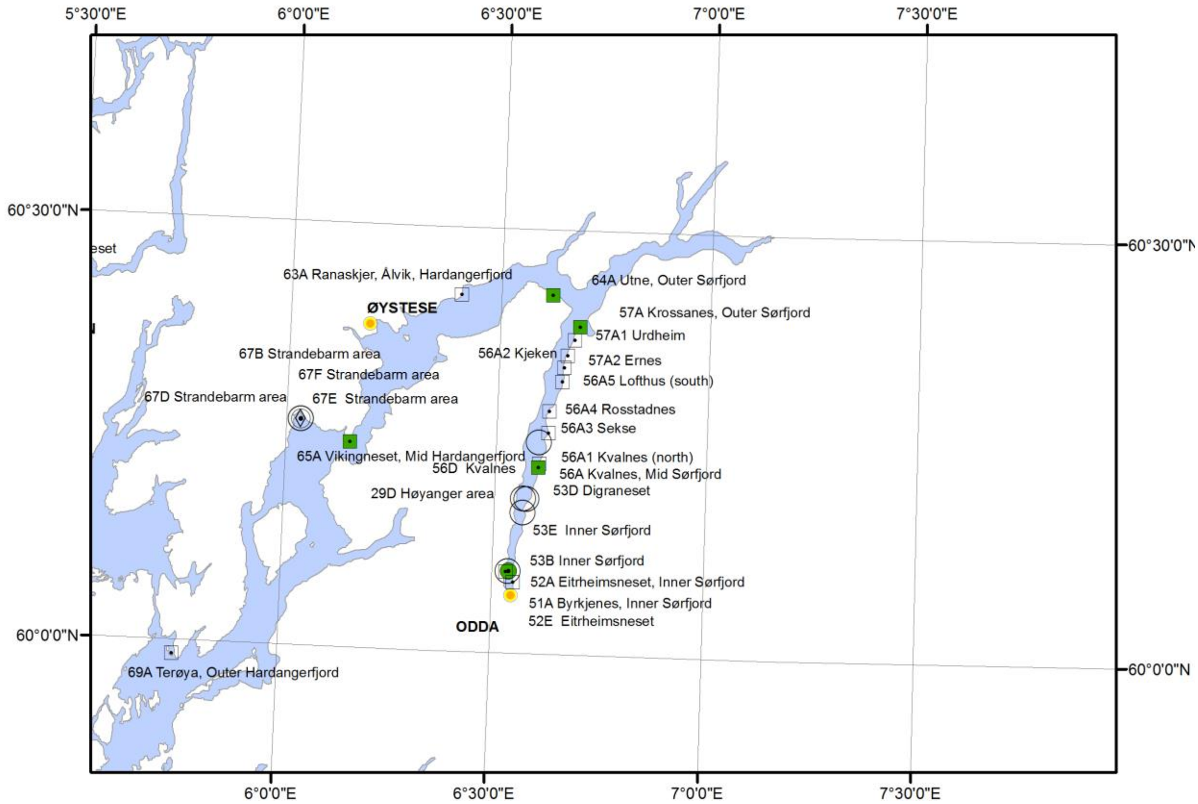
MAP 3


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 Skågskjera, Farsund
15F Ullerø area
15A Gåsøya-Ullerøya, Farsund
131G Lastad, Søgne
I131A Lastad, Søgne
15G Gåsøya-Ullerøya, Farsund
14A Aavigen
MANDAL
15C Gåsøy (Ullerø)
13A Langøsund

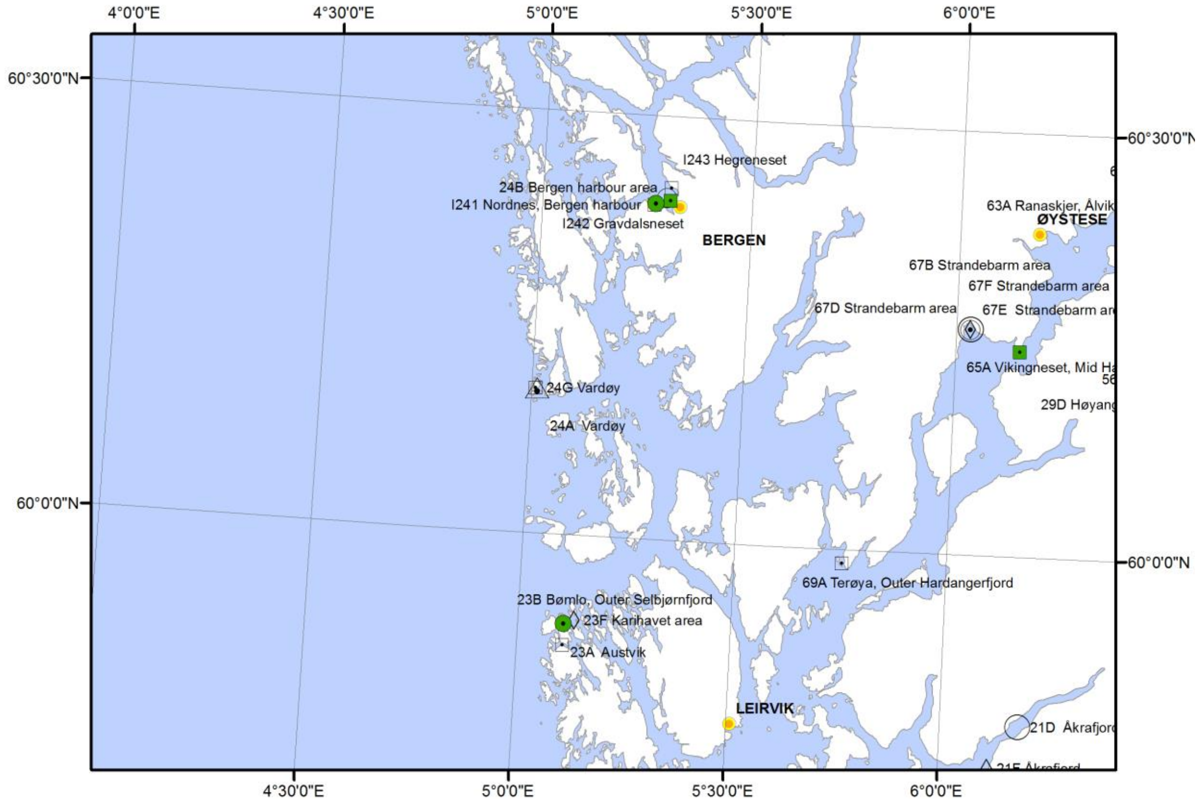
MAP 4


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
23A Austvik
LEIRVIK
21D Åkrafjord
21F Åkrafjord
22F Borøyfjord
SAUDA
I201 Ekkjegrunn (G1)
22G Espevær, Outer Bømlafjord
22A Espevær, Outer Bømlafjord
I205 Bølsnes (G5)
22C Bømlofjord
59°30'0"N
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
59°0'0"N

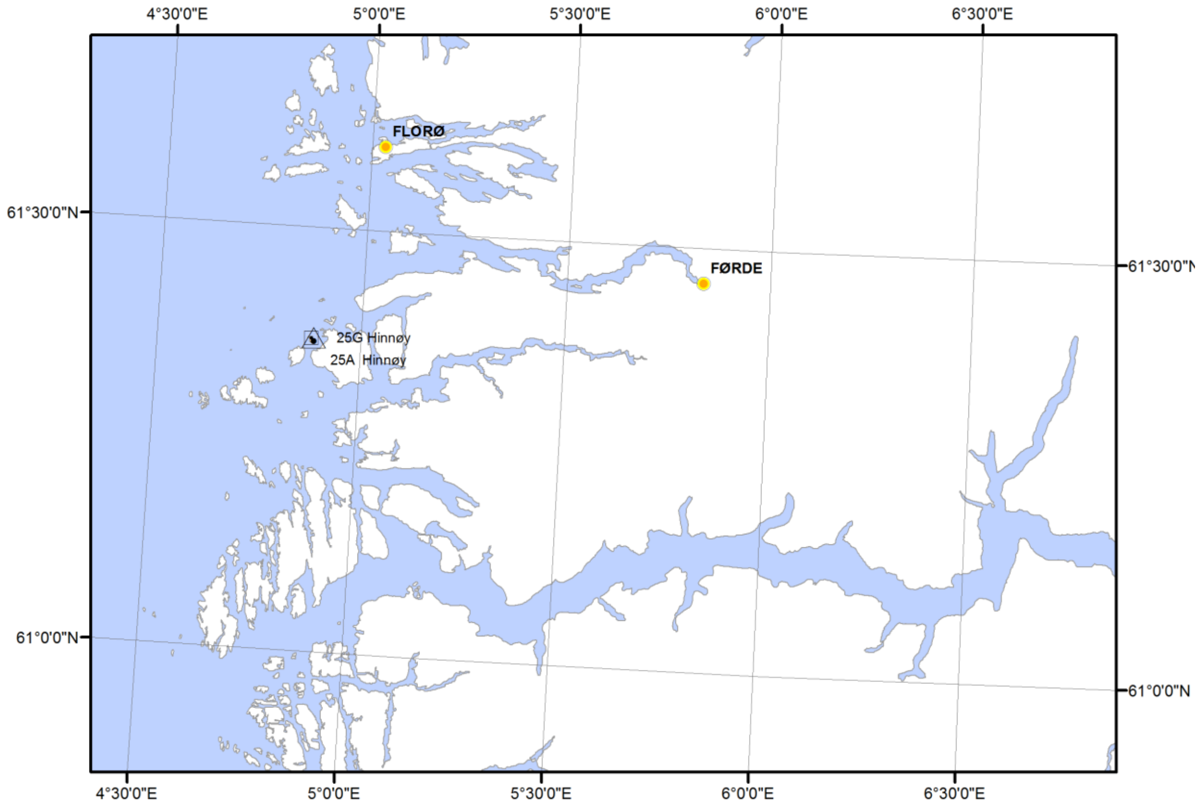
MAP 5


5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E
7°30'0"E
60°30'0"N
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
56D Kvalnes
56A1 Kvalnes (north)
56A Kvalnes, Mid Sørfjord
29D Høyanger area
53D Digraneset
53E Inner Sørfjord
53B Inner Sørfjord
52A Eitrheimsneset, Inner Sørfjord
51A Byrkjenes, Inner Sørfjord
ODDA
52E Eitrheimsneset
60°0'0"N
69A Terøya, Outer Hardangerfjord

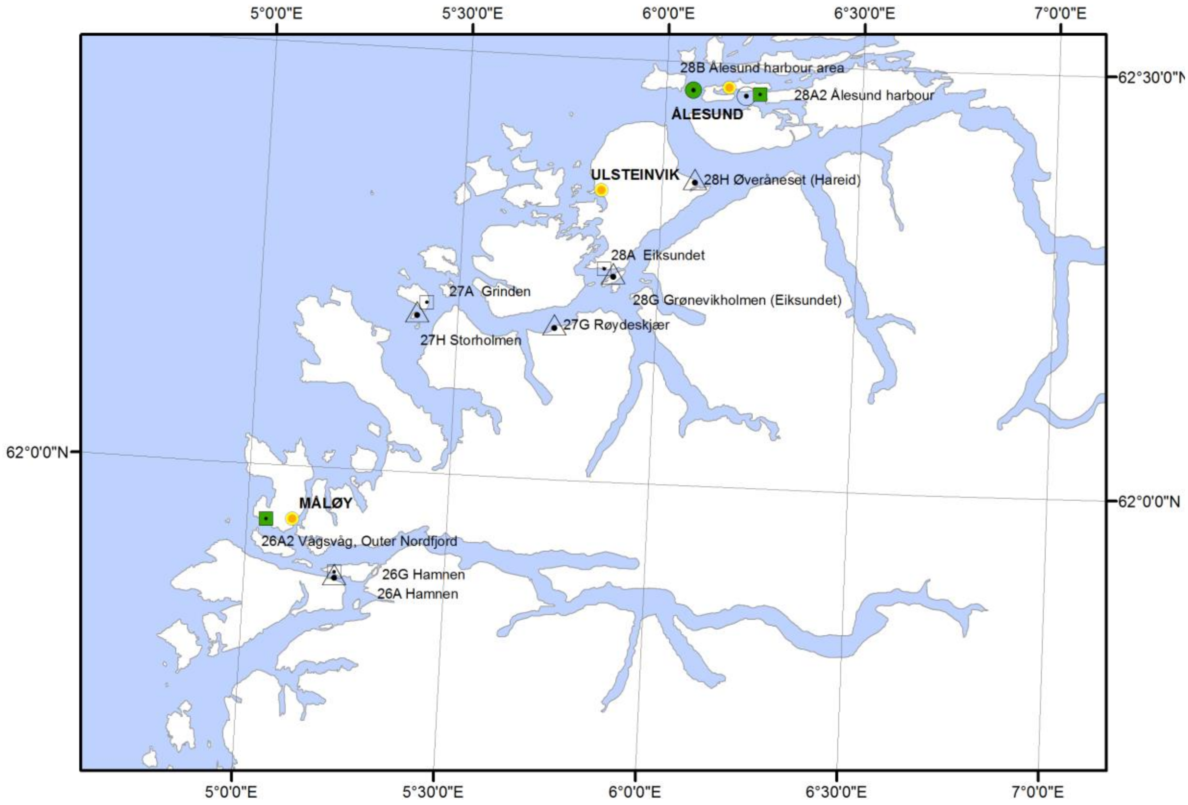
MAP 6


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

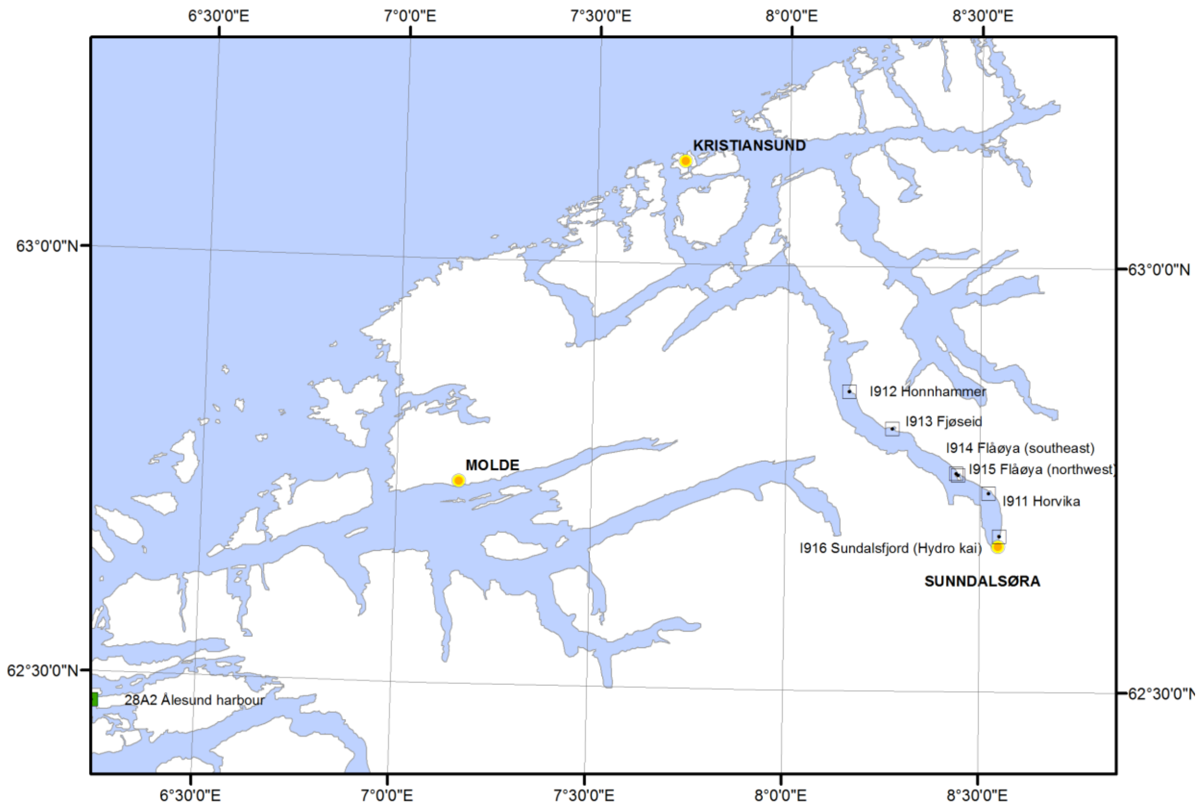
MAP 7


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

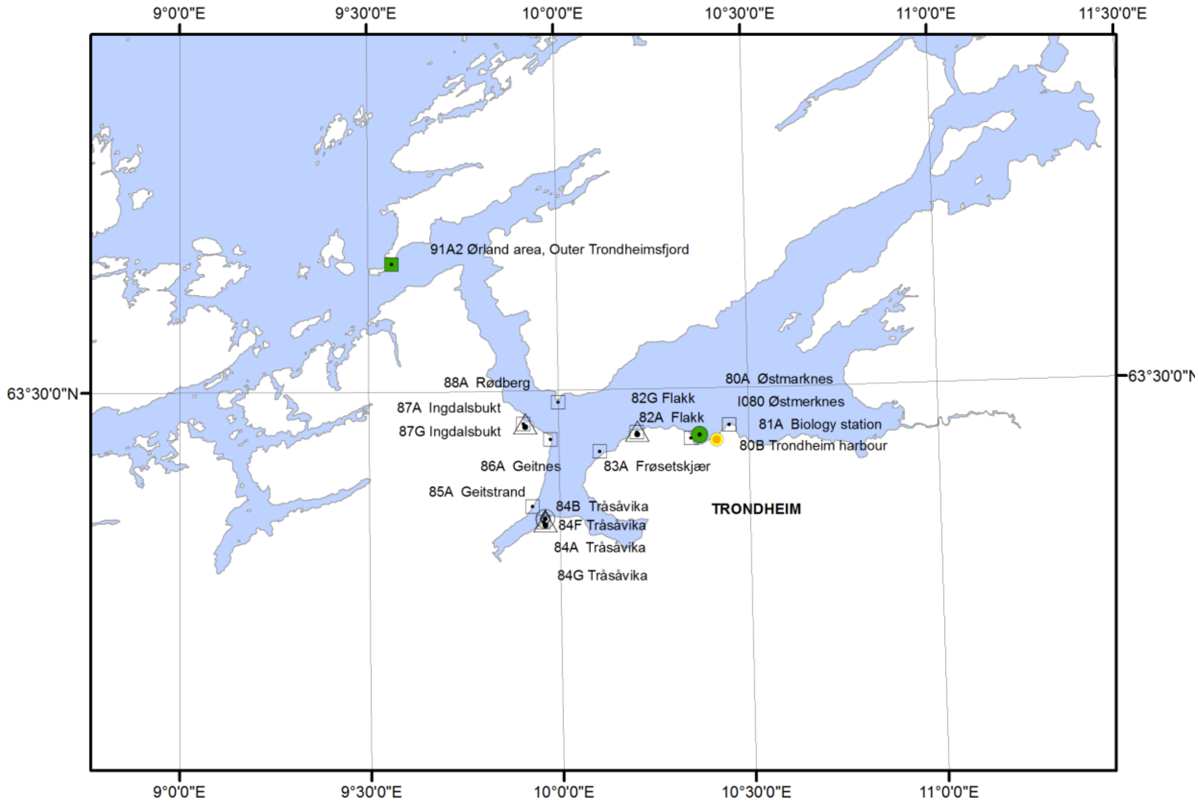
MAP 8


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
28G Grønevikholmen (Eiksundet)
27A Grinden
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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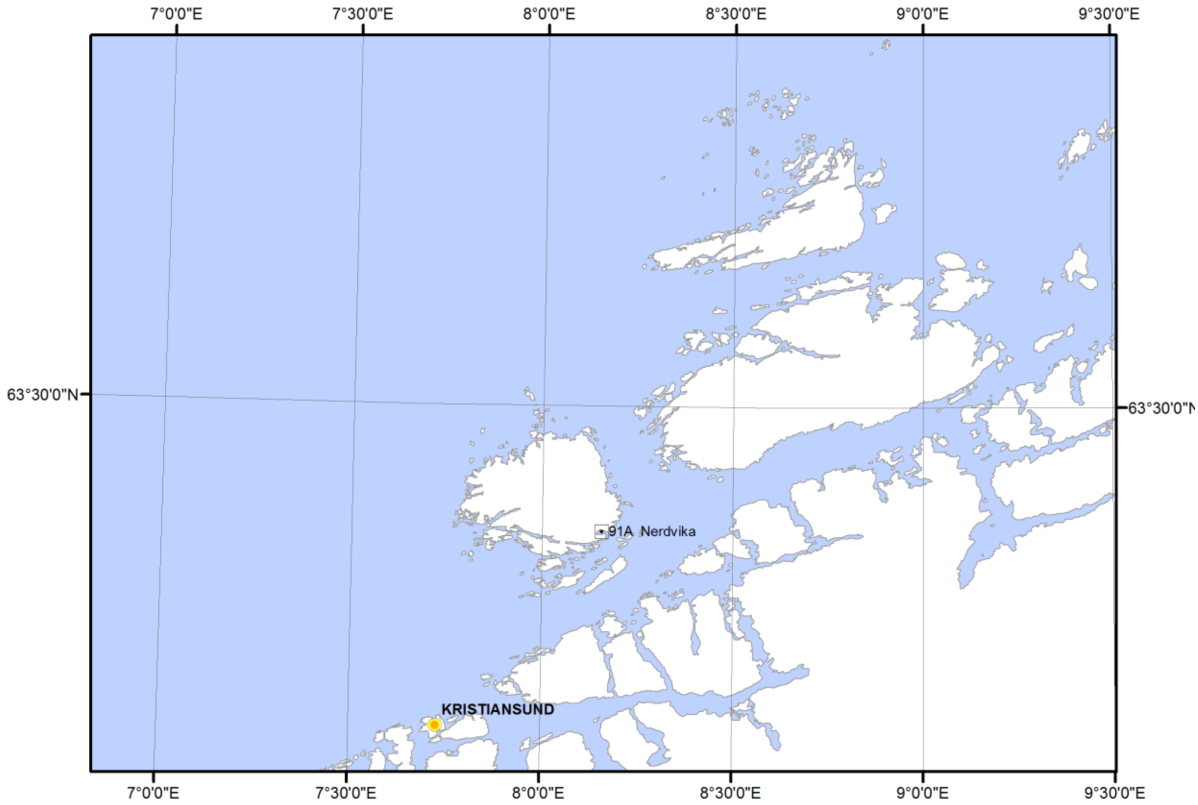
9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
63°30'0"N
91A2 Ørland area, Outer Trondheimsfjord
88A Rødberg
87A Ingdalsbukt
87G Ingdalsbukt
86A Geitnes
85A Geitstrand
84B Tråsåvika
84F Tråsåvika
84A Tråsåvika
84G Tråsåvika
83A Frøsetskjær
82G Flakk
82A Flakk
80A Østmarknes
I080 Østmerknes
81A Biology station
80B Trondheim harbour
TRONDHEIM

MAP 11


7°0'0"E
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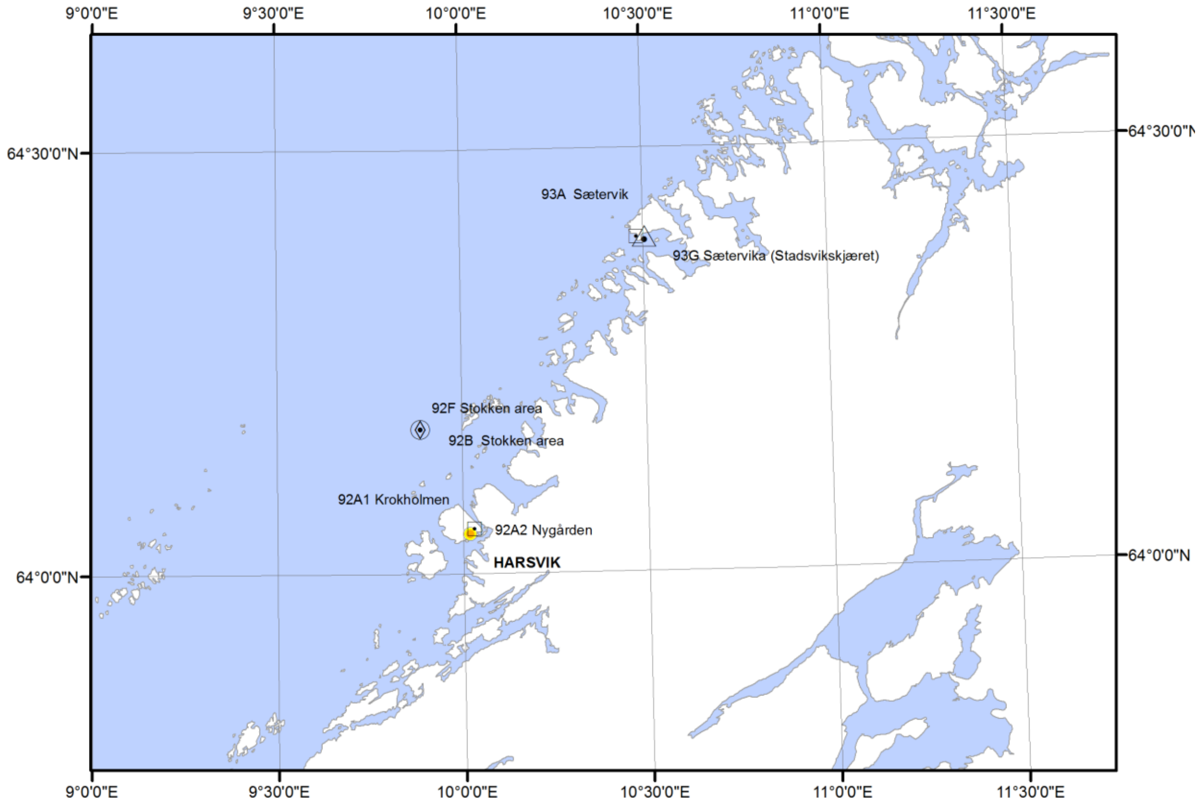
8°0'0"E
8°30'0"E
9°0'0"E
9°30'0"E
63°30'0"N
91A Nerdvika
KRISTIANSUND

MAP 12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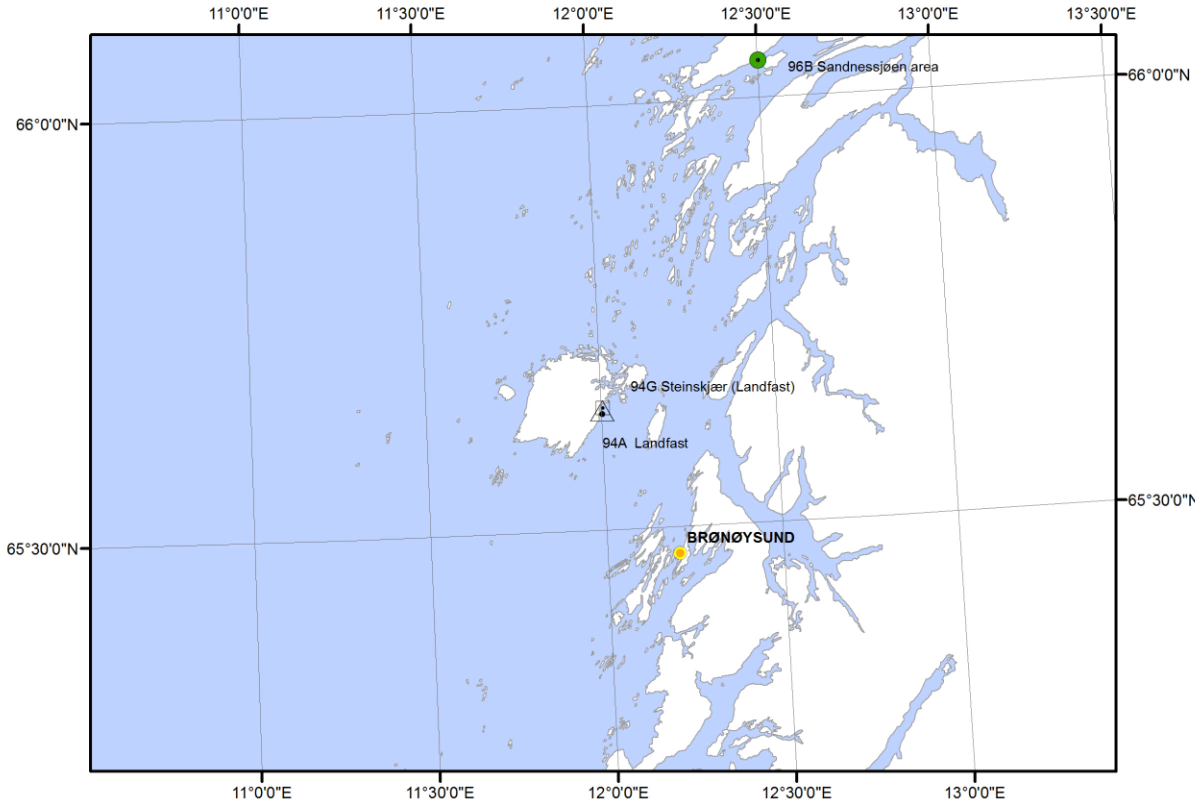
10°30'0"E
11°0'0"E
11°30'0"E
64°30'0"N
64°0'0"N
93A Sætervik
93G Sætervika (Stadsvikskjæret)
92F Stokken area
92B Stokken area
92A1 Krokholmen
92A2 Nygården
HARSVIK

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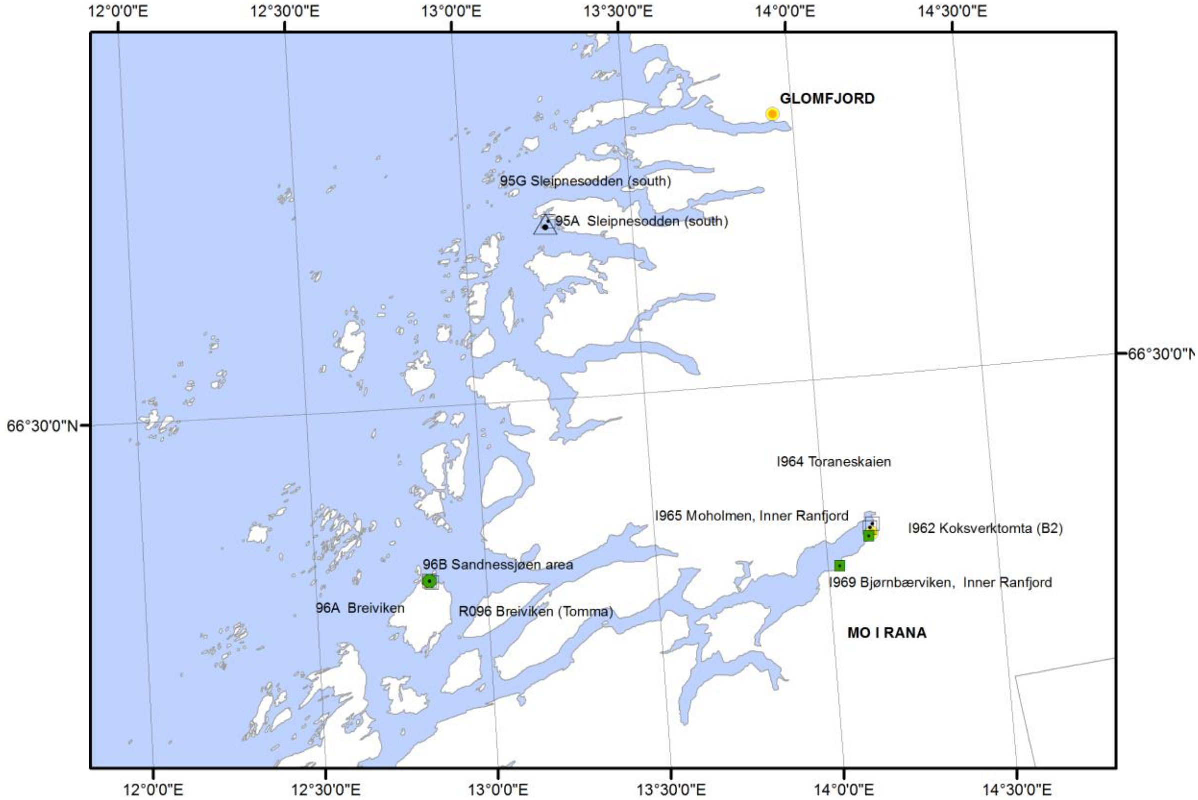
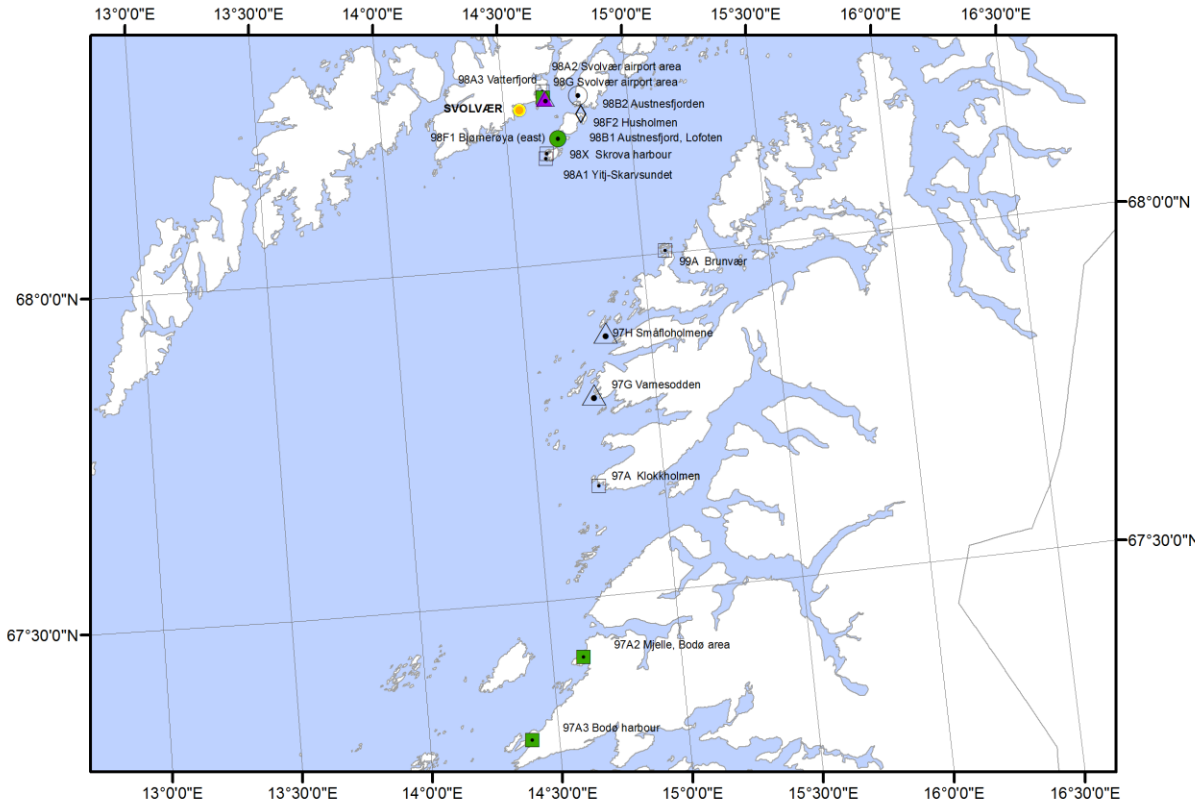
12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
66°0'0"N
65°30'0"N
96B Sandnessjøen area
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

MAP 14



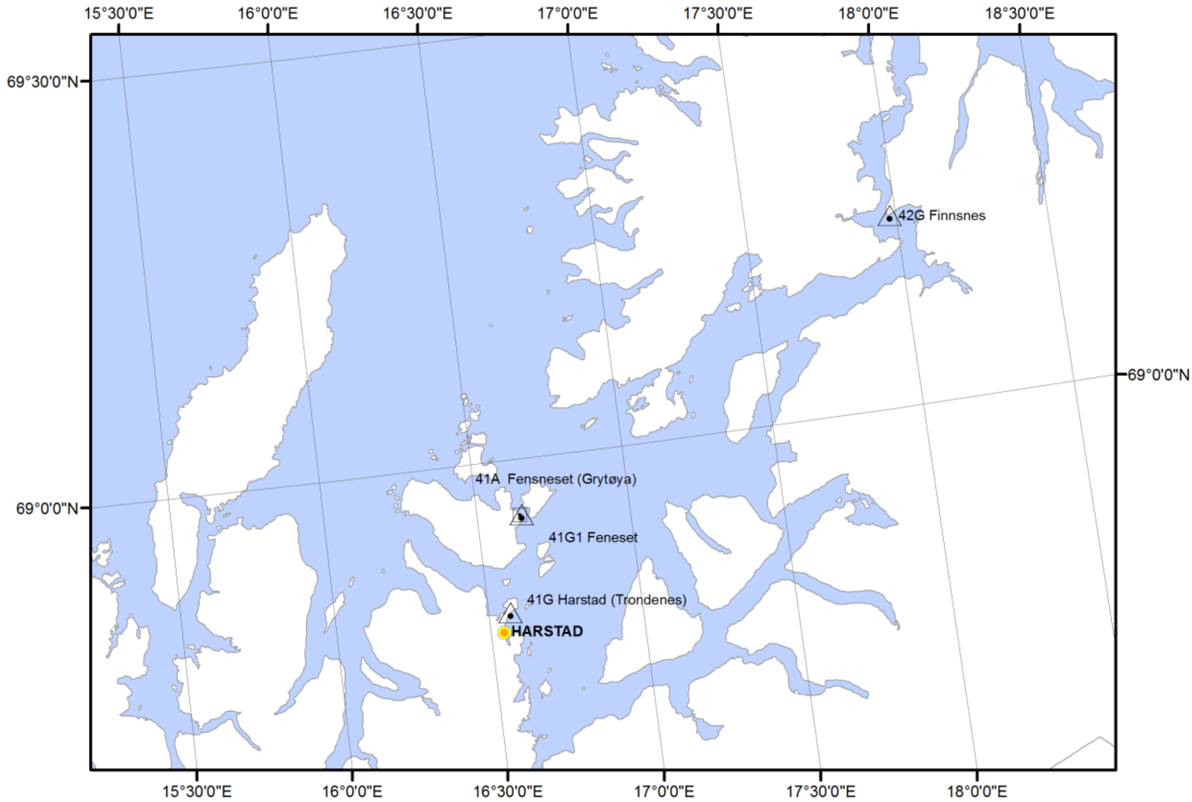
GLOMFJORD
95G Sleipnesodden (south)
95A Sleipnesodden (south)
I964 Toraneskaien
I965 Moholmen, Inner Ranfjord
I962 Koksverktomta (B2)
96B Sandnessjøen area
I969 Bjørnbærviken, Inner Ranfjord
96A Breiviken
R096 Breiviken (Tomma)
MO I RANA

MAP 15

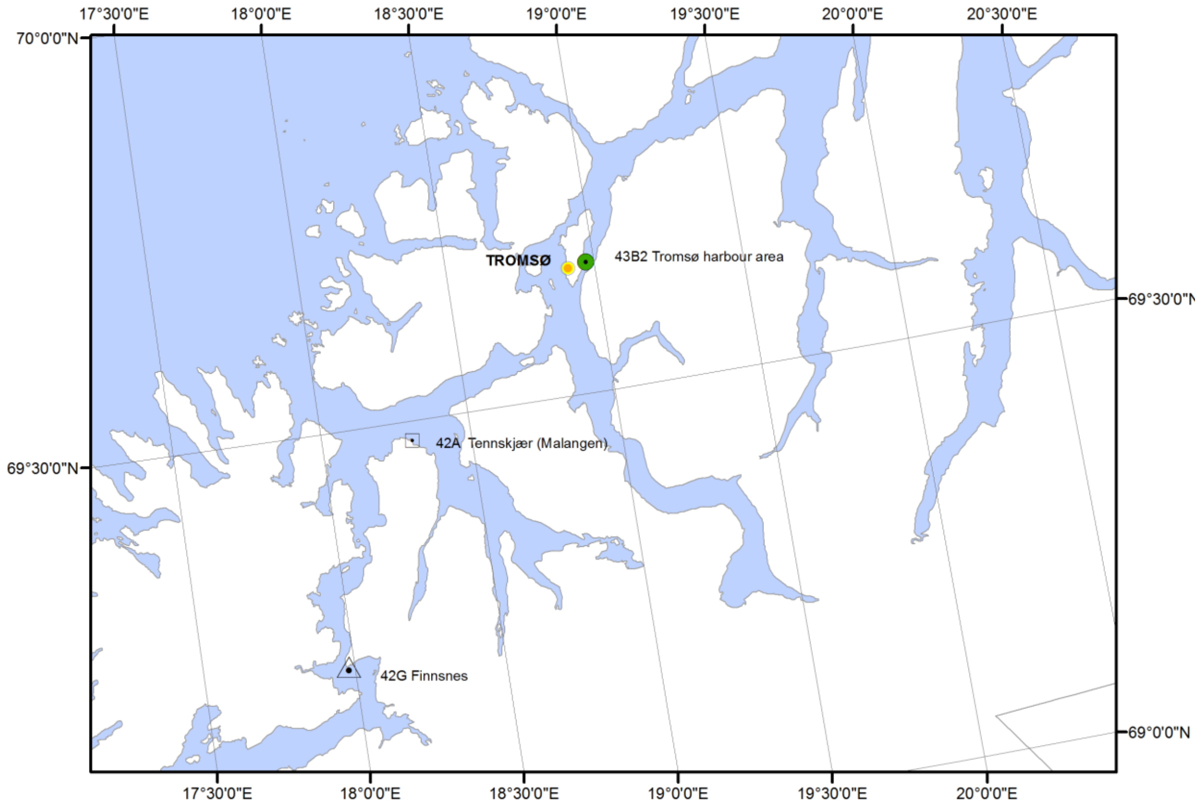


98A2 Svolvær airport area
98A3 Vatterfjord
98G Svolvær airport area
SVOLVÆR
98B2 Austnesfjorden
98F2 Husholmen
98F1 Bjørnerøya (east)
98B1 Austnesfjord, Lofoten
98X Skrova harbour
98A1 Yitj-Skarvsundet
99A Brunvær
97H Småfloholmene
97G Vamesodden
97A Klokkholmen
97A2 Mjelle, Bodø area
97A3 Bodø harbour

MAP 16


15°30'0"E
16°0'0"E
16°30'0"E
17°0'0"E
17°30'0"E
18°0'0"E
18°30'0"E
69°30'0"N
69°0'0"N
42G Finnsnes
41A Fensneset (Grytøya)
41G1 Feneset
41G Harstad (Trondenes)
HARSTAD
15°30'0"E
16°0'0"E
16°30'0"E
17°0'0"E
17°30'0"E
18°0'0"E

MAP 17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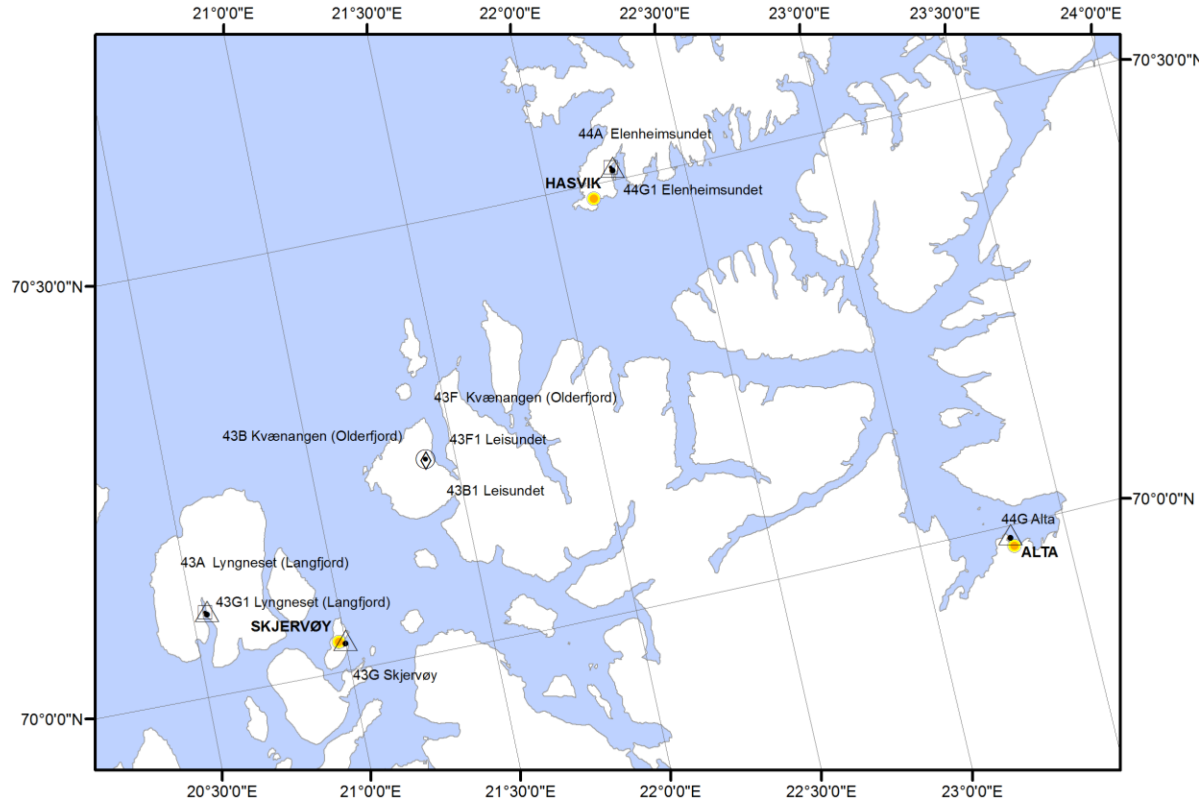
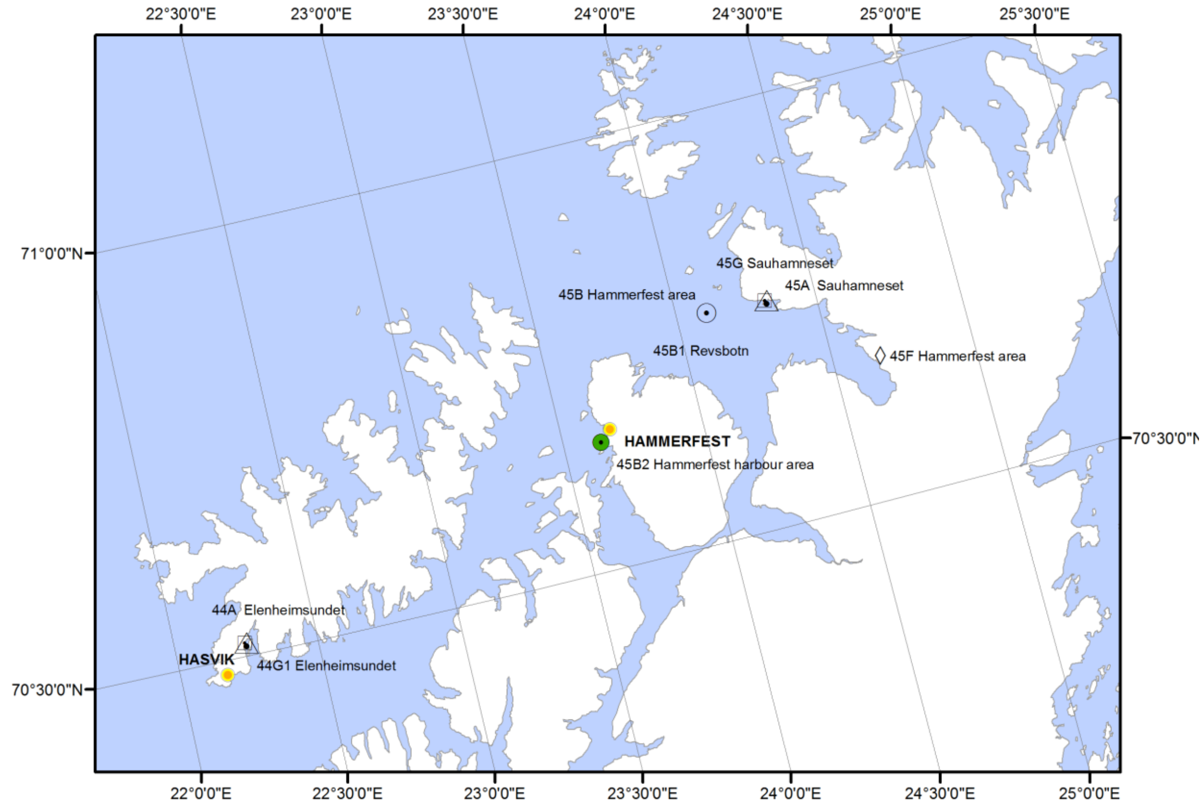
18°0'0"E
18°30'0"E
19°0'0"E
19°30'0"E
20°0'0"E
20°30'0"E
70°0'0"N
69°30'0"N
69°0'0"N
TROMSØ
43B2 Tromsø harbour area
42A Tennskjær (Malangen)
42G Finnsnes
17°30'0"E
18°0'0"E
18°30'0"E
19°0'0"E
19°30'0"E
20°0'0"E

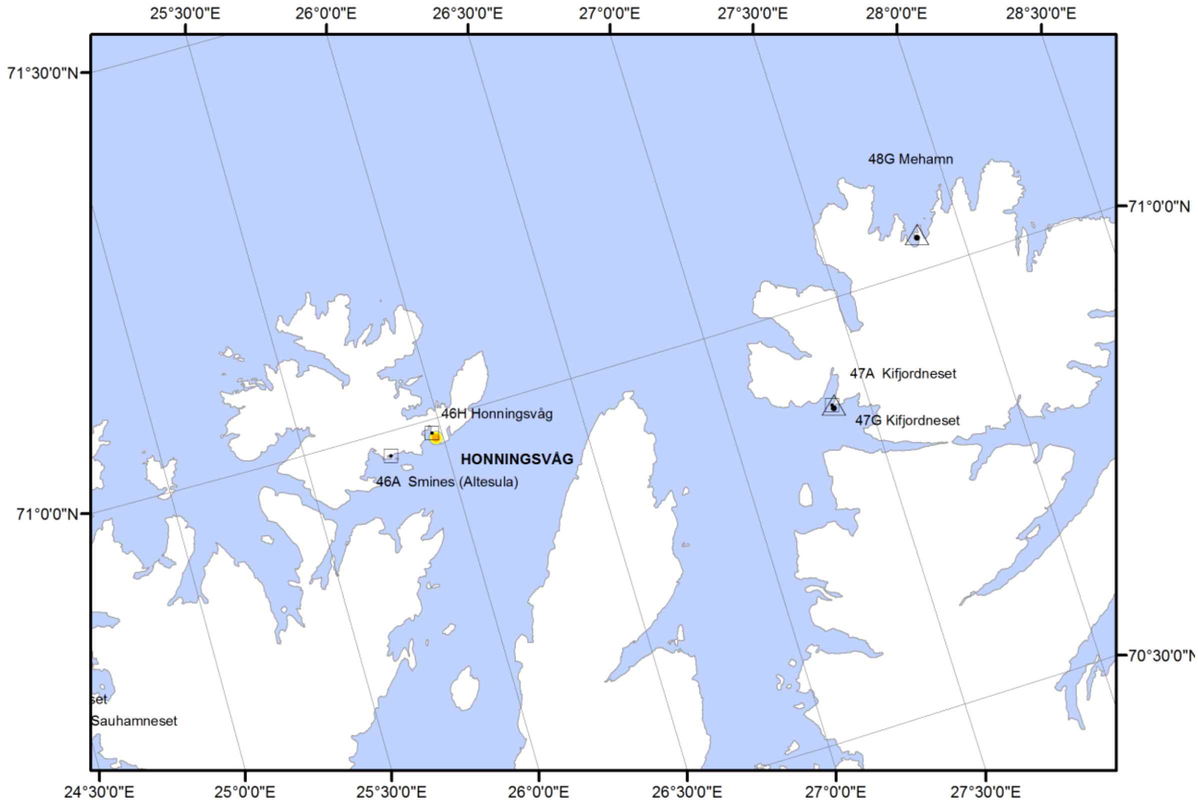
MAP 18


21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
70°30'0"N
70°0'0"N
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
20°30'0"E
21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E

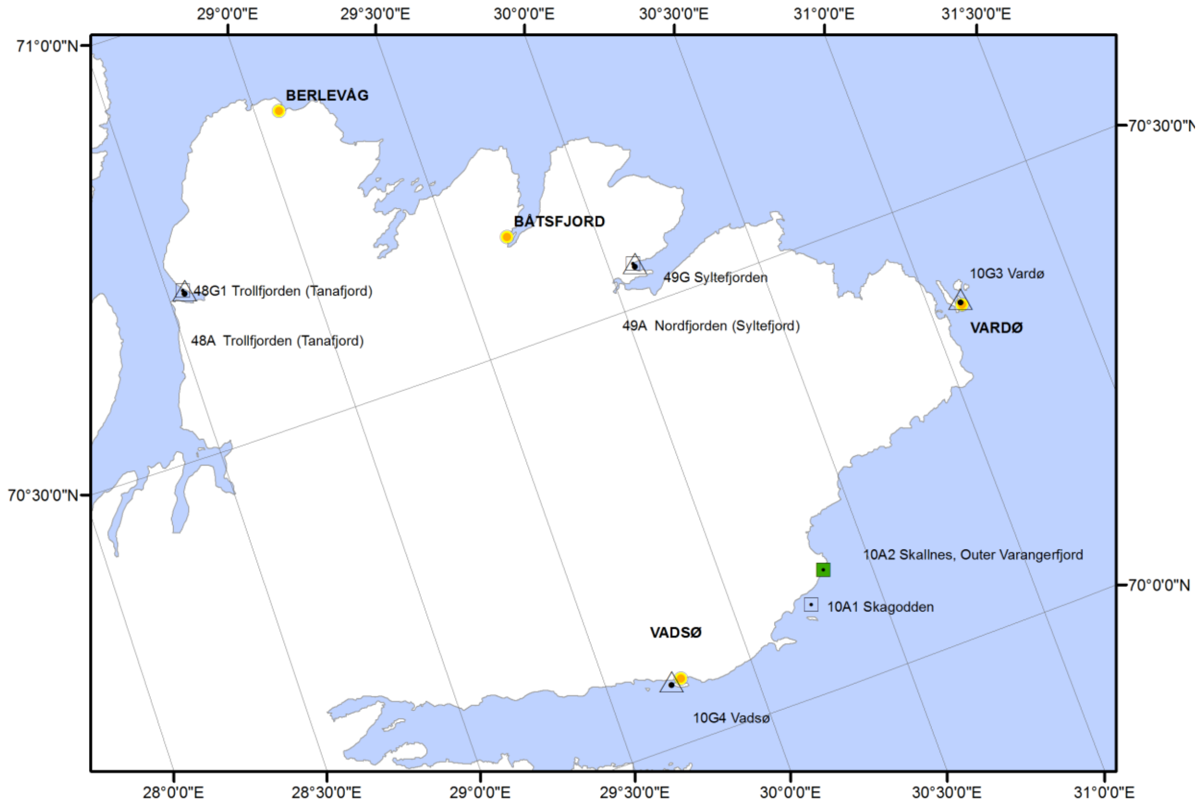
MAP 19


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

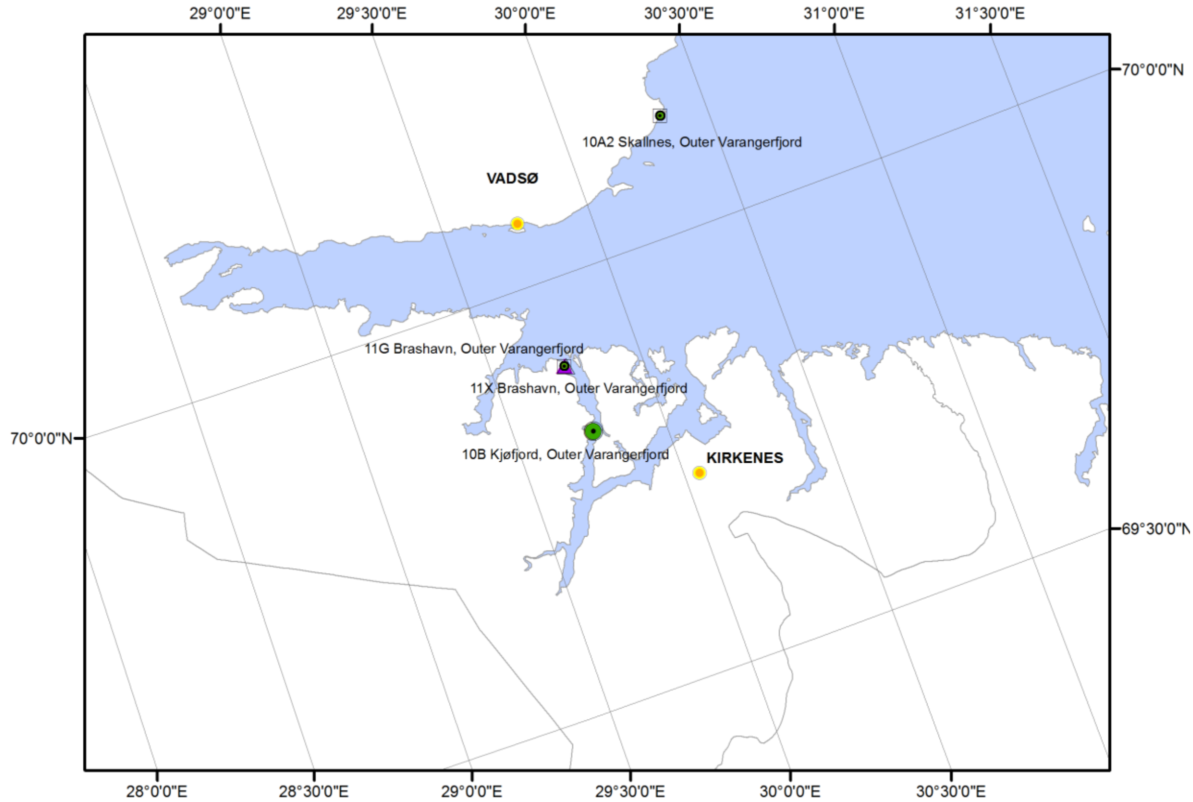
MAP 20


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

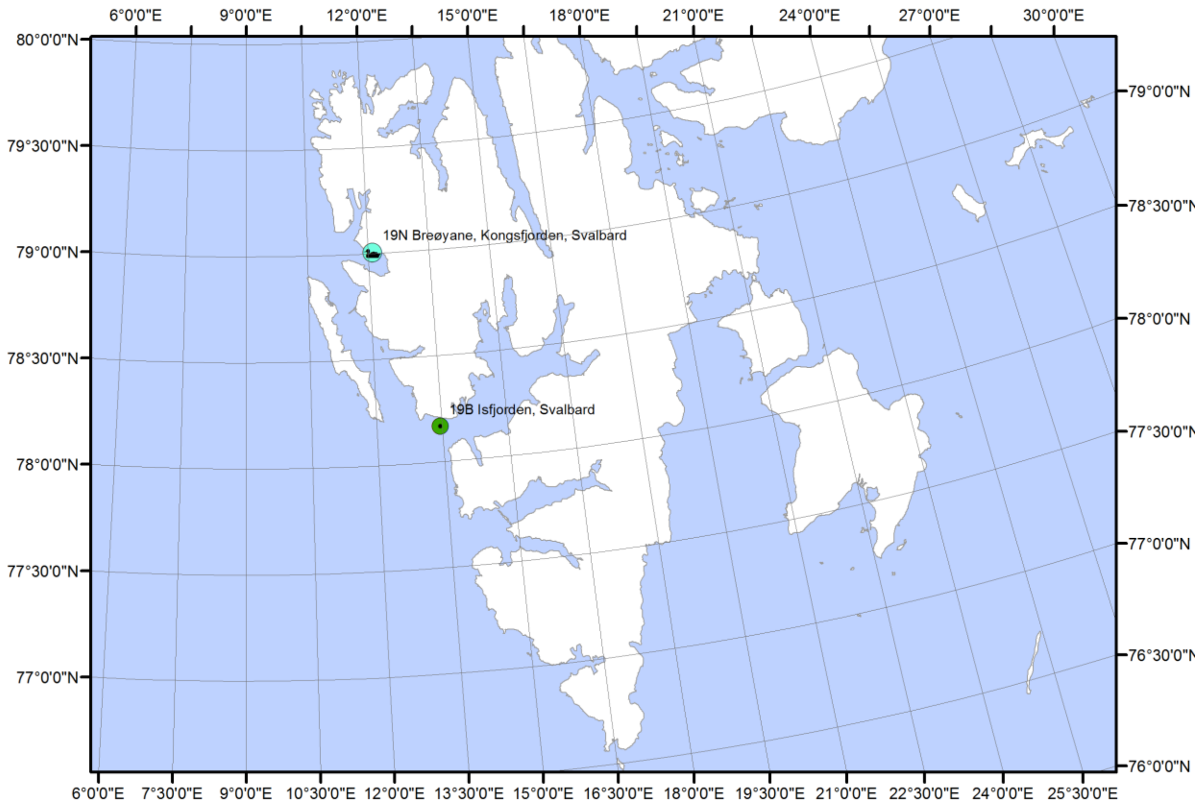
MAP 21


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

MAP 22


29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
70°0'0"N
10A2 Skallnes, Outer Varangerfjord
VADSØ
11G Brashavn, Outer Varangerfjord
11X Brashavn, Outer Varangerfjord
10B Kjøfjord, Outer Varangerfjord
KIRKENES
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

MAP 23


6°0'0"E
9°0'0"E
12°0'0"E
15°0'0"E
18°0'0"E
21°0'0"E
24°0'0"E
27°0'0"E
30°0'0"E
80°0'0"N
79°30'0"N
79°0'0"N
78°30'0"N
78°0'0"N
77°30'0"N
77°0'0"N
76°30'0"N
76°0'0"N
19N Breøyane, Kongsfjorden, Svalbard
19B Isfjorden, Svalbard
6°0'0"E
7°30'0"E
9°0'0"E
10°30'0"E
12°0'0"E
13°30'0"E
15°0'0"E
16°30'0"E
18°0'0"E
19°30'0"E
21°0'0"E
22°30'0"E
24°0'0"E
25°30'0"E

MAP 24

Appendix E
Overview of materials and analyses 2019-2020

Nominal station positions are shown on maps in Appendix D

Year:
2019t - samples taken in 2019
2020p - samples planned in 2020
2020t – samples taken in 2020

Species:
Blue mussel (*Mytilus edulis*)
Dogwhelk (*Nucella lapillus*)
Common periwinkle (*Littorina littorea)*
Atlantic cod (*Gadus morhua*)
European flounder (*Platichthus flesus*)
Common eider duck (*Somateria mollissima*)

Tissue:
SB-Soft body tissue
LI-Liver tissue, in fish
MU-Muscle tissue, in fish
BL-Blood, in fish or eider
BI-Bile, in fish
EG-Eggs (homogenate of yolk and albumin), in eider

Overview follows on next page

Parameter-group codes (see **Appendix B** for descriptions of codes) 2019-2020:

code	Description	Me-SB	Nl/Ll-SB	Gm-BI	Gm-BL	Gm/Pf-LI	Gm/Pf-MU	Sm-BL	Sm-EG
I-MET	metals [1]	X				X			
I-MET	Hg	X					X	X	X
ISOTO	$\delta^{15}N$ and $\delta^{13}C$	X					X	X	X
O-BR	PBDEs [2]	X				X		X	X
OC-CB	PCBs [3]	X				X			
OC-CL	HCB	X				X		X	X
OC-CP	SCCP, MCCP	X				X		X	X
OC-DD	DDT, DDE, DDD	X				X			
OC-HC	α-, γ-HCH	X				X			
O-FL	PFAS [4]					X		X	X
O-PAH	PAHs [5]	X				X			
O-MET	TBT [6]	X	X						
SLX	Siloxanes[7]					X			
BEM	Biological effects met.[8]		Imposex	OH-pyrene	ALA-D	EROD-activity[9]			

[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: PFNA, PFOA, PFHpA, PFHxA, PFOS, PFBS, PFOSA.

[5] 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.

[6] Includes: DBTIN, DPTIN, MBTIN, MPTIN, TBTIN, TPhT.

[7] SLX – Siloxanes includes: D4, D5, D6.

[8] Biological effects methods.

[9] Cod only.

***Appendix E**. Sampling and analyses for 2019-2020 - biota.*

Year	Latin name	Tissue	Station	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	ISOTO	BEM	SLX
2019t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3		3			
2020p	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3		3			
2020t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3		3			
2019t	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3	3	3	3		
2020p	**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		
2020t	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3	3	3	3		
2019t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	2	2		2	2		2	2		2	2		
2020p	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3		3	3		
2020t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3		3	3		
2019t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3					
2020p	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3					
2020t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3					
2019t	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3	3		3		
2020p	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3	3		3		
2020t	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3	3		3		
2019t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3				3	3		
2020p	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3				3	3		
2020t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3				3	3		
2019t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	2			2							2		
2020p	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	3			3							3		
2020t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	3			3							3		
2019t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	0		0		0	0	0	0		0	0		
2020p	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	3		3		3	3	3	3		3	3		
2020t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	1		1		1	1	1	1		1	1		
2019t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	0		0		0	0	0	0		0	0		
2020p	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3		3	3		
2020t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	0		0		0	0	0	0		0	0		
2019t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3					
2020p	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3					
2020t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3					

Year	Latin name	Tissue	Station	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	ISOTO	BEM	SLX
2019t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3									3			
2020p	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3									3			
2020t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3									3			
2019t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3		3	3		
2020p	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3		3	3		
2020t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3		3	3		
2019t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3							3		
2020p	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3							3		
2020t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3							3		
2019t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3			3		
2020p	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3			3		
2020t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3			3		
2019t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3			3		
2020p	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3			3		
2020t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3			3		
2019t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3						
2020p	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3						
2020t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3						
2019t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3					
2020p	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3					
2020t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3					
2019t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3	3	3	3		
2020p	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3	3	3	3		
2020t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3	3	3	3		
2019t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3			3		3		
2020p	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3			3		3		
2020t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3			3		3		
2019t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3					3		
2020p	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3					3		
2020t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3					3		

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2019t	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3			3		3		
2020p	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3			3		3		
2020t	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3			3		3		
2019t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3					3		
2020p	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3					3		
2020t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3					3		
2019t	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3					3		
2020p	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3					3		
2020t	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3					3		
2019t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3					3		
2020p	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3					3		
2020t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3					3		
2019t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3			3	3	3		
2020p	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3			3	3	3		
2020t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3			3	3	3		
2019t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	0			0	0		0	0			0		
2020p	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	3		3	3			3		
2020t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	3		3	3			3		
2019t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	0			0	0		0	0					
2020p	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3					
2020t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	3		3	3					
2019t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458	0	1			0		0	0		0		1	
2020p	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458	1	1			1		1	1		1		1	
2020t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458	1	1			1		1	1		1		1	
2019t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1										1	
2019t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1										1	

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2019t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1										1	
2019t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1										1	
2019t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G)**	59.33960	5.31220		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G)**	59.33960	5.31220		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G)**	59.33960	5.31220		1										1	
2019t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1										1	
2019t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1										1	
2019t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1										1	
2020p	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1										1	
2020t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1										1	
2019t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	13		14	14	13	12	13	13	5			14	15
2020p	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15		15	15	15	15	15	15	15			15	15
2020t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	12		12	12	12	12	12	12	12			15	14
2019t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050		5		5	6	5	5	5	5	6				
2020p	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050		15		15	15	15	15	15	15	15				
2020t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050		15		15	15	15	15	15	15	15				
2019t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	11		11	11		11							
2020p	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15		15	15		15							
2020t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	7		8	8		8							
2019t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	13		13			13							
2020p	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15		15			15							
2020t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	10		10			10							

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2019t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	9		9	10		10			10				
2020p	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15		15	15		15			15				
2020t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	7		8	8		7			8				
2019t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15					
2020p	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15					
2020t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15					
2019t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15	15			15	
2020p	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15	15			15	
2020t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15	15			15	
2019t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15		15	15	15	15	15	15	15			15	
2020p	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15		15	15	15	15	15	15	15			15	
2020t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15		15	15	15	15	15	15	15			16	
2019t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	14		14	14		14			14				15
2020p	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15			15				15
2020t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	14		14	14		13			14				15
2019t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	14		15	15		15							
2020p	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15							
2020t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	14		14	10		14							
2019t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	11		11	11		11			11				
2020p	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15			15				
2020t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15			15				
2019t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15									
2020p	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15									
2020t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15									
2019t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	15	15	15	15	15				
2020p	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	15	15	15	15	15				
2020t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	15	15	15	15	14				
2019t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			15				15
2020p	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			15				15
2020t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			15				15

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2019t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15			15									
2020p	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15			15									
2020t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	14			14									
2019t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	0			0	0		0	0					0
2020p	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	15		15	15					15
2020t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	15		15	15					15
2019t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15			15				15
2020p	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15			15				15
2020t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15			15				15
2019t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15										15		
2020p	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15										15		
2020t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15										15		
2019t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050		9										9		
2020p	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050		15										15		
2020t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050		15										15		
2019t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15										15		
2020p	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15										15		
2020t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15										15		
2019t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15										15		
2020p	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15										15		
2020t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15										15		
2019t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	13										13		
2020p	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15										15		
2020t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15										15		
2019t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15										15		
2020p	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15										15		
2020t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15										15		
2019t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15										15		
2020p	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15										15		
2020t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15										15		

Year	Latin name	Tissue	Station	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	ISOTO	BEM	SLX
2019t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15										15		
2020p	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15										15		
2020t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15										15		
2019t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15										14		
2020p	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15										15		
2020t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15										15		
2019t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15										15		
2020p	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15										15		
2020t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15										15		
2019t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	11										11		
2020p	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15										15		
2020t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15										15		
2019t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15										15		
2020p	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15										15		
2020t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15										15		
2019t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15										15		
2020p	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15										15		
2020t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15										15		
2019t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15										15		
2020p	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15										15		
2020t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15										15		
2019t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15										15		
2020p	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15										15		
2020t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15										15		
2019t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	0										0		
2020p	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15										15		
2020t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15										15		
2019t	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15										15		
2020p	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15										15		
2020t	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15										15		

Year	Latin name	Tissue	Station	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	ISOTO	BEM	SLX
2019t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183												15	
2020p	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183												15	
2020t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183												15	
2019t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972												15	
2020p	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972												15	
2020t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972												15	
2019t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857												15	
2020p	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857												15	
2020t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857												17	
2019t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183												13	
2020p	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183												15	
2020t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183												14	
2019t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690												14	
2020p	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690												15	
2020t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690												15	
2019t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972												15	
2020p	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972												15	
2020t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972												15	
2019t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857												13	
2020p	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857												15	
2020t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857												16	
2019t	**Platichthys flesus**	Liver	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3			3	3		3	3					
2020p	**Platichthys flesus**	Liver	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3			3	3		3	3					
2020t	**Platichthys flesus**	Liver	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3			3	3		3	3					
2019t	**Platichthys flesus**	Muscle	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3												
2020p	**Platichthys flesus**	Muscle	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3												
2020t	**Platichthys flesus**	Muscle	**Sande, Mid Oslofjord (st. 33F)**	59.52833	10.35000	3												
2019t	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	14		14	14	14	14			14		14		14
2020p	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15
2020t	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		17
2019t	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15
2020p	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15
2020t	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2020

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 2019 or 2020 is shown. The column headings are as follows:

Parameter Code: are described in **Appendix B**
IUPAC: International Union of Pure and Applied Chemistry (IUPAC) parameter name (if any).
CAS: Chemical Abstracts Services (CAS) parameter number (if any).
Parameter Name: Common name
Parameter Group: Parameters belong to one of 14 groups
Unit: µg/kg, mg/kg, ng/kg, etc.
Station Code
Station Name
Area: general area (if defined).
County
Water region: Water framework directive (WFD) water region
Water body ID: WFD water body identification
Water body name: WFD water body name

Species:

- **MYTI EDU**-Blue mussel (*Mytilus edulis*)
- **LITT LIT**-Common periwinkle (*Littorina littorea*)
- **NUCE LAP**-Dogwhelk (*Nucella lapillus*)
- **GADU MOR**-Atlantic cod (*Gadus morhua*)
- **PLAT FLE** European flounder (*Platichthys flesus*)
- **SOMA MOL**-Common eider (*Somateria mollissima*)

Tissue:

- **SB**-Soft body tissue
- **LI**-Liver tissue
- **MU**-Muscle tissue
- **BL**-Blood
- **BI**-Bile
- **EG**-Eggs-homogenate of yolk and albumin

Basis: wet weight (**WW, WWa**), dry weight (**DW, DWa**) or lipid weight (**FB, FBa**), the "a" indicates concentration adjusted to length (concerns only cod).
PROREF: Norwegian provisional high reference contaminant concentration.
V[Year columns]: median value for years 1981-2020. The gray-shade coding refers to relation to exceedances to Norwegian provisional high reference contaminant concentration (PROREF): below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 20
Q[Year columns]: symbol for years 1981-2020 that indicates the relation of the median to Environmental Quality Standards (2013/39/EU 2013) and other risk-based standards developed nationally (Norwegian_Environment_Agency 2016), and these are referred to collectively in this report as Environmental Quality Standards (EQS). Green-filled circle indicates no exceedances and red-filled circle indicates exceedances of the quality standard.

N_string_[last/this] year: where "last year" is 2019 and "this year" is 2020. Number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample.
SD [last/this] year: standard deviation.
PROREF-class [last/this] year: exceedances to Norwegian provisional high reference contaminant concentration (PROREF): below PROREF (1) or exceeding PROREF by a factor of: 1-2 (2), 2-5 (3), 5-10 (4), 10-20 (5) or greater than 20 (6) (see ***Appendix C***).
EQS-class [last/this] year: below (1) or above (2) EU Environmental Quality Standard (EQS). Note: the EU EQRs are based on the whole organism whereas monitoring of fish in MILKYS is on a particular tissue. Hence, comparison is only relevant if it is assumed that the concentration found is the same for all tissues in the fish.
EQS threshold this year
Trend p(long) [last/this] year: The statistical significance (p)[year] of the trend for the entire time series.
Detectable % change(long) [last/this] year: the percent change that can be detected with 90 % confidence.
First Year(long) [last/this] year: first year in time series.
Last Year(long) [last/this] year: last year in time series.
No. of Years(long) [last/this] year: number of years with data.

Trend p(short) [last/this] year: The statistical significance (p)[year] of the trend for the last 10-year sampling period.
Detectable % change(short) [last/this] year: the percent change that can be detected with 90 % confidence.
First Year(short) [last/this] year: first year in time series for the last 10-year sampling period.
Last Year(short) [last/this] year: last year in time series for the last 10-year sampling period.
No. of Years(short) [last/this] year: number of years with data in time series for the last 10-year sampling period.

Trends [last/this] year: trends in concentrations of contaminants monitored. The analyses were done on time series with five or more years. An upward (🡅) or downward (🡇) arrow indicates statistically significant trends, whereas a zero (**O**) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed, but the results were insufficient to do a trend analysis. Results marked with a star (★) indicates that there is insufficient data above the quantification limit (LOQ) to perform a trend analysis. The result from the trend analysis for the entire time series (long-term) is shown before the slash "/", and the result for the last 10 years (short-term) is shown after the slash.

TREND_CHANGE last year-this year: indicates the difference (if any) between last year's results and this year's results.
PROREF_CHANGE last year-this year: indicates the difference (if any)) between last year's results and this year's results.
EQS_CHANGE last year-this year: indicates the difference (if any)) between last year's results and this year's results.

Note on quantification limit in trend analyses: (see **Chapter 2.6**).

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