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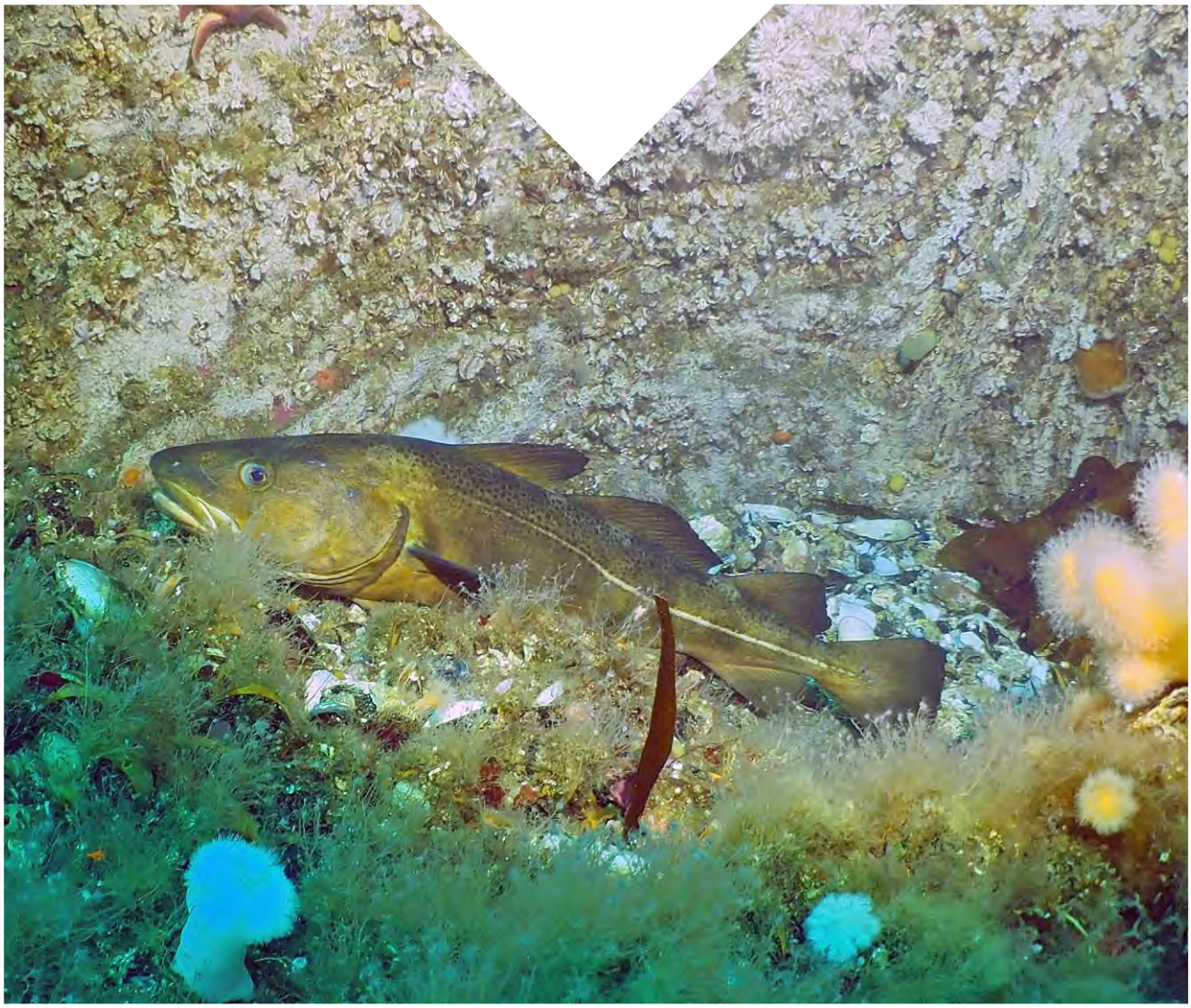
Contaminants in coastal waters of Norway 2017

Miljøgifter i norske kystområder 2017



Foreword

This report presents the results of the programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS), with investigations of contaminants in coastal waters of Norway in 2017, which also represents the Norwegian contribution to Coordinated Environmental Monitoring Programme (CEMP, a part of and referred to in earlier reports as the Joint Assessment and Monitoring Programme JAMP). CEMP is administered by the Oslo and Paris Commissions (OSPAR) in their effort to assess and remedy anthropogenic impact on the marine environment of the North East Atlantic. The current focus of the Norwegian contribution is on the concentration levels, trends and effects of hazardous substances. The results from Norway and other OSPAR countries provide a basis for a paramount evaluation of the state of the marine environment. OSPAR receives guidance from the International Council for the Exploration of the Sea (ICES).

The 2017 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 and the project manager at NIVA is Norman W. Green.

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Abstract
This programme examines the levels, trends and effects of contaminants in biota along the coast of Norway. The 2017-investigation included analyses of 93 different contaminants or biological effect parameters in five species (blue mussel, dogwhelk, common periwinkle, cod and the common eider). The contaminants include metals (Hg, Cd, Pb, Cu, Zn, Ag, As, Ni, Cr and Co), tributyltin (TBT), organochlorines (e.g. PCBs, DDT), PAHs, polybrominated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS) as well as contaminants that have recently received much attention such as hexabromocyclododecane (HBCDs), chlorinated paraffins (SCCP, MCCP), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), alkyphenols and siloxanes. Biological effects parameters included VDSI, OH-pyrene metabolites, ALA-D and EROD. In the report, 30 representative substances or parameters were chosen for analyses of 809 time series (last 10 years). Of these there were statistically significant trends in 193 cases: 83 were downwards and 35 upwards. The dominance of downward trends indicated that contamination is decreasing for the measured substances. The downwards trends for TBT-concentrations and effect parameter (VDSI) confirmed that the legislation banning the use of TBT has been effective. Of the 2017-medians (last year) for all 809 time series, there were 262 cases that could be classified against EQS, of which 157 (59.9 %) were below the EQS and 105 (40.1 %) were above the EQS. All of the 2017-medians from the 809 time series could be classified using a provisional high reference concentrations (PROREF). Of these 578 were below PROREF and 231 exceeded PROREF: 148 by a factor of less than two, 61 by a factor between two and five, 13 by a factor between five and 10, seven by a factor between 10 and 20, and two by a factor greater than 20. Some cases warrant special concern, such as high concentrations of several organic contaminants in cod liver from the Inner Oslofjord. High concentrations of DDE in mussels from the Sørfjord were related to earlier use of DDT as pesticide in orchards along the fjord. The influence of fish length on contaminant concentration was examined. Results of analyses of stable isotopes of carbon and nitrogen are presented to investigate the role of food origin and trophic levels for observed contaminant concentrations. In addition microplastics were investigated in blue mussel collected in 2016 and 2017.

4 keywords, Norwegian	4 keywords, English
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2. Biologiske effekter	2. Biological effects
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4. Norge	4. Norway

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

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English summary

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

The main conclusion is that most trends of contaminant concentrations in marine organisms collected at stations in the Norwegian coastal water were downwards. The Inner Oslofjord is an area where more contaminants have relatively higher concentrations and hence this area warrants special concern. Furthermore, in this area the investigation found an upward long-term trend for mercury (Hg) in cod (*Gadus morhua*) fillet and medium chain chlorinated paraffins (MCCP) in cod liver. No short-term trend for Hg in cod fillet was detected in the Oslofjord. No long-term or short-term trend was found when concentrations in cod frm the inner Oslofjord were adjusted for fish length.

Monitoring contaminants and associated parameters along the Norwegian coast contributes to OSPAR’s Coordinated Environmental Monitoring Programme (CEMP). The 2017-investigation monitored blue mussel (*Mytilus edulis*) at 33 stations, dogwhelk (*Nucella lapillus*) at eight stations, common periwinkle (*Littorina littorea*) at one station, Atlantic cod (*Gadus morhua*) at 17 stations and eider (*Somateria mollissima*) at one station. The stations are located both in areas with known or presumed point sources of contaminants, in areas of diffuse load of contamination like city harbour areas, and in more remote areas with presumed low exposure to pollution. The programme for 2017 included analyses of metals (Hg, cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), nickel (Ni), chromium (Cr), cobalt (Co)), tributyltin (TBT), polychlorinated biphenyls (PCBs), pesticides (DDE), polycyclic aromatic hydrocarbons (PAHs), polybromated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS), hexabromocyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), alkylphenols, siloxanes as well as biological effects parameters (VDSI, OH-pyrene, ALA-D, EROD) and microplastics.

The results from 2017 supplied data for a total of 3069 data sets (contaminant-station-species) on 93 different contaminants. Thirty representative contaminants and biological effect parameters were chosen for presentation in this report. This selection had 809 time series of which there were statistically significant time (2008-2017) related trends in 193 cases: 83 were downwards and 35 upwards. The downward trends were largely associated with concentrations of metals (45.8 %) and tributyltin (TBT) and effect of TBT (VDSI - *vas deferens sequence index*). The dominance of downward trends indicated that contamination was decreasing. The upward trends were also associated with metals (88.6 %), primarily Hg (22.9 %).

Of the 809 time series, 262 cases could be classified against Environmental Quality Standard (EQS) for EU priority substances and Water region specific substances, of which 157 (59.9 %) were below the EQS.

All 809 time series could be compared to a new concept denoted provisional high reference concentration (PROREF). PROREF is comprehensive set of species-tissue-basis-specific contaminant concentrations that are statistically low when considering all MILKYS-results for the period 1991-2016. Of the 809 time series, 578 (71.4 %) were below PROREF, and 231 (28.6 %) exceeded PROREF: 148 (18.3 %) by a factor of less than two, 61 (7.5 %) by a factor between two and five, 13 (1.6 %) by a factor between five and 10, seven (0.9 %) by a factor between 10 and 20, and two (0.2 %) by a

factor greater than 20. Even though most concentrations observed were below PROREF or did not exceed PROREF beyond a factor of two, the cases that exceeded PROREF should not be disregarded. For example, the blue mussel in the Mid Sørfjord exceeded PROREF for pesticides (DDE) by a factor greater than 20.

Levels and trends in fish

All concentrations of Hg in cod fillet exceeded the EQS in 2017. Cod fillet from the Inner Oslofjord exceeded the PROREF for Hg by a factor of two to five, and a significant upward long-term trend was found for the period 1984-2017 using the OSPAR method which targets specific length-groups. When adjusting to expected concentrations for 50 cm cod using the method taking into considerations fish-length, the cod fillet from the Inner Oslofjord exceeded the PROREF for Hg by a factor of two to five, but no long-term trend (1984-2017) was found. Cod fillet from the Outer Oslofjord exceeded the PROREF for Hg by a factor up to two, and no short-term trends (2008-2017) were found by using both the OSPAR method and after adjusting for fish length effects.

Cod liver from Bergen harbour exceeded the PROREF for PCBs by a factor between five and 10 times. Cod liver from the Inner Oslofjord exceeded the PROREF for PCBs, by a factor between two and five. The high concentrations of PCBs in Oslo and Bergen are probably related to urban activities in the past in combination with little water exchange with the outer fjords.

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

PBDEs have been investigated in cod liver for several fjords since 2005. In 2017, the two highest median concentrations of sum PBDEs were found in Bergen harbour and Inner Oslofjord, and lowest at Svalbard. BDE47 was the dominant congener in all samples and was significantly higher in the Bergen harbour and the Inner Oslofjord than the six other stations in remote areas. As for PCBs, the high concentrations of PBDEs are probably related to urban activities and water exchange conditions.

PFAS in cod liver has been investigated from several fjords since 2005. PFOS and PFOSA, both abundant PFAS-compounds, were significantly higher in cod from the Inner Oslofjord than the other stations. The reason behind the differences in concentrations between the stations are not fully understood, but it appears likely that as for PCBs and PBDEs a combination of urban sources and restricted water exchange provide the highest concentrations in the Inner Oslofjord. The lowest concentrations of PFOS and PFOSA were found at Svalbard.

All concentrations of hexabromocyclododecanes (HBCD) in cod liver were below the EQS in 2017, and α–HBCD was the most abundant component. The concentration of α–HBCD in cod liver was significantly higher in the Inner Oslofjord compared to the 12 other cod stations investigated, and in blue mussel it was significantly higher in Bodø harbour than the 11 other blue mussel stations investigated. The high concentrations of HBCD are probably related to urban activities, and especially for the Inner Oslofjord, reduced water exchange with the outer fjord. Decreasing levels of HBCD were found. There were both significant downward long- and short-term trends for HBCD in cod liver from Stathelle area in the Langesundfjord. A significant downward short-term trend was also found for HBCD in cod liver from Tjøme in the Outer Oslofjord.

Short chain chlorinated paraffins (SCCP) were highest in cod liver in Bergen harbour whereas medium chain chlorinated paraffins (MCCP) were highest in Ålesund harbour. There were both significant long- and short-term upward trends for SCCP in cod liver from the Austnesfjord in

Lofoten. There was a significant upward short-term trend for SCCP in cod liver from the Inner Oslofjord when using data adjusted for fish length. There were both significant upward long- and short-term trends for MCCP in cod liver from the Inner Oslofjord. A significant upward long-term trend was found for MCCP in cod liver from Bømlo in the Outer Selbjørnfjord. A significant downward long-term trend was found for SCCP in cod liver from the Inner Sørfjord.

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

For siloxanes in cod liver, D5 was the most dominant, and the levels were highest in the Inner Oslofjord and lowest in the Isfjord at Svalbard. The same patterns were found for D4 and D6.

Levels and trends in blue mussel

The concentration of Pb in blue mussel was highest at Odderøya in the Kristiansandfjord. There were both significant upward long- and short-term trends for Pb at Gressholmen in the Oslofjord and in Tromsø harbour. There were significant upward long- and short-term trends for Cr at Gressholmen in the Inner Oslofjord, Terøya in the Hardangerfjord, and Brashavn in the Varangerfjord. In general, the loads of metals from riverine inputs and direct discharges to Norwegian coastal waters in 2016 were considerably lower than the long-term average for the period 1990-2015. This could have an impact on trends found in blue mussel and cod, but the link between loads and concentrations found in these species is uncertain and needs to be better understood.

Concentrations of PCB-7 in blue mussel at 23 stations had increased PROREF factors since 2016.

For DDE, blue mussel from two stations in the Mid and Outer Sørfjord area exceeded PROREF by a factor of greater than 20. Two other stations in this area exceeded PROREF for DDE by a factor between 5 and 10. As for cod liver, contamination of this substance is related to earlier use of DDT in the area of Sørfjord.

Concentrations of PAH were highest in Oslo harbour area, and KPAH were highest at one station in the Langesundfjord. Concentrations of PBDEs (sum of six compounds – BDE6S) were higest in Bodø harbour area.

All concentrations of HBCD were below the EQS in 2017, and the highest median concentrations of α-HBCD was found in Bodø harbour. Decreasing levels were found, and a significant downward long-term trend for HBCD in blue mussel from Gressholmen in the Inner Oslofjord.

SCCP was highest in blue mussel from Ålesund harbour, whereas MCCP was highest in blue mussel from the Bodø harbour. There were significant upward long- and short-term trends for SCCP in mussels from Svolvær airport area.

Bisphenol A, TBBPA and alkylphenols were generally not detected in blue mussel, and no conclusion can be drawn regarding possible differences between stations.

Levels in eider

Contaminants were analyzed in the blood and egg (homogenate of yolk and albumin) of the eider duck from Svalbard. This was the first time this species was used under the MILKYS programme. Concentrations of Hg, Pb, As, CB153 BDE47, PFOS and PFOSA in egg were in the same level as from comparable studies from the region.

Biological effects

The ICES/OSPARs assessment criterion[1] (background assessment criteria, BAC) for OH-pyrene in cod bile was exceeded at all stations investigated (Inner Oslofjord, Farsund area, Inner Sørfjord), including the reference station (Bømlo-Sotra area) in 2017 and indicates that the fish have been exposed to PAH. The median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) and the Inner Sørfjord (st. 53B) were significantly higher in 2017, than in 2016, and the concentrations were highest in the Sørfjord (st. 53B).

The ALA-D activity in the the Inner Sørfjord and Inner Oslofjord in 2017 were lower than at Bømlo. Reduced activities of ALA-D reflect higher exposure to lead.

The median EROD-activity in liver of cod from Bømlo, the Inner Oslofjord and the Inner Sørfjord all were about 30% higher than in 2016. The median EROD-activity also appeared higher in the Oslofjord, than at Bømlo and in the Sørfjord. The EROD activities were below the ICES/OSPARs BAC. Concentrations over BAC would indicate possible impact by planar PCBs, PCNs, PAHs or dioxins.

For the first time since 1991, there were no effects of TBT on dogwhelk (imposex parameter VDSI=0) at all eight stations. There were significant downward long-term trends for TBT at all stations, except for Brashavn in the Varangerfjord where no trend could be seen and previous VDSI-levels were low. The synchronous decreases in both TBT concentrations and imposex parameters in dogwhelk coincides with the TBT bans. The results indicate that the legislation banning the use of TBT since 2008 has been effective.

Stable isotopes

The stabile isotope $\delta^{15}N$ is analysed as a measure of trophic position. Results showed very similar isotopic signatures among the stations in 2017 as in 2012-2016, indicating a geographical trend persistent in time. The isotopic signatures in mussels from the programme thus provide valuable information about the isotopic baselines along the Norwegian coast. The geographical differences in the baseline isotopic signatures must be taken into consideration when interpreting accumulation of contaminants in relation to trophic position. The $\delta^{15}N$ data in cod are assessed in relation to concentrations of selected contaminants. Generally, as fish grow through their lifetimes, they feed on larger prey organisms, thus a small increase in trophic level is likely to occur. At specific stations, particularly Hg increased with higher $\delta^{15}N$, i.e. higher concentrations in individuals with slightly higher trophic position.

Microplastics in blue mussel

This is the second year that MILKYS stations have been investigated for microplastics in blue mussels. At least one individual from each of the 17 stations contained suspected plastic particles. The percentage ingestion for those mussels containing particles ranged from 15.0 % to 92.3 % per station. In total, 177 out of 319 individuals contained potential plastic particles (55.5%). The average microplastic load per individual was 1.40 (± 2.27) whereas the average microplastic load per gram w.w. was 2.84 (± 10.84). A total of 445 particles were extracted from the 177 mussels and 81.2% were categorised as small microplastics (<1mm), and the rest were larger (1-5mm).

Available data is not sufficient to observe conclusive trends in microplastic presence and composition over the two years of initial monitoring. However, one station Skallneset in the far north of Norway stood out in both years as having the largest number of particles per g (w.w.).

[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.

Mussels collected here were the smallest sized individuals analysed which generated a need to evaluate size as a parameter in microplastic monitoring. Going forward, it will be important to further evaluate standardisation of mussel size with regards to microplastic monitoring. Overall, the composition of particles regarding both shape and polymeric composition appears to be comparable between 2016 and 2017, with fibres dominating and cellulosic particles being the most identified material. The comparability between the polymeric composition of microplastic detected in mussels from 2016 and 2017, illustrates that sources of anthropogenic material in the environment were similar. This finding support that mussels can be used to qualitatively monitor small microplastics (<1 mm) in coastal environments, and this may be used in the future to track the sources of this plastic pollution.

Sammendrag

Overvåkingsprogrammet «Miljøgifter i norske kystområder 2017 - MILKYS» omhandler nivåer, trender og effekter av miljøgifter langs norskekysten. Undersøkelsen gir grunnlag for bestemmelse av miljøstatus langs norskekysten.

Resultatene viser at det hovedsakelig var nedadgående trender for konsentrasjon av de undersøkte miljøgiftene. Indre Oslofjord er et område med flere miljøgifter med relative høye konsentrasjoner som gir grunnlag for bekymring og behov for nærmere undersøkelser. I dette området observeres det tillegg oppadgående langtidstrend for kvikksølv (Hg) i torskefilet og for mellomkjedete klorparafiner i torskelever. Det var ingen korttidstrender for kvikksølv i torskefilét fra Oslofjorden. Ingen langtids- eller kortidstrend ble funnet når konsentrasjoner i torsk fra indre Oslofjord var justert for fiskelengde.

Undersøkelsen inngår som en del av OSPARs koordinerte miljøovervåkingsprogram Coordinated Environmental Monitoring Programme *(CEMP). I 2017 omfattet overvåkingen miljøgifter i blåskjell (Mytillus edulis) fra 33 stasjoner, purpursnegl (Nucella lapillus) fra 8 stasjoner, strandsnegl (Littorina littorea) fra én stasjon, torsk (Gadus morhua) fra 17 stasjoner og ærfugl (Somateria mollissima) fra én stasjon. Stasjonene er plassert i områder med kjente eller antatt kjente punktkilder for tilførsler av miljøgifter, i områder med diffus tilførsel av miljøgifter slik som byens havneområder og i fjerntliggende områder med antatt lav eksponering for miljøgifter. Overvåkingen i 2017 omfattet analyser av metaller [kvikksølv (Hg), kadmium (Cd), bly (Pb), kobber (Cu), sink (Zn), sølv (Ag), arsen (As), nikkel (Ni), krom (Cr) og kobolt (Co)], tributyltinn, polyklorerte bifenyler (PCBer), pestisider (DDE), polysykliske aromatiske hydrokarboner (PAHer), polybromerte difenyletere (PBDEer), perfluorerte alkylforbindelser (PFAS), heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP), bisfenol A (BPA), tetrabrombisfenol A (TBBPA), alkyfenoler, siloksaner, samt biologiske effekt parametere (VDSI, OH-pyren, ALA-D, EROD) og i tillegg mikroplast.*

2017-resultatene omfatter totalt 3069 datasett (miljøgifter-stasjoner-arter) for 93 forskjellige miljøgifter. Et utvalg på 30 representative miljøgifter og biologiske parametere presenteres i denne rapporten. Dette utvalget består av 809 tidsserier hvorav 193 viste statistisk signifikante trender for perioden 2008 til 2017: 83 var nedadgående og 35 var oppadgående. De nedadgående trendene omfattet metaller (45,8 %) og i noe mindre grad også tributyltinn (TBT) og effekt av TBT (VDSI – sædlederindeks). Dominansen av nedadgående trender indikerer avtagende nivåer av miljøgifter. De oppadgående trendene var i hovedsak også for metaller (88,6 %), og da primært kvikksølv (22,9 %).

Av de 809 tidsseriene kunne 262 av dem klassifiseres i forhold til miljøkvalitetsstandarder (EQS) for EUs prioriterte miljøgifter og vannregionspesifikke stoffer. I 2017 var 157 (59,9 %) lavere enn miljøkvalitetsstandardene.

Alle de 809 tidsseriene ble vurdert i forhold til et nytt begrep kalt provisorisk høy referansekonsentrasjon (PROREF). Av disse var 578 (71,4 %) lavere enn PROREF og 231 (28,6 %) overskred PROREF. For 148 tidsserier (18,3 %) var overskridelsen av PROREF på en faktor lavere enn to. For 61 tidsserier (7,5 %) var overskridelsen av PROREF på en faktor på mellom to og fem. For 13 tidsserier (1,6 %) var overskridelsen av PROREF på en faktor mellom fem og 10. For sju tidsserier (0,9 %) var overskridelsen av PROREF på en faktor mellom 10 og 20, og for to tidsserier (0,2 %) var overskridelsen av PROREF på en faktor høyere enn 20.

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

Konsentrasjoner av miljøgifter i fisk

I 2017 var det overskridelse av miljøkvalitetsstandard for kvikksølv i torskefilét fra samtlige stasjoner. Torsk fra indre Oslofjord hadde konsentrasjon av kvikksølv i filét som var fem til 10 ganger høyere enn PROREF, og det var signifikant oppadgående langtidstrend for perioden 1984 til 2017. Langtidstrend ble beregnet med OSPARs metode for spesifikke lengdegrupper. Ved beregning med metode som tar hensyn til fiskelengde, var konsentrasjonen av kvikksølv i torskefilét fra indre Oslofjord to til fem ganger høyere enn PROREF, men da var det ikke signifikant oppadgående langtidstrend. Torsk fra ytre Oslofjord hadde konsentrasjon av kvikksølv i filét som var opptil to ganger høyere enn PROREF, og det var ingen signifikante trender (2007-2017) ved beregning med OSPAR-metoden og ved justering for fiskelengde.

Det var forhøyede nivåer av PCB i torskelever fra Bergen havn, med overskridelse av PROREF for PCB7 med en faktor på mellom fem og 10. I torskelever fra Indre Oslofjord var det overskridelse av PROREF for PCB7 med en faktor på to til fem. De høye konsentrasjonene av PCBer 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 fra Indre Sørfjorden var lavere enn EQS, men overskred PROREF med en faktor på mellom to og fem. Forurensning av dette stoffet skyldes tidligere bruk av DDT som insektmiddel i forbindelse med fruktdyrking langs fjordene (ca. 1945-1970).

PBDEer er undersøkt i torskelever fra flere fjorder siden 2005. I 2017 var de høyeste nivåene av PBDEer i torskelever fra indre Oslofjord og fra Bergen havn, og lavest nivå 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 Bergen havn og Indre Oslofjord enn i torsk fra seks stasjoner fra områder lengre unna urbane områder. Som for PCBer, er urban påvirkning og vannutskiftingsforhold trolig årsaker til de høye nivåene.

Perfluorerte alkylerte forbindelser (PFAS) har blitt undersøkt i torskelever siden 2005. PFOS og PFOSA som begge er vanlige PFAS-forbindelser, var høyest i torskelever fra indre Oslofjord. Nivåforskjellene mellom de ulike områdene kan foreløpig ikke forklares fullt ut, men det er sannsynlig at en kombinasjon av urbane kilder og begrenset vannutskifting gir de høyeste konsentrasjonene i indre Oslofjord, slik som resultatene var for PCBer og PBDEer. Laveste konsentrasjoner av PFOS og PFOSA ble registrert på Svalbard.

I 2017 var alle konsentrasjonene av heksabromsyklododekaner (HBCD) i torskelever lavere enn EQS. Av HBCDene var α-HBCD den mest dominerende diastereomeren. Torskelever fra indre Oslofjord hadde signifikant høyere konsentrasjon av α-HBCD enn torsk fra de 12 andre stasjonene i denne undersøkelsen. De høye HBCD-konsentrasjonene er sannsynligvis relatert til urban påvirkning, og, særlig for indre Oslofjord, lav vannutskifting med ytre fjord. Blåskjell fra Bodø hadde konsentrasjon av α-HBCD som var signifikant høyere enn de 11 andre blåskjelstasjonene. Det ble funnet flere nedadgående nivåer for HBCD. Det var signifikant nedadgående langtidstrend og korttidstrend for HBCD i torskelever fra Stathelleområdet i Langesundsfjorden. Det var også signifikant nedadgående korttidstrend for HBCD i torskelever fra Tjøme i Ytre Oslofjord.

Det var høyest konsentrasjon av kortkjedete klorerte parafiner (SCCP) i torskelever fra Bergen havn, og det var høyest nivå av mellomkjedete klorparafiner (MCCP) i torskelever fra Ålesund havn. Det

var signifikante oppadgående langtidstrend og kortidstrend for SCCP i torskelever fra Austnesfjord i Lofoten. Det var også signifikat oppadgående korttidstrend for SCCP i torskelever fra Indre Oslofjord, når konsentrasjonene ble justert fiskelengde. Det var også signifikant oppadgående langtidstrend og korttidstrend for MCCP i torskelever fra Indre Oslofjord, og det var signifikat oppadgående langtidstrend for MCCP i torskelever fra Bømlo i Ytre Selbjørnfjord. Det var signifikant nedadgående langtidstrend for SCCP i torskelever fra Indre Sørfjorden.

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

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

Konsentrasjoner av miljøgifter i blåskjell
Blåskjell fra Odderøya i Kristiansandsfjorden hadde høyest konsentrasjon av bly i denne undersøkelsen. Det var signifikant oppadgående langtidstrend og kortidstrend for bly i blåskjell fra Gressholmen i Indre Oslofjord og fra Tromsø havn. Det var signifikant oppadgående langtidstrend og korttidstrend for krom i blåskjell fra Gressholmen i Indre Oslofjord, fra Terøya i Hardangerfjorden og fra Brashavn i Varangerfjorden. Det var generelt lavere tilførsel av metaller til sjø via elver og direkte utslipp, enn i perioden 1990-2015. Dette kan ha påvirket konsentrasjonene funnet i blåskjell og torsk, men sammenheng mellom tilførsler og konsentrasjoner funnet i disse artene krever bedre kunnskap.

Konsentrasjoner av PCB7 i blåskjell fra 23 stasjoner hadde en overskridelse av PROREF med en faktor på mellom fem og 10.

Blåskjell fra to stasjoner i midtre og ytre del av Sørfjorden hadde konsentrasjon av DDE som var mer enn 20 ganger høyrere enn PROREF. To andre stasjoner i dette området hadde overskridelse av PROREF for DDE med en faktor på mellom fem og 10. Forurensning av denne miljøgiften skyldes tidligere bruk av DDT som sprøytemiddel.

Det var høyest konsentrasjoner av PAH-forbindelser i blåskjell fra havneområdet i Indre Oslofjord, og nivået av KPAH var høyest i blåskjell fra en stasjon i Langesundsfjorden. Det var høyest nivå av PBDEer (sum av seks PBDE-forbindelser) i blåskjell fra Bodø havn.

I 2017 var alle konsentrasjonene av HBC i blåskjell lavere enn miljøkvalitetsstandarden (EQS). Det var høyest konsentrasjon av α-HBCD I blåskell fra Bodø havn. Det ble funnet nedadgående nivåer for HBCD i blåskjell, bl.a. var det signifikant nedadgående langtidstrend for HBCD i blåskjell fra Gressholmen i Indre Oslofjord.

Bisfenol A, TBBPA og alkylfenoler ble i hovedsak ikke påvist i blåskjell. Nivåene anses derfor som generelt lave, men ingen konklusjon kan trekkes vedrørende mulige forskjeller mellom stasjonene.

Konsentrasjoner av miljøgifter i ærfugl
Det ble gjort analyser av blodprøver og egg fra ærfugl fra Svalbard. Dette er første gang ærfugl er brukt i MILKYS-programmet. Konsentrasjonene av kvikksølv, bly, arsen, PCB153, BDE47, PFOS og PFOSA i egg var på samme nivå som er funnet i lignende studier fra denne regionen.

Biologiske effekter

ICES/OSPARs vurderingskriterium for bakgrunnsnivå[2] («background assessment criteria», BAC) for OH-pyren i torskegalle ble overskredet på alle undersøkte stasjoner (indre Oslofjord, Farsund-området og Indre Sørfjorden), inkludert referansestasjonen (Bømlo-Sotra området) i 2017, og dette viser at fisken har vært eksponert for PAH. Median-konsentrasjonen av OH-pyren metabolitter i galle i torsk fra Indre Oslofjord og Indre Sørfjorden var signifikant høyere i 2017 enn i 2016, med høyest konsentrasjon i torsk fra Sørfjorden.

I 2017 var ALA-D aktivitet i torsk fra Indre Oslofjord og Indre Sørfjorden lavere enn i torsk fra Bømlo. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly.

I 2017 var median EROD-aktivitet i lever fra Bømlo, Indre Oslofjord og Indre Sørfjorden omtrent 30 % høyere enn i 2016. EROD-aktiviteten var høyest i torsk fra Indre Oslofjord. EROD-aktiviteten var lavere enn ICES/OSPARs bakgrunnsvurderingsnivå (BAC). Konsentrasjoner over dette nivået ville indikere mulig påvirkning fra plane PCBer, PCNer, PAHer eller dioksiner.

For første gang siden 1991 var det ingen effekter av TBT på purpursnegl (imposex parameter VDSI=0) på noen av de åtte stasjonene. Det var signifikante langtidstrender for TBT på alle stasjoner, unntatt for Brashavn i Varangerfjorden hvor det ikke var noen trend og også tidligere VDSI-nivåer har vært lave. Den synkrone nedgangen i både TBT-konsentrasjoner og imposex-parametere i purpursnegl startet da bruk av TBT ble forbudt siden 2008. Resultatene indikerer at forbudet mot bruk av TBT har vært effektivt.

Stabile isotoper

Stabile isotoper av nitrogen (uttrykt som $\delta^{15}N$) er analysert for å tolke en organismes posisjon i næringskjeden. Resultatene viste veldig like isotop-signaturer i 2017 som i årene 2012-2016. Dette tyder på at den romlige trenden er stabil over tid og at isotopsignaturer i muslinger gir verdifull informasjon om bakgrunnsnivået for isotopsignaturer langs norskekysten. Det må tas hensyn til geografiske forskjeller i bakgrunnsnivå for isotopsignaturer når en skal tolke akkumulering av miljøgifter i forhold til trofisk nivå. Data for stabile isotoper ($\delta^{15}N$) i torsk er vurdert i sammenheng med konsentrasjoner av utvalgte miljøgifter. I hovedsak spiser fisk større byttedyr etterhvert som de vokser, og dette medfører ofte overgang til høyere trofisk nivå. Det ble funnet økende konsentrasjon av kvikksølv og PCB-153 (miljøgifter med kjente biomagnifiserende egenskaper) med økende nivå av $\delta^{15}N$, dvs. høyere konsentrasjoner i individer på noe høyere trofisk nivå.

Mikroplast i blåskjell

Dette er det andre året hvor blåskjell fra MILKYS-stasjoner har blitt undersøkt for mikroplast. Minst ett individ fra hver av de 17 stasjonene inneholdt plastpartikler som var antatt å være plast. Prosentvis opptak for skjellene, etter antall individer som inneholdt partikler, varierte fra 15,0 % til 92,3 % per stasjon. Totalt 177 av 319 undersøkte blåskjell inneholdt plastpartikler (55,5 %). Gjennomsnittlig mikroplastbelasting per individ var 1,4 (± 2,27), gjennomsnittlig belastning av mikroplast per gram våtvekt var 2,84 (± 10,84). Totalt 445 partikler ble funnet i de 177 undersøkte blåskjellene, og 81,2 % ble karakterisert å være mikroplast (< 1 mm), og resten var større plastpartikler (1-5 mm).

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

De tilgjengelige dataene er ikke tilstrekkelig til å komme med konkluderende trender om tilstedeværelse av mikroplast og sammensetning for disse to årene som overvåkingen har vart. En stasjon skilte seg ut, Skallneset i Varangerfjorden, som hadde størst antall partikler per gram våtvekt blåskjell. Blåskjellene fra denne stasjonen var minst i størrelse, og dette kan indikere at det er behov for å vurdere skjellstørrelse når det gjøres overvåking av mikroplast i blåskjell. Generelt var partiklene ganske like i form og polymersammensetning i 2016 og 2017, med fibre som dominerende og cellulosepartikler som det hyppigst forekommende materialet. Likheten når det gjelder polymersammensetning og mikroplast påvist i blåskjell i 2016 og 2017, illustrerer at det var sannsynligvis samme kilder til det antropogene materialet i miljøet. Dette funnet betyr at blåskjell kan brukes til kvantitativ overvåkning av mikroplastpartikler (< 1 mm) i kystmiljøet, og at funn i blåskjell kan brukes i framtiden til å spore kilder til mikroplast-forurensning.

Contents

1. Introduction

1.1 Background

The programme "Contaminants in coastal waters of Norway" (*Miljøgifter i norske kystområder* - MILKYS) is administered by the Norwegian Environment Agency (*Miljødirektoratet*). The programme focuses on the levels, trends and effects of hazardous substances in fjords and coastal waters, which also represents the Norwegian contribution to the Coordinated Environmental Monitoring Programme (CEMP). CEMP is a common European monitoring programme under the auspices of Oslo and Paris Commissions (OSPAR). The Norwegian contribution to CEMP addresses several aspects of OSPAR's assessment of hazardous substances. All the results in this report are considered part of the Norwegian contribution to the CEMP programme as well as to the European Environment Agency (EEA) as part of the assessment under the EU Water Framework Directive.

The objective for the performed monitoring is to obtain updated information on levels and trends of selected hazardous substances known or suspected to have a potential for causing detrimental biological effects.

Concentrations of hazardous substances in sediment, pore water, mussels and fish constitute time-integrating indicators for the quality of coastal water. Many of these substances have a tendency to accumulate in tissues (bioaccumulation) in the organisms, and show higher concentrations relative to their surroundings (water and in some cases sediment). Hence, it follows that substances may be detected, which would otherwise be difficult to detect when analysing water or sediment only. Using concentrations in biota as indicators, as opposed to using water or sediment, are of direct ecological importance as well as being important for human health considerations and quality assurance related to commercial interests involved in harvesting marine resources. Blue mussel has been proven as a promising indicator organism for contaminants (Beyer *at al*. 2017). In general, blue mussel is widely used to monitoring in controlled field studies. (Schøyen *et al*. 2017).

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

An overview of MILKYS stations in Norway is shown in maps in **Appendix D**. The program has included monitoring in sediment (Green *et al*. 2010a – TA-2566/2010[3]) and to a larger degree biota, the main emphasis being:

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

The previous investigations have shown that the Inner Oslofjord area has elevated levels of polychlorinated biphenyls (PCBs) in cod liver, mercury, lead and zinc in sediments and elevated concentrations of mercury in cod fillet. Cod liver in the Inner Oslofjord also revealed the highest

[3] Norwegian Environment Agency monitoring report.

median concentration of α–HBCD in 2014. Investigations of the Sørfjord/Hardangerfjord have shown elevated levels of PCBs, dichlorodiphenyltrichloroethane (DDT, using dichlorodiphenyldichloroethylene (DDE) - principle metabolite of DDT as an indicator), cadmium, mercury and lead. Investigations in Orkdalsfjord focused on three blue mussel stations. The results from these investigations have been reported earlier (Green *et al*. 2007 – TA-2214/2006, Green & Ruus 2008 – TA-2372/2008).

It can be noted that environmental status has in previously reports been classified according to environmental quality criteria based on the classification system of the Norwegian Environment Agency (Molvær *et al*. 1997 – TA-1467/1997), or presumed background levels applied in a previous report (see Green *et al*. 2016 – M-618|2016[4], **Appendix C**). In this report, the results were assessed primarily in relation to Environmental Quality Standards (EQS) for priority substances and River Basin Specific Substances (Miljødirektorat, 2016 – M-608|2016), according to the EU Water Framework Directive. Furthermore, in lieu of the aforementioned classification system (i.e. Molvær *et al*. 1997 – TA-1467/1997), *provisional high reference concentrations* (termed herein as PROREF) have been calculated based on MILKYS data (see section 2.7).

In addition to the monitoring of Oslofjord area and Sørfjord/Hardangerfjord, MILKYS also includes the annual monitoring of contaminants at selected stations in Lista and Bømlo areas on the south and west coast of Norway, respectively. During the periods 1993-1996 and 2006-2007, MILKYS also included sampling of blue mussel from reference areas along the coast from Lofoten to the Russian border. The sampling also includes fish from four key areas north of Lofoten in the Finnsnes-Skjervøy area, Hammerfest-Honningsvåg area, and Varanger Peninsula area. Fish from the Lofoten and Varanger Peninsula areas are sampled annually. The intention is to assess the level of contaminants in reference areas, areas that are considered to be little affected by contaminants, and to assess possible temporal trends.

Biological effects methods (BEM) or biomarkers were introduced in the Norwegian MILKYS in 1997. The purpose of these markers is, by investigations on molecular/cell/individual level, to give warning signals if biota is affected by toxic compounds and to assist in establishing an understanding of the specific mechanisms involved. The reason to use biological effects methods within monitoring programmes is to evaluate whether marine organisms are affected by contaminant inputs. Such knowledge cannot be derived from tissue levels of contaminants only. One reason is the vast number of chemicals (known and unknown) that are not analysed. Another reason is the possibility of combined effects ("cocktail effects") of multiple chemical exposures. In addition to enabling conclusions on the health of marine organisms, some biomarkers assist in the interpretation of contaminant bioaccumulation. The biological effects component of MILKYS includes imposex in snails as well as biomarkers in fish. The methods were selected because they can reflect the impact of specific contaminants or specific groups of contaminants on organisms. The methods were also selected because they are relatively robust compared to other biological effects methods.

The state of contamination is divided into three issues of concern: levels, trends and effects. Different monitoring strategies are used, especially with regards to the selection of indicator media (blue mussel, snail, cod liver etc.) and selection of contaminants to be monitored. Sample frequency is annual for biota. The programme underwent an extensive revision in 2012 and again in 2017, both in regards to stations and choice of contaminants to be analyzed. Monitoring of flatfish was discontinued in 2012. Three more cod-stations were added in 2012, and a fourth added in 2015 and another station (Svalbard) was added in 2017 bringing the total to 17. The blue mussel stations

[4] Norwegian Environment Agency monitoring report.

were reduced from 38 to 26 in 2012. Investigations of blood and egg of the eider duck from Svalbard were also added in 2017.

Choice of contaminants for each station has changed considerably after 2011. Pesticides and dioxin analyses have since been discontinued except for DDTs at some stations in the Sørfjord/Hardangerfjord. However, many new contaminant analyses were added, including analyses of: short- and medium chain chlorinated paraffins (SCCP and MCCP), phenols (e.g. bisphenol A, tetrabrombisphenol A), organophosphorus flame retardants (PFRs) and stabile isotopes. PFRs were discontinued in 2017. The Norwegian Pollution and Reference Indices (cf. Green *et al.* 2011b – TA-2862/2011, 2012a – TA-2974/2012) are not included in the revised programme, and for the years 2012-2015 passive sampling of contaminants in water was included. This report on the 2017-investigations also included, for the first time, investigations of siloxanes and microplastics.

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

All the results are publically available. The results for flatfish are not included in this report, but are included in the submission to ICES and the national database *Vannmiljø*[5] (including results for the eider duck). This additional funding from the Ministry also ensured that investigation of biological effect in cod from the Inner Sørfjord and from Bømlo on the West Coast could be continued. The results for blue mussel and cod from these investigations are included in this report.

Where possible, MILKYS is integrated with other national monitoring programmes to achieve a better practical and scientific approach for assessing the levels, trends and effects of contaminants. In particular, this concerns sampling for the Norwegian sample bank, a programme funded by the Norwegian Ministry of Climate and Environment to sustain time trend monitoring and local (county) investigations. Other programmes that can be relevant are: Comprehensive Study on Riverine Inputs and Direct Discharges (RID, *Elvetilførsler og direkte tilførsler til norske kystområder*), Ecosystem Monitoring of Coastal Waters (*Økosystemovervåking i kystvann* (ØKOKYST)), Environmental Contaminants in an Urban Fjord (*Miljøgifter i en urban fjord*) as well as MAREANO[6] and Arctic Monitoring and Assessment Programme (AMAP)[7]. The first three programmes are operated by NIVA on behalf of Norwegian Environment Agency.

1.2 Purpose

An aim of the Norwegian Environment Agency is to obtain an overview of the status and trends of the environment as well as to assess the importance of various sources of pollution. The Norwegian

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

[6] 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.

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

Environment Agency seeks to develop a knowledge-base for the public and for the management of the environment.

MILKYS is used as a tool to promote "cessation of discharges, emissions and losses of hazardous substances by the year" (OSPAR[8]) This will be accomplished through:

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

MILKYS is part of the Norwegian contribution to CEMP and is designed to address issues relevant to OSPAR (OSPAR 2014) including OSPAR priority substances (OSPAR 2007). The programme will also contribute to the demands on Norway by the EU Water Framework Directive (WFD) (2000/60/EC) and its daughter directive the Environmental Quality Standards Directive (EQSD – 2013/39/EU) to achieve good chemical and ecological status by assessing the results using EU EQSD. The results from MILKYS can also be useful in addressing aspects of the EU Marine Strategy Framework Directive (MSFD) (2008/56/EC). One of the goals of WFD and MSFD is to achieve concentrations of hazardous substances in the marine environment near background values for naturally occurring substances and close to zero for manmade synthetic substances. OSPAR has also adopted this goal (OSPAR 1998).

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

2. Material and methods

2.1 Sampling

2.1.1 Stations

Samples for the investigation of contaminants were collected along the Norwegian coast, from the Swedish border in the south and to the Russian border in the north, as well as Svalbard (***Figure 1***, ***Figure* 2, *Figure 3*, Appendix D**). The sampling involved blue mussel at 34 stations (whereof eight were completely funded by the Ministry of Climate and Environment, see Chapter 1.1), dogwhelk at eight stations (nine were planned), periwinkle at one station, cod at 17 stations and the common eider at one station. In addition, microplastics were investigated in blue mussel from 17 stations.

Samples were collected during 2017 and analysed according to OSPAR guidelines (OSPAR 2003, 2012)[9] 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 shore line. 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 2017-programme also included investigation of contaminants in the common eider (*Somateria mollissima*).

As mentioned above (see Chapter 1.1) the results from some supplementary monitoring to maintain long-term trends are included in this report. These concern some contaminants in blue mussel and cod (cf. ***Table 2***).

Some details on methods applied in previous years of monitoring are provided in Green *et al.* (2008 – TA-2370/2007).

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

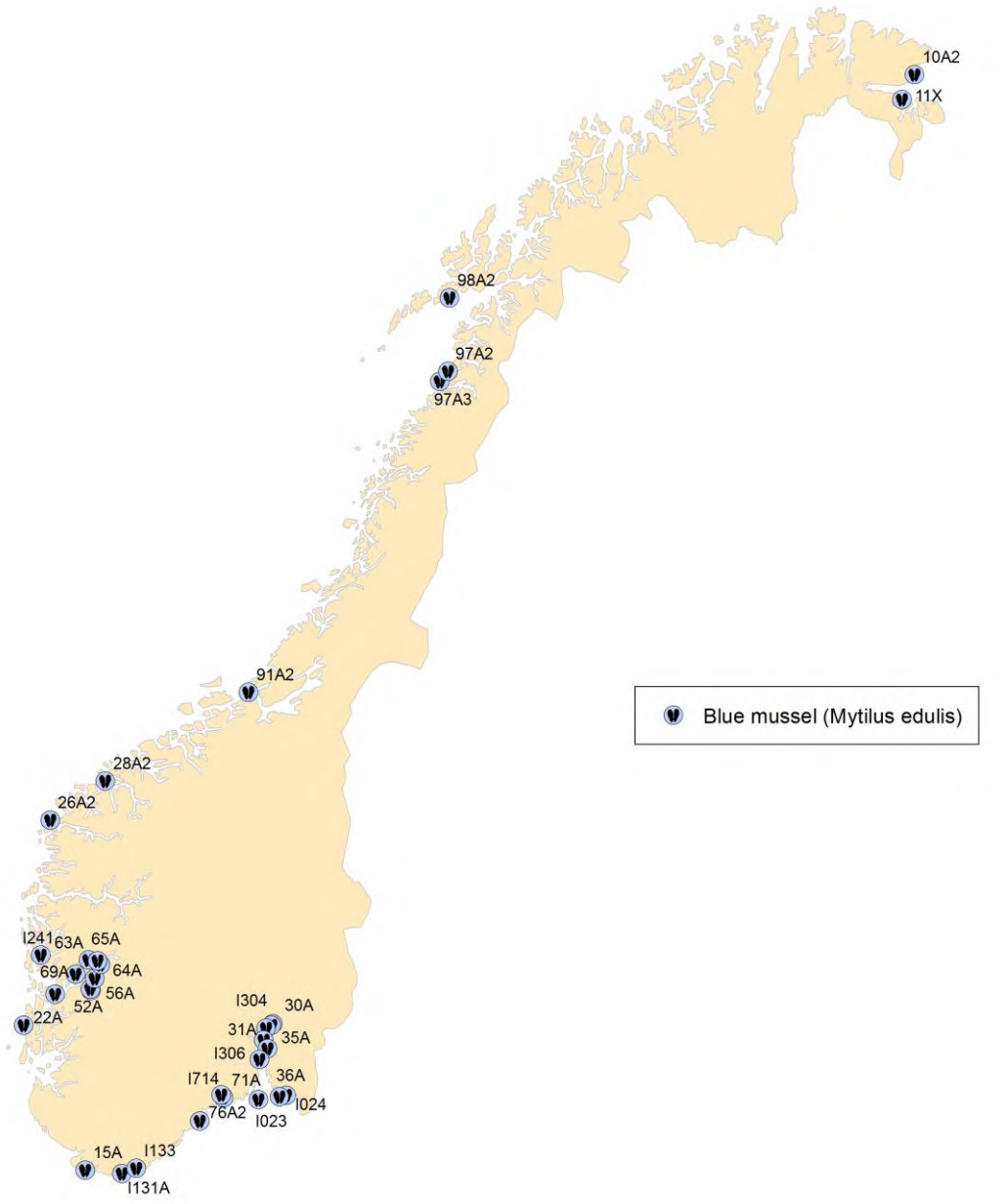


***Figure 1**. Stations where blue mussel were sampled in 2017. See also station information in detailed maps in **Appendix D** (See also selection of blue mussel stations for monitoring of microplastic in **Figure 4**).*

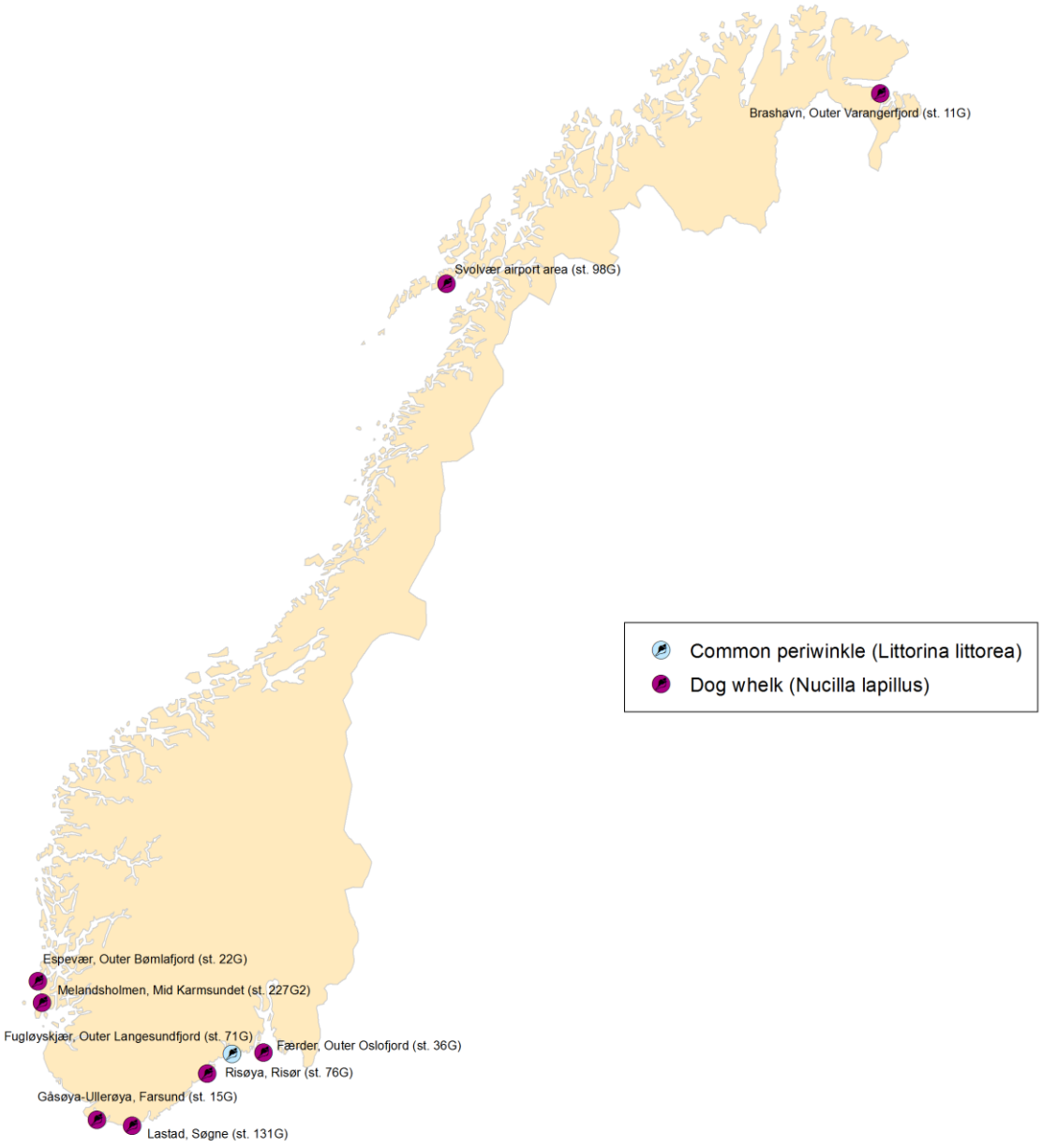


***Figure 2**. Stations where dogwhelk and periwinkle were sampled in 2017. See also station information in detailed maps in **Appendix D**.*

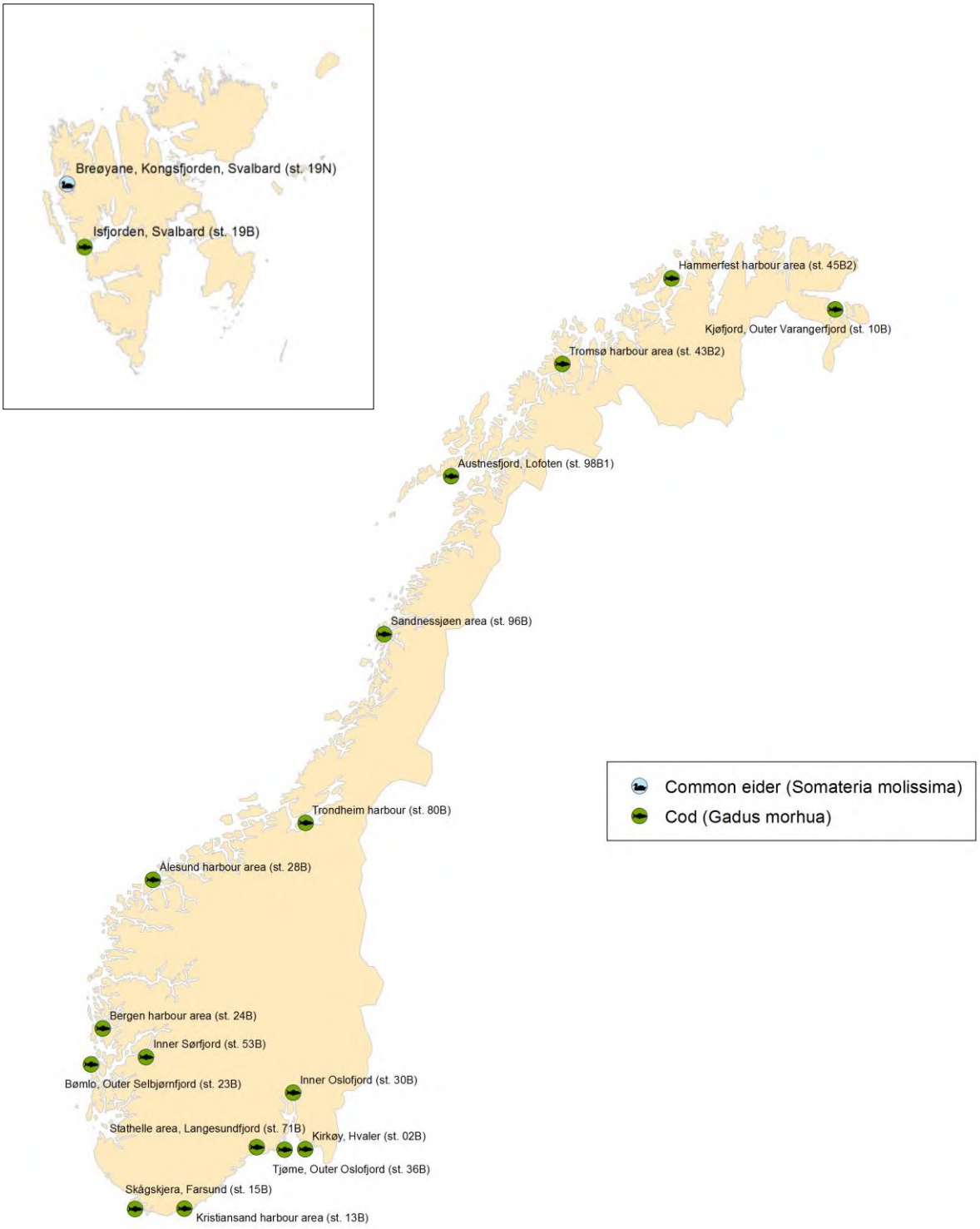


***Figure 3**. Stations where cod and the common eider were sampled in 2017. Note insert map of Svalbard and see also station information in detailed maps in **Appendix D**.*

2.1.2 Blue mussel

A sufficient number of individuals for three pooled samples of blue mussel were found at nearly all of the 33 stations, including the seven stations funded directly by the Ministry of Climate and Environment[10]. The exceptions being one station with two samples (Kirkøy st. I024) and one station with one sample (Bjørkøya st. 71A). The stations are located as shown in ***Figure 1*** (see also maps in **Appendix D**). The stations were chosen to represent highly polluted or reference stations distributed along the Norwegian coast. It has been shown that the collected individuals are not all necessarily *Mytilus edulis* (Brooks & 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 22nd August to 27th November 2017.

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

The method for collecting and preparing blue mussels was based on the National Standard for mussel collection (NS 9434:2017). Three pooled samples of 20 individuals (size range of 3-5 cm) were collected at each station and kept frozen until later treatment. Shell length was measured by slide callipers. The blue mussel was scraped clean on the outside by using knives or scalpels before taking out the tissue for the analysis. Mussel samples were frozen (-20°C) for later analyses.

For certain stations prior to the 2012-investigations the intestinal canal was cleared for contents (depuration) in mussels following OSPAR guidelines (OSPAR 2012, cf. Green *et al.* 2012a – TA-2974/2012). There is some evidence that for a specific population/place the depuration has no significant influence on the body burden of the contaminants measured (cf. Green 1989; Green *et al.* 1996, Green *et al.* 2001 – TA-1780/2001). This practice was discontinued in 2012.

2.1.3 Dogwhelk and periwinkle

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

Effects (imposex, ICES 1999) and concentrations of organotin in dogwhelk were investigated using 50 individuals from each station. Individuals were kept alive in a refrigerator (at +4°C) until possible effects (imposex) were quantified. All snails were sampled by NIVA except for the dogwhelk collected in Lofoten and in the Varangerfjord. The snail samples were collected from 26th September to 13th November 2017.

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

2.1.4 Atlantic cod

Fifteen individuals of Atlantic cod were sampled at all 17 stations (***Figure 3***). Cod from Svalbard were included for the first time in the programme.

The cod were sampled from 17th August 2017 to 29th January 2018. All the cod were sampled by local fishermen except for the cod in the Inner Oslofjord (st. 30B) that was collected by NIVA by trawling from the research vessel *F/F Trygve Braarud* owned and operated by the University of Oslo. Instructions were given to the fisherman to catch coastal cod. Coastal cod is more attached to one place than open ocean cod which migrate considerably farther than coastal cod. Some spot checks were taken looking at the cross-section pattern of the otoliths which confirmed, at least for these samples, that only coastal cod were caught. The otoliths are stored for further verification if necessary. If possible, cod were sampled in five length classes (***Table 1***), three individuals in each class. Tissue samples from each fish were prepared in the field and stored frozen (-20°C) until analysis or the fish was frozen directly and prepared later at NIVA.

Table 1*. Target length groups for sampling of cod.*

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

Livers were in general not large enough to accommodate all the analyses planned (see **Appendix E**). Trondheim harbour (st. 80B), Sandnessjøen area (st. 96B), Tromsø harbour (st. 43B2) and Isfjorden, Svalbard (st. 19B) were the four stations where all 15 individuals had sufficient liver size to complete all of the intended analyses. The general lack of material was partially compensated for by making pooled samples of livers. These are noted in the tables below. The concerns using pooled samples or small sample size in cod are discussed in an earlier report (Green *et al.* 2015 – M-433|2015).

The age of the fish was determined by noting the number opaque and hyaline zones in otoliths.

2.1.5 Common eider

Contaminants in the Common eider were investigated at one station in Svalbard (Breøyane st. 19N), which this study considered as a reference station. Blood samples were collected from 15 individuals (two subsamples from each) on the 16th June 2017 and eggs from another 15 individuals on the 9th June 2017 were analyzed (***Figure 3***). All samples are from adult nesting females.

2.2 Chemical analyses of biological samples

2.2.1 Choice of chemical analyses and target species/tissues

An overview of chemical analyses performed on 2017-samples is shown in ***Table 2***. Note that the table also includes an overview of some supplementary investigations funded by the Ministry of Climate and Environment that are relevant to this report.

Table 2. *Analyses and target organisms of 2017. The value indicates the total number of stations investigated of which those funded by the Ministry of Climate and Environment as a supplement are indicated in parentheses*. (See also* ***Appendix B*** *for complete list of chemical codes.)*

Parameter	Blue mussel	Dogwhelk	Common periwinkle	Cod liver	Cod fillet	Eider blood	Eider egg***
Metals Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)	33 (8)			17		1	1
Mercury (total Hg)	33 (8)				17	1	1
Organotin (MBT, DBT, TBT, TPT)	7 (7)	8	1				
PCB-7 (PCB-28, 52, 101, 118, 138, 153, and 180**)**	31 (8)			15		1	1
HCB, OCS, 5CS**	8 (8)			8 (7)			
∑DDT (p-p`-DDT, p-p`-DDE, p-p`-DDD**)**	19 (8)			7 (6)			
PAH-16	10						
Polybrominated diphenyl ethers (PBDEs) BDE28, 47, 99, 100, 126, 153, 154, 183, 196 and 209	10			10		1	1
Hexabromocyclododecane (HBCDs: α-, ß-, γ-HBCD**)**	9			12		1	1
Perfluorinated alkylated substances (PFAS) PFNA, PFOA, PFHpA, PFHxA, PFHxS, PFOS, PFBS, PFOSA				9		1	1
Chlorinated paraffins (SCCP (C10-C13) and MCCP (C14-C17)**)**	10			12		1	1
Alkylphenoln (Octylphenol, nonylphenol**)**	8			11		1	1
Tetrabrombisphenol A (TBBPA)	10			11		1	1
Bisphenol A (BPA)	10			11		1	1
Siloxanes (D4, D5, and D6)				4		1	1
Microplastics	14 (2)						

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

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

***) Homogenate of yolk and albumin

An overview of the applied analytic methods is presented in ***Table 3***. Chemical analyses were performed separately for each cod liver, if possible, otherwise a pooled sampled was taken (see «count» for the relevant tables, e.g. ***Table 14)***. Mercury was analysed on a fillet sample from each cod. Furthermore, Biological Effects Methods (BEM) were performed on individual cod.

***Table 3**. Overview of method of analyses (see **Appendix B** for description of chemical codes). Limit of quantification (LOQ, usually taken at three times the standard deviation) is indicated. See 2.2.2 for description of the labs used for the different analysis.*

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
Metals						
cadmium (Cd)	7440-43-9	**NIVA/EFM**	0.001 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
cadmium (Cd)	7440-43-9	**NILU**	0.002 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
copper (Cu)	7440-50-8	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
copper (Cu)	7440-50-8	**NILU**	0.06 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
lead (Pb)	7439-92-1	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
lead (Pb)	7439-92-1	**NILU**	0.01 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
zinc (Zn)	7440-66-6	**NIVA/EFM**	0.5 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
zinc (Zn)	7440-66-6	**NILU**	0.5 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
silver (Ag)	7440-22-4	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
silver (Ag)	7440-22-4	**NILU**	0.02 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
arsenic (As)	7440-38-2	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
arsenic (As)	7440-38-2	**NILU**	0.03 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
chrome (Cr).	7440-47-3	**NIVA/EFM**	0.02 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
chrome (Cr).	7440-47-3	**NILU**	0.03 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
nickel (Ni)	7440-02-0	**NIVA/EFM**	0.04 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
nickel (Ni)	7440-02-0	**NILU**	0.03 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
cobalt (Co)	7440-48-4	**NIVA/EFM**	0.005 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
cobalt (Co)	7440-48-4	**NILU**	0.002 mg/kg	20 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
tin (Sn)	7440-31-5	**NIVA/EFM**	0.1 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
tin (Sn)	7440-31-5	**NILU**	0.5 mg/kg	30 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
Total-Hg	7439-9-76	**NIVA/EFM**	0.005 mg/kg	25 %	Standard method	ISO 17025, accredited
Total-Hg	7439-9-76	**NILU**	0.0003-0.003 mg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
PCBs						
PCB-28	7012-37-5	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-28	7012-37-5	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025
PCB-52	35693-99-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-52	35693-99-3	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
PCB-101	37680-73-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-101	37680-73-2	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
PCB-118	31508-00-6	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-118	31508-00-6	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
PCB-138	35065-28-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-138	35065-28-2	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
PCB-153	35065-27-1	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-153	35065-27-1	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
PCB-180	35065-29-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-180	35065-29-3	**NILU**	0.02-0.2 µg/kg	25 %	Standard method NS EN ISO/IEC 17025	ISO 17025, accredited
p-p`-DDT	50-29-3	**NIVA/EFM**	0.2 µg/kg low fat. 4 µg/kg high fat	60 %	Internal method	ISO 17025
p-p`-DDE	82413-20-5	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
p-p`-DDD	72-54-8	**NIVA/EFM**	0.1 µg/kg low fat. 2 µg/kg high fat	50 %	Internal method	ISO 17025
PBDEs						
BDE47	5436-43-1	**NIVA/EFM**	0.005 µg/kg mussels. 0.1 µg/kg high fat	30 %	Internal method	ISO 17025
BDE47	5436-43-1	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE99	60348-60-9	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE99	60348-60-9	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE100	189084-64- 8	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE100	189084-64- 8	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
BDE126*	366791-32-4	**NIVA/EFM**	0.01 µg/kg mussels	50 %	Internal method	ISO 17025
BDE126*	366791-32-4	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE153	68631-49-2	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE153	68631-49-2	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE154	207122-15-4	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	Internal method	ISO 17025
BDE154	207122-15-4	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE183	207122-16-5	**NIVA/EFM**	0.03 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025
BDE183	207122-16-5	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE196	32536-52-0	**NIVA/EFM**	0.05 µg/kg mussels. 0.3 µg/kg high fat	40 %	Internal method	ISO 17025
BDE196	32536-52-0	**NILU**	0.1 µg/kg	30-45 %	Internal method	ISO 17025
BDE209	1163-19-5	**NIVA/EFM**	0.5 µg/kg mussels. 0.5 µg/kg high fat	50 %	Internal method	ISO 17025
BDE209	1163-19-5	**NILU**	1.0 µg/kg	30-45 %	Internal method	ISO 17025
α, ß, γ-HBCD	134237-50-6 (α isomer), 134237-51-7 (ß isomer), 134237-52-8 (γ isomer)	**EF-GFA**	0.006 ng/g	40 %	Internal method, validated	ISO 17025
α, ß, γ-HBCD	134237-50-6 (α isomer), 134237-51-7 (ß isomer), 134237-52-8 (γ isomer)	**NILU**	0.03-0.2 µg/kg	40-50 %	Internal method	ISO 17025
Tetrabrombisphenol A (TBBPA)	79-94-7	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
		NILU	3-15 µg/kg	30-40 %	Internal method	ISO 17025
Bisphenol A (BPA)	80-05-7	**EF-GFA**	1-5 ng/g	40 %	Internal method, validated	ISO 17025
		NILU	3-15 µg/kg	30-40 %	Internal method	ISO 17025
PFAS						
PFNA	375-95-1	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOA	335-67-1	**NIVA**	0.4 µg/kg	40 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHpA	375-85-9	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFHxA	307-24-4	**NIVA**	0.4 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOS	1763-23-1	**NIVA**	0.1 µg/kg	25 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFBS	29420-49-3	**NIVA**	0.1 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
PFOSA	4151-50-2	**NIVA**	0.1 µg/kg	30 %	Internal method, validated	Not accredited but follows the routines and systems of ISO 17025
S/MCCP						
SCCP (C10-C-13)	85535-84-8	**EF-GFA**	0.6-3.5 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
SCCP (C10-C-13)	85535-84-8	**NILU**	0.3-30 µg/kg	>50 %	Internal method	ISO 17025
MCCP (C14-C17)	85535-85-9	**EF-GFA**	5-10 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
MCCP (C14-C17)	85535-85-9	**NILU**	0.3-30 µg/kg	>50 %	Internal method	ISO 17025
Phenols						

Name	[CAS-number]	Lab.	LOQ	Est. uncer-tainty	Standard or internal method	Accreditation status
Octylphenol	27193-28-8 (1806-26-4, 67632-66-0, 140-66-9,)	**EF-GFA**	10-50 ng/g	40 %	Internal method, validated	ISO 17025
Octylphenol	27193-28-8 (1806-26-4, 67632-66-0, 140-66-9,)	**NILU**	0.5-1 µg/kg	30-40 %	Internal method	ISO 17025
4-nonylphenol	104-40-5 (25154-52-3, 84852-15-3)	**EF-GFA**	10-50 ng/g	40 %	Internal method, validated	ISO 17025
4-nonylphenol	104-40-5 (25154-52-3, 84852-15-3)	**NILU**	0.5-1 µg/kg	30-40 %	Internal method	ISO 17025
Tin compounds						
Monobutyltin (MBT)	2406-65-7 (78763-54-9)	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Dibutyltin (DBT)	1002-53-5	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Tributyltin (TBT)	688-73-3	**EF-GFA**	0.5 ng/g	30 %	Internal method, validated	ISO 17025
Triphenyltin (TPT)	668-34-8	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Siloxane						
Octamethylcyclo-tetrasiloxane (D4)	556-67-2	**NILU**	2.7 µg/kg	20 %	Internal method	ISO 17025
Decamethylcyclo-pentasiloxane (D5)	541-02-6	**NILU**	1.5 µg/kg	20 %	Internal method	ISO 17025
Dodecamethylcyclo-hexasiloxane (D6)	540-97-6	**NILU**	1.5-2.0 µg/kg	20 %	Internal method	ISO 17025
BEM						
VDSI		**NIVA**		10-20%	ICES 1999	Not accredited
EROD		**NIVA**		10-20%	ICES 1991	Not accredited
ALA-D		**NIVA**		20 %	ICES 2004	Not accredited

2.2.2 Laboratories and brief method descriptions

The 2017-samples were largely analysed by Eurofins Moss (EFM), and by one of the Eurofins laboratories in Germany (GFA) and one Eurofins laboratory in Bulgaria (Sofia) (see ***Table 3***). Norwegian Institute for Atmosphere Research (NILU) performed all siloxane-analyses as well as all analyses (except PFAS) in the blood and eggs (homogenate of yolk and albumin) of the common eider (*Somateria mollissima*). NIVA was responsible for all PFAS analyses. A brief description of the analytical methods can be found in Green *et al.* (2008 – TA-2372/2008).

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

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

Samples for NILU analyses of PCB7 were extracted with a suitable organic solvent. The lipid and other interferences are removed with the use of sulfuric acid and silica SPE (solid phase extraction) before the compounds are detected with help of GC-HRMS or GC-QTOf-MS.

Among the individual PCBs quantified, seven (ΣPCB-7) are commonly used for interpretation of the results[11] (***Table 4***).

Table 4. *The seven suggested PCB-congeners (the sum is denoted as PCB-7), which according to OSPAR (2018) are to be quantified in biota.*

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

Polycyclic aromatic hydrocarbons (PAH) were analysed at Eurofins Moss 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 with LOQs).

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**).

[11] Several marine conventions (e.g. OSPAR and HELCOM[11]) use ΣPCB-7 to provide a common basis for PCB assessment.

Analysis of organotin (TBT, MBT, DBT and TPT) in *N. lapillus* and *M. edulis* were done by NIVA until 2010. The method included solvent extraction, derivatization, and detection by gas chromatography - mass spectrometry (GC-MS) as described by Følsvik *et al.* (1999) and Green *et al.* (2008). Since 2010, these analyses were carried out by Eurofins GFA Lab Service GmbH with a method that is similar with the one described for NIVA. One exception was the samples from 2016 which were analyzed at GALAB Laboratories GmbH. Here the extraction was similar, but the detection was done by gas chromatography – atomic emission detector (GC-AED). All the three labs are accredited according to ISO 17025, but the analysis at NIVA was not accredited. Quantification of individual organotin components was performed by using the internal standard method and the limit of quantification (LOQ) was set individual on each sample. The range of the LOQ was from 0.2 to 5 µg/kg w.w. Quality assurance of organotin analyses included routine analyses of Standard Reference Materials and in-house reference materials. All three laboratories have participated in QUASIMEME international intercalibration exercises of organotin analyses with acceptable results Green *et al.* (2017 – M-856|2017).

Analyses of polybrominated diphenylether (PBDE) in cod liver and blue mussel were done at Eurofins Moss in 2017/2018. Results are given based on the total extractable fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

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

Analysis of perfluorinated alkylated substances (PFAS) in cod liver in 2017 were done at NIVA. The general procedures include extractions with solvents using ultrasonic bath before intensive clean up and LC/MS/MS-analysis (liquid chromatography mass spectrometry) (ESI negative mode). Since 2013, LC-qTOF (liquid chromatography quadropole time of flight) has been used for detection and quantification. The limit of quantification has improved for analyses with regards to the 2016-samples and later, primarily due to a slight modification in the method and better access to internal standards. Previously most of the analyses were performed at NIVA, using different procedures and instrumentation. In order to minimize methodical inconsistencies in time series, the transfer of analyses from NIVA to Eurofins Moss has also included several intercalibrations between the two labs.

Chlorinated paraffins (SCCP (C10-C13), MCCP (C14-C17)) and nonyl- and octylphenols were determined by GC-MS at Eurofins GFA. Determination of bisphenol A (BPA) and tetrabromobisphenol A (TBBPA) were done at Eurofins GFA by GC-MS while hexabromocyclododecane (α, ß, γ-HBCD) were determined by LC-MS-MS also by Eurofins GFA.

Samples for NILU analyses of chlorinated paraffins (SCCP/MCCP) were extracted with a suitable organic solvent. The lipid and other interferences were removed with the use of sulfuric acid and silica SPE (solid phase extraction) before the compounds were detected with help of GC-HRMS or GC-QTOf-MS. Samples for HBCD were extracted and cleaned together with the PBDEs, but the quantification was done with LC-TOF-MS. Samples of alkylphenols and bisphenols were extracted with organic solvents, cleaned up with SPE before determination on LC-QTOF-MS or LC-TOF-MS.

Siloxanes, i.e. octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed by NILU – Norwegian Institute for Air Research. Already established methods based on liquid/liquid extraction (Warner *et al.* 2010, 2012) were used to extract and quantify siloxanes. Biota tissues were extracted using solid-liquid extraction

with a biphasic solvent system of acetonitrile and hexane. Collected extracts from biota tissues were analysed using concurrent solvent recondensation large volume injection gas chromatography mass spectrometry.

For fish, the target tissues for quantification of hazardous substances were liver and fillet (***Table 2***), whereas for the biological effects methods (BEM) liver, blood, and bile were used (cf. ***Table 5***). In addition, the age, sex, and visual pathological state for each of the individuals was determined. Other measurements include: fish weight and length, weight of liver, liver dry weight and fat content (% total extractable fat), the fillet dry weight and its % fat content. These measurements are stored in the database and have been published periodically, the latest edition in 2008 (Shi *et al*. 2008 – TA-2369/2008).

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

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

2.3 Biological effects analysis

Four biological effects methods (BEM) are assessed using methods described by ICES (see ***Table 3***) and includes the measurement of OH-pyrene. These methods have been applied for this investigation, as has been done in previous annual MILKYS investigations. Each method is in theory generally indicative of one or a group of contaminants. For EROD however, some interaction effects are known. Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs, and is thus a marker of PAH exposure. An overview of the methods, tissues sampled and contaminant specificity is shown in ***Table 5***. One of the major benefits of BEM used at the individual level (biomarkers) is the feasibility of integrating biological and chemical methods, as both analyses are done on the same individual.

Table 5*. The relevant contaminant-specific biological effects methods applied.*

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

Sampling for BEM-analyses is performed by trained personnel, most often under field conditions. Analyses for ALA-D and EROD-activity requires that the target fish is kept alive until just prior to tissue or blood sampling. The tissue samples are removed immediately after the fish are inactivated by a blow to the head. Samples are then collected and stored in liquid nitrogen. Analyses of a metabolite of pyrene (OH-pyrene) were done on bile samples stored at -20°C.

Imposex (on dogwhelk) and intersex analysis (on the common periwinkle) are a measure of effects of TBT, and are usually performed on fresh samples, but can be performed after that samples have been frozen.

2.3.1 Rationale and overview

A thorough analysis and review of BEM-results has been performed twice since their inclusion in 1997 (Ruus *et al*. 2003 – TA-1948/2003; Hylland *et al*. 2009). Clear relationships were shown between tissue contaminants, physiological status, and responses in BEM parameters in cod (Hylland *et al*. 2009). Although metals contributed substantially to the models for ALA-D (and also for metallothionein - MT included in the programme 1997-2001) and organochlorines in the model for CYP1A activity, other factors were also shown to be important. Liver lipid and liver somatic index (LSI) contributed for all three BEM-parameters, presumably reflecting the general health of the fish. Size or age of the fish also exerted significant contributions to the regression models. It was concluded that the biological effect methods clearly reflected relevant processes in the fish even if they may not be used alone to indicate pollution status for specific stations at given times. Furthermore, the study showed that it is important to integrate a range of biological and chemical methods in any assessment of contaminant impacts. Through continuous monitoring within CEMP, a unique BEM time series/dataset are generated, that will also be of high value as a basis of comparison for future environmental surveys.

Since the biological effect methods were included in the programme, there have been some modifications of the methods in accordance to the ICES guidelines (cf. ***Table 3***). In 2002, reductions were made in parameters and species analysed. There have also been improvements in the methods, such as discontinuation of single wavelength fluorescence and use of HPLC in the analysis of bile metabolites since 2000.

The MILKYS programme for 2017 included four biological effects methods (BEM) (cf. ***Table 5***). Measures of OH-pyrene and EROD-activity increase with increased exposure to their respective inducing contaminants. The activity of ALA-D on the other hand is inhibited by contamination (i.e., lead), thus lower activity means a response to higher exposure.

The impact of TBT can impact the reproductive capabilities of on dogwhelks and common periwinkles. This impact is assessed when dogwhelks and the common periwinkles are analysed for imposex and intersex[12], respectively see ***Table 3***).

2.4 Information on quality assurance

2.4.1 International intercalibrations

The laboratories (NIVA and subcontractors Eurofins and NILU) have participated in the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, QUASIMEME Round 2017-1 apply to the 2017-samples, and the results were considered as acceptable. These QUASIMEME exercises included nearly all the contaminants and the imposex analysed in this programme. The quality assurance programme was corresponding to the analyses of the 2016-samples (cf. Green *et al*. 2017 – M-856|2017).

NIVAs group has satisfactorily participated regularly in international intercalibration exercises of imposex determination (BE-1 exercise for 1997 (Davies *et al*. 1999), 2002 (Davies *et al*. 2002), 2004, 2005, 2006, 2007, 2008, 2009, 2012 and 2017) under the organisation QUASIMEME (Minchin *et al*. 2000). To ensure consistency, evaluations of imposex were determined by the same persons for individual *N. lapillus*.

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

2.4.2 Analyses of certified reference materials

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

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

2.5 Stable isotopes

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

2.6 Analyses of microplastics

In this short assessment of microplastics in blue mussel from the Norwegian environment, we build on the data collected previously to better map microplastic prevalence. This includes relative differences between stations and whether a difference can be tracked between years. Utilizing this approach allows Norway the opportunity to use a large-scale coordinated survey to assess microplastic contamination applying a tested and validated approach. Microplastic under NIVA definition is any particles < 1 mm in length which is based on current UN approach. However, in respect to other monitoring and international agreements that report any particle < 5mm, NIVA reports two sizes: small microplastics < 1 mm and large micropalastics 1 - 5 mm.

Blue mussel were efficiently analysed for microplastics presence using the alkali digestive protocol, visual identification and chemical verification using Fourier transform infrared spectroscopy (FT-IR) described in more detail below.

2.6.1 Sample collection

Blue mussel samples were collected in parallel with MILKYS sampling 2016 and 2017 at several stations along the coast of Norway (***Table 6***, ***Figure 4***). Only living individuals with no visible signs of damage were collected. Individuals were frozen (-20 °C) whole (in their shell) as soon as possible after collection. A total of 17 stations were investigated for microplastics in 2017. Six stations were selected having been used previously for the 2016-investigation and 11 stations were added for investigation in 2017 (***Figure 4***). In the discussion we include data from two stations within the Oslofjord also sampled in 2017. This data was recently published (Bråte *et al.*, 2018). There were 20 individuals from each station used for analysis with the exception of Bjørkøya, Langesundfjord (st. 71A) and Gåsøya, Inner Oslofjord (st. I304) where only 13 and six individuals were collected for analysis, respectively.

***Table 6**. Stations for blue mussel collection and analysis for microplastic (MP) (* Published in Bråte et al, 2018).*

Station	Station name	Previously assessed for MPs by NIVA (2016)	Analysis in 2017
I023	Singlekalven, Hvaler	X	X
I301	Akershuskaia, Inner Oslofjord	X	*
30A	Gressholmen, Inner Oslofjord		X
I304	Gåsøya, Inner Oslofjord	X	X
I306	Håøya, Inner Oslofjord		X
I307	Ramtonholmen, Inner Oslofjord	X	*
31A	Solbergstrand, Mid Oslofjord	X	X
35A	Mølen, Mid Oslofjord		X
36A	Færder, Outer Oslofjord		X
71A	Bjørkøya, Langesundfjord		X
65A	Vikingneset, Mid Hardangerfjord		X
28A2	Ålesund harbour		X
26A2	Vågsvåg, Outer Nordfjord	X	X
97A3	Bodø harbour	X	X
97A2	Mjelle, Bodø area		X
98A2	Svolvær airport area		X
(n.e.)	Tromsø harbour area		X
11X	Brashavn, Outer Varangerfjord		X
10A2	Skallnes, Outer Varangerfjord	X	X

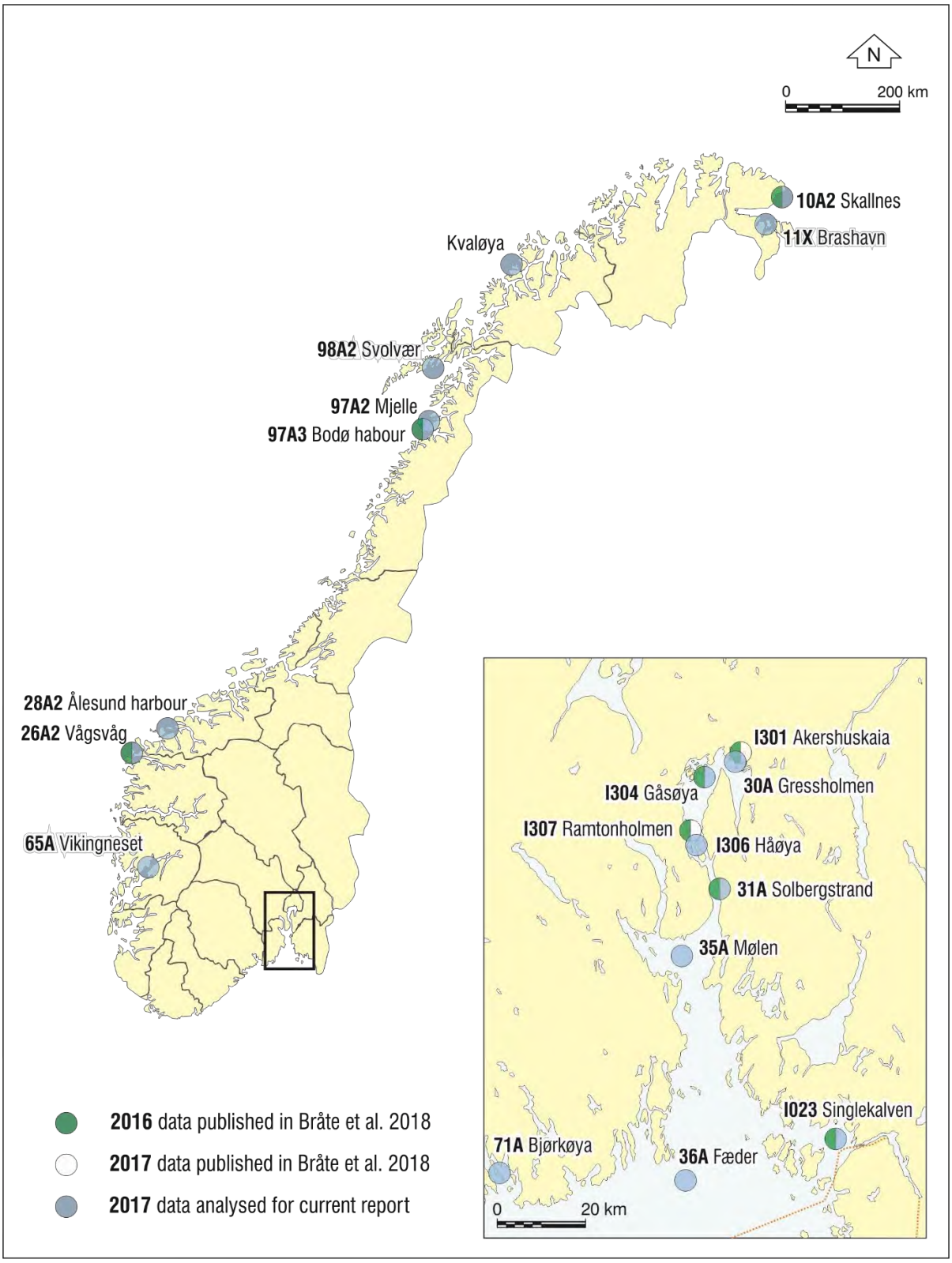


***Figure 4**. Stations where blue mussel were sampled in 2016 and 2017 with respect to microplastics. See also station information in detailed maps in **Appendix D**.*

2.6.2 Sample preparation

Maximum length of each individual mussel was measured (mm) using callipers. Excess water was discharged before the soft tissue was carefully dissected out with a scalpel. Byssus filaments and the foot were removed. Individual mussels were weighed (g w.w.), added to individual glass beakers and covered with aluminium foil.

Soft tissue was degraded following the method based on Dehaut *et al.* (2016) and presented in Lusher *et al.* (2017 - M-897|2017) and recently published in Bråte *et al.*, 2018. In short, 10% KOH (10 times v/v) was added before the beakers were placed in an incubator (New Brunswick™Innova® 44/44R) at 60°C and agitated at 140 rpm for 24h. The digestate was filtered under vacuum onto glass microfibre filters (Whatman GF/D, pore size 2.7µm). The filters were stored in sealed petri dishes at room temperature prior to analysis.

2.6.3 Sample analysis

Suspected microplastics were tested using a combination of visual and chemical techniques (for more detailed information see Lusher *et al.* 2017 - M-897|2017).

In short, all samples (on separate filter papers) were visually inspected for the presence of anthropogeic particles. Each filter paper (representing one individual) was transversed for the presence of microplastics under a microscope (20 x magnification). Image analysis software (Infinity Analyse) was used to photograph and measure the dimension of each individual particles. All particles were measured along two axis, representing the longest (axis x) and shortest dimensions (axis y). All particles were recorded in a corresponding excel spread sheet. A subsample of all identified particles was tested further using Fourier Transform Infrared (FTIR) spectroscopy. Each suspected plastic particle was flattened and held in place using a diamond compression cell before being exposed to a beam of infrared light (4 000 – 400 cm-1). The infrared absorption spectrum was recorded and compared against library spectra to obtain the chemical characterisation of the sample. Polymer identification was verified based on the % match. Only spectra that matched greater the reference spectra with than 70 % were accepted.

2.6.4 Procedural blanks

Contamination control was carried out throughout the processing and analysis. Any presence of contamination in blank samples was accounted for in the results.
Blanks were prepared and processed at the same time as mussel samples. If contamination was observed in blanks, the corresponding samples were adjusted by taking away the average value of the blanks from the average result per site. As no fragments were identified in the blanks no correction was needed in the mussel.

2.7 Classification of environmental quality

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 – TA-1467/1997). 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) by Norway in 2007 and the subsequent application of the daughter directive on Environmental Quality Standards (EQS) (2013/39/EU) the assessment of the environment using EQS became imperative. The daughter directive outlines 45 priority substances or groups of substances. Several of these substances are monitored by MILKYS. The EQS apply to concentrations in water, and for fifteen substances it also applies to concentrations in biota (***Table 11***, ***Table 12***). There is a provision in this daughter directive which allows a country to develop their own EQS for water, sediment and biota provided

these offer the same level of protection as the EQS set for water. Norway used this approach and developed their own EQS for biota, water, and sediments for "River Basin Specific Pollutants" not otherwise accounted for by the EU directives (Arp *et al*. 2014 – M-241|2014, Miljødirektoratet 2016 – M-608|2016).

Assessing the risk to human consumption from elevated concentrations of contaminants in seafood has not been the task of this programme and hence, the EU foodstuff limits have not been applied. However, it should be noted that the background dossiers for the EQS (2013/39/EU) as well as the national environmental quality standards (Arp *et al*. 2014 – M-241|2014, Miljødirektoratet 2016 – M-608|2016) applied foodstuff limits if these are lower than the limits found by assessing risk of secondary poisoning or marine organisms.

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

The application of these standards has been discussed previously (see Green *et al*. 2016 – M-618|2016), and three main challenges were noted. The first is that the standards for biota are generally not species or tissue specific but refer to whole organisms. The second is that the standards are often in large conflict with the system based on background concentrations. And lastly, the standards do not address all the contaminants in all the tissues that are monitored, for example, there are no EQS metals in biota except for Hg. To address this issue for this report, and in dialogue with the Norwegian Environment Agency, *provisional high reference concentrations* (PROREF) were derived and used in parallel with the risk-based standards (see method description below).

This report of the 2017-investigations addresses the principle cases primarily where median concentrations exceeded EQS and secondarily where median concentrations exceeded PROREF (***Table 11***, ***Table 12***). Exceedances of PROREF (x) were grouped in six factor-intervals: <x, 1-2x (between PROREF and two times PROREF), 2-5x, 5-10x, 10-20x and >20x.

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

2.7.1 Derivation of provisional high reference concentrations - PROREF

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

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

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

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

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

An overview of the PROREF applied in this report is shown in **Appendix C**, and a summary comparing PROREF with the existing EQS and the national classification system used in previous reports is shown in ***Table 7***. For this report, 174 PROREF values are defined based on 1 to 29 stations and 5 to 4074 values. For example, following the procedure outlined above, we were left with only one station to determine PROREF for, *inter alia*, TBT and KPAH in blue mussel and, *inter alia,* Hg, PCB7, BDE6S, HBCDA, PYR10, ALAD in cod. PROREF could not be calculated for three PCBs (CB81, CB126 and CB169) in blue mussel and 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 of similar compounds which can lead to a PROREF of a single compound to be considerably higher than the PROREF of a sum where it is included. A case in point is for the carcinogen PAH BGHIP in blue mussel which has a PROREF of 2.07 µg/kg w.w. This value is the upper 95 percentile of all 254 BGHIP-concentrations on a wet weight basis from seven stations (98A2, 0123, I304, I306, I307, I913, and 71A) since 1991 (Appendix C). Whereas the PROREF for the sum of carcinogen PAHs (KPAH) in blue mussel is 0.622 µg/kg w.w., which is based on only 17 KPAH-concentrations from one station (98A2) and which is considerably lower than the PROREF for BGHIP.

Thirtyone PROREF values could be compared to 23 EQS. PROREF was lower than EQS in 11 cases (including some PAHs and PBDEs). Twentysix PROREF values could be compared to 26 "Class I" values, i.e. the upper limit to Class I (insignificantly[13] polluted) in the national system used in previous reports (i.e. Molvær *et al.* 1997, ***Table 7***), and was lower in four cases.

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

Table 7*. Overview of provisional high reference concentration (PROREF) used in this report for the stations from which PROREF was derived. Also shown are the Environmental Quality Standards (EQS) for "biota" [1*)] (2013/39/EU) and national environmental quality standards [2*] (Miljødirektoratet 2016 – M-608|2016) (these two are collectively referred to as EQS) and the upper limit to Class I (insignificant degree of pollution) in the environmental classification system (Molvær et al. 1997 – TA-1467/1997) used in previous reports. These two systems are compared to PROREF values. Yellow and orange cells indicate where PROREF is under or over the Class I upper limit, respectively. Green and red cells indicate where PROREF is under or over EQS, respectively. Concentrations are given in wet weight. Q95 is the upper 95 percentile. (See complete list of PROREF used in this report in* ***Appendix C****).*

Parameter Code	Species	Tissue	Reference stations	Station count	Total number of values	Unit M=mg/kg U=µg/kg	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
HG	Gadus morhua	Fillet	10B	1	504	M	**0.06**	0.1	*1.667*	0.02	*0.333*
CD	Gadus morhua	Liver	80B, 67B, 15B, 23B	4	1655	M	**0.14**	0.3	*2.143*		
CU	Gadus morhua	Liver	10B, 15B, 80B	3	1101	M	**14**	20	*1.429*		
PB	Gadus morhua	Liver	10B, 36B, 67B, 92B, 15B, 43B, 98B1, 13B, 23B, 43B2	10	3616	M	**0.05**	0.1	*2.000*		
ZN	Gadus morhua	Liver	98B1, 10B, 92B, 43B2, 80B	5	1351	M	**35**	30	*0.857*		
CB_S7 [3*] [4*]	Gadus morhua	Liver	98B1, 10B, 92B, 43B	4	1229	U	**614**	500	*0.814*	0.6	*0.001*
DDEPP [5*]	Gadus morhua	Liver	23B, 10B, 98B1	3	1498	U	**161**	200	*1.244*	610	*3.795*
HCHG	Gadus morhua	Liver	53B, 36B, 10B, 15B, 30B, 43B, 92B, 23B, 67B, 98B1	10	4074	U	**12**			61	*5.083*
HCB	Gadus morhua	Liver	36B, 53B	2	1079	U	**14**	20	*1.429*	10	*0.714*
4-N-NP	Gadus morhua	Liver	80B, 43B2	2	135	U	**131**			3000	*22.901*
4-N-OP	Gadus morhua	Liver	43B2, 80B	2	135	U	**23.5**			0.004	*0.0002*
4-T-NP	Gadus morhua	Liver	43B2, 80B	2	135	U	**241**			3000	*12.453*
4-T-OP	Gadus morhua	Liver	80B, 43B2	2	135	U	**20**			0.004	*0.0002*
BDE47 [7*]	Gadus morhua	Liver	98B1, 36B, 23B	3	557	U	**16**			0.009	*0.001*
BDE6S [8*]	Gadus morhua	Liver	98B1	1	173	U	**19.8**			0.009	*0.0004*
BDESS	Gadus morhua	Liver	98B1	1	173	U	**19.8**	50	*2.528*		
HBCDA	Gadus morhua	Liver	43B2	1	65	U	**7**			167	*23.857*
PFOA	Gadus morhua	Liver	13B, 43B2, 80B, 53B, 23B, 36B, 30B, 98B1	8	1289	U	**10**			91.3	*9.130*
PFOS	Gadus morhua	Liver	43B2, 80B	2	251	U	**10.3**	50	*4.878*	9.1	*0.888*

[13] In this context the term has no statistical implications

Parameter Code	Species	Tissue	Reference stations	Station count	Total number of values	Unit M=mg/kg U=µg/kg	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
PFOSA	Gadus morhua	Liver	43B2, 98B1, 53B, 80B, 23B	5	718	U	**6.24**	10	*1.603*		
SCCP	Gadus morhua	Liver	23B, 43B2, 80B	3	245	U	**154**			6000	*38.961*
MCCP	Gadus morhua	Liver	23B, 43B2	2	174	U	**393**			170	*0.433*
CD	Mytilus edulis	Soft body	I241, 26A2, I969	3	106	M	**0.18**	0.4	*2.222*		
CR	Mytilus edulis	Soft body	52A, 15A, 26A2, I131A, 64A	5	100	M	**0.36**	0.6	*1.667*		
CU	Mytilus edulis	Soft body	I307, I712, 63A, I306, I304, 57A, B11, 51A, B6, 64A, I023, 56A, B10	13	517	M	**1.42**	2	*1.408*		
HG	Mytilus edulis	Soft body	36A, 46A, 10A2	3	137	M	**0.01**	0.04	*4.000*	0.02	*2.000*
NI	Mytilus edulis	Soft body	I241, I131A, 52A, 57A, 26A2	5	101	M	**0.29**	1	*3.448*		
PB	Mytilus edulis	Soft body	11X, 48A	2	75	M	**0.2**	0.6	*3.000*		
AG	Mytilus edulis	Soft body	26A2, 63A, 65A, 97A2, I023, I131A, I306, I712, I241, 22A, I304	11	232	M	**0.01**	0.06	*6.000*		
ZN	Mytilus edulis	Soft body	43A, I712, 48A	3	49	M	**17.7**	40	*2.265*		
AS	Mytilus edulis	Soft body	31A, B5, I301, I023, B2, 30A	6	204	M	**3.32**	2	*0.602*		
CB_S7 [3*] [4*]	Mytilus edulis	Soft body	11X, 10A2	2	96	U	**0.93**	4	*4.301*	0.6	*0.645*
DDEPP [5*]	Mytilus edulis	Soft body	43A, 41A, 10A2, 11X	4	147	U	**0.22**	2	*9.091*	610	*2772.73*
HCB	Mytilus edulis	Soft body	22A, 11X, 43A, 48A, 10A2, 15A, 30A, 31A, 36A, 41A, 44A, 46A	12	517	U	**0.1**	0.1	*1.000*	10	*100.000*
NAP [6*]	Mytilus edulis	Soft body	98A2, I023, 71A	3	47	U	**17.3**			2400	*138.728*
ANT [6*]	Mytilus edulis	Soft body	30A, 71A, 98A2, I023	4	112	U	**1.1**			2400	*2181.82*
FLU [6*]	Mytilus edulis	Soft body	98A2, I023	2	32	U	**5.35**			30	*5.607*
BAA [6*]	Mytilus edulis	Soft body	98A2, I023	2	32	U	**1.49**			304	*204.03*
BAP [6*]	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A	5	177	U	**1.3**	1	*0.769*	5	*3.846*
P_S [6*]	Mytilus edulis	Soft body	98A2	1	17	U	**6.04**	50	*8.284*		
BDE47 [7*]	Mytilus edulis	Soft body	98A2, 26A2, I023, 71A, 91A2	5	79	U	**0.14**			0.009	*0.061*
BDE6S [8*]	Mytilus edulis	Soft body	98A2, 26A2, 71A, 91A2, I023	5	79	U	**0.19**			0.009	*0.044*
HBCDA	Mytilus edulis	Soft body	I023, 97A2, 91A2	3	44	U	**0.11**			167	*1518-18*
SCCP	Mytilus edulis	Soft body	I023, 71A, 91A2, 97A2, 26A2, 30A	6	90	U	**20.3**			6000	*296.150*
MCCP	Mytilus edulis	Soft body	I023, 26A2, 71A, 91A2, 97A2, 30A	6	89	U	**87.6**			170	*1.941*
TBT	Mytilus edulis	Soft body	11X	1	20	U	**7.11**	20	*2.813*	150	*21.097*
TBT	Nucella lapillus	Soft body	11G, 131G, 15G, 98G	4	66	U	**23.5**			150	*6.372*

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 – M-241|2014) and modified by the Norwegian Environment Agency (Miljødirektoratet 2016 – M-608|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 og 180.

4*) In report M-608 (Miljødirektorat, 2016 – M-608|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 – M-241|2014) (Miljødirektorat, pers. comm. 16th June 2017, ref. TA-2013/10729).

5*) For this study the same limit was applied to p,p DDE.

6*) Apply to Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish). Benzo(a)pyrene is considered a marker for other PAHs (2013/39/EU).

7*) Not official EQS for BDE47, but this PBDE is often the most dominant BDE.

8*) Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa).

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

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

Biological effect	Applicable to:	BAC	EAC	Units, method
EROD	cod liver	145	-	pmol/min/ mg microsomal protein
OH-pyrene	cod liver	0.7*	-	ng/ml; HPLC-F
VDSI	dogwhelk	0.3	2	

*) Values in this report are normalized and the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380nm. Normalization in this investigation reduced the BAC from 21 to 0.7 ng/ml or by a factor of about 30.

2.8 Statistical time trend analysis

2.8.1 Treatment of values below the quantification limit

Values below the limit of quantification (LOQ) are set to half of the value of this limit for calculation for use in time trends or set to zero when included in a sum (e.g. PCB-7). This is in accordance to EU directive (2009/90/EC). Hence, a sum of a group of compounds (like BDE6S) could be zero whereas a compound included in the sum, and could be used as a proxy for the sum, would assigned half the LOQ. This could then result in a situation where the sum was below the EQS but the proxy compound was above the EQS. The annual median is classified as less-than if over half of the values are below the limit of quantification and is assigned the median value prefixed with a "<" sign in **Appendix F**. When such values are presented in tables of the main text, then the cells are shaded and the half value is shown. It should be noted that the LOQ can vary within and among sets of samples and comparisons of quantification limits should be made with caution.

Dominance of values below the LOQ could invalidate the statistical assumption behind the trend analysis (Rob Fryer, pers. comm.). 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 a less-than value has on the trend analysis has not been quantified; however, the results should be treated with caution.

2.8.2 The model approach

A simple model approach has been developed to study time trends for contaminants in biota based on median concentration (ASMO 1994). The method has been applied to Norwegian data and results are shown in **Appendix E**. The results can be presented as shown in ***Figure 5***. It should be noted that this robust method has been developed so that it could provide a rough guide to possible trends in the OSPAR region. Further investigation is necessary to better understand the factors affecting a particular trend. This may lead to different conclusions. As an exercise in this respect the times series for mercury in cod filet from the Inner Oslofjord was examined more closely (see Green *et al*. 2015 – M-433|2015).

The model approach uses a Loess smoother based on a running six-year interval where a non-parametric curve is fitted to median log-concentration (Nicholson *et al*. 1991, 1994 and 1997 with revisions noted by Fryer & 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**). 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 (cf. Nicholson *et al*. 1998). A constant of +1 was added to VDSI data prior to log transformation to enable analysis of observations that were equal to zero.

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

The assessment method used up to and including the 2011 investigation have differed slightly from the method now employed by OSPAR. Before a linear trend for the whole time series period was tested whereas now OSPAR currently uses linear or non-linear tests, based on the number of years of data with at least one non-censored measurement (N_+). If N_+ is 5-6, a linear trend is tested, if N_+ is ≥7, one tests whether there is a significant difference in the smoothed annual concentration at the beginning of the time series compared the smoothed annual concentration at the end of the time series. This report presents an assessment in line with the current OSPAR approach. The smoothed values were determined for the whole time series. The whole time series is termed in this report as a long-term trend. The smooth values were also used as a basis for assessing the trend for the last 10 years of the series, which is referred to in this report as short-term or recent trend. Be aware that a series may have gaps and recent trend may not necessarily include data for 2017. Time series is truncated from the left (omitting early years) until (1) at least 50% of the years should have at least one non-censored measurement, and (2) the first year has at least one non-censored measurement. If the measurements in the most recent year(s) of the time series are all less-thans, then the expected concentration in the most recent year(s) is assumed to be constant.

The term “significant” refers to the results of a statistical analysis at 0.05 significance level used for detecting differences between the beginning and the end of the time series and can be found in the tables in **Appendix F**. In this appendix the statistical significance (p) is given as well as the annual detectable change (%) that can be detected with statistical probability of 90 % (Power) in two-sided testing with a 10 % significance level (alpha). It can be noted that difference between significant and not-significant trends is not always readily evident in a figure. A case in point is shown for SCCP; *with no adjustment for cod length (**Figure 57a**) the p-value for the trend analysis is 0.0592, whereas when adjusted for cod length (**Figure 57b**) the p-values is 0.0379, and hence significant*.

No attempt has been made to compensate for differences in size groups or number of individuals of blue mussel or fish in this 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 this study (i.e. 2-3, 3-4 and 4-5 cm) (WGSAEM 1993).

The statistical analysis of time trends was carried out on all the results, including those for biological effects parameters.

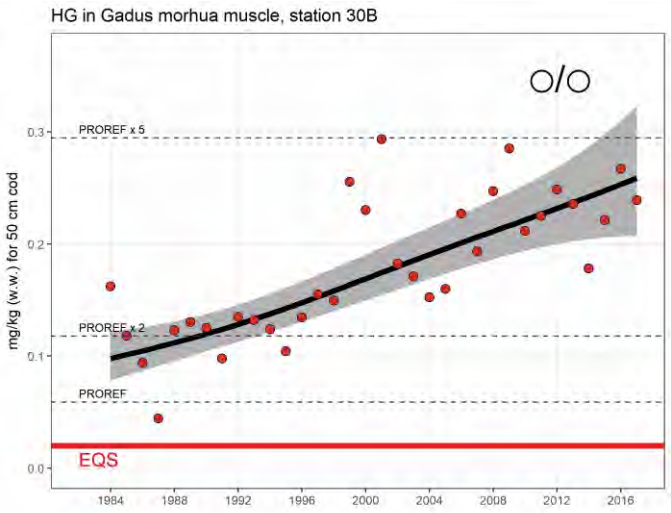


***Figure 5**. Example of time series (Hg in cod fillet from Inner Oslofjord, normalized for length) that show the median concentration (dots), running mean of median values (Loess smoother - thick black line) and 95 % confidence intervals surrounding the running mean (grey zone). A horizontal thick red line indicates the Environmental Quality Standard (EQS) if it can be applied and if it can be shown on the scale of concentration provided. A red dot indicates that the median value is above the EQS, a blue dot indicates that the value is below the EQS, and a grey dot indicates that not EQS can be applied. The horizontal dashed grey lines indicate the lower boundaries relative to PROREF[14]; where exceedances are indicated, by a factor of: <2, 2-5, 5-10, 10-20 and greater than 20 (the latter three categories are not shown in the figure, cf. **Table 28**). A light blue triangle (see for example **Figure 17 A**) indicates that the median was below the LOQ. A summary of the trend analyses is indicated on time series with five or more years and the results, before the slash "/" (i.e. long-term trend which means the entire time series), are indicated by an upward (🡅) or downward (🡇) arrow where significant trends were found, or a zero (O) if no trend was detected. Where there was sufficient data a time series analysis was performed for the last ten-year for the period 2008-2017 (short-term or recent trend) and the result is shown after the slash. A small filled square (▪) indicates that chemical analysis has been performed, but data either were insufficient to do a trend analysis or was not presented. Results marked with a star (★) indicate that there is insufficient data above the quantification limit to perform a trend analysis. Note that scales for the x axis and y axis can vary from figure to figure.*

2.9 Note on presentation of contaminant tables

Summaries of the results for some organic contaminants are presented in ***Table 14*** to ***Table 20***. These tables provide some extensive details and warrant explanation. Some of the analyses, especially of the "New" contaminants (e.g. HBCD, SCCP/MCCP, BPA, TBBPA, alkyphenols), revealed a vast number of results been 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 14*** is shown below in ***Table 9*** in regards to the PBDE compound BDE28. With respect to "Count" the first number indicates the number of individuals or pooled samples that were analysed. For example, for blue mussel from Gressholmen three samples were analysed and all three were pooled samples, and the maximum number of individual mussels that went into the pooled sample was 50. For cod liver from the Inner Oslofjord there were 12 samples whereof eight were pooled with a maximum of three fish livers in each pool. This means that analyses were done

[14] 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.

on 4 individual cod (12-8=4). Note that the values for median ("Med.") and standard deviation ("S.d.") are rounded, and for example "0.000" represents a number greater than zero but less than 0.0005. The "D.d.i." for blue mussel from Singlekalven is blank and indicates that none of the three values were above LOQ, whereas for the eider duck, the D.d.i. indicates that only five of the 15 samples of egg had concentrations of BDE28 above LOQ and these ranged from 0.0348 to 0.104 µg/kg w.w. Note that when a dataset contains values below LOQ the median takes these as half the LOQ (see chapter 2.8.1). Also note that when there are only three samples the median can be the minimum or maximum of this range shown by the "D.d.i.".

***Table 9**. Example table – extract from **Table 14**. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in any one of the pooled samples. Shaded cells indicate that the median (Med.) was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See text for more detail.)*

Component	Count	BDE28		
Species and sampling locality	2017	Med.	S.d.	D.d.i
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.001	0.000	2 (0.0011-0.0011)
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.001	0.000	
Cod, liver				
Inner Oslofjord (st. 30B)	12 (8-3)	0.381	0.484	12 (0.244-1.92)
Isfjorden, Svalbard (st. 19B)	15	0.053	0.044	15 (0.0416-0.2)
Eider, blood				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.000	
Eider, egg				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.031	5 (0.0348-0.104)

3. Results and discussion

3.1 General information on measurements

A summary of the levels and trends of selected set of contaminants or their effects in Atlantic cod, blue mussel, dogwhelk and periwinkle along the coast of Norway in 2017 is shown in ***Table 11*** and ***Table 12***. More details on trend analyses for the entire monitored period that include results from either 2016 or 2017 are shown in **Appendix F**. The results from 2017 present data for a total of 3069 data sets (contaminant[15]-station-species-tissue) on 93 different contaminants. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period[16], whereas a short-term trend refers to the analysis on data for the last 10 years, i.e. 2008-2017 and can also be referred to as recent trend.

Assessment of levels and time trend analyses were performed on a selection of 30 representative contaminants (excluding the results for the common eider[17]) or their effect (VDSI), and totalled 809 data series[18] for the 2017 data (***Table 10***). Of the 809 cases, 262 cases could be classified against EQS, of which 157 (59.9 %) were below the EQS and 105 (40.1 %) were above the EQS (***Figure 6A***). All 809 cases could be compared to PROREF, and of these 578 (71.4 %) were below PROREF. Of the 809 cases 231 (28.6 %) exceeded PROREF: 148 (18.3 %) by a factor of less than two, 61 (7.5 %) by a factor between two and five, 13 (1.6 %) by a factor between five and 10, seven (0.9 %) by a factor between 10 and 20, and two (0.2 %) by a factor greater than 20 (***Figure 6B***). Of the 809 data series recent and significant trends were registered in 193 cases: 83 (10.3 %) were downwards trends and 35 (4.3 %) were upwards (***Figure 6C***). The downward trends were primarily associated with metals (45.8 %), tributyltin (TBT, 7.2 %) and VDSI (the effect of TBT) (4.8 %) (***Figure 7C***). The upward trends were also mainly associated with metals (88.6 %), primarily Hg (22.9 %).

Primary focus was on those cases where median concentrations in 2017 were over EQS and, secondarily, on those cases where provisional high reference concentration (PROREF) were exceeded, and where significant upward trends were found, and to a lesser degree where no significant trends or significant downward trends were found. The evaluation also focused to a lesser degree on cases where median concentrations in 2017 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, Arp *et al*. 2014 – M-241|2014, Miljødirektoratet 2016 – M-608|2016).

A summary of the results when assessed by EU EQS (2013/39/EU) and supplemented with national environmental quality standards (Arp *et al*. 2014 – M-241|2014, Miljødirektoratet 2016 – M-608|2016) is presented in **Appendix C**.

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

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

[17] The results are excluded because this was the first year this bird species has been investigated within the MILKYS programme, and there are currently no EQS or PROREF values to assess the levels and insufficient data to do a temporal trend analysis.

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

***Table 10**. Selection of representative contaminants and number of time series assessed for each target species-tissue. Counts include supplementary investigations funded by the Ministry of Climate and Environment and are marked with an asterisk " * " [1*]. The specific results are shown in **Table 12**.*

Contaminant /BEM	Description	Blue mussel	Dogwhelk, periwinkle	Cod, liver	Cod fillet	Eider, blood	Eider, egg [2*)]	TOTAL
Ag	Silver	31*		17		1	1	50
As	Arsenic	31*		17		1	1	50
Cd	Cadmium	31*		17		1	1	50
Co	Cobalt	31*		17		1	1	50
Cr	Chromium	31*		17		1	1	50
Cu	Copper	31*		17		1	1	50
Hg	Mercury	33*			17	1	1	52
Ni	Nickel	31*		17		1	1	50
Pb	Lead	31*		17		1	1	50
Zn	Zinc	31*		17		1	1	50
PCB-7 (CB_S7)	sum of PCB congeners 28+52+101+118+138+153+180	30*		16		1	1	48
ppDDE (DDEpp)	p,p'-DDE (a DDT metabolite)	19*		7				26
HBCDa	α—hexabromocyclododecane	12		13		1	1	27
SCCP	short chain chlorinated paraffin (C10-C13)	12		13		1	1	27
MCCP	medium chain chlorinated paraffin (C14-C17)	12		13		1	1	27
BDE47	Tetrabromdiphenylether	12		11		1	1	25
BDE100	Pentabromdiphenylether	12		11		1	1	25
BDE209	Decabromdiphenylether	12		11		1	1	25
PAHs (P_S)	sum nondicyclic PAHs	8						8
KPAHs (PK_S)	sum carcinogen PAHs	8						8
BKF	benzo[k]fluoranthene	8						8
B[ghi]P	benzo[ghi]perylene	8						8
ICDP	Indeno[1,2,3-cd]pyrene	8						8
B[a]P	benzo[a]pyrene	8						8
FLU	Fluoranthene	8						8
PFOS	perfluorooctanoic sulfonate			10		1	1	12
PFOSA	perfluorooctylsulfonate acid amide			10		1	1	12
PFBS	Potassium perfluorobutanesulfonat			10		1	1	12
TBT	tributyltin (formulation basis)	7*	9					16
VDSI	Vas Deferens Sequence Index		9					9
TOTAL		**496**	**18**	**278**	**17**	**20**	**20**	**849**

1*) Supplementary investigations funded by the Ministry of Climate and Environment involved additional analyses on samples from blue mussel stations 30A, I301, I304, 31A, 36A (alt. 36A1), 71A, I712, 51A, 56A, 65A, 22A, 10A2 and 11X; cod stations 30B, 36B, 15B, 53B, 23B, 98B1 and 10B; as well as all analyses for blue mussel stations: 35A, 52A, 57A, 63A, 69A, 76A2, I133, I306, I307.

2*) Egg homogenate of yolk and albumin.

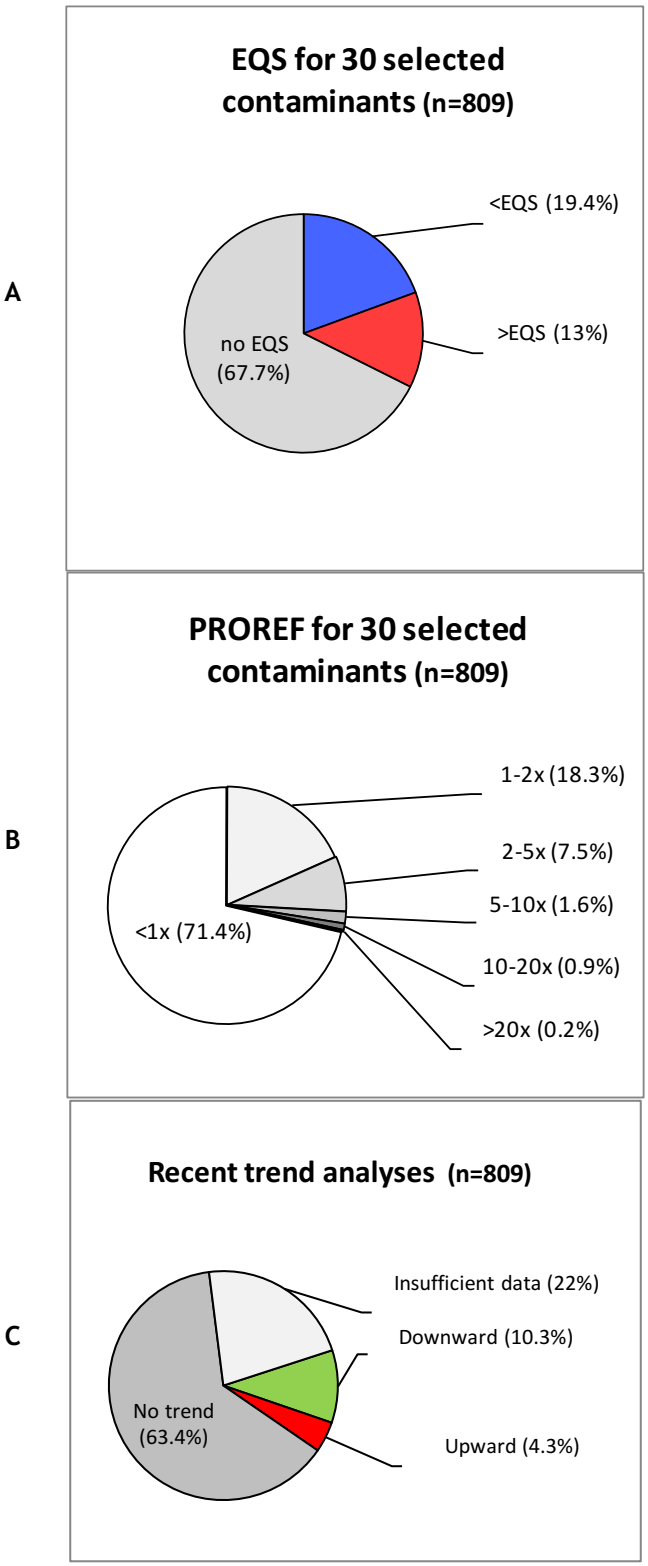
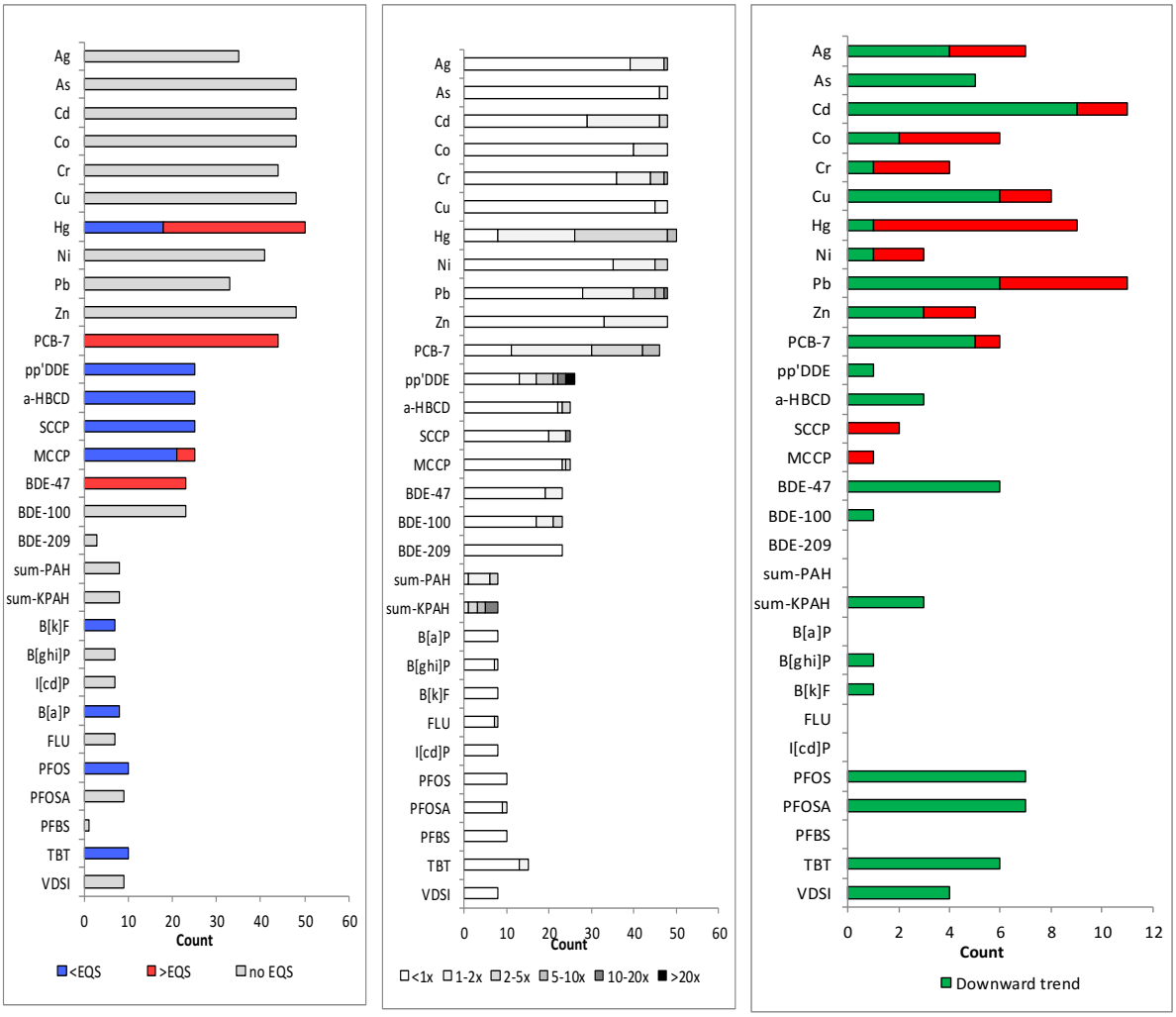


Figure 6. *Summary of frequency of exceedance to EQS (**A**), provisional high reference concentration (PROREF) (**B**) and the results from short-term trend analyses (**C**) and for 30 selected contaminants (excluding results from the common eider, cf.* ***Table 10****). Grey-shade coding in Figure B refers to relation to PROREF[19] (cf.* ***Table 28****).*

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



A **B** **C**

Figure 7. *Summary of frequency of exceedance to EQS (**A**), provisional high reference concentration (PROREF) (**B**) and short-term trends (**C**) and for each of the 30 selected contaminants (excluding results from the common eider, cf.* ***Table 10****, (see* ***Appendix B*** *for description of chemical codes). Grey-shade coding in Figure A refers to relation to PROREF (cf.* ***Table 28****).*

Table 11. *Assessment of levels of median concentrations of contaminants with respect to EQS (EU-priority substances* and River Basin Specific Pollutants**) and PROREF in samples collected in 2017 in four species: blue mussel, dogwhelk, common periwinkle and cod. Tissues***: soft body (for blue mussel, dogwhelk and periwinkle), liver*** (cod except for Hg***) and fillet (cod, Hg). The* grey-shade coding refers to exceedances of provisional high reference concentration (PROREF): *below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 20* (see **Appendix C**). *Blue-filled circles indicate no exceedances and red-filled circles indicate exceedances of EQS with respect to Environmental Quality Standards from the Water Framework Directive (WFD) (cf. Environmental Quality Standard Directive-2013/39/EU) or national quality standards (*) by Norwegian Environment Agency (Miljødirektoratet 2016 – M-608|2016)) for hazardous substances in "biota" 1. Abbreviations for contaminants can be seen in Appendix B.*

Station name	Species	Tissue***	HG***	TBT*	CB_S7**	DDEPP*	ANT*	BAA**	BAP*	FLU*	BDE6S*	BDE47	PFOA*'	PFOS*	HBCDA*	SCCP*	MCCP*'	4-N-NP*	4-T-NP*	4-N-OP*	4-T-OP*
Gressholmen (st. 30A)	Blue mussel	Soft body	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Akershuskaia (st. I301)	Blue mussel	Soft body	●	●	●	●	●	●	●	●											
Gåsøya (st. I304)	Blue mussel	Soft body	●	●	●	●	●	●	●	●											
Solbergstrand (st. 31A)	Blue mussel	Soft body	●	●	●	●															
Færder (st. 36A)	Blue mussel	Soft body	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●
Singlekalven (st. I023)	Blue mussel	Soft body	●		●		●	●	●	●	●	●			●	●	●	●	●	●	●
Kirkøy (st. I024)	Blue mussel	Soft body	●		●																
Bjørkøya (st. 71A)	Blue mussel	Soft body	●			●	●	●	●	●	●	●			●	●	●	●	●	●	●
Sylterøya (st. I714)	Blue mussel	Soft body	●			●	●	●	●	●	●	●			●	●	●	●	●	●	●
Risøy (st. 76A2)	Blue mussel	Soft body	●		●	●															
Lastad (st. I131A)	Blue mussel	Soft body	●				●	●	●	●											
Odderøya (st. I133)	Blue mussel	Soft body	●	●	●	●															
Gåsøy (st. 15A)	Blue mussel	Soft body	●		●																
Byrkjenes (st. 51A)	Blue mussel	Soft body	●		●	●							●	●							
Eitrheimsneset (st. 52A)	Blue mussel	Soft body	●		●	●															
Kvalnes (st. 56A)	Blue mussel	Soft body	●		●	●															
Krossanes (st. 57A)	Blue mussel	Soft body	●		●	●															
Utne (st. 64A)	Blue mussel	Soft body	●		●	●															
Vikingneset (st. 65A)	Blue mussel	Soft body	●		●	●															
Espevær (st. 22A)	Blue mussel	Soft body	●	●	●	●							●	●							
Nordnes (st. I241)	Blue mussel	Soft body	●		●						●	●	●	●	●	●	●	●	●	●	●
Måløy (st. 26A2)	Blue mussel	Soft body	●		●						●	●			●	●	●	●	●	●	●
Ålesund harbour (st. 28A2)	Blue mussel	Soft body	●		●						●	●	●	●	●	●	●	●	●	●	●
Outer Trondheimsfjord (st. 91A2)	Blue mussel	Soft body	●		●						●	●			●	●	●	●	●	●	●
Bodø harbour (st. 97A2)	Blue mussel	Soft body	●		●						●	●			●	●	●	●	●	●	●
Bodø harbour (st. 97A3)	Blue mussel	Soft body	●		●						●	●			●	●	●	●	●	●	●
Lofoten, Svolvær (st. 98A2)	Blue mussel	Soft body	●		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Skallneset (st. 10A2)	Blue mussel	Soft body	●		●	●															
Brashavn (st. 11X)	Blue mussel	Soft body	●		●	●															

Station name	Species	Tissue***	HG***	TBT*	CB_S7**	DDEPP*	ANT*	BAA**	BAP*	FLU*	BDE6S*	BDE47	PFOA*'	PFOS*	HBCDA*	SCCP*	MCCP*'	4-N-NP*	4-T-NP*	4-N-OP*	4-T-OP*
Inner Oslofjord (st. 30B)	Cod	Liver	●		●	●					●	●	●	●	●	●	●	●	●	●	●
Færder area (st. 36B)	Cod	Liver	●		●	●					●	●	●	●	●	●	●	●	●	●	●
Hvaler (st. 02B)	Cod	Liver	●		●										●	●	●	●	●	●	●
Grenlandsfjord (st. 71B)	Cod	Liver	●												●	●	●	●	●	●	●
Kristiansand harbour (st. 13B)	Cod	Liver	●		●						●	●	●	●	●	●	●	●	●	●	●
Farsund area (st. 15B)	Cod	Liver	●		●	●															
Inner Sørfjord (st. 53B)	Cod	Liver	●		●	●					●	●	●	●	●	●	●	●	●	●	●
Bømlo north (st. 23B)	Cod	Liver	●		●	●					●	●	●	●	●	●	●	●	●	●	●
Bergen harbour (st. 24B)	Cod	Liver	●		●						●	●	●	●	●	●	●	●	●	●	●
Ålesund area (st. 28B)	Cod	Liver	●		●						●	●			●	●	●	●	●	●	●
Inner Trondheimsfjord (st. 80B)	Cod	Liver	●		●						●	●	●	●	●	●	●	●	●	●	●
Helgeland (st. 96B)	Cod	Liver	●		●																
Lofoten, Skrova (st. 98B1)	Cod	Liver	●		●	●					●	●	●	●	●	●	●				
Tromsø harbour (st. 43B2)	Cod	Liver	●		●						●	●	●	●	●	●	●	●	●	●	●
Hammerfest harbour (st. 45B2)	Cod	Liver	●		●																
Varangerfjord (st. 10B)	Cod	Liver	●		●	●															
Isfjorden, Svalbard (st. 19B)	Cod	Liver	●		●						●	●	●	●	●	●	●	●	●	●	●
Breøyane, Svalbard (st. 19N)	Eider duck	Blood	●																		
Breøyane, Svalbard (st. 19N)	Eider duck	Egg	●																		
Fugløyskjær (st. 71G)	Periwinkle	Soft body	●																		
Færder (st. 36G)	Dog whelk	Soft body	●																		
Risøy (st. 76G)	Dog whelk	Soft body	●																		
Lastad (st. 131G)	Dog whelk	Soft body	●																		
Gåsøy (st. 15G)	Dog whelk	Soft body	●																		
Flatskjær (St. 227G)	Dog whelk	Soft body	●																		
Espevær (st. 22G)	Dog whelk	Soft body	●																		
Lofoten, Svolvær (st. 98G)	Dog whelk	Soft body	●																		
Brashavn (st. 11G)	Dog whelk	Soft body	●																		

***) In cod Hg i measured in fillet

Table 12. *Assessment of levels and trends of median concentrations of contaminants with respect to PROREF in samples collected in 2017 with indication of levels and trends in four species: blue mussel, dogwhelk, common periwinkle and cod.* Tissues: soft body (for blue mussel, dogwhelk and periwinkle), liver (cod except for Hg) and fillet (cod, mercury. *The grey-shade coding refers to relation to exceedances to provisional high reference concentration (PROREF):* below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 20 *(see* ***Appendix C***). *For biota, trend analyses were done on time series with data from five or more years. An upward (🡅) or downward (🡇) arrow indicates statistically significant trends, whereas a zero (O) indicates no trend. A small filled square (▪) indicates that chemical analysis was performed but the results were insufficient to do a trend analysis. Results marked with a star (★) indicate that there is insufficient data above the quantification limit to perform a trend analysis. The result from the trend analysis for the entire time series (long-term) is shown before the slash "/", and the result for the last 10 years (short-term) is shown after the slash. (See* ***Appendix B*** *for description of chemical codes.). The asterisk after the station name indicates those stations considered less impacted by contamination. Abbreviations for contaminants can be seen in Appendix B.*

Station name	Species	Tissue	AG	AS	CO	CD	CR	CU	HG*	NI	PB	ZN	CB_S7	DDEPP	HBCDA	SCCP	MCCP	BDE47	BDE100	BDE209	PAHSS	PK_S	BKF	BGHIP	ICDP	BAP	FLU	PFOS	PFOSA	TBT	VDSI
Gressholmen (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	
Akershuskaia (st. I301)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	🡅/O	O/O	🡇/O	O/O	🡇/O	🡇/O							🡇/O	🡇/🡇	O/O	🡇/O	O/O	O/O	🡇/O			🡇/🡇	
Gåsøya (st. I304)	Blue mussel	Soft body	O/O	O/O	O/O	🡅/🡅	O/O	🡇/O	O/🡅	O/O	O/O	O/O	🡇/🡇	O/O							O/O	O/O	★/★	O/O	★/★	★/★	🡇/O			O/O	
Solbergstrand (st. 31A)	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	
Færder (st. 36A)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	🡇/▪	O/▪	O/▪	🡇/O	O/▪	O/▪	O/▪	🡇/O	O/O	▪/▪	▪/▪	▪/▪	★/▪	★/▪	▪/▪								▪/▪	▪/▪	🡇/★	
Singlekalven (st. I023)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	🡇/O		O/O	O/O	O/O	O/O	O/O	★/★	O/O	🡇/🡇	★/★	★/★	★/★	★/★	O/O				
Kirkøy (st. I024)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	🡇/O	O/O	O/O	O/O	O/O	🡇/O																		
Bjørkøya (st. 71A)	Blue mussel	Soft body	O/O	🡇/🡇	O/O	🡇/O	O/O	🡇/🡇	🡇/O	O/O	O/O	O/O		O/O	O/O	O/O	O/O	🡇/🡇	O/O	★/★	O/O	O/O	O/O	O/O	★/★	★/★	O/O				
Sylterøya (st. I714)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪				
Risøy (st. 76A2)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	★/★																	
Lastad (st. I131A)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	🡇/O									O/O	O/O	🡇/O	🡇/O	🡇/★	★/★	O/O				
Odderøya (st. I133)	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																🡇/🡇	
Gåsøy (st. 15A)	Blue mussel	Soft body	🡇/🡇	🡇/🡇	O/O	O/O	O/O	O/🡇	O/O	O/O	O/O	O/O	O/O																		
Byrkjenes (st. 51A)	Blue mussel	Soft body							🡇/O				🡇/O	O/O														▪/▪	▪/▪		
Eitrheimsneset (st. 52A)	Blue mussel	Soft body	O/O	O/O	O/O	🡇/O	O/O	🡇/O	🡇/🡅	O/O	🡇/O	🡇/O	🡇/O	O/O																	
Kvalnes (st. 56A)	Blue mussel	Soft body							🡇/O				🡇/O	🡅/O																	
Krossanes (st. 57A)	Blue mussel	Soft body	O/O	O/O	O/O	🡇/🡇	O/O	🡇/O	🡇/O	O/O	🡇/O	🡇/O	🡇/O	O/O																	
Utne (st. 64A)	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																	
Vikingneset (st. 65A)	Blue mussel	Soft body	🡇/🡇	O/O	🡇/🡇	🡇/🡇	O/O	🡇/🡇	O/O	O/O	🡇/O	🡇/🡇	🡇/O	O/O																	
Espevær (st. 22A)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	🡇/🡇	🡇/O	🡇/O	O/O														▪/▪	▪/▪	🡇/🡇	
Nordnes (st. I241)	Blue mussel	Soft body	★/★	O/O	O/O	🡇/🡇	O/O	O/O	O/O	O/O	🡇/🡇	O/O	🡇/O		O/O	▪/▪	▪/▪	O/O	★/★	★/★								▪/▪	▪/▪		
Måløy (st. 26A2)	Blue mussel	Soft body	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	🡅/🡅		O/O	O/O	O/O	O/O	O/O	★/★											
Ålesund harbour (st. 28A2)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪		
Outer Trondheimsfjord (st. 91A	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	★/★											
Bodø harbour (st. 97A2)	Blue mussel	Soft body	O/O	O/O	O/O	O/O	O/O	🡇/🡇	O/O	O/O	O/O	O/O	O/O		O/O	O/O	O/O	O/O	O/O	★/★											
Bodø harbour (st. 97A3)	Blue mussel	Soft body	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪											
Lofoten, Svolvær (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	★/★	O/O	★/★	★/★	★/★	★/★	★/★	O/O	▪/▪	▪/▪		
Skallneset (st. 10A2)	Blue mussel	Soft body	🡇/🡇	🡇/🡇	O/O	O/O	O/O	O/O	🡇/O	O/O	🡇/🡇	O/O	🡇/O	🡇/O																	
Brashavn (st. 11X)	Blue mussel	Soft body	🡇/🡇	🡇/🡇	O/O	O/O	🡅/🡅	O/O	O/O	🡅/🡅	🡇/O	O/O	O/O	🡇/O																	

Station name	Species	Tissue	AG	AS	CO	CD	CR	CU	HG*	NI	PB	ZN	CB_S7	DDEPP	HBCDA	SCCP	MCCP	BDE47	BDE100	BDE209	PAHSS	PK_S	BKF	BGHIP	ICDP	BAP	FLU	PFOS	PFOSA	TBT	VDSI
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/↓		
Færder area (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	O/O	★/★								↓/↓	↓/↓		
Hvaler (st. 02B)	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														
Grenlandsfjord (st. 71B)	Cod	Liver	O/O	O/O	O/O	↓/↓	O/O	O/O	O/O	O/O	O/O	O/O			↓/↓	O/O	O/O														
Kristiansand harbour (st. 13B)	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	★/★								↓/↓	↓/↓		
Farsund area (st. 15B)	Cod	Liver	↑/↑	O/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	↓/O	O/O	O/O	O/O	★/★								↓/↓	↓/↓		
Bømlo north (st. 23B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/↑	O/O	O/↑	O/O	↓/O	↓/O	O/O	O/O	↑/O	↓/↓	↓/O	★/★								O/↓	↓/↓		
Bergen harbour (st. 24B)	Cod	Liver	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪		
Ålesund area (st. 28B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	★/★	O/O	O/O		O/O	O/O	O/O	O/O	O/O	★/★											
Inner Trondheimsfjord (st. 80B)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	↓/↓		O/O	O/O	O/O	↓/↓	O/O	★/★								O/O	O/O		
Helgeland (st. 96B)	Cod	Liver	↑/↑	O/O	↑/↑	O/O	O/O	↑/↑	O/O	O/O	★/★	↑/↑	O/O																		
Lofoten, Skrova (st. 98B1)	Cod	Liver	O/O	O/O	O/O	O/O	O/O	O/O	O/↑	O/O	O/↑	O/O	↓/O	O/O	O/O	↑/↑	O/O	↓/O	O/O	★/★								↓/↓	↓/↓		
Tromsø harbour (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/O	★/★								↓/↓	↓/↓		
Hammerfest harbour (st. 45B2)	Cod	Liver	O/O	O/O	↑/↑	O/O	O/O	O/O	↓/↓	O/O	★/★	O/O	↓/↓																		
Varangerfjord (st. 10B)	Cod	Liver	O/O	O/O	O/O	O/O	↓/↓	↓/O	↓/O	O/O	O/↑	O/O	↓/O	↓/O																	
Isfjorden, Svalbard (st. 19B)	Cod	Liver	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪		
Breøyane, Svalbard (st. 19N)	Eider duck	Blood	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪		
Breøyane, Svalbard (st. 19N)	Eider duck	Egg	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪		
Fugløyskjær (st. 71G)	Periwinkle	Soft body																												↓/▪	↓/▪
Færder (st. 36G)	Dog whelk	Soft body																												↓/↓	↓/↓
Risøy (st. 76G)	Dog whelk	Soft body																												↓/O	↓/O
Lastad (st. 131G)	Dog whelk	Soft body																												↓/★	↓/O
Gåsøy (st. 15G)	Dog whelk	Soft body																												↓/★	↓/O
Flatskjær (St. 227G2)	Dog whelk	Soft body																												↓/↓	↓/O
Espevær (st. 22G)	Dog whelk	Soft body																												↓/↓	↓/↓
Lofoten, Svolvær (st. 98G)	Dog whelk	Soft body																												↓/O	↓/↓
Brashavn (st. 11G)	Dog whelk	Soft body																												★/★	O/O

*) In cod, Hg is measured in fillet.

3.2 Levels and trends in contaminants

3.2.1 Overview of metals

In 2017, metals were analysed in blue mussels from 33 stations, in cod from 17 stations and in eider from one station (***Table 13***). They are discussed in more detail in sections 3.2.2 - 3.2.11, and only a brief summary is provided here.

EQS was only applicable for Hg, and it was exceeded at 32 (64 %) of these 50 stations (***Figure 7*** **A**). Applying PROREF, 70.3 % of the stations were below PROREF and the rest were above it, but none exceeded PROREF by a factor of more than 20 (***Figure 8*** *A*). Analyses of showed that 70.7 % of the data series for metals indicated no short-term trends, but for 14.3 % of the series a significant trend was found; 7.9 % downward and 6.4 % upward (***Figure 8*** *B*).

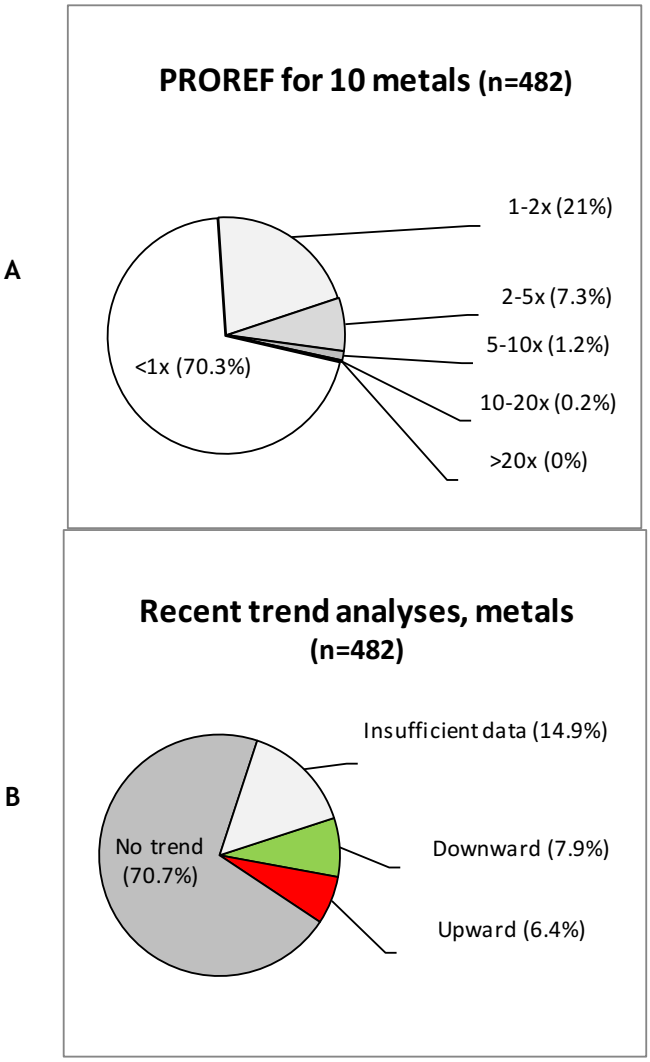


Figure 8. *Summary of frequency of exceedance to provisional high reference concentration (PROREF) (A) and the results from short-term trend analyses (**B**) and for 30 selected contaminants (excluding results from the common eider, cf.* ***Table 10****). Grey-shade coding in Figure B refers to relation to PROREF[20] (cf.* ***Table 28****).*

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

Table 13. *Median concentrations (µg/kg w.w.) and standard deviations for metals in blue mussel, cod liver, and eider blood and eggs in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See also Chapter 2.9 for more details and* ***Appendix B*** *for description of chemical codes.)*

Component	Count	TBT			AG			AS			CD			CO			CR			CU			HG			NI			PB			ZN		
Species and sampling locality	2017	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel																																		
Akershuskaia, Inner Oslofjord (st. I301)	3 (3-50)	12.000	3.000	3[9-15]	0.006	0.001	3[0.0046-0.0056]	1.100	0.153	3[1-1.3]	0.190	0.021	3[0.18-0.22]	0.088	0.007	3[0.077-0.091]	0.570	0.142	3[0.39-0.67]	1.400	0.058	3[1.3-1.4]	0.012	0.001	3[0.012-0.013]	0.380	0.050	3[0.32-0.42]	0.300	0.035	3[0.3-0.36]	21.000	2.082	3[20-24]
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	14.000	0.577	3[14-15]	0.012	0.002	3[0.011-0.015]	1.500	0.058	3[1.4-1.5]	0.180	0.017	3[0.15-0.18]	0.130	0.035	3[0.13-0.19]	0.840	0.464	3[0.48-1.4]	1.200	0.208	3[1.1-1.5]	0.015	0.002	3[0.015-0.018]	0.530	0.279	3[0.34-0.89]	0.900	0.085	3[0.83-1]	15.000	3.055	3[13-19]
Gåsøya, Inner Oslofjord (st. I304)	3 (3-50)	4.900	0.252	3[4.6-5.1]	0.004	0.002	1[0.007]	1.700	0.058	3[1.7-1.8]	0.230	0.017	3[0.2-0.23]	0.098	0.004	3[0.093-0.1]	0.160	0.012	3[0.14-0.16]	0.700	0.044	3[0.69-0.77]	0.016	0.011	3[0.012-0.032]	0.210	0.012	3[0.19-0.21]	0.380	0.062	3[0.35-0.47]	19.000	1.528	3[17-20]
Håøya, Inner Oslofjord (st. I306)	3 (3-50)				0.004	0.000	1[0.004]	2.000	0.058	3[2-2.1]	0.170	0.006	3[0.17-0.18]	0.072	0.001	3[0.071-0.073]	0.160	0.025	3[0.14-0.19]	0.660	0.093	3[0.64-0.81]	0.016	0.001	3[0.015-0.017]	0.200	0.006	3[0.2-0.21]	0.170	0.010	3[0.16-0.18]	15.000	0.577	3[15-16]
Solbergstrand, Mid Oslofjord (st. 31A)	3 (3-50)	3.100	0.709	3[2.6-4]	0.010	0.001	3[0.0099-0.011]	2.900	0.115	3[2.9-3.1]	0.190	0.006	3[0.19-0.2]	0.100	0.006	3[0.098-0.11]	2.200	0.651	3[1.6-2.9]	1.300	0.058	3[1.2-1.3]	0.015	0.002	3[0.014-0.018]	1.200	0.306	3[1-1.6]	0.170	0.010	3[0.16-0.18]	24.000	4.041	3[19-27]
Mølen, Mid Oslofjord (st. 35A)	3 (3-50)				0.005	0.001	3[0.0044-0.0067]	3.400	0.208	3[3.1-3.5]	0.160	0.010	3[0.15-0.17]	0.089	0.003	3[0.087-0.092]	0.250	0.045	3[0.21-0.3]	1.000	0.081	3[0.94-1.1]	0.014	0.002	3[0.013-0.016]	0.220	0.049	3[0.21-0.3]	0.120	0.006	3[0.11-0.12]	14.000	1.528	3[13-16]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.480	0.012		0.005	0.001	3[0.0047-0.0057]	2.700	0.153	3[2.5-2.8]	0.160	0.026	3[0.12-0.17]	0.072	0.005	3[0.072-0.081]	0.097	0.014	3[0.095-0.12]	1.200	0.058	3[1.2-1.3]	0.009	0.001	3[0.008-0.01]	0.130	0.006	3[0.13-0.14]	0.130	0.015	3[0.11-0.14]	18.000	1.528	3[16-19]
Singlekalven, Hvaler (st. I023)	3 (3-50)				0.004	0.003	1[0.008]	1.900	0.100	3[1.8-2]	0.200	0.045	3[0.16-0.25]	0.052	0.014	3[0.046-0.072]	0.390	0.149	3[0.16-0.44]	0.590	0.113	3[0.58-0.78]	0.019	0.003	3[0.016-0.021]	0.290	0.114	3[0.13-0.35]	0.067	0.021	3[0.06-0.1]	14.000	6.075	3[8.9-21]
Kirkøy, Hvaler (st. I024)	2 (2-50)				0.004	0.000		1.300	0.000	2[1.3-1.3]	0.195	0.007	2[0.19-0.2]	0.145	0.021	2[0.13-0.16]	0.695	0.233	2[0.53-0.86]	1.080	0.311	2[0.86-1.3]	0.030	0.000	2[0.03-0.03]	0.645	0.205	2[0.5-0.79]	0.325	0.177	2[0.2-0.45]	20.500	4.950	2[17-24]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)				0.008		1[0.00]	1.500		1[1.]	0.210		1[0.2]	0.079		1[0.07]	1.500		1[1.]	1.000		1[]	0.032		1[0.03]	0.840		1[0.8]	0.430		1[0.4]	20.000		1[2]
Sylterøya, Langesundfjord (st. I714)	3 (3-50)				0.004	0.000		1.600	0.058	3[1.6-1.7]	0.230	0.021	3[0.2-0.24]	0.063	0.004	3[0.059-0.067]	0.410	0.076	3[0.36-0.51]	0.660	0.097	3[0.53-0.72]	0.033	0.004	3[0.027-0.035]	0.200	0.025	3[0.18-0.23]	0.180	0.025	3[0.16-0.21]	13.000	2.646	3[12-17]
Risøya, Risør (st. 76A2)	3 (3-50)				0.005	0.001	3[0.004-0.0053]	1.800	0.058	3[1.8-1.9]	0.110	0.006	3[0.11-0.12]	0.060	0.009	3[0.055-0.073]	0.210	0.127	3[0.21-0.43]	0.790	0.114	3[0.76-0.97]	0.018	0.001	3[0.017-0.019]	0.200	0.101	3[0.19-0.37]	0.210	0.031	3[0.19-0.25]	13.000	2.309	3[13-17]
Lastad, Søgne (st. I131A)	3 (3-50)				0.004	0.000		2.100	0.289	3[1.6-2.1]	0.140	0.029	3[0.14-0.19]	0.058	0.003	3[0.056-0.061]	0.370	0.177	3[0.074-0.39]	1.200	0.058	3[1.2-1.3]	0.015	0.001	3[0.013-0.015]	0.320	0.124	3[0.11-0.33]	0.270	0.026	3[0.23-0.28]	17.000	2.082	3[14-18]
Odderøya, Kristiansand harbour (st. I133)	3 (3-50)	4.900	0.700	3[3.8-5.1]	0.005	0.003	3[0.0041-0.009]	1.300	0.058	3[1.3-1.4]	0.210	0.006	3[0.21-0.22]	0.120	0.006	3[0.11-0.12]	0.220	0.040	3[0.19-0.27]	1.200	0.058	3[1.2-1.3]	0.025	0.005	3[0.022-0.032]	0.550	0.035	3[0.52-0.59]	2.800	1.345	3[2.1-4.7]	22.000	1.732	3[22-25]
Gåsøya-Ullerøya, Farsund (st. 15A)	3 (3-50)				0.005	0.001	2[0.0048-0.0067]	2.100	0.058	3[2.1-2.2]	0.140	0.015	3[0.12-0.15]	0.054	0.006	3[0.049-0.061]	0.081	0.033	3[0.068-0.13]	0.750	0.163	3[0.64-0.96]	0.012	0.001	3[0.012-0.013]	0.120	0.044	3[0.11-0.19]	0.210	0.023	3[0.17-0.21]	22.000	4.163	3[16-24]
Byrkjenes, Inner Sørfjord (st. 51A)	3 (3-50)																						0.041	0.007	3[0.033-0.047]									
Eitrheimsneset, Inner Sørfjord (st. 52A)	3 (3-50)				0.019	0.006	3[0.01-0.02]	1.600	0.115	3[1.4-1.6]	0.450	0.051	3[0.42-0.52]	0.054	0.006	3[0.051-0.063]	0.150	0.056	3[0.08-0.19]	0.970	0.025	3[0.95-1]	0.031	0.003	3[0.03-0.035]	0.150	0.041	3[0.085-0.16]	1.900	0.058	3[1.9-2]	16.000	3.512	3[13-20]
Kvalnes, Mid Sørfjord (st. 56A)	3 (3-50)																						0.041	0.011	3[0.035-0.057]									
Krossanes, Outer Sørfjord (st. 57A)	3 (3-50)				0.006	0.003	3[0.0048-0.011]	2.000	0.153	3[1.9-2.2]	0.220	0.032	3[0.21-0.27]	0.066	0.005	3[0.059-0.068]	0.230	0.112	3[0.097-0.32]	0.640	0.075	3[0.57-0.72]	0.033	0.005	3[0.026-0.035]	0.220	0.095	3[0.11-0.3]	0.540	0.114	3[0.36-0.57]	10.000	1.323	3[9.5-12]
Ranaskjer, Ålvik, Hardangerfjord (st. 63A)	3 (3-50)				0.004	0.000	1[0.004]	2.100	0.058	3[2.1-2.2]	0.180	0.029	3[0.13-0.18]	0.053	0.007	3[0.052-0.064]	0.360	0.115	3[0.19-0.41]	0.720	0.110	3[0.53-0.72]	0.020	0.007	3[0.017-0.03]	0.310	0.100	3[0.16-0.35]	0.340	0.079	3[0.22-0.37]	11.000	0.693	3[9.8-11]
Utne, Outer Sørfjord (st. 64A)	3 (3-50)				0.011	0.003	3[0.0086-0.015]	3.100	0.100	3[3-3.2]	0.230	0.010	3[0.22-0.24]	0.074	0.005	3[0.071-0.08]	0.240	0.194	3[0.052-0.44]	0.980	0.042	3[0.92-1]	0.017	0.001	3[0.016-0.018]	0.260	0.130	3[0.14-0.4]	0.250	0.006	3[0.25-0.26]	12.000	0.000	3[12-12]
Vikingneset, Mid Hardangerfjord (st. 65A)	3 (3-50)				0.004	0.000		2.300	0.252	3[2.1-2.6]	0.140	0.040	3[0.1-0.18]	0.052	0.010	3[0.043-0.062]	0.260	0.057	3[0.18-0.29]	0.700	0.075	3[0.61-0.76]	0.022	0.006	3[0.014-0.026]	0.270	0.040	3[0.2-0.27]	0.320	0.155	3[0.17-0.48]	16.000	2.309	3[12-16]
Terøya, Outer Hardangerfjord (st. 69A)	3 (3-50)				0.006	0.002	2[0.0055-0.0081]	2.100	0.200	3[1.9-2.3]	0.130	0.012	3[0.11-0.13]	0.059	0.007	3[0.059-0.071]	0.260	0.289	3[0.17-0.71]	0.960	0.103	3[0.9-1.1]	0.016	0.002	3[0.013-0.017]	0.240	0.178	3[0.19-0.52]	0.130	0.015	3[0.12-0.15]	14.000	0.577	3[14-15]
Espevær, Outer Bømlafjord (st. 22A)	3 (3-50)	1.700	0.351	3[1.4-2.1]	0.004	0.000		1.900	0.265	3[1.8-2.3]	0.093	0.009	3[0.083-0.1]	0.060	0.008	3[0.052-0.068]	0.130	0.055	3[0.092-0.2]	0.940	0.165	3[0.77-1.1]	0.023	0.004	3[0.019-0.027]	0.190	0.046	3[0.11-0.19]	0.180	0.023	3[0.18-0.22]	14.000	1.528	3[12-15]
Nordnes, Bergen harbour (st. I241)	3 (3-50)				0.004	0.000		2.400	0.208	3[2.1-2.5]	0.140	0.015	3[0.12-0.15]	0.051	0.006	3[0.045-0.057]	0.200	0.035	3[0.14-0.2]	1.100	0.000	3[1.1-1.1]	0.021	0.001	3[0.02-0.022]	0.110	0.021	3[0.079-0.12]	0.630	0.118	3[0.47-0.7]	23.000	2.309	3[23-27]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)				0.004	0.000		3.300	0.416	3[3.1-3.9]	0.150	0.006	3[0.15-0.16]	0.052	0.006	3[0.047-0.058]	0.200	0.015	3[0.18-0.21]	1.400	0.058	3[1.4-1.5]	0.023	0.008	3[0.01-0.025]	0.170	0.031	3[0.13-0.19]	0.230	0.015	3[0.22-0.25]	26.000	8.386	3[25-40]
Ålesund harbour (st. 28A2)	3 (3-50)				0.004	0.000	2[0.0043-0.0046]	3.100	0.321	3[3-3.6]	0.140	0.017	3[0.14-0.17]	0.053	0.011	3[0.043-0.064]	0.510	0.306	3[0.24-0.85]	1.100	0.265	3[1-1.5]	0.030	0.002	3[0.029-0.032]	0.380	0.205	3[0.18-0.59]	0.190	0.038	3[0.18-0.25]	21.000	2.082	3[18-22]
Ørland area, Outer Trondheimsfjord (st. 9	3 (3-50)				0.004	0.000	1[0.004]	3.800	0.200	3[3.6-4]	0.160	0.017	3[0.16-0.19]	0.081	0.006	3[0.07-0.081]	0.820	0.165	3[0.81-1.1]	1.100	0.153	3[0.9-1.2]	0.013	0.001	3[0.013-0.014]	0.230	0.167	3[0.23-0.52]	0.190	0.035	3[0.13-0.19]	16.000	2.082	3[15-19]
Bodø harbour (st. 97A3)	3 (3-50)				0.006	0.001	3[0.0046-0.0068]	1.900	0.058	3[1.9-2]	0.130	0.010	3[0.12-0.14]	0.074	0.016	3[0.059-0.091]	0.350	0.030	3[0.32-0.38]	2.600	0.700	3[1.9-3.3]	0.010	0.001	3[0.009-0.01]	0.380	0.078	3[0.27-0.42]	0.230	0.032	3[0.22-0.28]	21.000	3.000	3[18-24]
Mjelle, Bodø area (st. 97A2)	3 (3-50)				0.004	0.005	1[0.01]	1.900	0.153	3[1.8-2.1]	0.110	0.025	3[0.09-0.14]	0.063	0.008	3[0.049-0.063]	0.300	0.035	3[0.27-0.34]	1.100	0.142	3[0.92-1.2]	0.018	0.005	3[0.012-0.022]	0.290	0.055	3[0.2-0.3]	1.300	0.979	3[0.96-2.8]	14.000	2.517	3[12-17]
Svolvær airport area (st. 98A2)	3 (3-50)				0.010	0.001	3[0.0089-0.011]	2.600	0.173	3[2.6-2.9]	0.230	0.040	3[0.2-0.28]	0.060	0.003	3[0.057-0.063]	0.210	0.050	3[0.15-0.25]	1.400	0.115	3[1.2-1.4]	0.021	0.002	3[0.018-0.021]	0.210	0.032	3[0.16-0.22]	0.170	0.010	3[0.16-0.18]	18.000	1.000	3[17-19]
Brashavn, Outer Varangerfjord (st. 11X)	3 (3-50)				0.007	0.001	3[0.0064-0.0088]	1.400	0.173	3[1.4-1.7]	0.250	0.025	3[0.22-0.27]	0.052	0.007	3[0.048-0.061]	0.180	0.006	3[0.17-0.18]	1.000	0.081	3[0.86-1]	0.010	0.001	3[0.009-0.011]	0.300	0.055	3[0.29-0.39]	0.058	0.009	3[0.05-0.067]	13.000	4.163	3[11-19]
Skallnes, Outer Varangerfjord (st. 10A2)	3 (3-50)				0.012	0.002	3[0.011-0.014]	1.800	0.100	3[1.7-1.9]	0.290	0.010	3[0.28-0.3]	0.060	0.006	3[0.057-0.068]	0.400	0.323	3[0.4-0.96]	1.100	0.115	3[1.1-1.3]	0.009	0.004	3[0.008-0.016]	0.350	0.176	3[0.34-0.65]	0.120	0.014	3[0.096-0.12]	17.000	3.606	3[15-22]

Table 13. (cont.)

Component	Count	TBT			AG			AS			CD			CO			CR			CU			HG			NI			PB			ZN		
Species and sampling locality	2017	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Cod, liver (all metals except Hg), filet (Hg)																																		
Inner Oslofjord (st. 30B)	12 (8-3)				5.350	2.812	12[0.45-9.2]	11.500	11.026	12[2.1-33]	0.112	0.083	12[0.047-0.29]	0.040	0.021	12[0.021-0.092]	0.085	0.066	11[0.043-0.26]	3.600	2.649	12[3.2-10]	0.203	0.112	15[0.076-0.533]	0.110	0.037	10[0.067-0.15]	0.145	1.084	10[0.053-3.9]	21.500	4.697	12[15-29]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)				0.290	0.109	10[0.12-0.49]	3.400	0.404	10[2.8-4.1]	0.020	0.005	10[0.014-0.029]	0.032	0.007	10[0.021-0.042]	0.054	0.024	9[0.049-0.12]	5.400	1.266	10[3-7.2]	0.080	0.036	15[0.032-0.156]	0.040	0.011	1[0.07]	0.030	0.000		29.000	5.174	10[23-39]
Kirkøy, Hvaler (st. 02B)	9 (7-2)				0.250	0.258	9[0.05-0.81]	4.700	1.783	9[1.9-7.5]	0.030	0.013	9[0.0086-0.052]	0.035	0.008	9[0.019-0.044]	0.035	0.101	7[0.033-0.34]	5.100	2.016	9[2.7-8.2]	0.111	0.049	15[0.05-0.241]	0.040	0.043	2[0.05-0.17]	0.030	0.000		23.000	2.828	9[17-27]
Stathelle area, Langesundfjord (st. 71B)	15 (6-2)				0.130	0.171	15[0.046-0.6]	3.100	1.412	15[2.1-6.4]	0.016	0.017	15[0.0094-0.064]	0.026	0.013	15[0.012-0.063]	0.031	0.020	8[0.031-0.092]	6.600	3.139	15[2.4-13]	0.211	0.154	15[0.1-0.604]	0.040	0.011	3[0.048-0.082]	0.030	0.002	1[0.03]	23.000	4.992	15[17-36]
Kristiansand harbour area (st. 13B)	12 (5-2)				0.915	0.594	12[0.091-2]	3.950	1.577	12[1.8-7.6]	0.045	0.029	12[0.02-0.11]	0.056	0.016	12[0.034-0.092]	0.170	0.759	12[0.091-2.8]	13.000	6.706	12[0.97-27]	0.175	0.091	15[0.1-0.423]	0.130	0.453	12[0.077-1.7]	0.030	0.010	2[0.03-0.064]	36.000	6.067	12[22-42]
Skågskjera, Farsund (st. 15B)	15 (3-2)				1.100	0.470	15[0.31-1.9]	5.100	1.947	15[2.9-9.8]	0.024	0.012	15[0.014-0.064]	0.045	0.015	15[0.028-0.078]	0.130	0.047	15[0.044-0.2]	11.000	2.227	15[6.6-15]	0.172	0.093	15[0.125-0.454]	0.083	0.038	14[0.042-0.19]	0.030	0.000		41.000	5.226	15[31-49]
Inner Sørfjord (st. 53B)	15 (3-2)				0.640	0.362	15[0.11-1.3]	4.800	1.660	15[2.9-8.7]	0.072	0.082	15[0.023-0.26]	0.032	0.013	15[0.016-0.056]	0.030	0.013	4[0.034-0.075]	14.000	3.875	15[8.6-22]	0.300	0.146	15[0.066-0.644]	0.040	0.000		0.062	0.092	14[0.033-0.35]	26.000	3.936	15[19-31]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)				1.200	0.614	13[0.25-1.9]	6.600	1.946	13[2.4-10]	0.036	0.021	13[0.026-0.1]	0.047	0.021	13[0.029-0.093]	0.160	0.125	13[0.056-0.5]	16.000	7.070	13[4-26]	0.152	0.094	15[0.07-0.334]	0.082	0.086	11[0.044-0.34]	0.030	0.047	1[0.]	34.000	9.609	13[27-62]
Bergen harbour area (st. 24B)	15 (4-2)				0.320	0.309	15[0.016-1]	3.300	1.941	15[1.9-8.6]	0.029	0.025	15[0.0051-0.094]	0.035	0.018	15[0.0065-0.065]	0.030	0.003	1[0.04]	5.200	7.325	15[0.96-24]	0.176	0.213	15[0.032-0.655]	0.040	0.005	1[0.05]	0.030	0.036	7[0.034-0.16]	34.000	10.662	15[14-49]
Ålesund harbour area (st. 28B)	15 (3-2)				0.370	1.138	15[0.088-4.6]	6.800	12.945	15[2.9-37]	0.036	0.114	15[0.0087-0.42]	0.021	0.025	15[0.0059-0.09]	0.079	0.080	13[0.035-0.31]	7.900	7.842	15[1.9-30]	0.321	0.089	15[0.166-0.476]	0.083	0.061	10[0.044-0.2]	0.030	0.010	4[0.034-0.066]	29.000	12.609	15[15-52]
Trondheim harbour (st. 80B)	15				0.220	0.738	15[0.014-2.7]	8.600	11.425	15[1.8-49]	0.050	0.063	15[0.014-0.27]	0.057	0.025	15[0.013-0.096]	0.091	0.083	13[0.049-0.36]	4.400	5.131	15[1.3-19]	0.156	0.073	15[0.094-0.367]	0.050	0.050	10[0.045-0.23]	0.030	0.002	2[0.031-0.039]	26.000	8.844	15[11-42]
Sandnessjøen area (st. 96B)	15				0.280	0.351	15[0.082-1]	2.400	1.695	15[1.2-7.2]	0.052	0.071	15[0.019-0.3]	0.019	0.014	15[0.0063-0.055]	0.062	0.098	14[0.03-0.41]	5.500	4.938	15[1.5-17]	0.047	0.020	15[0.029-0.09]	0.053	0.062	10[0.043-0.24]	0.030	0.000		23.000	9.583	15[11-48]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)				0.230	1.371	11[0.019-4.3]	5.900	3.778	11[1.4-14]	0.120	0.194	11[0.0094-0.58]	0.037	0.025	11[0.0049-0.081]	0.030	0.072	5[0.031-0.27]	4.900	7.487	11[0.91-25]	0.109	0.096	15[0.051-0.444]	0.040	0.038	4[0.071-0.14]	0.030	0.002	1[0.03]	25.000	9.521	11[13-41]
Tromsø harbour area (st. 43B2)	15				0.340	0.324	15[0.082-1.1]	4.400	2.727	15[2.6-11]	0.040	0.135	15[0.023-0.44]	0.009	0.009	15[0.0035-0.031]	0.030	0.022	7[0.035-0.082]	3.100	4.601	15[1.5-19]	0.049	0.029	15[0.028-0.146]	0.040	0.012	6[0.043-0.076]	0.030	0.000		17.000	7.536	15[7-33]
Hammerfest harbour area (st. 45B2)	14 (6-2)				0.575	0.230	14[0.14-1]	7.600	3.325	14[3.4-14]	0.280	0.183	14[0.1-0.78]	0.035	0.013	14[0.023-0.065]	0.077	0.048	13[0.032-0.22]	7.050	2.649	14[2-11]	0.033	0.025	15[0.021-0.12]	0.079	0.036	13[0.058-0.19]	0.030	0.000		30.500	5.502	14[18-40]
Kjøfjord, Outer Varangerfjord (st. 10B)	15 (12-3)				0.260	0.224	15[0.12-0.94]	6.800	2.892	15[3.6-13]	0.210	0.064	15[0.11-0.3]	0.035	0.012	15[0.021-0.063]	0.048	0.034	15[0.035-0.17]	5.000	2.062	15[2.4-8.8]	0.035	0.008	15[0.025-0.052]	0.093	0.039	15[0.055-0.16]	0.030	0.002	2[0.034-0.036]	24.000	2.963	15[19-28]
Isfjorden, Svalbard (st. 19B)	15				0.250	0.152	15[0.12-0.67]	3.300	1.093	15[2.3-6]	0.170	0.135	15[0.098-0.63]	0.018	0.006	15[0.008-0.032]	0.039	0.024	10[0.033-0.11]	3.600	1.669	15[2.1-8.9]	0.030	0.010	15[0.015-0.052]	0.045	0.011	10[0.04-0.08]	0.030	0.000		16.000	3.432	15[13-25]
Eider, blood																																		
Breøyane, Kongsfjorden, Svalbard (st. 19N	15				0.001	0.003	15[2e-04-0.0094]	0.030	0.023	15[0.0123-0.0808]	0.003	0.001	15[0.0015-0.0049	0.003	0.002	15[0.0012-0.0065	0.035	0.007		0.519	0.088	15[0.4747-0.7454	#####	48.673	15[57.3927-214.0177	0.030	0.006		0.051	0.104	15[0.0178-0.4198]	6.881	1.737	15[5.4539-11.4881]
Eider, egg																																		
Breøyane, Kongsfjorden, Svalbard (st. 19N	15				0.003	0.006	15[0.0016-0.0189	0.164	0.221	15[0.0958-0.9676]	0.000	0.000	15[2e-04-9e-04]	0.007	0.002	15[0.0041-0.0098	0.023	0.013	8[0.0215-0.0569]	1.440	0.132	15[1.1606-1.6885	#####	28.741	15[61.0888-171.5715	0.019	0.010	8[0.0177-0.0544	0.008	0.010	15[0.0021-0.0337]	20.219	2.333	15[15.7483-24.4817

3.2.2 Mercury (Hg)

Mercury (Hg) is found naturally in the earth's crust. Hg can be organic, inorganic, or elemental, and has toxic effects on the nerve system. The toxic substance can be transported by water and air over long distances and end up in the environment in completely different parts of the globe than where it is released. In the present study, Hg was analysed in blue mussel at 33 stations, in cod fillet at 17 stations and in eider blood and eggs at one station.

Environmental Quality Standards (EQS) for EU-priority substances

EU has provided EQS of 0.02 mg/kg w.w. in biota (cf. ***Table 7***). Applying this EQS for blue mussel, concentrations of Hg were above or at the EQS at Kirkøy (st. I024, 0.030 mg/kg w.w.) in the Outer Oslofjord, at Bjørkøya (st. 71A, 0.032 mg/kg w.w.) and Sylterøya (st. I714, 0.033 mg/kg w.w.) in the Langesundfjord and at Odderøya (st. I133, 0.025 mg/kg w.w.) in the Kristiansandfjord. This was also the case at Byrkjenes (st. 51A, 0.041 mg/kg w.w.), Eitrheimsneset (st. 52A, 0.031 mg/kg w.w.), Kvalnes (st. 56A, 0.041 mg/kg w.w.) and Krossanes (st. 57A, 0.033 mg/kg w.w.) in the Sørfjord, and at Ranaskjer (st. 63A, 0.020 mg/kg w.w.) and Vikingneset (st. 65A, 0.022 mg/kg w.w.) in the Hardangerfjord. Concentrations of Hg above or at the EQS was also observed at Espevær (st. 22A, 0.023 mg/kg w.w.) and Nordnes (st. I241, 0.021 mg/kg w.w.) on the west coast, at Vågsvåg (st. 26A2, 0.023 mg/kg w.w.) in the Outer Nordfjord, at Ålesund (st. 28A2, 0.030 mg/kg w.w.) and at Svolvær airport area (st. 98A2, 0.021 mg/kg w.w.) in Lofoten.

The EQS for biota (0.020 mg/kg w.w.) is provided for fish and are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in this study only measured Hg in fillet. Converting concentrations in fillet to concentrations in whole fish is uncertain. Using fillet probably represents an overestimate of the whole fish concentration because Hg accumulates more in the fillet than in other tissues (Kwasniak & Falkowska 2012). If it is assumed, for this exercise, that the same concentration is found in all fish tissue types, then the results of Hg (in cod fillet) would have exceeded the EQS (0.020 mg/kg w.w.) for all 2017-samples, see ***Table 11***).

Levels exceeding PROREF

Blue mussel exceeded the provisional high reference concentration (PROREF) for Hg by a factor between two and five times at Kirkøy (st. I024) at Hvaler in the Outer Oslofjord, at Sylterøya (st. I714) and Bjørkøya in the Langesundfjord (st. 71A) and at Odderøya (st. I133) in the Kristiansandfjord (***Table 12***). This was also the case at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A) in the Sørfjord. This was also the result at Ranaskjer (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord, at Espevær (st. 22A) in the Outer Bømlafjord and Nordnes in the Bergen harbour (st. I241). This was also the result at Vågsvåg (st. 26A2) in the Outer Nordfjord, at Ålesund harbour (st. 28A2) and at Svolvær airport area (st. 98A2).

For blue mussel, the exceedances were a factor of up to two in the Oslofjord at Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Håøya (st. I306), Solbergstrand (st. 31A), Mølen (st. 35A), and Singlekalven (st. I023) in the Oslofjord. This was also the result at Risøya (st. 76A2) at Risør, Lastad (st. I131A) at Søgne, and Gåsøya-Ullerøya (st. 15A) in Farsund. This was also the case at Utne (st. 64A) and Terøya (st. 69A) in the western part of Norway, and at Ørland area (st. 91A2) in the Outer Trondheimfjord. This was also the result at Bodø harbour (st. 97 A3) and at Mjelle (st. 97A2) in the Bodø area, and at Brashavn (st. 11X) in the Outer Varangerfjord.

Cod fillet exceeded PROREF by a factor between five and 10 times in Ålesund harbour (st. 28B) and in the Inner Sørfjord (st. 53B). The exceedances were a factor between two and five times in the Inner Oslofjord (st. 30B), Stathelle area in the Grenlandfjord (st. 71B), Kristiansand harbour area (st. 13B), Skågskjera in Farsund (st. 15B), Bømlo (st. 23B), Bergen harbour (st. 24B), and Trondheim harbour (st. 80B). The exceedances were a factor up to two times at the areas of Tjøme (st. 36B), Kirkøy at Hvaler (st. 02B) and Austnesfjord in Lofoten (st. 98B1).

Increase in PROREF factor since 2016

Blue mussel that exceeded the PROREF by a factor between two and five times in 2017 and up to two times in 2016, were found at Kirkøy (st. I024) at Hvaler, Sylterøya (st. I714) in the Langesundfjord, Espevær (st. 22A) in the Outer Bømlafjord, Nordnes (st. I241) in Bergen harbour, Vågsvåg (st. 26A2) in the Outer Nordfjord, and at Svolvær airport area (st. 98A2). Blue mussel that exceeded the PROREF by a factor between two and five in 2017, while the exceedance was up to two times 2016, were found at Solbergstrand (st. 31A) in the Mid Oslofjord, Lastad (st. I131A) in Søgne, Gåsøya-Ullerøya (st. 15 A) in Farsund, and Terøya (st. 69A) in the Outer Hardangerfjord.

Cod fillet from the Inner Sørfjord (st. 53B) and Ålesund (st. 28B) exceeded the PROREF by a factor between five and 10 in 2017, while the exceedance was between two and five in 2016. The median concentration of Hg had increased to 0.300 mg/kg w.w. in 2017 from 0.162 mg/kg w.w. in 2016 in the Inner Sørfjord, and to 0.321 mg/kg w.w. in 2017 from 0.241 mg/kg w.w. in 2016 in Ålesund. In 2017, cod fillet from Trondheim harbour (st. 80B) exceeded the PROREF by a factor between two to five, while the exceedance was up two times in 2016.

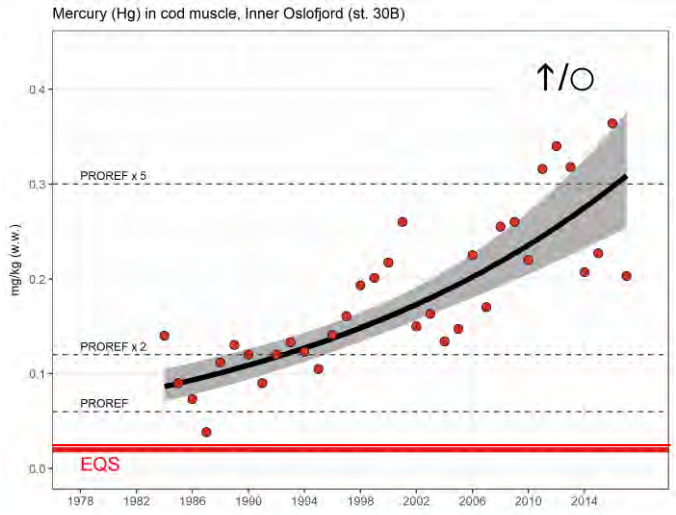
Upward trends

In blue mussel, a significant upward long-term trend was found in mussels from Akershuskaia (st. I301) in the Inner Oslofjord. Significant upward short-term trends were found at Gåsøya (st. I304) and Håøya (st. I306) in the Inner Oslofjord and at Eitrheimsneset (st. 52A) in the Inner Oslofjord.

In cod fillet, both significant upward long- and short-term trends were found in Kristiansand harbour (st. 13B) and Tromsø harbour (st. 43B2, ***Figure 10 A)***. Cod fillet from the Inner Oslofjord (st. 30B) showed a significant upward long-term trend (***Table 12***, ***Figure 9***) in 2017 using the OSPAR method which targets specific length-groups. When using the method taking into considerations fish-length, the cod fillet from the Inner Oslofjord and Tromsø harbour showed no significant trends (***Figure 10 B***, see also section **3.6**). When fish-length was taken into account, cod fillet at Kristiansnad harbour (st. 13B) showed both significant upward long- and short-term trends, whereas significant upward short-time trends were found at Skågskjera in Farsund and in Austnesfjord in Lofoten (***Figure 11 A***, ***B*** and ***C***, respectively).

Significant upward short-term trends were found at Skågskjera in Farsund (st. 15B), at Bømlo (st. 23B) in the Outer Selbjørnfjord, and at Austnesfjord (st. 98B1) in Lofoten.

A



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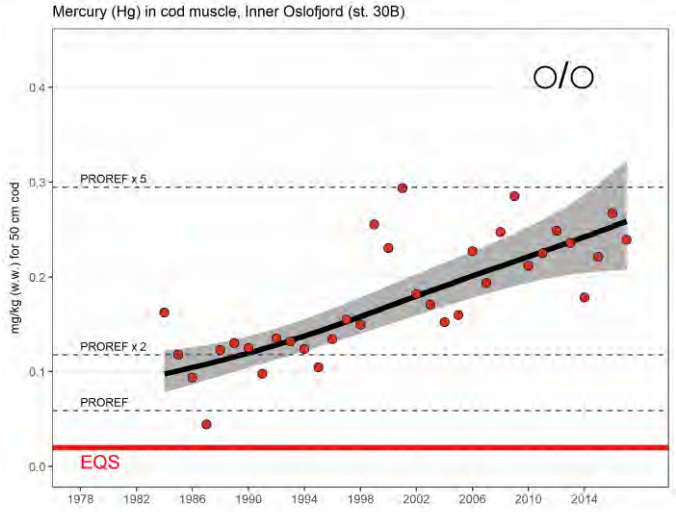
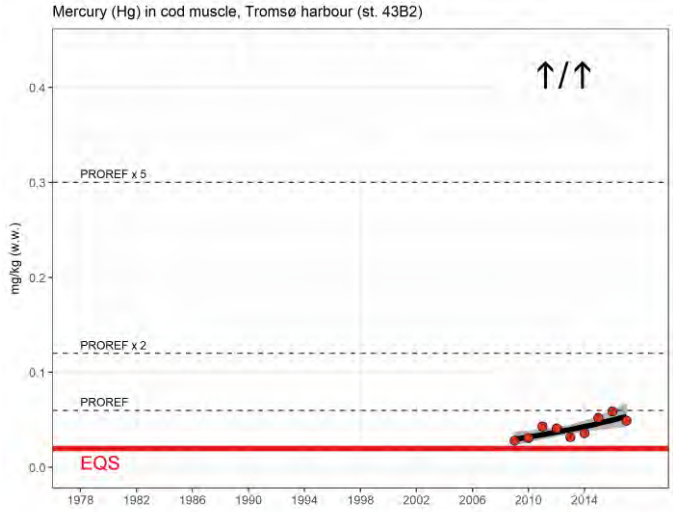


Figure 9. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from 1984 to 2017 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

A



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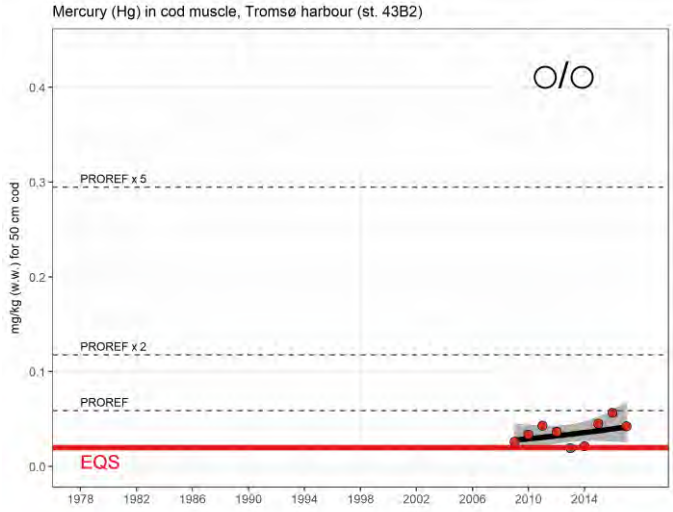
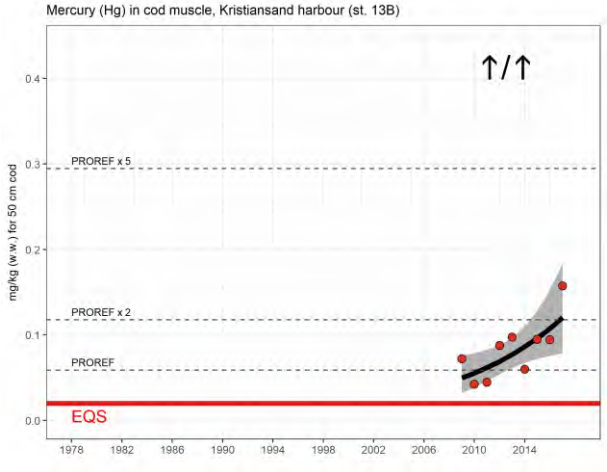


Figure 10. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from 2009 to 2017 in the Tromsø harbour (st. 43B2); no adjustment for length (***A***) and adjusted for length (***B***). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

A



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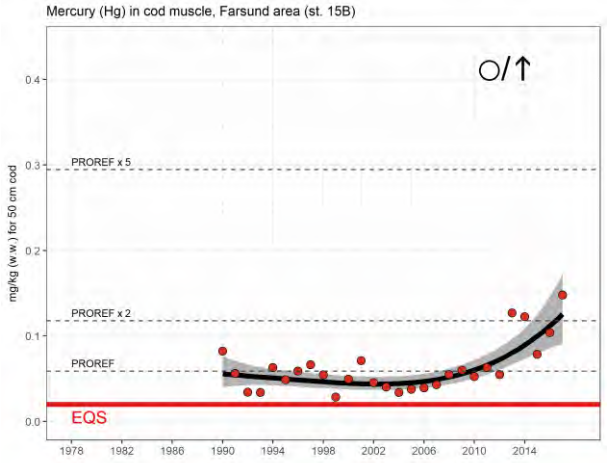


C

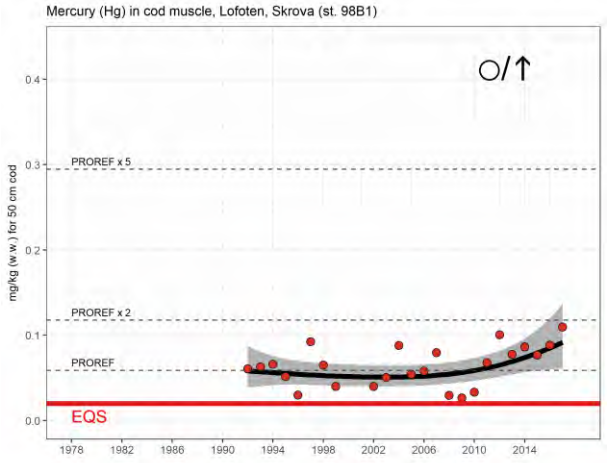


Figure 11. *Median concentrations (mg/kg w.w.) of mercury (Hg) adjusted for length in cod fillet from 1990, 1992 or 2009 to 2017 in the Inner Kristiansand harbour (st. 13B) (**A**), Skågskjera in Farsund (st. 15B) (**B**) and Austnesfjord in Lofoten (st. 98B1) (**C**). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C**).

Decrease in PROREF factor since 2016

Blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord and Utne (st. 64A) in the Outer Sørfjord exceeded PROREF by a factor up to two times in 2017, and between two and five in 2016.

Cod fillet from the Inner Oslofjord (st. 30B) exceeded the PROREF by a factor between two and five in 2017, and between five and 10 in 2016. The median concentration of Hg had decreased to 0.203 mg/kg w.w. in 2017 from 0.3640 mg/kg w.w. in 2016. In 2017, cod fillet from Tjøme (st. 36B) in the Outer Oslofjord and Austnesfjord (st. 98B1) in the Lofoten exceeded PROREF by a factor up to two, while the exceedance was between two and five in 2016. The median concentrations of Hg at Tjøme and Austnesfjord had decreased to 0.080 mg/kg w.w. and 0.109 mg/kg w.w. in 2017, from 0.154 mg/kg w.w. and 0.121, mg/kg w.w., respectively.

Downward trends

In blue mussel, significant downward long-term trends were found at Solbergstrand (st. 31A) and Mølen (st. 35A) in the Mid Oslofjord, Færder (st. 36A) in the Outer Oslofjord and Bjørkøya (st. 71A) in the Langesundfjord. This was also observed in the Sørfjord at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A), and in the Hardangerfjord at Ranaskjer (st. 63A) in Ålvik. The same result was seen in the Varangerfjord at Skallnes (st. 10A2).

In cod fillet, significant downward long-term trends were found in Hammerfest harbour (st. 45B2) and at Kjøfjord (st. 10B) in the Outer Varangerfjord.

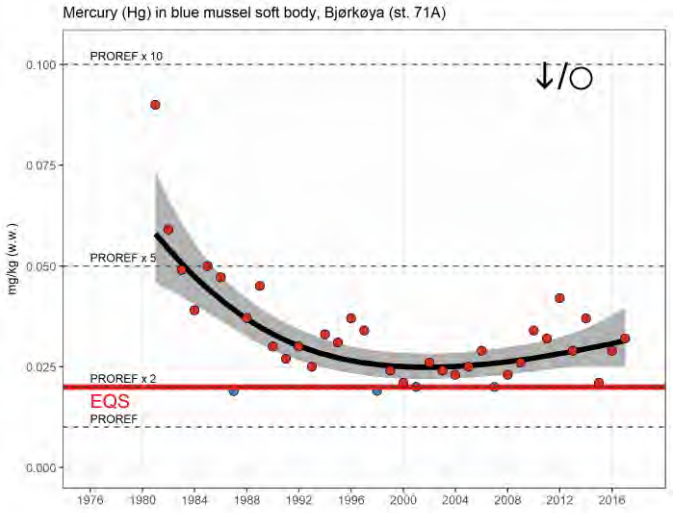


Figure 12. *Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from 1981 to 2017 at Bjørkøya (st. 71A) in the Grenlandfjord area. The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Hg-concentration was 0.147 mg/kg w.w. in blood, and 0.100 mg/kg w.w. in egg.

Other studies

Another recent survey in compliance with the EU Water Framework Directive, showed that blue mussel from Langøya in the Mid Oslofjord in 2017 exceeded EQS for Hg at two of three stations (Schøyen & Beylich 2018). Blue mussel at Mølen (st. 35A) had concentration (0.019 mg Hg/kg w.w.)

below EQS. In the same study, the concentration of Hg in cod fillet (mean 0.083 mg/kg w.w.) exceeded the EQS. The collection of blue mussel and cod took place during the autumn.

In this study, blue mussel at Byrkjenes in the Inner Sørfjord had lower concentration (0.041 mg/kg w.w.) than a comparable study at the same station in 2017 (mean 25 mg/kg w.w.) (Ruus *et al*. 2017b). The collection of blue mussel took place during the autumn.

In this study, cod fillet from the Inner Oslofjord had lower concentration (median 0.203 mg/kg Hg w.w.) than a comparable study from the Inner Oslofjord in 2017 (mean 0.351 mg/kg Hg w.w.) (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

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

Most of the Hg-pollution in Norwegian lakes is now due to atmospherically deposited Hg originating from other parts of the world (Fjeld *et al*. 2017 – M-807|2017). The concentration of Hg in trout from Mjøsa showed a decreasing trend in the period 1980-2005, and showed more or less unchanged concentrations during the period 2006-2014 (Løvik *et al*. 2016). Surveys from 2008 suggests that the length adjusted average Hg-concentrations in ten perch populations from forest lakes, increased with 63 % since the early 1990s (Fjeld & Rognerud 2009 – TA-2544/2009).

The Hg-concentration in burbot muscle was approximately at the same level as that found in fish eating trout (0.3-0.9 mg/kg w.w.) in Lake Mjøsa in 2016 (Garmo *et al*. 2017).

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

In this study, Hg-concentration (median 0.100 mg/kg w.w.) in eider egg at Svalbard was at the same level as in a comparable study (median 0.07 mg/kg w.w.) (Hill 2018).

General, large scale trends

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 115 kg in 2016 (Skarbøvik *et al*. 2017 – M-862|2017). The riverine inputs of Hg to different seawater were 48 kg to Skagerrak, 33 kg to the North Sea, 26 kg to the Norwegian Sea and 8 kg to the Barents Sea, indicating higher input in the southern part of Norway. Total Hg load dropped 59 % to 115 kg in 2016 compared to the mean for the period 1990-2015 (278 kg). In addition to riverine inputs was the contribution by direct discharges from sewage (5 kg) and industrial (8 kg) effluents amounting to 13 kg or about 10 % of the total (128 kg).

For MILKYS long-term trends, there is some evidence of downward trends. Eleven downward long-term trends and one upward long-term trend were found in blue mussel. However, two downward long-term trends were found in cod fillet from Hammerfest harbour and the Varangerfjord, while three upward long-term trends were found in cod fillet from the Inner Oslofjord, Kristiansand harbour and Tromsø harbour.

When considering the total of 48 possible recent short-term (2008-2017) trends for both cod and blue mussel, significant trends are limited to upwards at four stations and downwards at 13 stations (***Table 12***, ***Figure 13***).

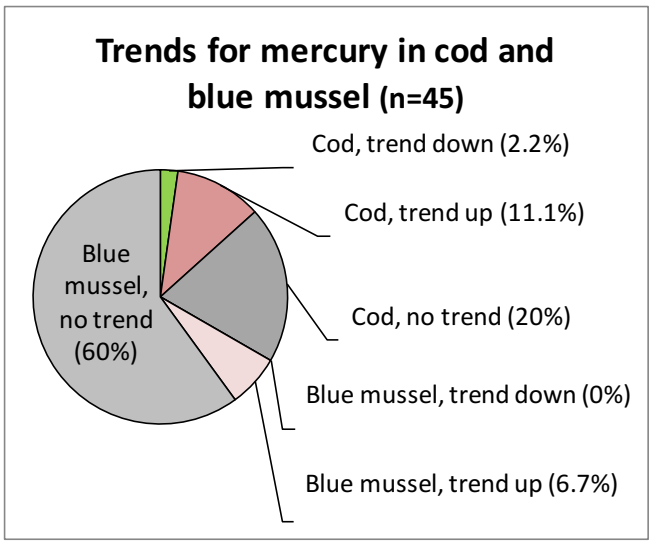


Figure 13. *Frequency of short-term (recent) trends (2008-2017) for Hg in blue mussel and cod fillet.*

In the present study, there were upward long-term trends in blue mussel at Akershuskaia and cod fillet from the Inner Oslofjord, Kristiansand harbour and Tromsø harbour. Furthermore, upward short-term trends in blue mussel at Gåsøya, Håøya and Eitrheimsneset, and cod fillet from Kristiansand harbour, Skågskjera in Farsund, Bømlo in the Outer Selbjørnfjord, Austnesfjord in Lofoten, and Tromsø harbour were registered. Possible explanations of increasing trends could be related to factors such as; climate change, more favourable conditions for methyl mercury formation, increased bioavailability of Hg stored in the sediments, increased access of cod to contaminated feeding areas due to improved oxygen levels in deep water, changes in what the cod eat, etc. It has also been speculated in that the increasing trend (long-term) in the Inner Oslofjord might be a result of sediment remediation works in Oslo harbour in 2006-2008. Neither explanation can be ruled out based on existing knowledge, but the monitoring designed to reveal spreading of mercury during the dredging operations (Berge 2014) gave little evidence to support the latter hypotheses. Neither can it explain why Hg and MCCP are the only contaminants, showing an upward long-term trend in the cod fillet from the Inner Oslofjord. Before speculating too much in potential causes, the nature of the trend data will be further investigated below.

Most of the upward trends in Hg-concentrations in cod fillet from the Inner Oslofjord could be attributed to the sampling of larger fish (Ruus *et al.* 2017b). Hg-concentrations in cod fillet from the Inner Oslofjord showed both significant upward long-term (1984-2014) and short-term (2005-2014) trends (when 2015 was included, the short-term trend was not significant). The median length of the cod also showed upward trends. This may have been caused by low cod recruitment in the area since the start of the 2000s, as indicated by beach seine surveys. To investigate how length would impact the trend analysis, the Hg-concentrations in the cod were normalised to 50 cm. No significant short-term trend in Hg-concentrations could be detected for length-normalised concentrations. The results indicated that most of the upward trend in Hg-concentrations could be

attributed to the sampling of larger fish. The reasons for the apparent change in the cod population demography are not conclusive, however, sampling bias must also be considered.

Atmospheric deposition is a major source to the seas surrounding Norway and considerably larger than other sources such as riverine discharges, shipping, and offshore installations (Green *et al*. 2013 – M-69|2013). Bjerkeng *et al*. (2009) found that more than 60 % of the Hg input to the Bunnefjord was from atmospheric deposition. Present discharge of Hg to the Inner Oslofjord has been calculated to be around 7.3 kg/year (Berge *et al*. 2013). There was some indication that Norwegian atmospheric deposition in southern Norway is decreasing for the period 1995-2006, but this was not statistically confirmed (Wängberg *et al*. 2010). Newer data show small downward trends for Hg at Birkenes (19 %) and Zeppelin (10 %), and a larger downward trend is observed in precipitation than in air for mercury at Lista/Birkenes (Bohlin-Nizzetto *et al*. 2018). The riverine input to the Inner Oslofjord from Alna river was 0.04 kg Hg in 2016 (Skarbøvik *et al*. 2017 – M-862|2017). VEAS sewage treatment plant reported a discharge of 0.25 kg Hg in 2017 to the Inner Oslofjord (VEAS 2018).

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 110 kg Hg/year in 2017 (***Figure 14***). The emissions to air varied between 216 kg Hg/year in 2008 to 86 kg Hg/year in 2015 for the period 2008-2017.

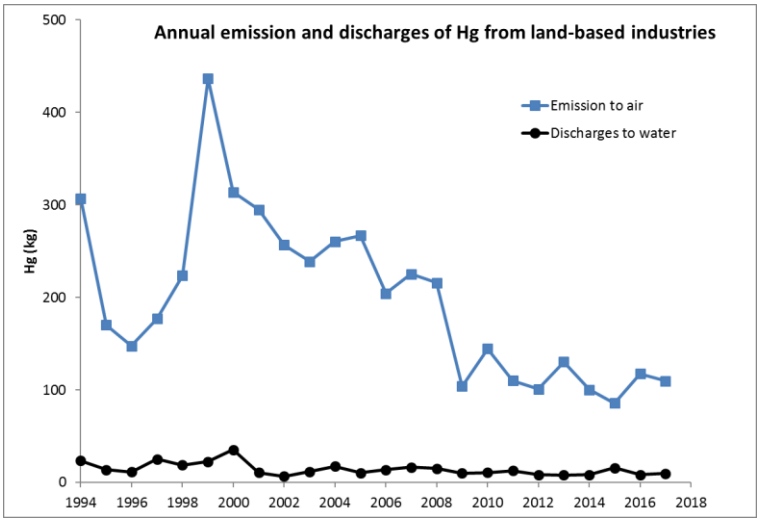


Figure 14. *Annual emissions of Hg to air and discharges to water from land-based industries for the period 1994-2017 (data from www.norskeutslipp.no, 28 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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)

In the present study, cadmium (Cd) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord exceeded the provisional high reference concentration (PROREF) for Cd by a factor between two and five (***Table 12***). Blue mussel at 15 other stations exceeded the PROREF by a factor of up to two. These blue mussel stations were in the Oslofjord at Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Solbergstrand (st. 31A), Singlekalven (st. I023) and Kirkøy (st. I024). A similar exceedance was also observed at Bjørkøya (st. 71A) and Sylterøya (st. I714) in the Langesundfjord, and at Odderøya (st. I133) in the Kristiansandfjord. This was also the result at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord, at Svolvær airport area (st. 98A2) in Lofoten, and in the Varangerfjord at Skallnes (st. 10A2) and Brashavn (st. 11X).

Cod liver at Hammerfest harbour area (st. 45B2) exceeded the PROREF by a factor between two and five, while the exceedance was up to two at Kjøfjord (st. 10B) in the Outer Varangerfjord and in the Isfjord (st. 19B) at Svalbard.

Increase in PROREF factor since 2016

Blue mussel exceeded PROREF by a factor up to two in 2017, but were below the limit in 2016 at Gressholmen (st. 30A), Solbergstrand (st. 31A) and Singlekalven (st. I023) in the Oslofjord. This was also the case at Sylterøya (st. I714) in the Langesundfjord, at Utne (st. 64A) in the Outer Sørfjord, at Ranaskjer (st. 63A) in Ålvik in the Hardangerfjord, and at Svolvær airport area (st. 98A2).

Cod liver from Hammerfest harbour area (st. 45B2) exceeded the PROREF by a factor between two and five in 2017, while the exceedance was by a factor of up to two in 2016. Cod liver from Kjøfjord (st. 10B) in the Varangerfjord exceeded the PROREF by a factor of up to two in 2017, while there was no exceedance in 2016.

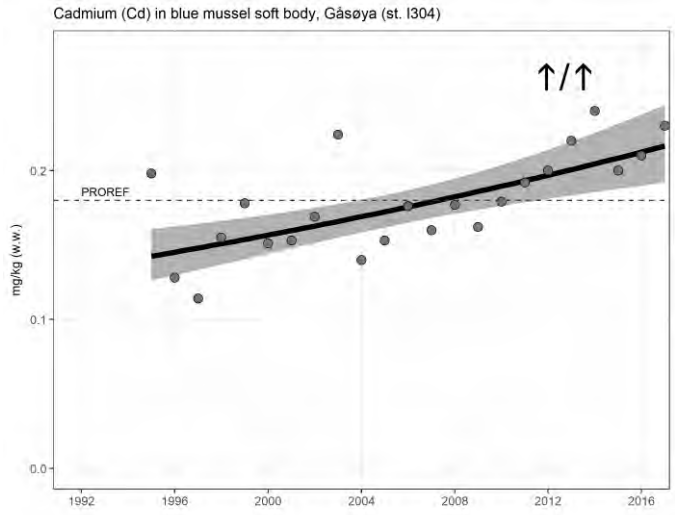
Upward trends

There were both significant upward long- and short-term trends in blue mussel at Gåsøya (st. I304) in the Inner Oslofjord (***Figure 15 A***). A significant upward short-term trend at Håøya (st. I306) (***Figure 15 B***) were also observed in the Inner Oslofjord (***Table 12***).

Decrease in PROREF factor since 2016

Blue mussel at Håøya (st. I306) in the Inner Oslofjord, Mølen (st. 35A) in the Mid Oslofjord and Lastad (st. I131A) in Søgne had Cd-concentrations below PROREF in 2017, while there was an exceedance with a factor up to two in 2016. The Cd-concentration in cod liver from Tromsø harbour (st. 43B2) was below PROREF in 2017, while there was an exceedance with a factor between two and five in 2016.

A



B

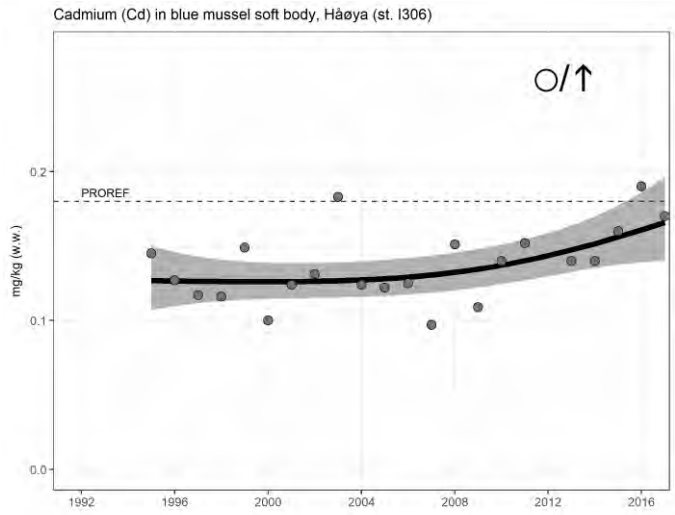


Figure 15. *Median concentrations (mg/kg w.w.) of cadmium (Cd) in blue mussel from the Inner Oslofjord from 1995 to 2017* at *Gåsøya (st. I304) (***A***) and* Håøya (st. I306) *(***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Downward trends

In blue mussel, there were both significant downward long- and short-term trends at Solbergstrand (st. 31A) in the Mid Oslofjord, at Krossanes (st. 57A) in the Sørfjord, and at Ranaskjer (st. 63A), Vikingneset (st. 65A) and Terøya (st. 69A) in the Hardangerfjord. This was also the case at Nordnes (st. st. I241) in Bergen harbour. There were significant downward long-term trends at Færder (st. 36A) and Mølen (st. 35A) in the Oslofjord, at Bjørkøya (st. 71A) in the Langesundfjord, and at Eitrheimsneset (st. 52A) in the Inner Sørfjord. There was a significant downward short-term trend at Gressholmen (st. 30A) in the Inner Oslofjord.

In cod liver, there were both significant downward long- and short-term trends at Stathelle (st. 71B) in the Langesundfjord, and a long-term trend at Tjøme (st. 36B) in the Outer Oslofjord. Significant downward short-term trends were found in the Inner Oslofjord (st. 30B) and in the Inner Sørfjord (st. 53B).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cd-concentration was 0.003 mg/kg w.w. in both blood and egg.

Other studies

In this study, cod liver from the Inner Oslofjord had higher concentration (median 0.112 mg/kg Cd w.w.) than a comparable study from the Inner Oslofjord in 2017 (mean 0.054 mg/kg Cd w.w.) (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

General, large scale trends

Discharges of Cd to water from land-based industries showed a decrease from 2000 (1734 kg Cd/year) to 2017 (89 kg Cd/year) (***Figure 16***). The emission of Cd to air showed a gradually decrease from 1999 (560 kg Cd/year) to 2017 (74 kg Cd/year).

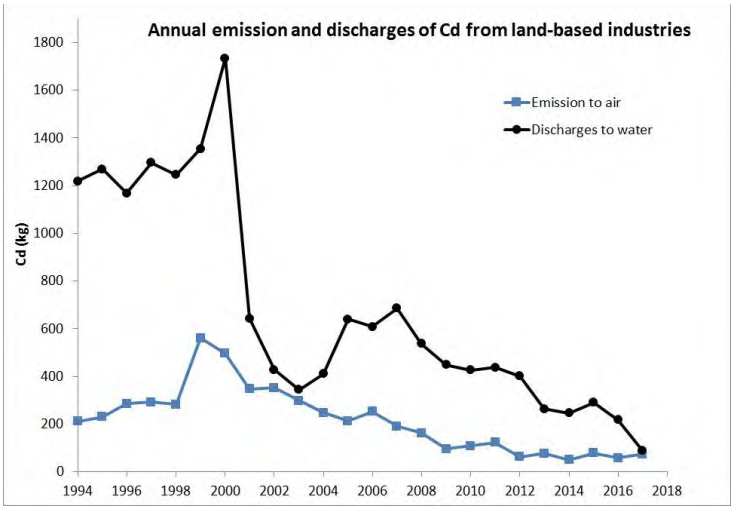


Figure 16. *Annual emissions of Cd to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

The discharge of Cd to water from local industry in Odda in the Inner Sørfjord had decreased from 46.76 kg/year in 2015 to 23.27 kg/year in 2017 (www.norskeutslipp.no). This might influence the Cd-concentration in blue mussel at Eitrheimsneset which exceeded the PROREF by a factor between two and five since 2015.

Total riverine input of Cd in Norway has been estimated to be 2 tonnes in 2016 (Skarbøvik *et al*. 2017 – M-862|2017). The total riverine inputs of Cd in different seawaters were 1 tonne to Skagerrak. Total Cd load dropped 50 % to 2 tonnes in 2016 compared to the mean for the period 1990-2015 (4 tonnes). VEAS sewage treatment plant reported a discharge of 4.8 kg Cd to the Inner Oslofjord in 2017 (VEAS 2018).

3.2.4 Lead (Pb)

In the present study, lead (Pb) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at Odderøya (st. I133) in the Kristiansandfjord exceeded the provisional high reference concentration (PROREF) for Pb by a factor between 10 to 20. The exceedance was by a factor between five and 10 at Eitrheimsneset (st. 52A) in the Inner Sørfjord and Mjelle (st. 97A2) in Bodø area. The exceedance was by a factor between two and five at Gressholmen (st. 30A) in the Inner Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord, Krossanes (st. 57A) in the Outer Sørfjord and Nordnes (st. I241) in the Bergen harbour area. Blue mussel exceeded PROREF by a factor of up to two at 11 stations (***Table 12***). These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, and Kirkøy (st. I024) in the Outer Oslofjord. This was also the result at Risøya at Risør (st. 76A2), Lastad in Søgne (st. I131A) and Gåsøya-Ullerøya in Farsund (st. 15A). This was also observed at Utne (st. 64A), Ranaskjer (st. 63A) and Vikingneset (st. 65A) in Hardanger. This was also the case at Vågsvåg (st. 26A2) in the Outer Nordfjord and at Bodø harbour (st. 97A3).

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of Pb by a factor between two and five (***Table 12***). Cod liver from the Inner Sørfjord (st. 53B) exceeded PROREF of Pb by a factor of up to two.

Increase in PROREF factor since 2016

Blue mussel at Mjelle (st. 97A2) exceeded PROREF of Pb by a factor between five and 10 in 2017, while the exceedance was between two and five in 2016. At Bjørkøya (st. 71A) in the Langesundfjord, the exceedance was between two and five in 2017, while it was no exceedance in 2016. Blue mussel at Kirkøy (st. I024) at Hvaler in the Outer Oslofjord, at Vikingneset (st. 65A) in the Mid Hardangerfjord and at Vågsvåg (st. 26A2) in the Outer Nordfjord exceeded PROREF by a factor up to two in 2017, while there were no exceedances in 2016.

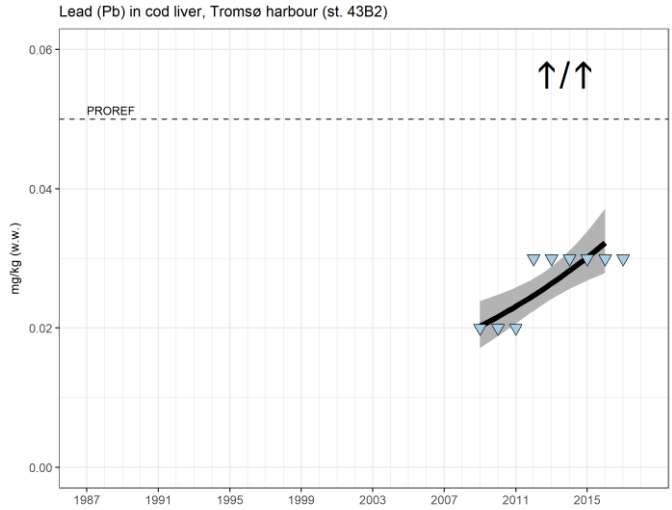
Cod liver from the Inner Oslofjord exceeded PROREF of Pb by a factor between two and five in 2017, while it was no exceedance in 2016.

Upward trends

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

There were both significant upward long- and short-term trends in cod liver at Tromsø harbour (st. 43B2) (***Figure 17 A***). There were significant upward short-term trends in cod liver from Bømlo (st. 23B) (***Figure 17 B***) in the Outer Selbjørnfjord, Austnesfjord (st. 98B1) in Lofoten (***Figure 18 A***), and Kjøfjord (st. 10B) in the Outer Varangerfjord (***Figure 18 B***). As is apparent from these figures, the trends were largely influenced by changes in LOQ, and caution is advised when interpreting these results.

A



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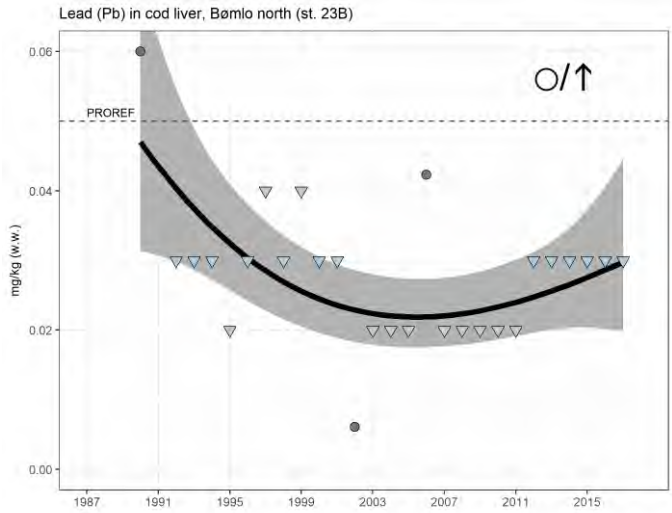
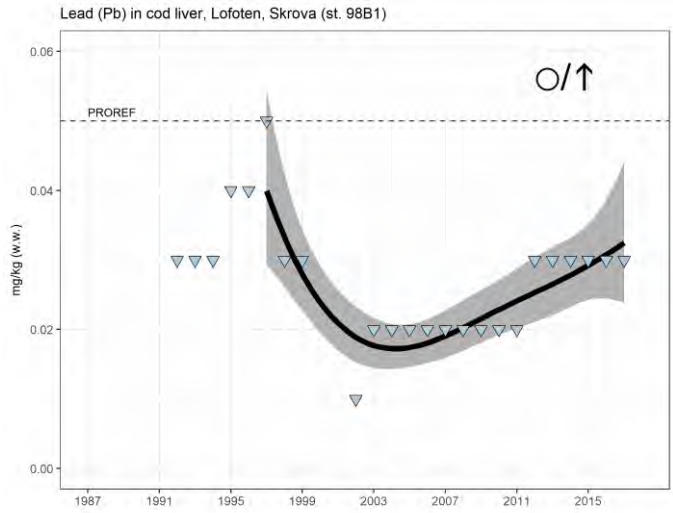


Figure 17. *Median concentrations (mg/kg w.w.) of lead (Pb) in cod liver from 1990 or 2009 to 2017 at Tromsø harbour (st. 43B2) (**A**) and in* the *Outer Selbjørnfjord at* Bømlo *(st. 23B) (**B**). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

A



B

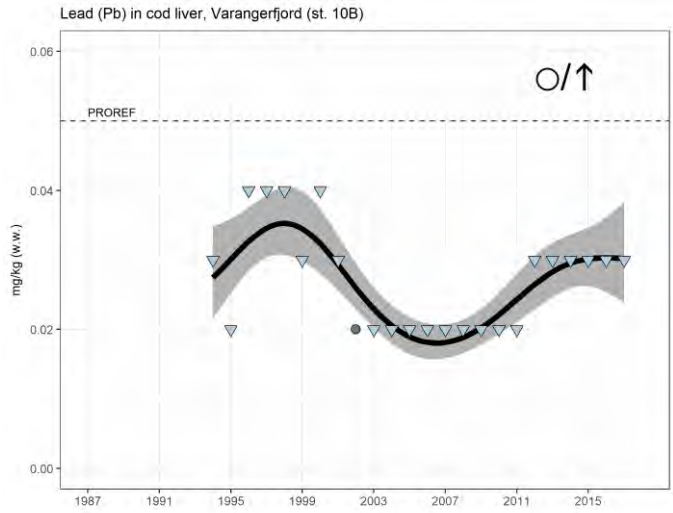


Figure 18. *Median concentrations (mg/kg w.w.) of lead (Pb) in blue mussel from 1992 or 1994 to 2017 in Lofoten* at *Outer Selbjørnfjord, Austnesfjord (st. 98B1) (**A**) and in the Outer Varangerfjord at Kjøfjord (st. 10B) (**B**). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Decrease in PROREF factor since 2016

Blue mussel at Eitrheimsneset (st. 52A) exceeded PROREF of Pb by a factor between five and 10 in 2017, while the exceedance was between 10 and 20 in 2016.

Downward trends

Of the trend analysis performed for blue mussel, 13 revealed significant downward long-term trends (***Table 12***). Both significant downward long- and short-term trends were observed at Ranaskjer (st. 63A) and Terøya (st. 69A) in the Hardangerfjord, at Nordnes (st. I241) in Bergen harbour, at Espevær (st. 22A) on the west coast and at Skallnes (st. 10A2) in the Varangerfjord. Significant downward long-term trends were found at Akershuskaia (st. I301) and Solbergstrand (st. 31A) in the Oslofjord, at Eitrheimsneset (st. 52A) and Krossanes (st. 57A) in the Sørfjord, and at Vikingneset (st. 65A) in the Hardangerfjord. This was also observed in blue mussel at Svolvær airport (st. 98A2), and at Brashavn (st. 11X) in the Varangerfjord. A significant downward short-term trend was found at Mølen (st. 35A) in the Mid Oslofjord.

In cod liver, significant downward long-term trends were found in Skågskjera in Farsund (st. 15B), and in the Inner Sørfjord (st. 53B).

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Pb-concentrations were 0.051 mg/kg w.w. in blood and 0.008 mg/kg w.w. in egg.

Other studies
In this study, cod liver from the Inner Oslofjord showed higher concentration (median 0.145 mg/kg Pb w.w.) than observed in a comparable study (mean 0.063 mg/kg Pb w.w.) in the Inner Oslofjord in 2017 (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

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

General, large scale trends
There were low levels of Pb in cod liver, except for in the Inner Oslofjord (st. 0.145 mg/kg w.w.). EU banned leaded-fuel in road vehicles 1 January 2000, but some countries had banned the fuel beforehand (e.g. Sweden, Germany, Portugal). The results indicate that the ban of Pb in gasoline has had a positive effect.

OSPAR (2010) found 50-80 % reduction in riverine and direct discharges of Pb to the North Sea for the period 1990-2006. While the total riverine input of Pb in Norway was 38 tonnes in 2016 (Skarbøvik *et al*. 2017 – M-862|2017), the riverine inputs of Pb in different areas were 25 tonnes to Skagerrak, 9 tonnes to the North Sea, 3 tonnes to the Norwegian Sea and 1 tonne to the Barents Sea, indicating higher input in the southern part of Norway. Total Pb load dropped 28 % to 38 tonnes in 2016 compared to the mean for the period 1990-2015 (53 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from industrial (1 tonnes) effluents amounting about 2.6 % of the total (38 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.02 tonnes Pb in 2016. VEAS sewage treatment plant reported a discharge of 36 kg Pb in 2017 (VEAS 2018).

Discharges of Pb to water from land-based industries in Norway showed a decrease from 2010 (6841 kg Pb/year) to 2017 (1870 kg Pb/year) (***Figure 19***).

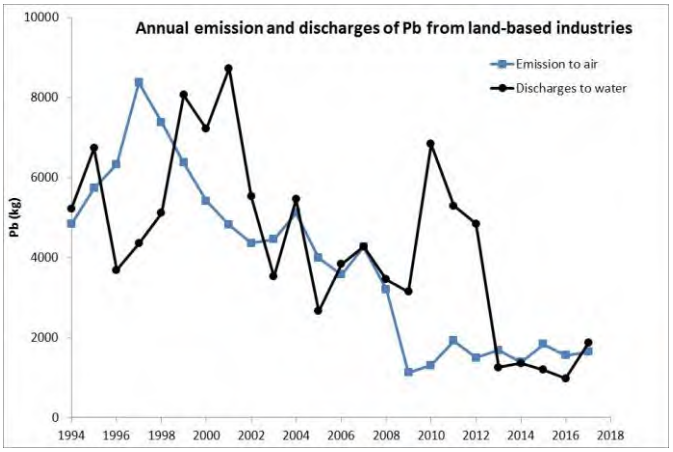


Figure 19. *Annual emissions of Pb to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.5 Copper (Cu)

In the present study, copper (Cu) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at Bodø harbour (st. 97A3) was the only station where the concentration exceeded the provisional high reference concentration (PROREF) for Cu, but in this case, less than a factor of two.

Cod liver from the Inner Sørfjord (st. 53B) and Bømlo (st. 23B) exceeded the PROREF of Cu by a factor of up to two.

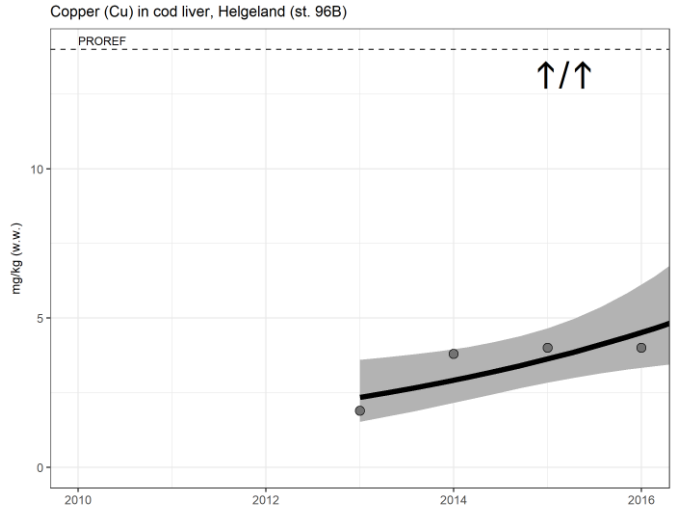
Increase in PROREF factor since 2016

Cod liver exceeded PROREF of Cu by a factor up to two in 2017, while the concentrations were below PROREF in 2016 at the Inner Sørfjord (st. 53B) and at Bømlo (st. 23B) in the Outer Selbjørnfjord.

Upward trends

In cod liver from Sandnessjøen area (st. 96B), both significant upward long- and short-term trends were found (***Figure 20 A***). A significant upward short-term trend was found at Skågskjera in Farsund (st. 15B) (***Figure 20 B***).

A



B

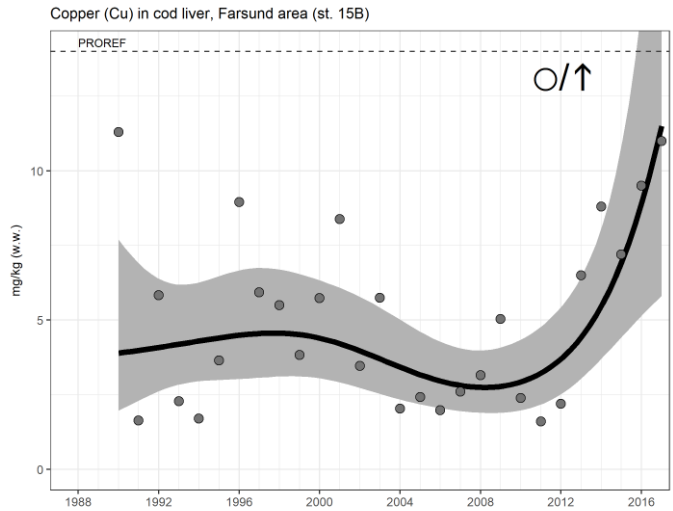


Figure 20. *Median concentrations (mg/kg w.w.) of copper (Cu) in cod liver from 1990 or 2013 to 2017 in Sandnessjøen area (st. 96B) (**A**) and in at Skågskjera in Farsund (st. 15B) (**B**).The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Decrease in PROREF factor since 2016

Blue mussel at Gressholmen (st. 30A) had Cu-concentration below PROREF in 2017, but exceeded PROREF by a factor up to two in 2016.

Downward trends

There were both significant downward long- and short-term trends in mussel from Bjørkøya (st. 71A) in the Langesundfjord, at Vikingneset (st. 65A) in the Hardangerfjord, at Ørland area (st. 91A2) in the Outer Trondheimfjord, and at Mjelle in the Bodø area (97A2). Significant downward long-term trends were observed at Gåsøya (st. I304), Håøya (st. I306) in the Inner Oslofjord, and at Kirkøy (st. I204) at Hvaler. A similar trend was also registered at Eitrheimsneset (st. 52A) and Krossanes (st. 57A) in the Inner Sørfjord, and at Ranaskjer (st. 63A) and in the Hardangerfjord. At Gåsøya-Ullerøya (st. 15A) in Farsund, a significant downward short-term trend was found.

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

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cu-concentrations were 0.519 mg/kg w.w. in blood and 1.440 mg/kg w.w. in egg.

Other studies

In this study, cod liver from the Inner Oslofjord (median 3.6 mg/kg Cu w.w.) was about the same level as in a comparable study from the Inner Oslofjord in 2017 (mean 4.077 mg/kg Cu w.w.) (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

General, large scale

Discharges of Cu to water from land-based industries showed a gradually decrease from 2005 (90 186 kg Cu/year) to 2017 (12 378 kg Cu/year) (***Figure 21***).

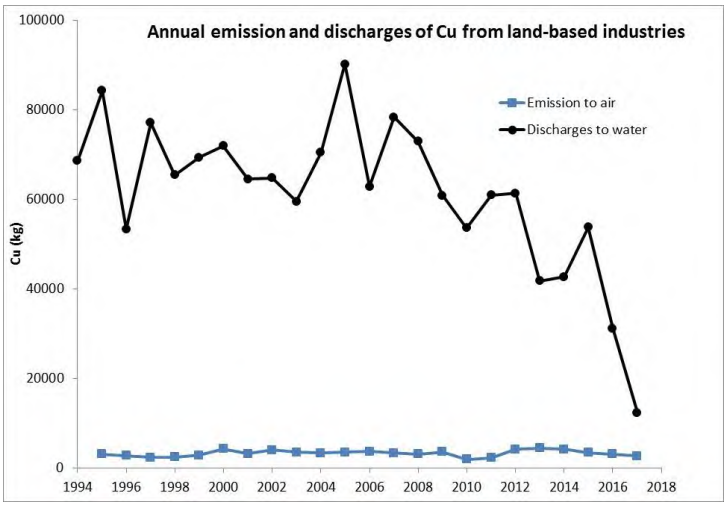


Figure 21. *Annual emissions of Cu to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Cu in Norway has been 154 tonnes in 2017 (Skarbøvik *et al*. 2017 – M-862|2017). The total riverine inputs of Cu were 58 tonnes to Skagerrak, 23 tonnes to the North Sea, 33 tonnes to the Norwegian Sea and 41 tonnes to the Barents Sea. Total Cu load in Norway decreased 34 % to 154 tonnes in 2016 compared to the mean for the period 1990-2015 (235 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (4 tonnes) and industrial (6 tonnes) effluents and fish farming (1088 tonnes) amounting to 1097 tonnes or about 88 % of the total (1251 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.11 tonnes Cu in 2016. VEAS sewage treatment plant reported a discharge of 414 kg Cu in 2017 (VEAS 2018).

3.2.6 Zinc (Zn)

In the present study, zinc (Zn) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel from 13 stations exceeded the provisional high reference concentration (PROREF) for Zn, but by less than a factor of two. These stations were Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, Solbergstrand (st. 31A) in the Mid Oslofjord, and Færder (st. 36A) and Kirkøy at Hvaler (st. I024) in the Outer Oslofjord. This was also the result at Bjørkøya (st. 71A) in the Langesundfjord, Odderøya (st. I133) in the Kristiansandfjord, and Gåsøy-Ullerøya (st. 15A) in Farsund. This was also the case at Nordnes (st. I241) in Bergen harbour area, Vågsvåg (st. 26A2) in the Outer Nordfjord and Ålesund harbour (st. 28A2). This was also observed at Bodø harbour (st. 97A3) and at Svolvær airport area (st. 98A2).

Cod liver exceeded PROREF for Zn by a factor up to two at Kristiansand harbour (st. 13B) and at Skågskjera (st. 15B) in Farsund.

Increase in PROREF factor since 2016

Blue mussel exceeded PROREF for Zn by a factor up to two in 2017, but no exceedances were found in 2016 at Akershuskaia (st. I301), Solbergstrand (st. 31A), Færder (st. 36A) and Kirkøy at Hvaler (st. I024) in the Oslofjord. This was also the result at Bjørkøya (st. 71A) in the Langesundfjord, at Gåsøya-Ullerøya (st. 15A) in Farsund, and at Svolvær airport area (st. 98A2) in Lofoten.

Cod liver exceeded PROREF for Zn by a factor up to two in 2017, while there were no exceedances in 2016 at Kristiansand harbour (st. 13B) and at Skågskjera (st. 15B) in Farsund.

Upward trends

No significant upward trends were found in blue mussel. A significant upward short-term trend was found in cod liver at Skågskjera in Farsund (st. 15B).

Decrease in PROREF factor since 2016

Blue mussel were below PROREF for Zn in 2017, but the exceedance was up to a factor of two in 2016 at Espevær (st. 22A) in the Outer Bømlafjord and Skallnes (st. 10A2) in the Outer Varangerfjord.

Cod liver were below PROREF for Zn in 2017, but the exceedance was up to two in 2016 at Kirkøy at Hvaler (st. 02B) in the Outer Oslofjord.

Downward trends

In blue mussel, both significant downward long- and short-term trends were found at Gressholmen (st. 30A) in the Inner Oslofjord, at Vikingneset (st. 65A) in the Mid Hardangerfjord and at Terøya (st. 69A) in the Outer Hardangerfjord. Downward long-term trends were found at and Håøya (st. I306) in the Inner Oslofjord, and at Lastad (st. I131A) in Søgne. A similar trend was also found in the Inner Sørfjord at Eitrheimsneset (st. 52A) and Krossanes (st. 57A), in the Hardangerfjord at Ranaskjer (st. 63A) and at Espevær (st. 22A) on the west coast.

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

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Zn-concentrations were 6.881 mg/kg w.w. in blood and 20.219 mg/kg w.w. in egg.

Other studies

In this study, cod liver from the Inner Oslofjord (median 21.5 mg/kg Zn w.w.) was about the same level as a comparable study from the Inner Oslofjord in 2017 (mean 18.5 mg/kg Zn w.w.) (Ruus *et al*. 2018, in prep). 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 2005 (200 785 kg Zn/year) to 2017 (17 730 kg Zn/year) (***Figure 22***).

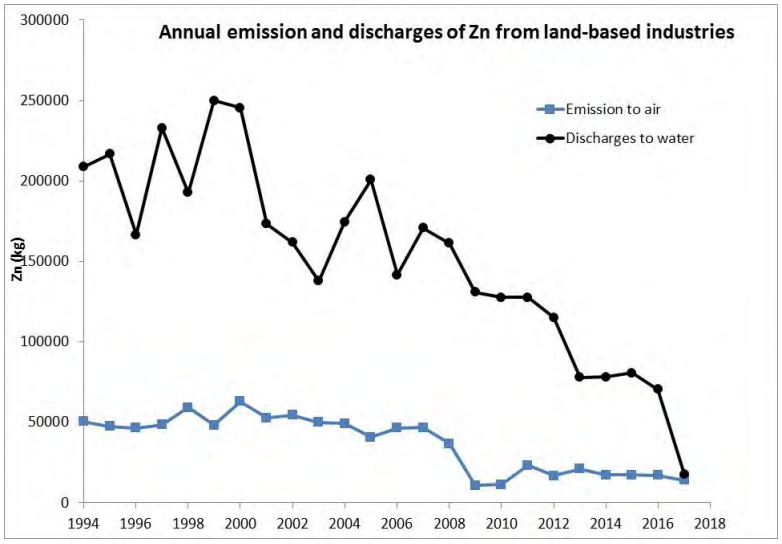


Figure 22. *Annual emissions of Zn to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Total riverine input of Zn in Norway has been 551 tonnes in 2016 (Skarbøvik *et al*. 2017 – M-862|2017). Total riverine inputs of Zn were 346 tonnes to Skagerrak, 121 tonnes to the North Sea, 61 tonnes to the Norwegian Sea and 23 tonnes to the Barents Sea, indicating higher input in the southern part of Norway. Total Zn load decreased 31 % to 551 tonnes in 2016 compared to the mean for the period 1990-2015 (795 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (12 tonnes) and industrial (13 tonnes) effluents amounting to 25 tonnes or about 4 % of the total (576 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.40 tonnes Zn in 2016. VEAS sewage treatment plant reported a discharge of 1924 kg Zn in 2017 (VEAS 2018).

3.2.7 Silver (Ag)

In the present study, silver (Ag) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at six stations exceeded the provisional high reference concentration (PROREF) of Ag by a factor up to two. These stations were located at Gressholmen (st. 30A) and Solbergstrand in the Oslofjord, at Eitrheimsneset (st. 52A) and Utne (st. 64A) in the Sørfjord, at Svolvær airport area (st. 98A2) in Lofoten, and at Skallnes (st. 10A2) in the Varangerfjord.

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

Increase in PROREF factor since 2016

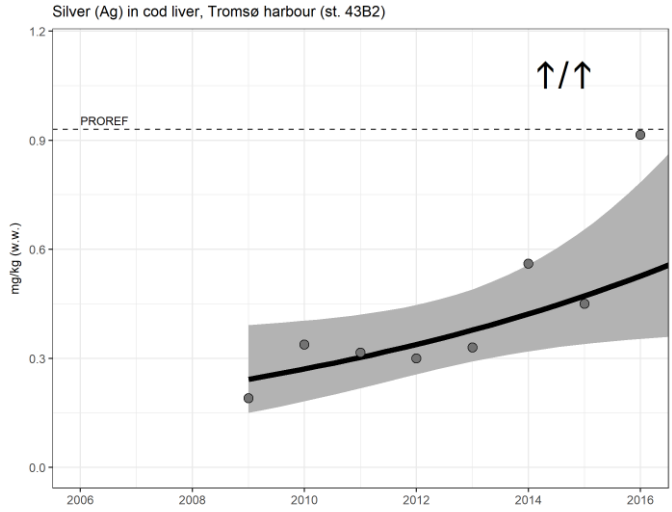
The Ag-concentration in blue mussel had increased to exceeding the PROREF by a factor of up to two in 2017, while it was no exceedance in 2016 at Solbergstrand (st. 31A) in the Mid Oslofjord, at Eitrheimsneset (st. 52A) in the Inner Sørfjord, and at Svolvær airport area (st. 98A2).

The Ag-concentration in cod liver had increased to exceeding the PROREF by a factor of up to two in 2017, while it was no exceedance in 2016 at Skågskjera (st. 15B) in Farsund, and Bømlo (st. 30B) in the Outer Selbjørnfjord.

Upward trends

There were both significant upward long-and short-term trends in cod liver from Tromsø harbour (st. 43B2), but no trends were detected for length-adjusted concentrations (***Figure 23a*** and ***b***, respectively). The unadjusted median concentration in 2016 was 0.340 mg Ag/kg. There were also both significant upward long-and short-term trends in cod liver from Skågskjera (st. 15B) in Farsund and Sandnessjøen area (st. 96B).

A



B

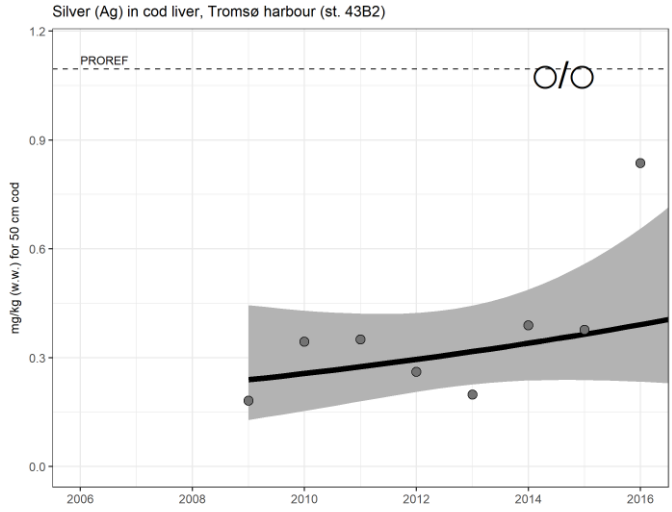


Figure 23. *Median concentrations (mg/kg w.w.) of silver (Ag) in cod liver from 2009 to 2017 in the Tromsø harbour (st. 43B2); no adjustment for length (***A***) and adjusted for length (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Decrease in PROREF factor since 2016

The Ag-concentration in blue mussel had decreased from exceeding the PROREF by a factor between two to five in 2016, to less than two in 2016 at Gressholmen (st. 30A) in the Inner Oslofjord. The exceedance of PROREF was below a factor of two in 2017, while it was up to a factor of two in 2016 at Akershuskaia (st. I301) in the Inner Oslofjord, at Færder (st. 36A) in the Outer Oslofjord, at Bjørkøya (st. 71A) in the Langesundfjord, and at Brashavn (st. 11X) in the Outer Varangerfjord.

The Ag-concentration in cod liver in the Inner Oslofjord (st. 30B) had decreased to exceeding the PROREF by a factor between five and 10 in 2017, from between two and five in 2016.

Downward trends

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

(st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord. There was a significant downward long-term trend at Mølen (st. 35A).

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 0.003 mg/kg w.w. in egg.

Other studies

The highest Ag-concentrations in this study were found in cod liver from the Inner Oslofjord in 2017 (5.350 mg/kg w.w.), as in 2016 (2.4 mg/kg w.w.) and 2015 (6.85 mg/kg w.w.). Equivalent concentration in the gills of Atlantic salmon was found to be lethal (Farmen *et al*. 2012), which indicates the need for a classification system to assess the possible effects in cod.

MILKYS samples of cod liver from the Inner Oslofjord collected in 2017 revealed a median concentration of 5.35 mg/kg Ag (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2017 showed lower mean concentration (3.640 mg/kg Ag w.w.) (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

Discharges of wastewater treatment plants and discharges from mine tailings are considered major and important sources for Ag to the aquatic environment (Tappin *et al*. 2010). The incorporation of Ag nanoparticles into consumer products is important in terms of inputs to wastewater treatment plants (Nowack 2010). Ag has very low toxicity to humans; however, this is not the case for microbe and invertebrate communities. There is increasing focus on the occurrence of Ag in both wastewater treatment plant effluent and sludge due to the increasing use of nanosilver in consumer products. Recent studies have shown that much of the Ag entering wastewater treatment plants is incorporated into sludge as Ag sulphide nanoparticles (Ag_2S), although little is known about the Ag-species that occurs in discharged effluent (Kim *et al*. 2010, Nowack 2010). From a study of eight Norwegian wastewater treatment plants, concentrations of silver in effluent ranged from 0.01 to 0.49 µg/L, and concentrations in sludge ranged from <0.01 to 9.55 µg/g (Thomas *et al*. 2011 – TA-2784/2011).

General, large scale

Discharges of Ag to water from land-based industries showed a decrease from 1994 (9.74 kg Ag/year) to 2009 (0.1 kg Ag/year) (***Figure 24***). The discharges to water in 2017 were 0.48 kg Ag).

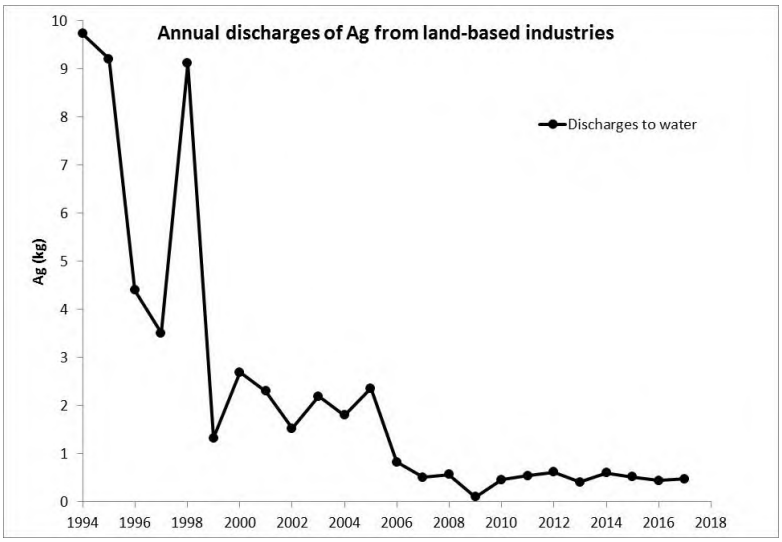


Figure 24. *Annual discharges of Ag to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

3.2.8 Arsenic (As)

In the present study, arsenic (As) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel exceeded the provisional high reference concentration (PROREF) for As by a factor of up to two at Mølen (st. 35A) in the Mid Oslofjord and in Ørland (st. 91A2) in the Outer Trondheimfjord.

Increase in PROREF factor since 2016

Blue mussel exceeded PROREF by a factor of up to two at Mølen (st. 35A) in the Mid Oslofjord and in Ørland (st. 91A2) in the Outer Trondheimfjord, while there were no exceedances in 2016.

Decrease in PROREF factor since 2016

Blue mussel at Espevær (st. 22A) on the west coast had As-concentration below the PROREF in 2017, but exceeded the limit by a factor of up to two in 2016.

Downward trends

In blue mussel, both significant downward long- and short-term trends were observed at Gåsøya-Ullerøya in Farsund (st.15A), at Bjørkøya (st.71A) in the Langesundfjord, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

In cod liver, both significant downward long- and short-term trends were observed in the Inner Oslofjord (st. 30B).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the As-concentrations were 0.030 mg/kg w.w. in blood and 0.164 mg/kg w.w. in egg.

Other studies

In this study, cod liver from the Inner Oslofjord, revealed median concentration of 11.5 mg/kg As (w.w.) in 2017 while it was 4.7 mg/kg As (w.w.) in 2016. Cod liver from a comparable study from the Inner Oslofjord in 2017 had higher mean concentration (17.6 mg/kg As w.w.) (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

In this study, As-concentration (median 0.164 mg/kg w.w.) in eider egg at Svalbard was on the same level as in a comparable study (median 0.12 mg/kg w.w.) (Hill 2018).

General, large scale trends

Discharges of As to water from land-based industries showed an increase from 2008 (517 kg As/year) to 2010 (2587 kg As/year) and from 2013 (1504 kg As/year) to 2016 (2195 kg As/year) (***Figure 25***). Discharges to water was 1955 kg As/year in 2017.

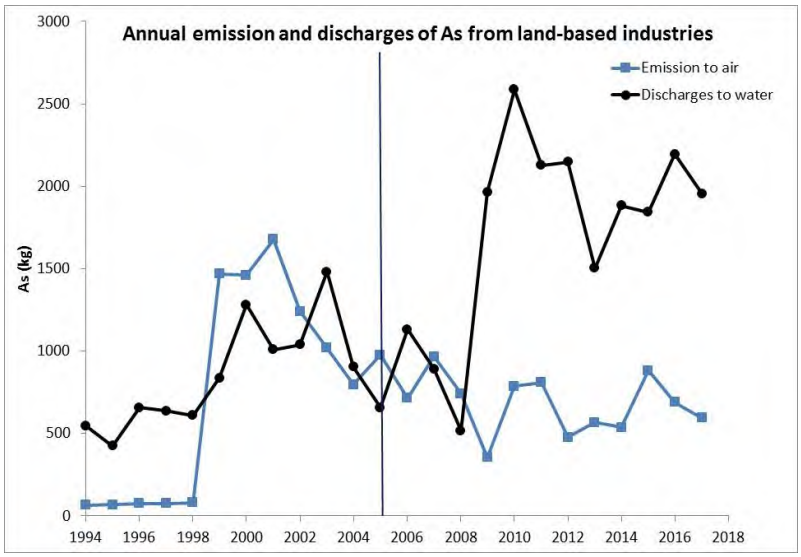


Figure 25. *Annual emissions of As to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). The vertical line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, 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 21 tonnes in 2016 (Skarbøvik *et al*. 2017 – M-862|2017). Total riverine inputs of As were 10 tonnes to Skagerrak, 4 tonnes to the North Sea, 4 tonnes to the Norwegian Sea and 3 tonnes to the Barents Sea, indicating higher input in the southern part of Norway. Total As load decreased 22 % to 21 tonnes in 2016 compared to the mean for the period 1990-2015 (27 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from industrial (2 tonnes) effluents amounting to 2 tonnes or about 9 % of the total

(23 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.01 tonnes As in 2016. VEAS sewage treatment plant reported a discharge of 50 kg As in 2017 (VEAS 2018).

3.2.9 Nickel (Ni)

In the present study, nickel (Ni) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at Solbergstrand (st. 31A) and Kirkøy at Hvaler (st. I204) in the Oslofjord and Bjørkøya (st. 71A) in the Langesundfjord exceeded the provisional high reference concentration (PROREF) for Ni by a factor between two and five. Blue mussel at 11 other stations exceeded this level by a factor of up to two. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A) and Singlekalven at Hvaler (st. I023) in the Oslofjord. This was also the case at Lastad (st. I131A) in Søgne, Odderøya (st. I133) in the Kristiansandfjord, Ranaskjer (st. 63A) in the Hardangerfjord, and in Ålesund harbour (st. 28A2). This was also the result in Bodø area at Mjelle (st. 97A) and Bodø harbour (st. 97A3), and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord.

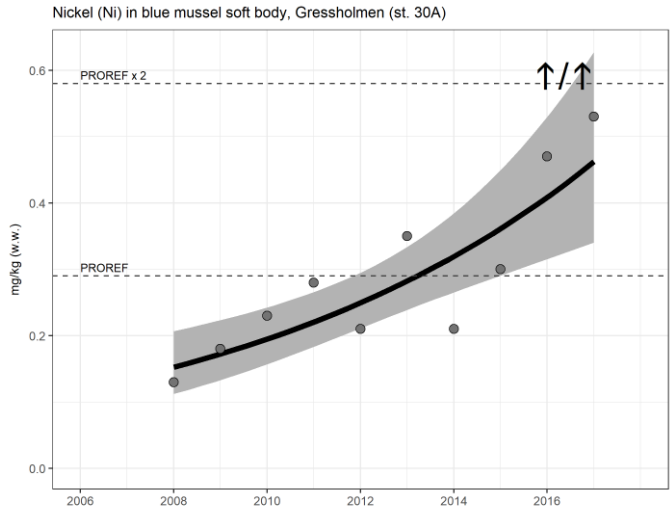
Increase in PROREF factor since 2016

Blue mussel at Solbergstrand (st. 31A) in the Mid Oslofjord exceeded the PROREF of Ni by a factor between two and five in 2017, while the exceedance was by a factor up to two in 2016. Blue mussel at Bjørkøya (st. 71A) in the Langesundfjord exceeded the PROREF of Ni by a factor between two and five in 2017, while it was below PROREF in 2016. Mussel had Ni-concentrations below the PROREF in 2016 while it exceeded this limit by a factor of up to two at three stations. This was at Lastad (st. I131A) in Søgne, Ranaskjer (st. 63A) in the Hardangerfjord, and at Mjelle (st. 97A2) in the Bodø area.

Upward trends

Both significant upward long-and short-term trends were found in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord (***Figure 26 A***) and at Brashavn (st. 11X) in the Varangerfjord (***Figure 26 B***).

A



B

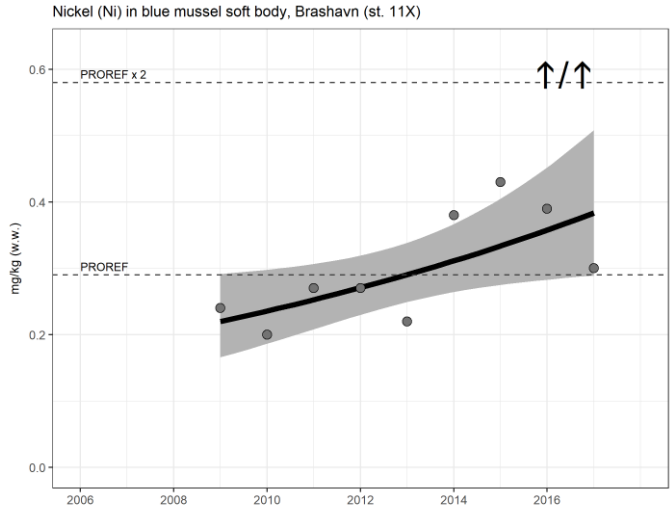


Figure 26. *Median concentrations (mg/kg w.w.) of nickel (Ni) in blue mussel from 2008 or 2009 to 2017 in Gressholmen in the Inner Oslofjord (st. 30A) (**A**) and in Brashavn (st. 11X) in the Varangerfjord (**B**). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Decrease in PROREF factor since 2016

The Ni-concentrations in blue mussel were below PROREF of Ni in 2017, but they exceeded the PROREF by a factor up to two in 2016 at Gåsøya (st. I304) in the Inner Oslofjord, at Risøya (st. 76A2) at Risør, and at Ørland area (st. 91A2) in the Outer Trondheimfjord.

The Ni-concentrations in cod liver were below the PROREF of Ni in 2017, while they exceeded this level in 2016 by factors more than 20 at Bømlo (st. 23B), between 10 and 20 at Bergen harbour area (st. 24B) between five and 10 in the Inner Sørfjord (st. 53B), and up to two at Austnesfjord in Lofoten (st. 98B1). The high concentrations of both Ni and Cr at these four stations in 2016 may indicate contamination during sample preparation.

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

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Ni-concentrations were <0.030 mg/kg w.w. in blood and 0.019 mg/kg w.w. in egg.

Other studies
In this study, cod liver from the Inner Oslofjord revealed a median concentration of 0.110 mg/kg Ni (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2017 showed a concentration of 0.244 mg/kg Ni w.w. (Ruus *et al*. 2018, in prep). 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 (22 590 kg Ni/year) to 2017 (6 649 kg Ni/year) (***Figure 27***).

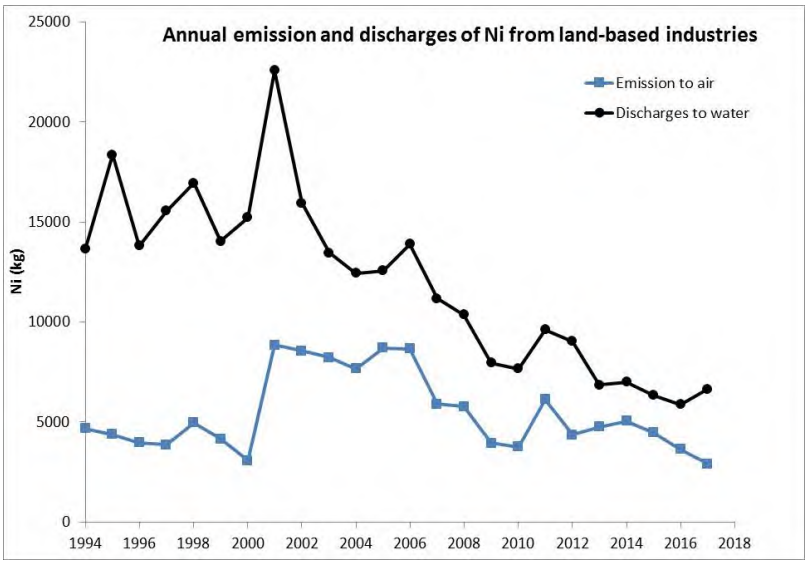


Figure 27. *Annual emissions of Ni to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 230 tonnes in 2016 (Skarbøvik *et al*. 2017 – M-862|2017). Total riverine inputs of Ni were 33 tonnes to Skagerrak, 13 tonnes to the North Sea, 24 tonnes to the Norwegian Sea and 161 tonnes to the Barents Sea. Total Ni load increased 63 % to 230 tonnes in 2017 compared to the mean for the period 1990-2015 (146 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (2 tonnes) and industrial (6 tonnes) effluents amounting to 8 tonnes or about 3 % of the total (238 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.04 tonnes Ni in 2016. VEAS sewage treatment plant reported a discharge of 288 kg Ni in 2017 (VEAS 2018).

3.2.10 Chromium (Cr)

In the present study, chromium (Cr) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at Solbergstrand (st. 31A) in the Mid Oslofjord exceeded the provisional high reference concentration (PROREF) for Cr by a factor between five and 10. The exceedances of PROREF of Cr were by a factor between two and five at Gressholmen (st. 30A) in the Inner Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord, and Ørland area (st. 30A) in the Outer Trondheimfjord. Blue mussel at eight other stations exceeded this level by a factor of up to two. These stations were Akershuskaia (st. I301), Singlekalven at Hvaler (st. I023) and Kirkøy (st. I024) in the Oslofjord. This was also the case at Sylterøya (st. I714) in the Langesundfjord, Lastad (st. I131A) in Søgne and Ranaskjer (st. 63A) in the Hardangerfjord. This was also observed at Ålesund harbour (st. 28A2) and at Skallnes (st. 10A2) in the Outer Varangerfjord.

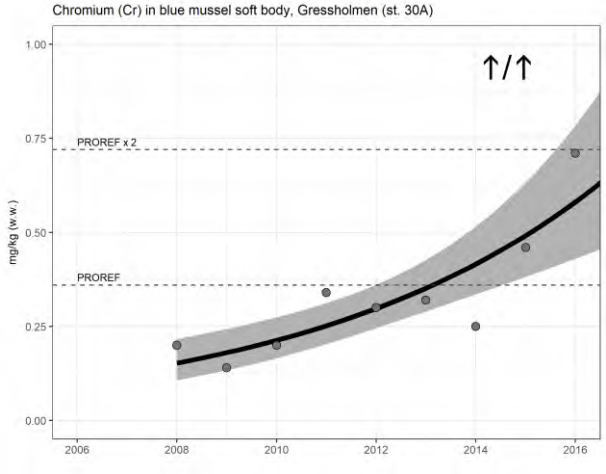
Increase in PROREF factor since 2016

Blue mussel exceeded the PROREF of Cr by a factor between five and 10 in 2017, while it was no exceedance in 2016 at Solbergstrand (st. 31A) in the Mid Oslofjord. Mussels exceeded the PROREF of Cr by a factor between two and five in 2017, while the exceedance was up to a factor of two in at Gressholmen (st. 30A) in the Inner Oslofjord, and at Ørland area (st. 91A2) in the Outer Trondheimfjord, and below PROREF at Bjørkøya (st. 71A) in the Langesundfjord in 2016. Blue mussel exceeded the PROREF of Cr by a factor up to two in 2017, while the concentrations were below this limit in 2016 in five stations. This was at Singlekalven (st. I023) at Hvaler in the Outer Oslofjord, Sylterøya (st. I714) in the Langesundfjord, Lastad (st. I131A) in Søgne, Ranaskjer (st. 63A) in the Hardangerfjord, and at Skallnes (st. 10A2) in the Outer Varangerfjord.

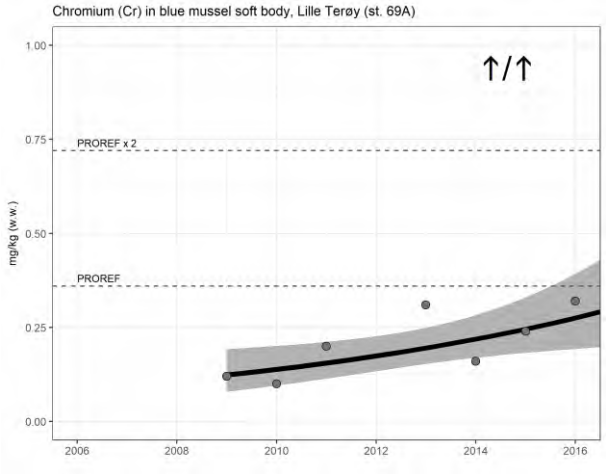
Upward trends

There were both significant upward long- and short-term trends in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord, at Terøya (st. 69A) in the Outer Hardangerfjord, and at Brashavn (st. 11X) in the Outer Varangerfjord (***Figure 28 A**, **B** and **C**, respectively*).

A



B



C

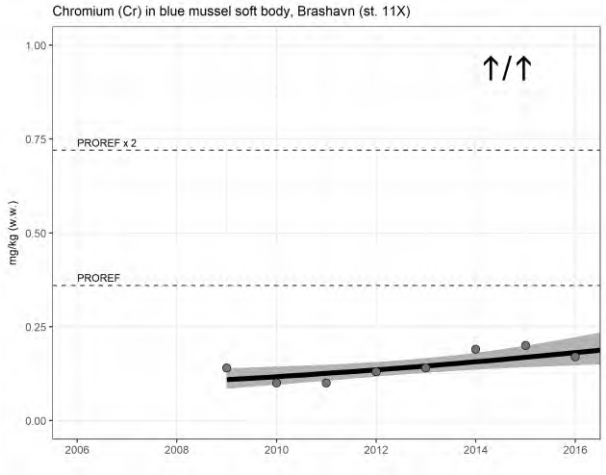


Figure 28. *Median concentrations (mg/kg w.w.) of chromium (Cr) in blue mussel from 2008 or 2009 to 2017 in Gressholmen in the Inner Oslofjord (st. 30A) (**A**), Terøya in the Outer Hardangerfjord (st. 69A) (**B**) and Brashavn (st. 11X) in the Outer Varangerfjord (**C**). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Decrease in PROREF factor since 2016
Blue mussel at Gåsøya (st. I304) in the Inner Oslofjord had Cr-concentrations below PROREF in 2017, while the exceedance was by a factor up to two in 2016.

The Cr-concentrations in cod liver were below the PROREF in 2017, while they exceeded this level in 2016 by factors more than 20 at Bømlo (st. 23B) and Bergen harbour area (st. 24B), between 10 and 20 in the Inner Sørfjord (st. 53B), and between two and five at Austnesfjord in Lofoten (st. 98B1). The high concentrations of both Ni and Cr at these four stations in 2016 may indicate contamination during sample preparation.

Downward trends
Both significant downward long- and short-term trends were found in cod liver from Kjøfjord in the Outer Varangerfjord (st. 10B).

Levels in eider
In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the Cr-concentrations were <0.035 mg/kg w.w. in blood and 0.023 mg/kg w.w. in egg.

Other studies
In this study, cod liver from the Inner Oslofjord revealed a median concentration of 0.085 mg/kg Cr (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2017 had higher mean concentration (0.318 mg/kg Cr w.w.) (Ruus *et al.* 2018, in prep). The collection of cod in both studies took place during the autumn.

General, large scale trends
Emissions of Cr to air and discharges to water from land-based industries had maintained stable levels the last years and are shown in ***Figure 29***. The discharges to water in 2017 was 1549 kg Cr/years.

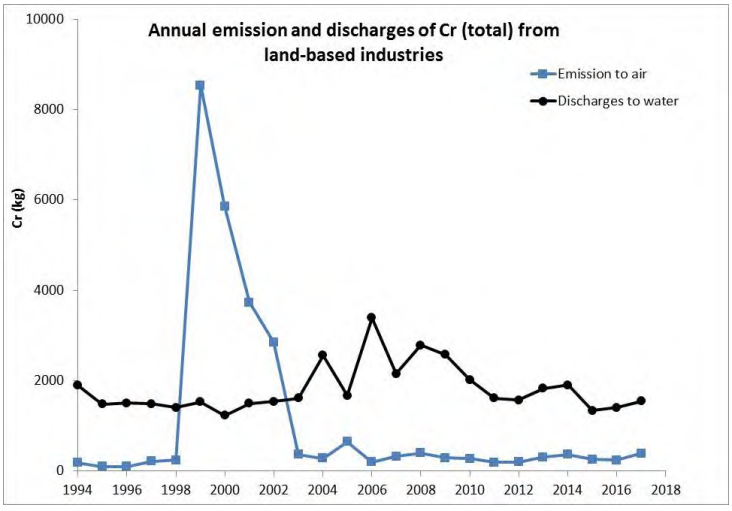


Figure 29. *Annual emissions of Cr to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 33 tonnes in 2016 (Skarbøvik *et al.* 2017 – M-862|2017). The ranges of total riverine inputs of Cr were 13 tonnes to Skagerrak, 4 tonnes to the North Sea, 10 tonnes to the Norwegian Sea and 6 tonnes to the Barents Sea. Total Cr load dropped 66 % to 33 tonnes in 2016 compared to the mean for the period 1990-2015 (98 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (1 tonnes) and industrial (1 tonnes) effluents amounting to 2 tonnes or about 6 % of the total (35 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.02 tonnes Cr in 2016. VEAS sewage treatment plant reported a discharge of 49 kg Cr in 2017 (VEAS 2018).

3.2.11 Cobalt (Co)

In the present study, cobalt (Co) was analysed in blue mussel at 31 stations, in cod liver at 17 stations and in eider blood and eggs at one station.

Levels exceeding PROREF

Blue mussel at eight stations exceeded the provisional high reference concentration (PROREF) for Co by a factor of up to two. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Solbergstrand (st. 31A), Mølen (st. 35A) and Kirkøy (st. I024) in the Oslofjord. This was also the case at Odderøya (st. I133) in the Kristiansandfjord and at Ørland area (st. 91A2) in the Outer Trondheimfjord.

Increase in PROREF factor since 2016

Blue mussel at Solbergstrand (st. 31A) and Mølen (st. 35A) in the Mid Oslofjord exceeded the PROREFF for Co by a factor up to two times in 2017, while there were no exceedances in 2016.

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 short-term trend was found at Mølen (st. 35A) in the Mid Oslofjord.

Both significant upward long- and short-term trends were observed in cod liver from Sandnessjøen area (st. 96B) and Hammerfest harbour area (st. 45B2).

Decrease in PROREF factor since 2016

Blue mussel at Odderøya (st. I133) exceeded the PROREF of Co by a factor up to two times in 2017, while the exceedance was between two and five in 2016. In 2017, there were no exceedances of PROREF in mussels from Færder (st. 36A) in the Outer Oslofjord and Skallnes (st. 10A2) in the Outer Varangerfjord, although the exceedances were by a factor up to two in 2016.

In 2017, the concentrations in cod liver were below the PROREF of Co, while the exceedances were by a factor of between five and 10 at Bømlo (st. 23B) in the Outer Selbjørnfjord, between two and five in Bergen harbour (st. 24B), and up to two in the Inner Sørfjord (st. 53B) in 2016.

Downward trends

Both significant downward long- and short-term trends were observed in blue mussel at Ranaskjer (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord.

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 egg.

General, large scale trends

Discharges of Co to water from land-based industries showed increasing values from 2013 (488 kg Co/year) to 2017 (725 kg Co/year) (***Figure 30***).

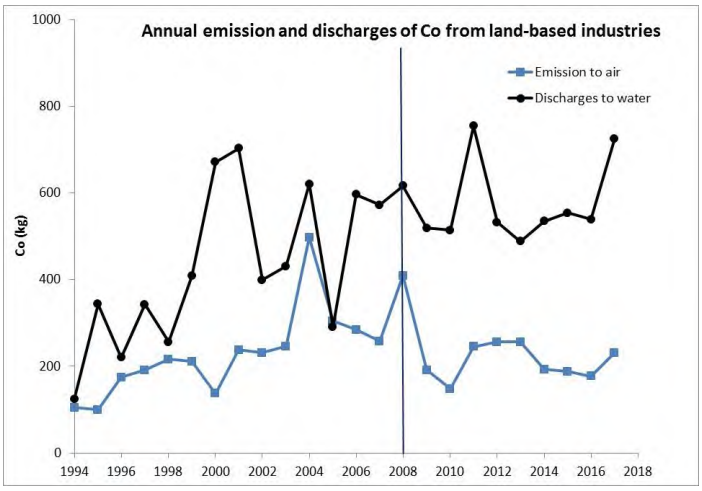


Figure 30. *Annual emissions of Co to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). The vertical grey line at 2008 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.12 Tributyltin (TBT)

Tributyltin (TBT) is an organic compound of tin used as a biocide especially in marine antifouling paints. TBT is toxic to marine life and was first known used in the 1960ties. In this study, TBT was analysed in blue mussel at seven stations, dogwhelk at eight stations and common periwinkle at one station. Imposex (VDSI) was investigated in dogwhelk at all eight stations.

Environmental Quality Standards (EQS) for EU-priority substances

When applying the EQS for TBT (150 µg/kg w.w.) in biota ("for fish") on blue mussel (< 14.0 µg/kg w.w.), dogwhelk (< 9.8 µg/kg w.w.) and periwinkle (< 1.1 µg/kg w.w.), all TBT-concentrations were below EQS in 2017 (***Table 11***), as in 2016.

Environmental Quality Standards (EQS) for River Basin Specific Pollutants

When applying the EQS for triphenyltin (TPTIN) (152 µg/kg w.w.) in biota on blue mussel (<2.2 µg/kg w.w.), dogwhelk (<32.0 µg/kg w.w.) and periwinkle (<0.5 µg/kg w.w.), all TPTIN-concentrations were below EQS in 2017, as in 2016 (***Table 11***).

Blue mussel

Levels exceeding PROREF

Blue mussel at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord exceeded the provisional high reference concentration (PROREF) for TBT by a factor of up to two.

Decrease in PROREF factor since 2016
Blue mussel at Akershuskaia (st. I301) and Gressholmen exceeded PROREF for TBT by a factor up to two in 2017, but exceeded this limit by a factor between two and five in 2016.

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

Dogwhelk
Levels of TBT
The TBT-levels in dogwhelk were low (<2.3 µg/kg w.w.) at seven stations, except for Risøya at Risør (st. 76G) where the concentration was <9.8 µg/kg w.w. due to matrix effects during analysis.

Downward trends of TBT
There were both significant downward long- and short-term trends for TBT at Færder (st. 36G) in the Outer Oslofjord, Melandsholmen (st. 227G2) in the Mid Karmsundet and at Espevær (st. 22G) in the Outer Bømlafjord. There were significant downward trends at Risøya at Risør (st. 76G), at Lastad in Søgne (st. 131G), at Gåsøya-Ullerøya in Farsund (st. 15G) and at Svolvær airport area (st. 98G) in Lofoten.

Biological effects of TBT (imposex/VDSI) in dogwhelk
The effects of TBT, the imposex parameter VDSI, were zero at all eight stations. For the first time since 1991, 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 2017.

Decrease in VDSI since 2016
The effect of TBT in dogwhelk was lower at Melandsholmen in the Mid Karmsundet (st. 227G2) in 2017 (VDSI=0) than in 2016 (VDSI=1.9). This was also the case at Brashavn (st. 11G) in the Varangerfjord where VDSI was 0 in 2017, while it was 0.04 in 2016.

Downward trends of VDSI
In dogwhelk, both significant downward long- and short-term trends for VDSI were observed at Færder (st. 36G) in the Outer Oslofjord, at Espevær (st. 22G) in the Outer Bømlafjord and at Svolvær airport area (st. 98G) in Lofoten. Significant downward long-term trends were found at Risøya at Risør (st. 76G), at Lastad in Søgne (st. 131G), at Gåsøya-Ullerøya in Farsund (st. 15G), and at Melandsholmen (st. 227G2) in the Mid Karmsundet.

Common periwinkle
Levels of TBT
The TBT-concentration in common periwinkle at Fugløyskjær (st. 71G) in the Outer Langesundfjord was 1.1 µg/kg (w.w.).

Trends of TBT
There was were insufficient data to determine if the trend was significantly downward for TBT at in common periwinkle at Fugløyskjær in the Outer Langesundfjord.

Biological effects of TBT (intersex/ISI) in common periwinkle
The effect of TBT in common periwinkle was zero (ISI=0) in 2017, as in 2016.

Other studies

Blue mussel from Langøya in the Holmestrandfjord in 2017 were below EQS for both TBT and TPTIN at all three stations, included Mølen (st. 35A) (Schøyen and Beylich 2018). At Mølen, the concentration of TBT was 3.8 µg/kg w.w. and the concentration of TPTIN was 0.9 µg/kg w.w. The collection of blue mussel took place during the autumn.

General, large scale trends

In this study, 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*. 2018a and 2018b, in prep). The decreases in TBT concentrations and imposex parameters coincides with the TBT-bans. Populations of dogwhelk have recovered all along the Norwegian coastline after the introduction of bans on the use of TBT in antifouling paint. Former maximum levels of these markers were detected at coastal sites close to active shipping channels like Færder and Karmsund. In populations close to much ship traffic, the recovery took longer time than at remote stations. In the Karmsund area, a maximum level of 46 % sterile females was measured in 2000, whereas there have not been detected any sterile females at any monitoring station after 2008, the year for the total ban. This recovery has also resulted in low levels of TBT and imposex in dogwhelk all along the Norwegian coast.

The results show that the Norwegian legislation banning application of organotin on ships shorter than 25 meters in 1990 and longer than 25 meters in 2003/2008, has been effective in reducing imposex in dogwhelk populations. The international convention that was initiated by the International Maritime Organization (IMO) did not only ban application of organotin on ships after 2003 but also stated that organotin after 2008 could not be part of the system for preventing fouling on ships. VDSI in dogwhelk was around level 4 in all dogwhelk stations before the ban in 2003, except for the Varangerfjord where the VDSI had been low (<0.3) in the whole monitoring period. It was a clear decline in VDSI as well as TBT at all stations between 2003 and the total ban in 2008 (***Figure 31***, ***Figure 32***). In the post-ban period since 2008, the VDSI levels have been below PROREF (3.68) at all stations, and the levels has been close to zero at many of the stations. A typical example of decreasing trends is shown for Færder in ***Figure 33***.

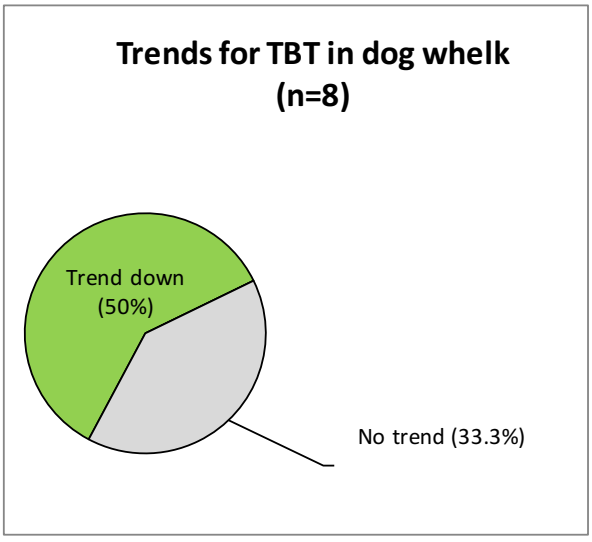


Figure 31. *Frequency of recent trends for the concentration of TBT in dogwhelk (n=8) (2008-2017). No upward trends were detected. Concerns about LOQ prevented some trend analyses.*

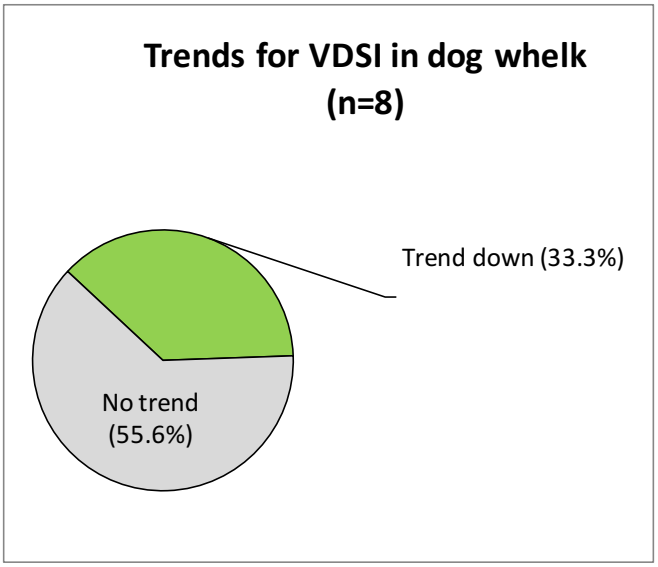


Figure 32. *Frequency of recent trends for VDSI in dogwhelk (n=8) (2008-2017). No upward trends were detected.*

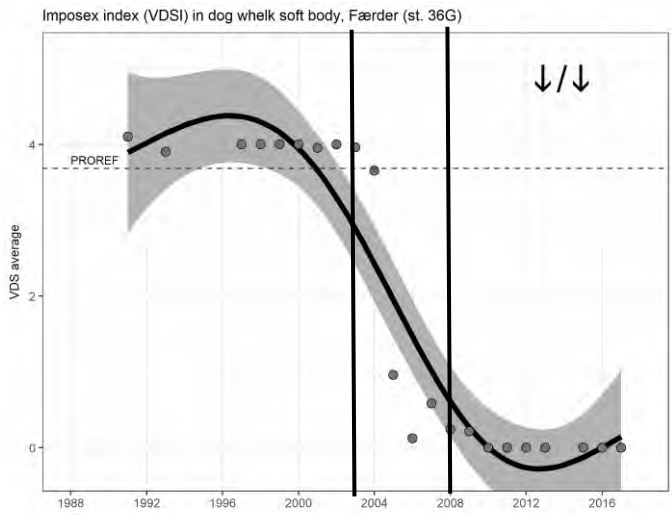


Figure 33. *Changes in VDSI for dogwhelk from Færder (st. 36G) (1991-2017). The vertical black lines indicate the initial ban of TBT in 2003 and total ban in 2008. The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

In the post-ban period since 2008, TBT concentrations in dogwhelk have been below PROREF (23.5 µg/kg w.w.) at all stations. Discharges of TBT and TPTIN to water from land-based industries from 1997 to 2017 is shown in ***Figure 34***, but do not adequately reflect loads to the marine environment because it does not include discharges from maritime activities for this period and do not include secondary inputs from organotin contaminated sediments. The values were high in 2003 (487 g TBT and TPTIN/year) and 2009 (504 g TBT and TPTIN/year), and these peaks were related to discharges to water from industry in Vestfold in the Outer Oslofjord. In 2017, the annual discharges were 4 g TBT and TPTIN.

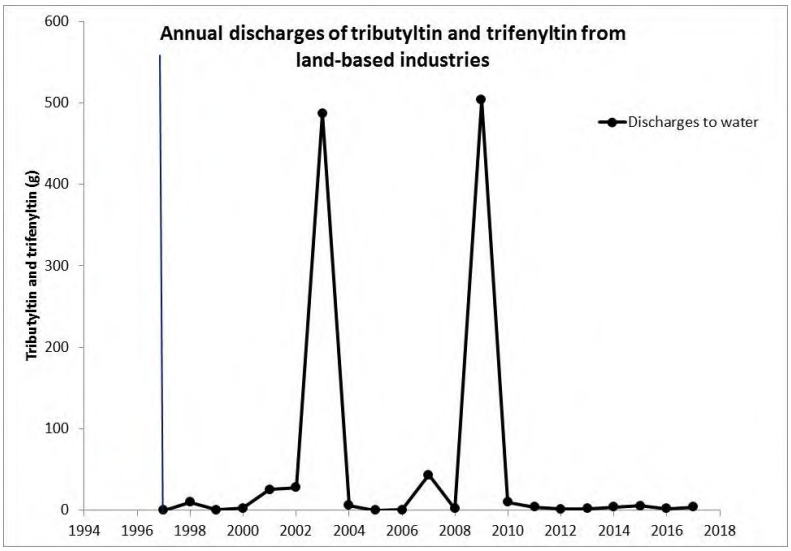


Figure 34. *Annual discharges of TBT and TPTIN to water from land-based industries in the period 1997-2017 (data from www.norskeutslipp.no, 8 June 2018). No data are reported for 1994-1996. The vertical grey line at 1997 marks when the MILKYS-measurements of TBT started. The MILKYS-measurements of VDSI started in 1991. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

3.2.13 Polychlorinated biphenyls (PCB-7)

Polychlorinated biphenyls (defined here as PCB-7, see ***Table 4***) are a group of chlorinated organic compounds that previously had a broad industrial and commercial application. In the present study, PCB-7 was analysed in blue mussel at 30 stations, in cod liver at 16 stations and in eider blood and eggs at one station.

Environmental Quality Standards (EQS) for River Basin Specific Pollutants

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

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

Levels exceeding PROREF

Blue mussel exceeded the provisional high reference concentration (PROREF) for PCB-7 at all stations. The mussels exceeded the limit by a factor between five to 10 times at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Oslofjord, and at Nordnes in Bergen harbour (st. I241). The exceedance was between a factor of two and five at Gåsøya (st. I304), Solbergstrand (st. 31A), Singlekalven (st. I023) and Kirkøy (st. I024) in the Oslofjord. This was also the result at Odderøya (st. I133) in the Kristiansandfjord, and Eitrheimsneset (st. 52A) and Kvalnes (st. 56A) in the Sørfjord. This was also the case at Ålesund harbour (st. 28A2), Ørland area in the Outer Trondheimfjord (st. 91A2), and 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 between five and 10 at Bergen harbour (st. 24B), between two and five in the Inner Oslofjord (st. 30B) and in the Inner Sørfjord (st. 53B), and up to two at the areas of Kristiansand harbour (st. 13B) and Ålesund harbour (st. 28B).

Increase in PROREF factor since 2016

Blue mussel at 23 stations had increased PROREF factors since 2016. The PROREF was exceeded by a factor between five and 10 in 2017, while the exceedance was between two and five in 2016 at Nordnes (st. I241) in Bergen harbour. The exceedance was a factor between two and five in 2017, while it was up to a factor of two in 2016 at Gåsøya (st. I304) in the Inner Oslofjord, Eitrheimsneset (st. 52A) in the Inner Sørfjord, and Ørland area (st. 91A2) in the Outer Trondheimfjord. The exceedance was a factor between two and five in 2017, while it was no exceedance in 2016 at Solbergstrand (st. 31A), Singlekalven (st. I023) and Kirkøy (st. I024) in the Oslofjord. This was also the case at Odderøya (st. I133) in the Kristiansand harbour and Kvalnes (st. 56A) in the Mid Sørfjord. At 14 blue mussel stations, the PROREF was exceeded by a factor up to two in 2017, while it was no exceedance in 2016. These stations were Mølen (st. 35A) and Færder (st. 36A) in the Oslofjord, Risøya (st. 76A2) at Risør, and Gåsøya-Ullerøya (st. 15A) in Farsund. This was also the case at Krossanes (st. 57A) and Utne (st. 64A) in the Sørfjord, and at Ranaskjer (st. 63A), Vikingneset (st. 65A) and Terøya (st. 69A) in the Hardangerfjord. The same result was found at Espevær (st. 22A) in the Outer Bømlafjord, Mjelle (st. 97A2) in Bodø area and Svolvær airport (st. 98A2). This was also observed at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord.

In 2017, the PROREF in cod liver was exceeded by a factor of two to five in the Inner Sørfjord, and by a factor up to two at Kristiansand harbour (st. 13B) and Ålesund harbour (st. 28B), while there were no exceedances in 2016.

Upward trends

In blue mussel, there were both significant upward long- and short-term trends at Vågsvåg (st. 26A2) in the Outer Nordfjord.

Decrease in PROREF factor since 2016

In cod liver, the PROREF was exceeded by a factor between five and 10 at Bergen harbour (st. 24B) in 2017, while the exceedance was by a factor between two and five in 2016.

Downward trends

For blue mussel, there were significant downward long-term trends at 20 of the 29 stations (***Table 12***). At Gåsøya (st. I301) in the Inner Oslofjord, there was also a significant downward short-term trend.

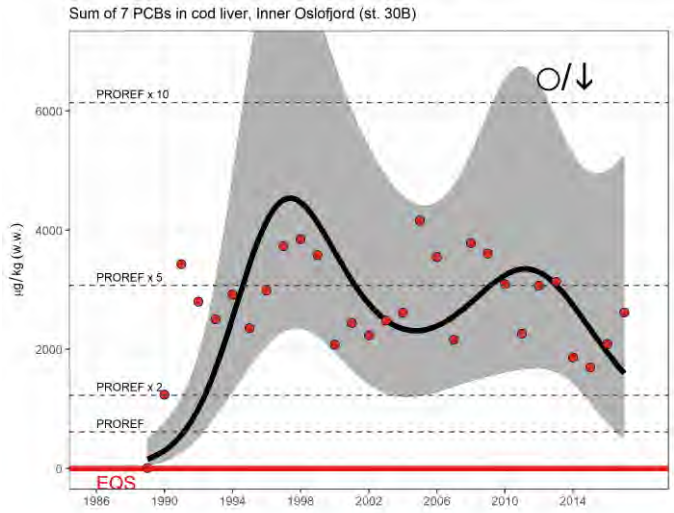
For cod liver, there were significant downward long-term trends at seven of the 16 stations. These stations were Skågskjera in Farsund (st. 15B), Bømlo (st. 23B), Austnesfjord (st. 98B1) in Lofoten and Kjøfjord in the Varangerfjord (st. 10B). Significant downward short-term trends were also observed in cod liver from Kirkøy at Hvaler (st. 02B), Trondheim harbour (st. 80B), and Hammerfest harbour area (st. 45B2). A significant downward short-term trend was found in the Inner Oslofjord (st. 30B).

The Inner Oslofjord

Blue mussel at Akershuskaia (st. I301) and Gressholmen (st. 30A) exceeded PROREF by a factor between five to 10 times in 2015, 2016 and 2017. Mussels at Gåsøya (st. I304) exceeded PROREF by a factor between two and five times in 2017.

Cod liver caught at 100 m depth in the Inner Oslofjord (st. 30B) exceeded PROREF by a factor between two to five in both 2015, 2016 and 2017. A significant downward short-term trend was detected in 2017 (***Figure 35a***). When adjusting for length, a significant downward short-term trend was also registered (***Figure 35b***).

A



B

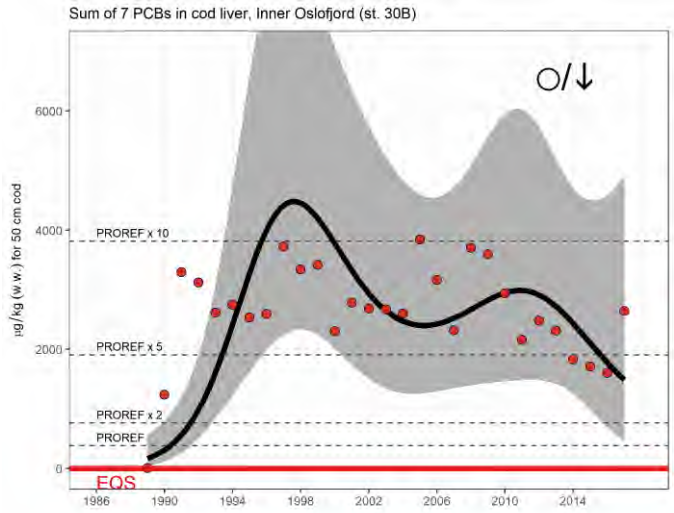


Figure 35. *Median concentrations (mg/kg w.w.) of PCB-7 in cod liver from 1990 to 2017 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PCB-7 were <0.692 µg/kg w.w. in blood and 12.811 µg/kg w.w. in eggs.

Other studies

In this study, cod liver from the Inner Oslofjord revealed a median concentration of 2 615.3 µg ΣPCB-7/kg (w.w.). Cod liver from a comparable study from the Inner Oslofjord in 2017 had almost the same mean concentration (2842.2 µg ΣPCB-7/kg w.w.) (Ruus *et al.* 2018, in prep). The collection of cod in both studies took place during the autumn.

Historical data on entry of PCBs to the Inner Oslofjord is not available. Present entry of PCBs to the fjord has however been calculated to be around 3.3 kg/year (Berge *et al.* 2013). 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 PCB, but their role as a current source of PCBs for uptake in biota is unclear. Parts of the Inner Oslofjord are densely populated with much urban activities. The high concentrations of PCBs observed in cod liver are probably related to these activities both in past and possibly also at present.

In this study, the concentration of PCB-153 (median <0.255 µg/kg w.w.) in eider blood at Svalbard were higher than in a comparable study from Svalbard (mean 0.187±0.023.8 µg/kg w.w. after 5 days of incubation) (Bustnes 2010).

In this study, the median concentrations of PCB-7 were <0.692 µg/kg w.w. in blood and 12.811 µg/kg w.w. in eggs at Svalbard. In a comparable study in the Inner Oslofjord from 2017, the mean concentrations of PCB-7 in eider were 10.52 µg/kg w.w. in blood and 138.31 µg/kg w.w. in eggs (Ruus *et al*. 2018, in prep).

General, large scale trends

In Norway, the use of PCBs has been prohibited since 1980, but leakage from old products as well as landfills and natural deposits and contaminated sediments may still be a source of contamination. Production and new use of PCBs are prohibited globally through the ECE-POPs protocol and the Stockholm Convention.

Emissions of PCBs to air and discharges to water from land-based industries are shown in ***Figure 36***. High emission to air was reported in 2008 (140 g PCB/year), while the emission was 53 g PCB/year in 2017. The discharges to water had increased to 53 g PCBs in 2017 from 40 g PCBs in 2016. Investigations by Schuster *et al*. (2010) indicate that emissions in the northern Europe have declined during the period 1994-2008 by about 50 %.

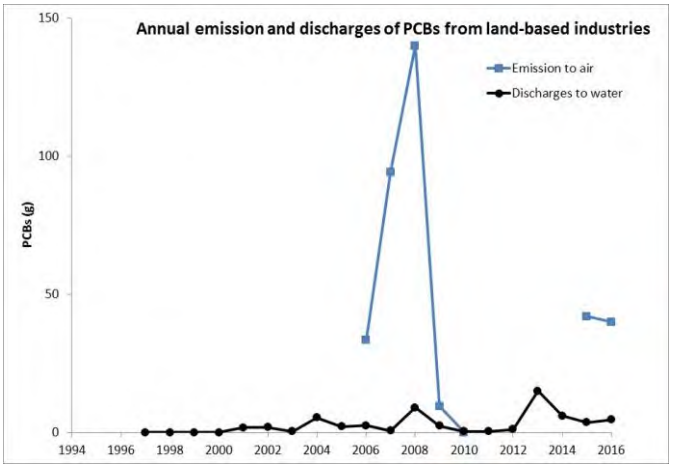


Figure 36. *Annual emissions of PCBs to air and discharges to water from land-based industries in the period 1997-2016 (data from www.norskeutslipp.no, 27 June 2018). No data for emissions to air are reported for 1994-2005 and 2011-2014. No data for discharges to water are reported for 1994-1996. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.14 Dichlorodiphenyldichloroethylene (ppDDE)

DDT (dichloro-diphenyl-trichloroethane) is the first modern synthetic pesticides developed in the 1940s. Dichlorodiphenyldichloroethylene (DDE) is a chemical compound formed by the loss of hydrogen chloride (dehydrohalogenation) from DDT, and DDE is one of the more common breakdown products. The compounds are used for insects and weed control. In this study, dichlorodiphenyldichloroethylene (p,p'-DDE, referred to herein as ppDDE) was analysed in blue mussel at 19 stations and in cod liver at seven stations.

Environmental Quality Standards (EQS) for EU-priority substances

EU has provided an EQS of 610 µg/kg w.w. for total DDT, but for this study we apply the same limit to ppDDE in biota (see ***Table 7***). Applying this EQS for blue mussel and cod liver, all concentrations were below EQS.

Levels exceeding PROREF

Concentrations of ppDDE exceeded the provisional high reference concentration (PROREF) at 12 blue mussel stations (***Figure 37***). 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 between 10 and 20 at Byrkjenes (st. 51A) in the Inner Sørfjord and at Krossanes (st. 57A) in the Outer Sørfjord. Mussel exceeded PROREF by a factor between five and 10 at Eitrheimsneset (st. 52A) in the Inner Sørfjord. Mussels at Akershuskaia (st. I301) in the Inner Oslofjord, and Ranaskjer (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord, exceeded PROREF by a factor between two and five. At Gressholmen (st. 30A) and Solbergstrand (st. 31A) in the Oslofjord, Risøy (st. 76A2) at Risør and Odderøya (st. I133) in the Kristiansandfjord, the exceedance was by a factor of up to two.

Concentrations of ppDDE exceeded PROREF by a factor between two and five in the Inner Sørfjord (st. 53B) (***Figure 37***).

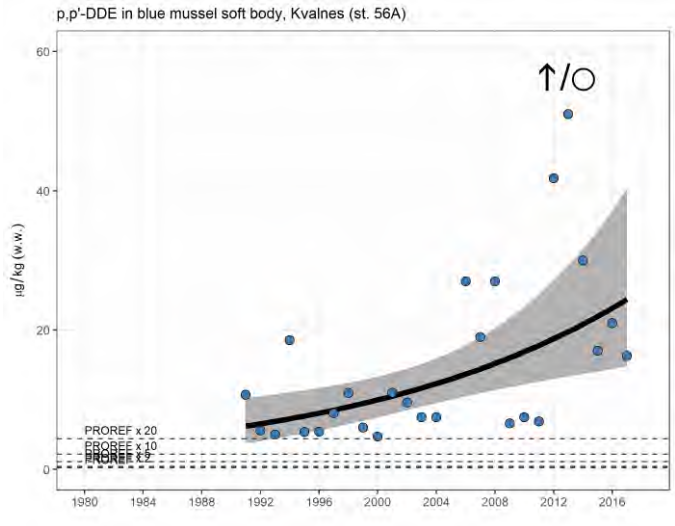


Figure 37. *Median concentrations (mg/kg w.w.) of ppDDE in blue mussel from 1992 to 2017 in the Mid Sørfjord at Kvalnes (st. 56A). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Increase in PROREF factor since 2016

Blue mussel exceeded the PROREF of ppDDE by a factor between 10 and 20 times in 2017, while the exceedance was between five and 10 in 2016. Mussels exceeded the PROREF by a factor between

two and five in 2017, while the exceedance was by a factor up to two times the year before. Blue mussel had concentrations below PROREF in 2016, but they exceeded this limit by a factor of up to two in 2017 at Solbergstrand (st. 31A) in the Mid Oslofjord, Risøya (st. 76A2) at Risør and Odderøya (st. I133) in the Kristiansandfjord.

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

Decrease in PROREF factor since 2016
Blue mussel at Krossanes (st. 57A) in the Outer Sørfjord exceeded PROREF by a factor between 10 and 20 in 2017, but the exceedance was by a factor over 20 in 2016.

Cod liver from the Inner Oslofjord had concentrations below the PROREF in 2017, while the exceedance was up to two times in 2016.

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

Significant downward long-term trends for ppDDE were found in cod liver at three stations. These stations were Skågskjera in Farsund (st. 15B), Bømlo (st. 23B), and Kjøfjord in the Outer Varangerfjord (st. 10B). There was also a significant downward long-term trend in cod liver from Skågskjera (st. 15B) at Farsund.

Other studies, Sørfjord
In the present study in the Outer Sørfjord, blue mussel from Krossanes (st. 57A) had concentration of 3.1 μg/kg ppDDE (w.w.) and mussels from Utne (st. 64A), on the opposite side of the fjord, had concentration of 4.8 μg/kg ppDDE (w.w.). Mussels from a comparable study in the Sørfjord in 2015 had higher concentrations at Krossanes (11.0 μg DDT/kg w.w.) and at Grimo (26.7 μg DDT/kg w.w.), on the opposite side (Ruus *et al*. 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 ppDDE in the Sørfjord area. It must however be noted that the use of DDT products has been prohibited in Norway since 1970. Green *et al*. (2004 – TA-2003/2003) concluded that the source of ppDDE in the Sørfjord was uncertain. Analyses of supplementary stations between Kvalnes and Krossanes in 1999 indicated that there could be local sources at several locations (Green *et al*. 2001 – TA-1780/2001).

A more intensive investigation in 2002 with seven sampling stations confirmed that there were two main areas with high concentrations, one north of Kvalnes and the second near Urdheim south of Krossanes (Green *et al*. 2004 – TA-2003/2003). The variations in concentrations of ΣDDT and the ratio between ppDDT/ppDDE (insecticide vs. metabolite) in blue mussel from Byrkjenes and Krossanes corresponds with periods with much precipitation, and it is most likely a result of wash-out from sources on shore) (Skei *et al*. 2005). Botnen and Johansen (2006) deployed passive samplers (SPMD- and PCC-18 samplers) at 12 locations along the Sørfjord to sample for DDT and its derivates in sea water. Blue mussel and sediments were also taken at some stations. The results

indicated that further and more detailed surveys should be undertaken along the west side of the Sørfjord between Måge and Jåstad, and that replanting of old orchards might release DDT through erosion. Concentrations of ΣDDT in blue mussel in the Sørfjord in 2008-2011 showed up to Class V (extremely polluted) at Utne (Ruus *et al*. 2009 –TA-2519/2009, 2010a, 2011, 2012 – TA-2947/2012). There was high variability in the concentrations of ΣDDT in replicate samples from Utne, indicating that this station was affected by DDT-compounds in varying degree, dependent on local conditions. The highest concentrations of ppDDE in sediment were observed in Mid Sørfjord (Green *et al*. 2010b – TA-2716/2010).

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

General, large scale trends

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

3.2.15 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds produced by incomplete combustion or high-pressure processes. PAHs form when complex organic substances are exposed to high temperatures or pressures. The main sources of PAH in coastal waters include discharges from smelting industry and waste incinerators. In this study, PAHs[21] were analysed in blue mussel at eight stations.

Levels exceeding PROREF

Blue mussel exceeded the provisional high reference concentration (PROREF) for PAH-16 by a factor between two and five at Akershuskaia (st. I301) in the Inner Oslofjord and Sylterøya (st. I714) in the Langesundfjord. Mussels at Gåsøya (st. I304) and Singlekalven (st. I023) in the Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord, Lastad (st. I131A) at Søgne and Svolvær airport area (st. 98A2) exceeded PROREF by a factor up to two.

Increase in PROREF factor since 2016

Seven out of eight blue mussel stations had increasing levels of PROREF of PAH-16 in 2017. Blue mussel exceeded PROREF by a factor between two and five at Akershuskaia (st. I301) in the Inner Oslofjord and Sylterøya (st. I714) in the Langesundfjord, while there were no exceedances in 2016. In 2017, mussels at Gåsøya (st. I304) and Singlekalven (st. I023) in the Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord, Lastad (st. I131A) at Søgne and Svolvær airport area (st. 98A2) exceeded PROREF by a factor up to two, while there were no exceedances the previous year.

Downward trends

Significant downward long-term trends were observed at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord.

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

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries can be seen in ***Figure 38***. In 2017, the emission to air was 63 587 kg PAHs. Most emission of PAHs to air came from Vest-Agder (46 672 kg in 2017). The discharges to water were 3 991 kg PAHs in 2017. In 2017, 2 296 kg PAHs was discharged to water from Møre and Romsdal and 1 185 kg PAHs from Vest-Agder, according to www.norskeutslipp.

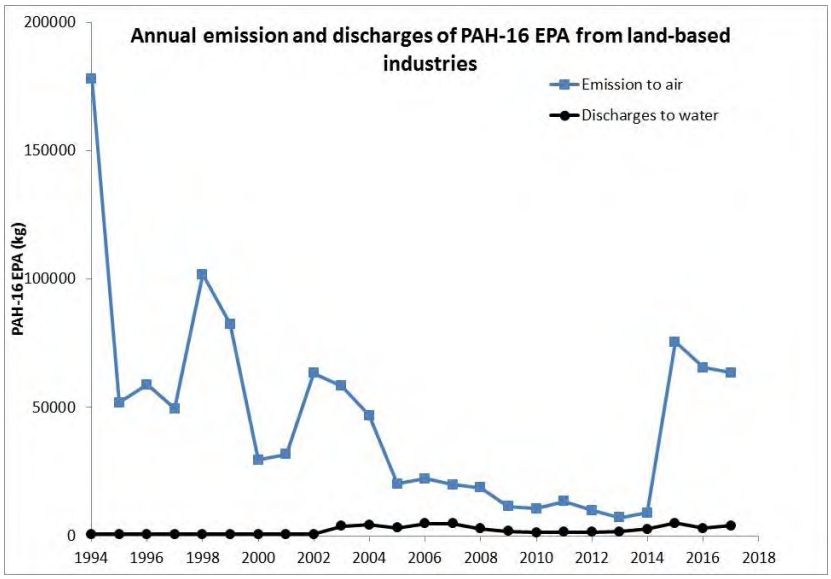


Figure 38. *Annual emissions of PAHs (PAH-16 EPA) to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.16 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

In this study, sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs, see Appendix B) was analysed in blue mussel at eight stations.

Levels exceeding PROREF

Blue mussel at all eight stations exceeded the provisional high reference concentration (PROREF) for KPAHs. The exceedances were by a factor between 10 and 20 at Akershuskaia (st. I301) in the Inner Oslofjord, and at Bjørkøya (st. 71A) and Sylterøya (st. I714) in the Langesundfjord. The exceedances were by a factor between five and 10 at Gåsøya (st. I304) in the Inner Oslofjord and at Lastad in Søgne (st. I131A), and between two and five at Svolvær airport area (st. 98A2). Mussels exceeded PROREF by a factor up to two times at Singlekalven (st. I023) at Hvaler in the Outer Oslofjord.

Increase in PROREF factor since 2016

Seven out of eight blue mussel stations had increasing levels of PROREF of KPAH in 2017 compared to 2016. In 2017, the exceedances were by a factor between 10 and 20, while it was over 20 times at Bjørkøya (st. 71A) and between five and 10 at Akershuskaia (st. I301) and Sylterøya (st. I714) in 2016. In 2017, the exceedances were by a factor between five and 10 at Gåsøya (st. I304) and at Lastad (st. I131A), while it was by a factor up to two times in 2016. In 2016, there were no exceedances of PROREF, while mussels from Svolvær airport area (st. 98A2) exceeded this limit

between two and five times, and mussels from Singlekalven (st. I023) exceeded this value up to a factor of two in 2017.

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

3.2.17 Anthracene
Anthracene is a PAH-compound. In this study, anthracene was analysed in blue mussel at eight stations.

Environmental Quality Standards (EQS) for EU-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 2017 (see ***Table 11***), as in 2015 and 2016.

PROREF
Blue mussel at all stations had concentrations below PROREF for anthracene.

Downward trends
A significant downward long-term trend was found at Gressholmen (st. 30A) in the Inner Oslofjord.

Other studies
Another recent survey implemented due to operational monitoring in compliance with the EU Water Framework Directive showed that blue mussel from Langøya in the Holmestrandfjord in 2017 were below EQS for anthracene at all three stations, included Mølen (st. 35A) (Schøyen & Beylich 2018). At Mølen, the concentration of anthracene was <0.345 µg/kg w.w. The collection of blue mussel took place during the autumn.

General, large scale trends
Emissions of anthracene to air and discharges to water from land-based industries can be seen in ***Figure 39***. In 2017, the emission to air was 2240 kg anthracene. The discharges to water were 22 kg anthracene in 2017.

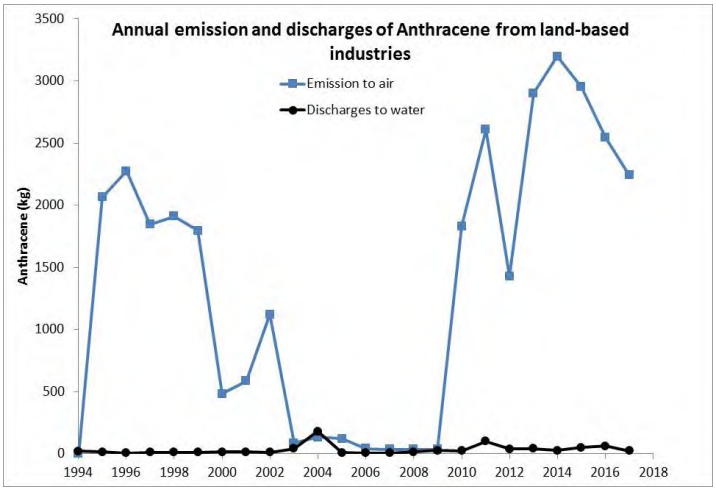


Figure 39. *Annual emissions of anthracene to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 24 September 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.18 Fluoranthene

Fluoranthene is a PAH-compound. In this study, fluoranthene was analysed in blue mussel at eight stations.

Environmental Quality Standards (EQS) for EU-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 (see ***Table 11***).

Levels exceeding PROREF

Blue mussel at Akershuskaia (st. I301) exceeded the provisional high reference concentration (PROREF) for fluoranthene by a factor between two and five times.

Downward trends

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

Other studies

Blue mussel from Langøya in the Holmestrandfjord in 2017 were below EQS for fluoranthene at all three stations, included Mølen (st. 35A) (Schøyen & Beylich 2018). At Mølen, the concentration of fluoranthene was 2.57 µg/kg w.w. The collection of blue mussel took place during the autumn.

General, large scale trends

Emissions of fluoranthene to air and discharges to water from land-based industries can be seen in ***Figure 40***. In 2017, the emission to air was 3 041 kg fluoranthene. The discharges to water were 473 kg fluoranthene in 2017.

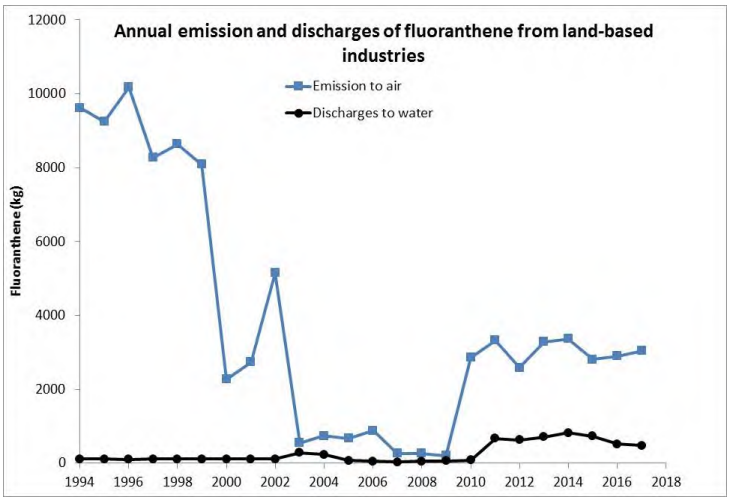


Figure 40. *Annual emissions of fluoranthene to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 24 September 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

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

Benzo[a]pyrene (B[a]P) is a PAH-compound. In this study, B[a]P was analysed in blue mussel at eight stations.

Environmental Quality Standards (EQS) for EU-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 (see ***Table 11***).

Decrease in PROREF factor since 2016

Blue mussel at Bjørkøya (st. I965) in the Langesundfjord exceeded the provisional high reference concentration (PROREF) for B[a]P by a factor up to two in 2016, while the concentration was below this limit in 2017.

Other studies

Another recent compliance monitoring survey with the EU Water Framework Directive showed that blue mussel from Langøya in the Holmestrandfjord in 2016 were below EQS for B[a]P at all three stations, included Mølen (st. 35A) (Schøyen & Beylich 2018). At Mølen, the concentration of B[a]P was 0.369 µg/kg w.w. The collection of blue mussel took place during the autumn.

General, large scale trends

Emissions of B[a]P to air and discharges to water from land-based industries can be seen in ***Figure 41***. In 2017, the emission to air was 451 393 kg B[a]P. The discharges to water were 49 292 kg B[a]P in 2017.

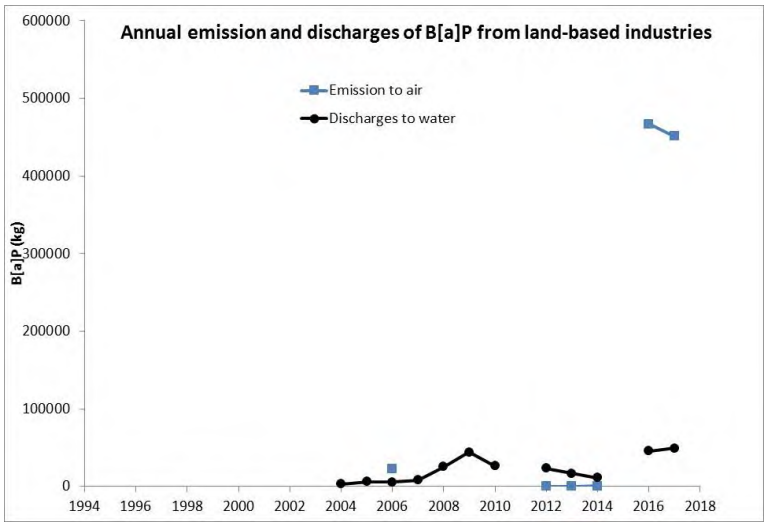


Figure 41. *Annual emissions of B[a]P to air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 24 September 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 Naphthalene

Naphthalene is a PAH-compound. Naphthalene was analysed in blue mussel at eight stations.

There are increasing LOQs for naphthalene from 2016 to 2017 (see Table with LOQs), and this might impact the results.

Environmental Quality Standards (EQS) for EU-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 (see ***Table 11***).

Levels exceeding PROREF

Blue mussel at Gåsøya (st. I304) in the Inner Oslofjord exceeded the provisional high reference concentration (PROREF) for naphthalene by a factor between two and five times. The exceedance of PROREF was up to two times at Akershuskaia (st. I301) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler, Bjørkøya (st. 71A) in the Langesundfjord, Lastad (st. I131A) at Søgne and Svolvær airport area (st. 98A2) in Lofoten.

Increase in PROREF factor since 2016

In 2017, blue mussel at Gåsøya (st. I304) in the Inner Oslofjord exceeded the PROREF for naphthalene by a factor between two and five times, while it was no exceedance in 2016. In 2017. the exceedance was up to two times at Akershuskaia (st. I301) in the Inner Oslofjord, Singlekalven (st. I023) at Hvaler, Bjørkøya (st. 71A) in the Langesundfjord, Lastad (st. I131A) at Søgne and Svolvær airport area (st. 98A2) in Lofoten, while there were no exceedances the previous year.

Other studies

Another recent survey due to operational monitoring in compliance with the EU Water Framework Directive showed that blue mussel from Langøya in the Holmestrandfjord in 2017 were below EQS for naphthalene at all three stations, included Mølen (st. 35A) (Schøyen & Beylich 2018). At Mølen,

the concentration of naphthalene was <34.2 µg/kg w.w. The collection of blue mussel took place during the autumn.

General, large scale trends

Emissions of naphthalene to air and discharges to water from land-based industries can be seen in ***Figure 42***. In 2017, the emission to air was 14 575 kg naphthalene. The discharges to water were 1 375 kg naphthalene in 2017.

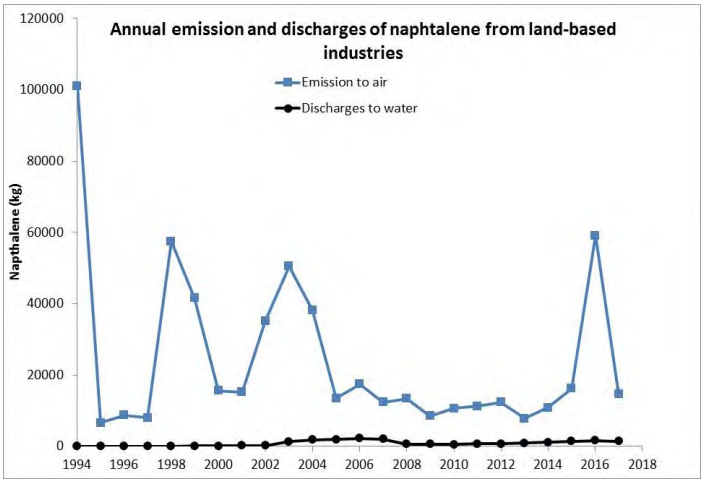


Figure 42. *Annual emissions* of *naphthalene* to *air and discharges to water from land-based industries in the period 1994-2018 (data from www.norskeutslipp.no, 24 September 2018). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.21 Benzo(a)anthracene

Benzo(a)anthracene is a PAH-compound. In this study, benzo(a)anthracene was analysed in blue mussel at eight stations.

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 (see ***Table 11***).

Levels exceeding PROREF

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

Increase in PROREF factor since 2016

In 2017, blue mussel Akershuskaia (st. I301) exceeded PROREF by a factor of up to two, while it was no exceedance in 2016.

Decrease in PROREF factor since 2015

Mussel at Bjørkøya (st. 71A) in the Langesundfjord exceeded PROREF by a factor up to two times in 2016, while the concentration was below this limit in 2017.

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

Other studies
Another recent survey due to operational monitoring in compliance with the EU Water Framework Directive showed that blue mussel from Langøya in the Holmestrandfjord in 2017 were below EQS for benzo(a)anthracene at all three stations, included Mølen (st. 35A) (Schøyen & Beylich 2018). At Mølen, the concentration of benzo(a)anthracene was 0.977 µg/kg w.w. The collection of blue mussel took place during the autumn.

3.2.22 Polybrominated diphenyl ethers (PBDEs)
Polybrominated diphenyl ethers (BDEs) are a group of brominated flame retardants used in a variety of consumer products. In this study, BDEs were analysed in blue mussel at 12 stations, cod liver at 11 stations and in eider blood and eggs at one station.

Environmental Quality Standards (EQS) for EU-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 both blue mussel and cod liver, sum BDEs were above EQS at all stations (see ***Table 11***).

The median concentration of BDE47 in both blue mussel and cod liver exceeded this EQS at all stations (***Table 11***). These results indicate that the EQS might not be a useful criterion to judge the condition of the environment with respect to this contaminant in biota.

Levels exceeding PROREF
Blue mussel at Nordnes (st. I241) in Bergen harbour and in Bodø harbour (st. 97A3) exceeded the provisional high reference concentration (PROREF) for sum BDEs (28, 47, 99, 100, 153 and 154) by a factor up to two. Blue mussel exceeded PROREF for both BDE47 and 99 by a factor of two times at Nordnes (st. I241) in Bergen harbour and Bodø harbour (st. 97A3).

Cod liver from Bergen harbour (st. 24B) exceeded PROREF of sum BDEs (28, 47, 99, 100, 153 and 154) by a factor of between two to five. Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF of sum BDEs (28, 47, 99, 100, 153 and 154) by a factor of up to two times. Cod liver exceeded PROREF by a factor of between two and five for BDE100 in the Inner Oslofjord (st. 30B), the Inner Sørfjord (st. 53B), Bergen harbour (st. 24B) and Ålesund harbour area (st. 28B). Cod liver exceeded PROREF by a factor of up to two for BDE47 in the Inner Oslofjord (st. 30B), and for BDE47 and 154 in Bergen harbour (st. 24B). Cod liver exceeded PROREF by a factor of up to two for BDE126 in Ålesund harbour area (st. 28B) (***Table 12***, ***Table 14***, ***Figure 45***).

BDE47
The most dominant congener in 2017 was BDE47, which was also the case in 2016. BDE47 was detected at all blue mussel and cod stations sampled in 2017, as in 2016. The highest median concentrations of BDE47 were found in mussels from Bodø harbour (st. 97A3) (0.195 µg BDE47/kg w.w.) and in cod liver from Nordnes (31.4 µg/kg w.w.).

Increase in PROREF factor since 2016
Blue mussel exceeded PROREF by a factor up to two times for BDE100 at Nordnes (st. I241) in Bergen harbor in 2017.

In 2017, cod liver exceeded PROREF by a factor up to two for BDE100 and 126 in Ålesund harbour (st. 28B), and for BDE100 in the Inner Sørfjord, while there were no exceedances in 2016. Cod liver was below PROREF in 2017 for BDE99 and 154 in the Inner Oslofjord (st. 30B), for BDE154 in the Inner Sørfjord (st. 53B), and for BDE100 at Tromsø harbour (st. 43B2), while the exceedances were by a factor up to two in 2016.

Decrease in PROREF factor since 2016
In 2017, blue mussel at all stations had concentrations of BDEs (28, 47, 99, 100, 153 and 154) below PROREF. In 2016, mussels exceeded PROREF for BDEs by a factor between two and five at Vågsvåg (st. 26A2) in the Outer Nordfjord, and Ørland (st. 91A2) in the Outer Trondheimfjord. In 2016, mussels exceeded PROREF for BDEs by a factor up to two times at Gressholmen (st. 30A), Færder (st. 36A), Singlekalven (st. I023), Bjørkøya (st. 71A), Sylterøya (st. I714), Bodø harbour (st. 97A2) and Svolvær airport area (st. 98A2). In 2017, blue mussel at Ørland (st. 91A2) in the Outer Trondheimfjord had concentrations of BDE47 below PROREF, while the exceedance was by a factor up to two times in 2016.

Cod liver exceeded PROREF by a factor up to two in 2017 in the Inner Oslofjord (st. 30B) for sum BDEs (28, 47, 99, 100, 153 and 154) and in Bergen harbour (st. 24B) for BDE47, while the exceedances were between two and five in 2016. Cod liver was below PROREF in 2017 in the Inner Oslofjord (st. 30B) for BDE47 and 99, and in in the Inner Sørfjord (st. 53B) for BDE154, while the exceedances were up to two in 2016.

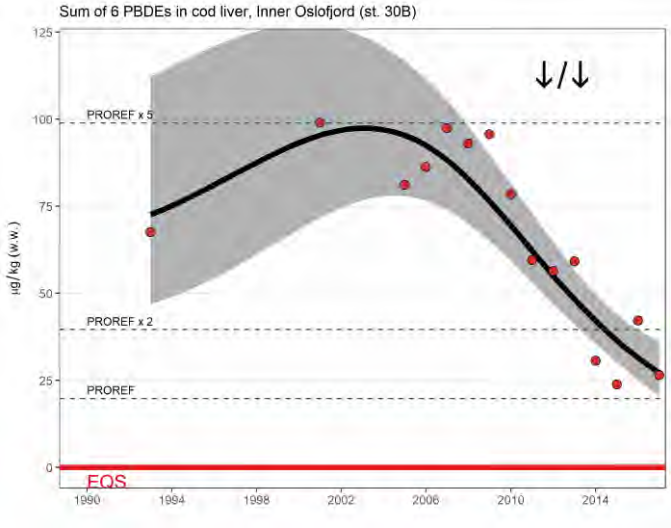
Upward trends
In cod liver, significant upward short-term trends were found for BDE154 at Tjøme (st. 36B), Bømlo (st. 23B) and Austnesfjord (st. 98B1) in Lofoten. In cod liver, a significant upward short-term trend was found for BDE154 at Bømlo (st. 23B) in the Outer Selbjørnfjord.

Downward trends
Both significant downward long- and short-term trends were found for BDE47 in blue mussel from Gressholmen (st. 30A) in the Inner Oslofjord and Bjørkøya (st. 71A) in the Langesundfjord. A significant downward long-term trend was also found for BDEs (28, 47, 99, 100, 153 and 154) at Bjørkøya (st. 71A).

Both significant downward long- and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B) for BDE28, 47, 66, 100 and sum BDEs (28, 47, 99, 100, 153 and 154) (***Figure 43 A***). This was also the result at Kristiansand harbour (st. 13B) for BDE28 and sum BDEs (28, 47, 99, 100, 153 and 154) (***Figure 44 A***). This was also the case at Bømlo (st. 23B) for BDE47 and for sum BDEs (28, 47, 99, 100, 153 and 154) (***Figure 43 B***). Similar trends were observed for Trondheim harbour (st. 80B) for BDE28, 47 and sum BDEs (28, 47, 99, 100, 153 and 154). This was also the result at Tromsø harbour (st. 43B2) for BDE28, 47, 99, 153 and for sum BDEs (28, 47, 99, 100, 153 and 154) (***Figure 44 B***).

Significant downward short-term trends were found for cod liver from the Inner Oslofjord (st. 30B) for BDE49, 99, 153, and 154. This was also the result at Færder (st. 36B) for BDE28, 47 and 99, at Bømlo (st. 23B) in the Outer Selbjørnfjord for BDE28, 49, 66, 99, 100 and 119, and in the Austnesfjord (st. 98B1) in Lofoten for BDE28, 47, 49 and 99.

A



B

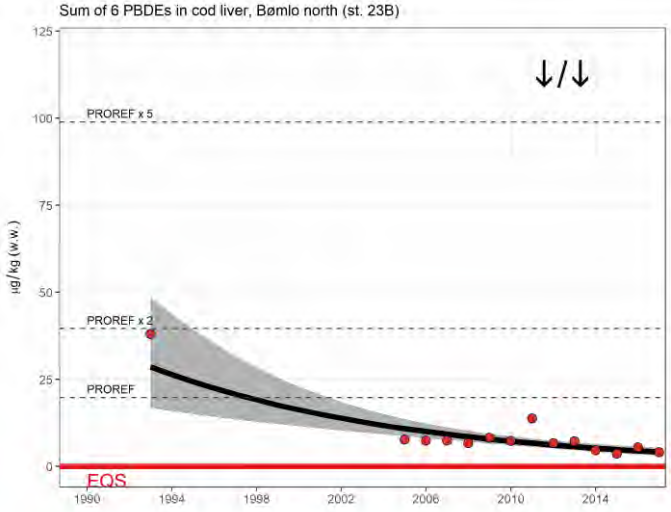
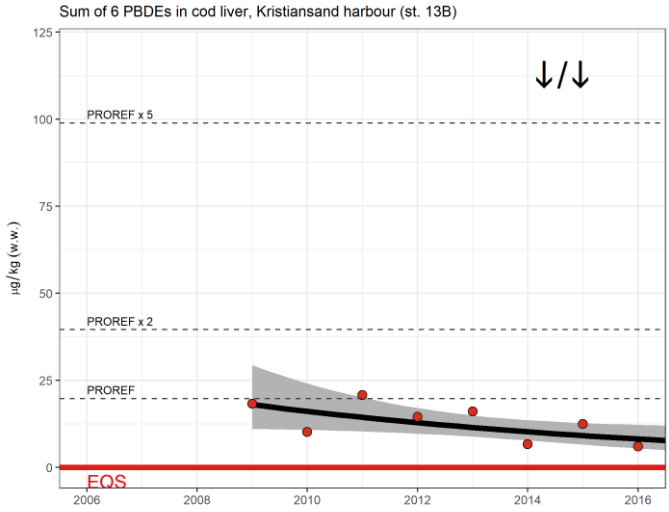


Figure 43. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 1993 or 2009 to 2017 in Inner Oslofjord (st. 30B) (**A**) and Bømlo (st. 23B) (**B**). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C**).

A



B

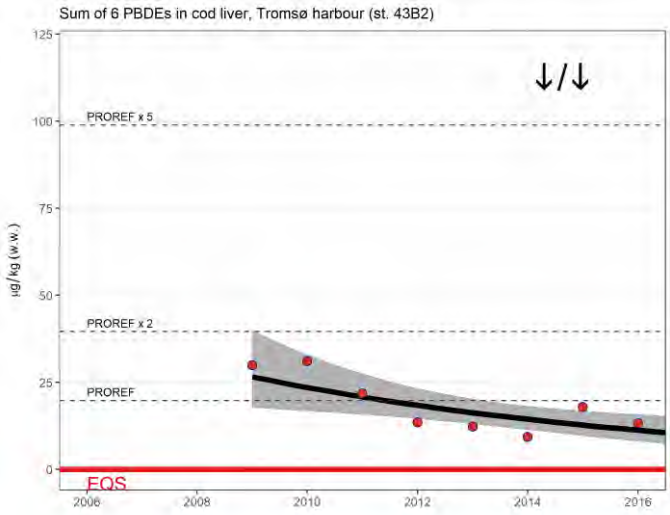


Figure 44. *Median concentrations (mg/kg w.w.) of sum BDEs (28, 47, 99, 100, 153 and 154) in cod liver from 1984 to 2017 at Kristiansand harbour (st. 13B) (**A**) and Tromsø harbour (st. 43B2) (**B**). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

Statistical considerations for cod liver

The standard deviation varied considerably among stations, also for other PBDEs. The highest standard deviation was found in Bergen harbour (st. 24B) for BDE47 (***Table 14***) in 2017. It seems like the deviations were highest in affected areas.

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

PBDEs have been investigated annually in cod liver since 2005. In the Inner Oslofjord (st. 30B), cod have also been analysed for PBDEs in 1993, 1996 and 2001 (***Figure 46***). Samples for similar analyses were also collected from Tjøme (st. 36B) in 1993 and 1996, and from Bømlo (st. 23B) on the west coast in 1996 and 2001. In 2017, PBDEs were analysed in cod from 11 stations (***Table 14***). Of the PBDEs, only congeners BDE28, 47, 99, 100, 154 and 209 were above the limit of quantification (LOQ) in at least half of the samples from each station in cod liver.

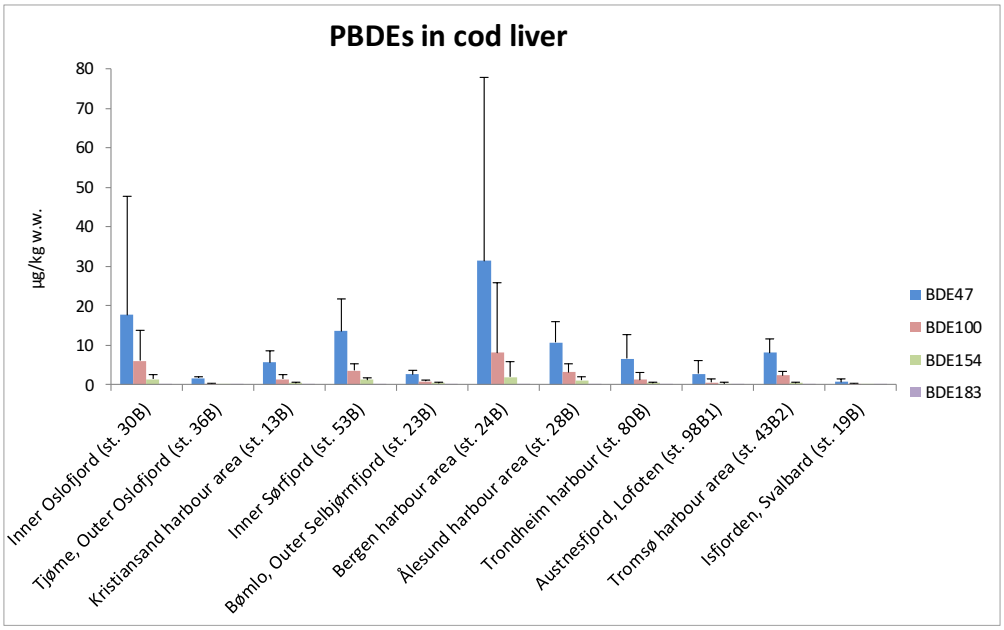


Figure 45. *Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2017. Only the results are shown where concentrations were above the limit of quantification for half or more of the samples. The error bar indicates one standard deviation above the median.*

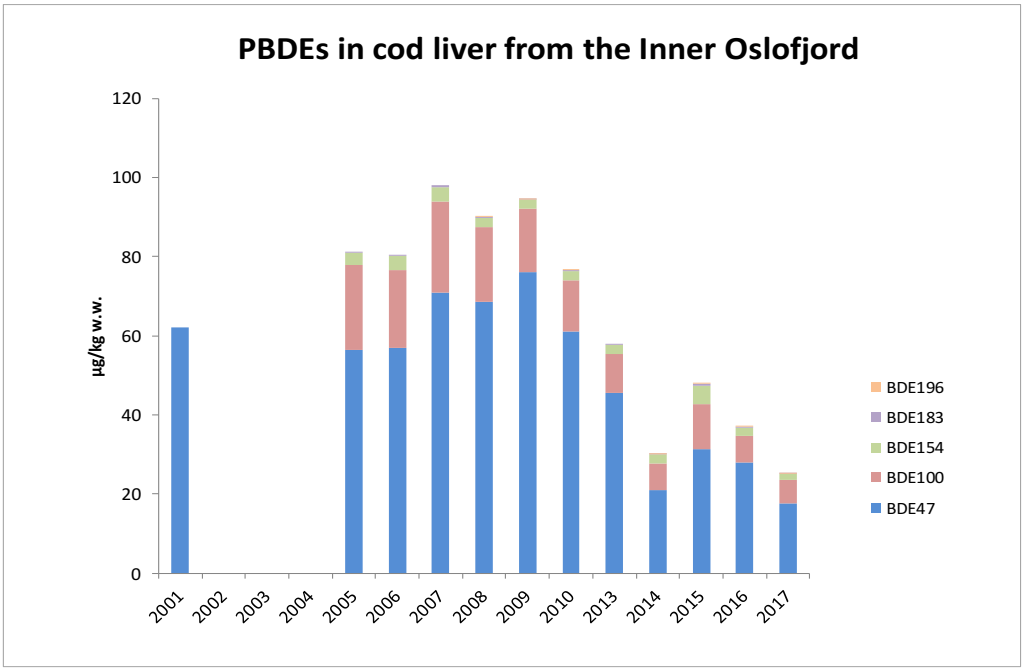


Figure 46. *Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2017 in the Inner Oslofjord (st. 30B).*

***Table 14**. Median concentrations (µg/kg w.w.) and standard deviations for PBDE congeners in blue mussel, cod liver, and eider blood and eggs in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. BDE6S is the sum of BDE -28, -47, -99, -100, -153 and -154 as used in the EQS, whereas BDESS is the sum of all PBDEs analysed (see **Table 7**, see also Chapter 2.9 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	BDE28			BDE47			BDE99			BDE100			BDE126			BDE153		
Species and sampling locality	2017	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[0.0011-0.0011]	0.034	0.004	3[0.0281-0.0348]	0.017	0.002	3[0.0151-0.0186]	0.008	0.001	3[0.0072-0.0087]	0.002	0.000		0.003	0.000	
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.002	0.000	3[0.002-0.002]	0.018	0.002	3[0.0156-0.0186]	0.008	0.001	3[0.0069-0.0091]	0.004	0.000	3[0.004-0.0044]	0.002	0.000		0.003	0.000	
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.001	0.000		0.018	0.002	3[0.0165-0.0201]	0.009	0.001	3[0.0083-0.0106]	0.004	0.000	3[0.0042-0.0049]	0.002	0.000		0.003	0.000	
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.001	0.000		0.020	0.000	1[0.019]	0.016	0.000	1[0.01]	0.007	0.000	1[0.006]	0.002	0.000		0.003	0.000	
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.001	0.000		0.031	0.003	3[0.0278-0.0344]	0.015	0.000	3[0.015-0.0159]	0.009	0.001	3[0.0078-0.0098]	0.002	0.000		0.003	0.000	
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.005	0.000	3[0.0042-0.005]	0.175	0.003	3[0.171-0.176]	0.095	0.003	3[0.0917-0.0974]	0.051	0.001	3[0.0498-0.0516]	0.002	0.000		0.007	0.000	
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.003	0.001	3[0.0024-0.0044]	0.063	0.011	3[0.0546-0.0771]	0.038	0.003	3[0.0365-0.0417]	0.022	0.002	3[0.0203-0.0247]	0.002	0.000		0.004	0.002	
Ålesund harbour (st. 28A2)	3 (3-50)	0.001	0.000	2[0.0011-0.0018]	0.039	0.010	3[0.0303-0.05]	0.026	0.006	3[0.0206-0.0318]	0.016	0.003	3[0.0137-0.0191]	0.002	0.000		0.003	0.000	
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.001	0.000		0.017	0.002	3[0.015-0.0189]	0.006	0.001	3[0.0051-0.0063]	0.005	0.000	3[0.004-0.0049]	0.002	0.000		0.003	0.000	
Bodø harbour (st. 97A3)	3 (3-50)	0.005	0.001	3[0.0043-0.0054]	0.195	0.027	3[0.165-0.219]	0.107	0.003	3[0.102-0.108]	0.055	0.007	3[0.0458-0.0596]	0.002	0.000		0.007	0.001	3[0.006-0.0089]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.001	0.001	2[0.0014-0.0021]	0.024	0.011	3[0.0177-0.0386]	0.016	0.008	3[0.0095-0.025]	0.009	0.004	3[0.0047-0.0128]	0.002	0.000		0.003	0.000	
Svolvær airport area (st. 98A2)	3 (3-50)	0.001	0.000		0.012	0.001	3[0.0099-0.012]	0.003	0.000	3[0.0028-0.0037]	0.004	0.000	3[0.0032-0.0039]	0.002	0.000		0.003	0.000	
Cod, liver																			
Inner Oslofjord (st. 30B)	12 (8-3)	0.381	0.484	12[0.244-1.92]	17.700	30.115	12[13-118]	0.531	0.409	12[0.22-1.37]	6.010	7.765	12[2.91-29]	0.099	0.063	11[0.0633-0.23]	0.064	0.041	11[0.0339-0.14]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	0.071	0.016	10[0.059-0.106]	1.620	0.383	10[1.26-2.65]	0.030	0.015	9[0.0235-0.0722]	0.351	0.095	10[0.239-0.571]	0.018	0.002		0.028	0.002	
Kristiansand harbour area (st. 13B)	12 (5-2)	0.225	0.145	12[0.0711-0.521]	5.680	2.863	12[2.88-10.6]	0.073	0.035	12[0.0299-0.151]	1.440	1.079	12[0.516-3.5]	0.059	0.024	10[0.0338-0.0932]	0.029	0.004	2[0.0319-0.0416]
Inner Sørfjord (st. 53B)	15 (3-2)	0.359	0.165	15[0.261-0.798]	13.600	8.189	15[7.61-35]	0.240	0.168	15[0.0703-0.589]	3.640	1.652	15[1.91-6.86]	0.067	0.025	14[0.0342-0.111]	0.030	0.012	9[0.0288-0.0672]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	0.118	0.075	13[0.0803-0.334]	2.650	1.061	13[1.4-5.42]	0.020	0.016	4[0.026-0.0769]	0.828	0.297	13[0.519-1.68]	0.036	0.015	11[0.0287-0.0699]	0.029	0.002	2[0.0307-0.034]
Bergen harbour area (st. 24B)	15 (4-2)	1.010	0.881	15[0.227-4.11]	31.400	46.580	15[6.65-196]	0.470	0.391	15[0.231-1.81]	8.130	17.773	15[1.74-73.3]	0.058	0.105	15[0.0236-0.414]	0.100	0.126	15[0.0333-0.506]
Ålesund harbour area (st. 28B)	15 (3-2)	0.352	0.172	15[0.0254-0.676]	10.700	5.171	15[0.628-17.9]	0.207	0.857	13[0.0506-2.76]	3.180	2.065	15[0.162-6.78]	0.126	0.120	14[0.0558-0.486]	0.045	0.160	8[0.0446-0.542]
Trondheim harbour (st. 80B)	15	0.333	0.255	14[0.0704-0.878]	6.540	6.272	15[0.0525-22.1]	0.094	0.116	12[0.0184-0.435]	1.290	1.798	14[0.786-5.92]	0.054	0.026	14[0.0219-0.106]	0.028	0.008	2[0.0357-0.0539]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)	0.108	0.221	11[0.0244-0.805]	2.790	3.337	11[0.318-11.7]	0.035	0.066	7[0.0279-0.218]	0.555	0.832	11[0.0464-2.94]	0.022	0.016	7[0.0138-0.0662]	0.029	0.011	1[0.038]
Tromsø harbour area (st. 43B2)	15	0.222	0.113	15[0.113-0.488]	8.080	3.387	15[2.72-14.9]	0.161	0.319	15[0.0418-1.11]	2.360	0.942	15[0.728-3.45]	0.024	0.010	14[0.0204-0.0499]	0.029	0.027	4[0.0397-0.115]
Isfjorden, Svalbard (st. 19B)	15	0.053	0.044	15[0.0416-0.2]	0.750	0.658	15[0.501-2.98]	0.020	0.001		0.162	0.135	15[0.0959-0.612]	0.020	0.003	2[0.0208-0.0326]	0.029	0.002	
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.000		0.032	0.000		0.019	0.000		0.005	0.000	1[0.005]	0.002	0.000		0.006	0.000	
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.031	5[0.0348-0.104]	0.064	0.038	14[0.0367-0.176]	0.027	0.028	10[0.0214-0.13]	0.042	0.027	15[0.0122-0.128]	0.003	0.001		0.014	0.007	12[0.0074-0.0323]

Table 14. *(cont.)*

Component	Count	BDE154			BDE183			BDE196			BDE209			BDE6S			BDESS		
Species and sampling locality	**2017**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**	**Med.**	**S.d.**	**D.d.i**	**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		0.005	0.000		0.010	0.000		0.066	0.006	3[0.0574-0.0692]	0.258	0.006	3[0.2503-0.2621]	0.258	0.006	3[0.2503-0.2621]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.003	0.000		0.005	0.000		0.010	0.000		0.039	0.003	3[0.0345-0.0392]	0.154	0.002	3[0.1505-0.1547]	0.154	0.002	3[0.1505-0.1547]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.003	0.000		0.005	0.000		0.009	0.001		0.036	0.003	3[0.0356-0.0419]	0.148	0.012	3[0.1448-0.1679]	0.148	0.012	3[0.1448-0.1679]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.003	0.000		0.005	0.000		0.010	0.000		0.049	0.000	1[0.049]	0.269	0.000	1[0.268]	0.269	0.000	1[0.268]
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.003	0.000		0.005	0.000		0.010	0.000		0.061	0.005	3[0.0575-0.0669]	0.246	0.007	3[0.2442-0.2568]	0.246	0.007	3[0.2442-0.2568]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.007	0.000	3[0.0063-0.0071]	0.005	0.000	1[0.005]	0.010	0.000		0.339	0.002	3[0.3356-0.3404]	0.556	0.002	3[0.5544-0.5591]	0.556	0.002	3[0.5544-0.5591]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.003	0.001	1[0.005]	0.005	0.000		0.010	0.000		0.135	0.019	3[0.1199-0.1575]	0.338	0.030	3[0.3157-0.3755]	0.338	0.030	3[0.3157-0.3755]
Ålesund harbour (st. 28A2)	3 (3-50)	0.003	0.000		0.005	0.000		0.010	0.000		0.088	0.019	3[0.0714-0.1087]	0.370	0.038	3[0.3665-0.4339]	0.370	0.038	3[0.3665-0.4339]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.003	0.000		0.005	0.000		0.009	0.001		0.033	0.003	3[0.0309-0.0362]	0.139	0.003	3[0.136-0.1428]	0.139	0.003	3[0.136-0.1428]
Bodø harbour (st. 97A3)	3 (3-50)	0.011	0.001	3[0.01-0.0124]	0.013	0.003	3[0.0095-0.0154]	0.010	0.000		0.379	0.035	3[0.3384-0.408]	0.799	0.087	3[0.7749-0.9365]	0.799	0.087	3[0.7749-0.9365]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.003	0.000		0.005	0.000		0.010	0.000		0.055	0.022	3[0.04-0.0843]	0.242	0.028	3[0.2307-0.283]	0.242	0.028	3[0.2307-0.283]
Svolvær airport area (st. 98A2)	3 (3-50)	0.003	0.000		0.005	0.000		0.010	0.001		0.026	0.002	3[0.0227-0.0272]	0.227	0.013	3[0.2119-0.2384]	0.227	0.013	3[0.2119-0.2384]
Cod, liver																			
Inner Oslofjord (st. 30B)	12 (8-3)	1.355	1.146	12[0.498-4.73]	0.045	0.022	2[0.0656-0.117]	0.095	0.011		26.471	38.926	12[18.1258-152.775]	30.218	42.405	12[21.4923-168.8753]	30.218	42.405	12[21.4923-168.8753]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	0.135	0.032	10[0.0988-0.205]	0.046	0.004		0.092	0.008		2.253	0.521	10[1.7053-3.6038]	4.281	0.644	10[3.5156-5.8447]	4.281	0.644	10[3.5156-5.8447]
Kristiansand harbour area (st. 13B)	12 (5-2)	0.413	0.274	12[0.137-0.997]	0.049	0.003		0.097	0.006		7.728	4.330	12[3.7823-15.6427]	10.235	5.037	12[5.4788-20.3648]	10.235	5.037	12[5.4788-20.3648]
Inner Sørfjord (st. 53B)	15 (3-2)	1.250	0.377	15[0.719-2.02]	0.047	0.002	1[0.04]	0.094	0.004		19.200	10.175	15[11.3836-44.0784]	23.886	10.791	15[14.8402-49.1676]	23.886	10.791	15[14.8402-49.1676]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	0.439	0.151	13[0.287-0.768]	0.048	0.002		0.096	0.004		4.077	1.521	13[2.3998-8.2615]	7.329	3.650	13[4.6375-18.145]	7.329	3.650	13[4.6375-18.145]
Bergen harbour area (st. 24B)	15 (4-2)	1.990	3.985	15[0.633-14.4]	0.048	0.164	3[0.0897-0.653]	0.096	0.004		41.336	67.211	15[9.7946-282.491]	47.577	71.661	15[13.3218-304.7123]	47.577	71.661	15[13.3218-304.7123]
Ålesund harbour area (st. 28B)	15 (3-2)	1.170	0.739	15[0.0529-2.66]	0.048	0.011	3[0.0541-0.084]	0.095	0.004		15.143	8.745	15[0.9118-31.003]	18.332	10.456	15[2.6398-37.143]	18.332	10.456	15[2.6398-37.143]
Trondheim harbour (st. 80B)	15	0.393	0.289	14[0.219-0.985]	0.048	0.005	1[0.052]	0.096	0.010		8.842	8.426	15[0.1766-29.6379]	12.314	9.472	15[2.135-36.5033]	12.314	9.472	15[2.135-36.5033]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)	0.217	0.325	10[0.117-1.19]	0.049	0.019		0.097	0.037		3.844	4.748	11[0.4664-16.8913]	5.940	5.372	11[2.3472-21.2678]	5.940	5.372	11[2.3472-21.2678]
Tromsø harbour area (st. 43B2)	15	0.473	0.236	15[0.206-0.883]	0.049	0.002	2[0.0476-0.0507]	0.097	0.004		10.897	4.559	15[4.0494-19.6017]	14.442	5.007	15[6.5983-23.2852]	14.442	5.007	15[6.5983-23.2852]
Isfjorden, Svalbard (st. 19B)	15	0.078	0.061	15[0.0576-0.279]	0.049	0.003		0.097	0.005		1.170	0.891	15[0.7449-4.119]	3.327	1.094	15[2.5221-6.8778]	3.327	1.094	15[2.5221-6.8778]
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.004	0.000	1[0.004]	0.005	0.001	1[0.0]	0.009	0.000		0.070	0.000	2[0.0701-0.071]	0.313	0.089	6[0.3169-0.6242]	30.218	42.405	3[60-66.6667]
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.034	0.011	15[0.0152-0.0502]	0.005	0.000	2[0.0049-0.006]	0.009	0.000		0.208	0.101	15[0.0884-0.4351]	0.550	0.496	15[0.3838-2.0896]	30.218	42.405	15[17.2027-102.4178]

Levels in blue mussel

Only the congener BDE47 showed concentrations above the LOQ for half or more of the samples at all stations (***Table 12***, ***Table 14***, ***Figure 47***).

The most dominant congener in 2017 was BDE47, which was also the case in 2016. BDE47 was detected at all stations in 2017, as in 2016. The highest median concentration was found in mussels from Bodø harbour (st. 97A3) (0.195 µg BDE47/kg w.w.).

Statistical considerations of blue mussel

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

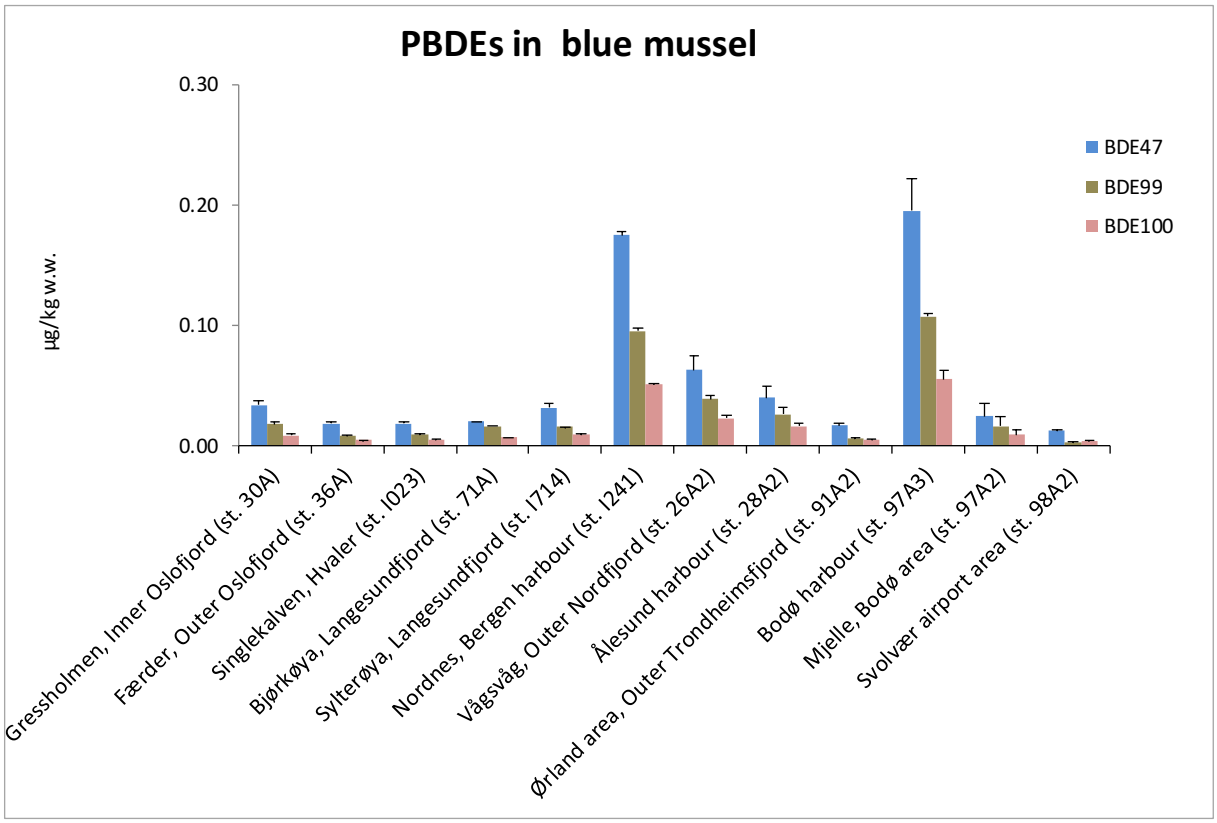


Figure 47*. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2017. Only the results where concentrations were above the limit of quantification for half or more of the samples are shown. The error bar indicates one standard deviation above the median.*

Inner Oslofjord

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

In the present study, cod liver from the Inner Oslofjord showed a median concentration of 17.7 µg BDE47/kg (w.w.), while the mean concentration in a comparable study in 2017 (Ruus *et al*. 2018, in prep) was 42.0 µg BDE47/kg (w.w.). The median concentration of BDE100 was

6.0 µg /kg (w.w.) in the present study, while the mean concentration was 11.3 µg/kg (w.w.) in the study performed by Ruus *et al*. (2018, in prep). The median concentration of BDE154 was 1.4 µg/kg (w.w.) in the present study, while the mean concentration was 1.9 µg/kg (w.w.) in the comparable study (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn. The median concentration of sum BDE in cod liver in the Inner Oslofjord was 30.218 µg/kg (w.w.) in the present study, while mean sum BDEs was 57.396 µg/kg w.w. (1.059 (BDE-28), 42.001 (BDE-47), 0.923 (BDE-99), 11.334 (BDE-100), 0.134 (BDE-153) and 1.945 (BDE-154)) in the comparable study in the Inner Oslofjord (Ruus *et al*. 2018, in prep).

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of BDEs (28, 47, 99, 100, 153 and 154) were <0.070 µg/kg w.w. in blood and 0.208 µg/kg w.w. in egg. The concentrations of BDE47 in eider were <0.031800 µg/kg w.w. in blood and 0.064 µg/kg w.w. in egg.

Other studies

Median concentrations for the sum BDEs (BDE28, 47, 66, 49+71, 77, 99, 100, 119, 153, 154, 183, 209) found at presumed reference stations like Lofoten (8.49 µg/kg w.w.), Færder (9.61 µg/kg w.w.), Lista (12.9 µg/kg w.w.) and Bømlo-Sotra (23.8 µg/kg w.w.) indicate background levels in diffusely contaminated areas for cod liver (Fjeld *et al*. 2005 – TA-2096/2005). This is lower than the sum BDEs (28, 47, 99, 100, 153 and 154) (26.3 µg/kg w.w.) found at MILKYS cod stations in the Inner Oslofjord (st. 30B) (cf. ***Figure 45***).

The congeners BDE47 and 100 were the most dominant in 2017, as in previous years. The low concentrations of BDE99 could be due to the debromination to BDE47, because BDE99 is more prone to biotransformation than other common PBDE such as BDE47 (Streets *et al*. 2006). Furthermore, BDE47 is also reported to be a more stable congener than BDE99, (Benedict *et al*. 2007). Investigations of brown trout (*Salmo trutta)*, smelt (*Osmerus eperlanus*) and vendace (*Coregonus albula*) in lake Mjøsa showed that the decrease was greatest for BDE99, which probably is due to a biotransformation (debromination) to BDE47 (Fjeld *et al*. 2012 – TA-2889/2012). In recent years, there has been a clear reduction of PBDE-concentrations in freshwater fish from Mjøsa (Fjeld *et al*. 2017).

In this study, the median concentration of PBDE47 (0.064 µg/kg w.w). in eider egg from Svalbard was within the same range as in another study of eider from three stations in northern Norway and one at Svalbard (mean 0.12 ± 0.06 µg/kg w.w.) (Harju *et al*. 2013).

General, large scale trends

No significant upward long-term trends were found. The only significant upward short-term trend was found in cod liver from Bømlo (st. 23B).

There was a total of 31 significant downward long-term trends (sum BDE not included), two were found in blue mussel and 29 in cod liver. Of 14 significant downward short-term trends, two were found in blue mussel and 12 in cod liver.

These results of dominating downward trends are more in line with the general decreasing trends for penta-mix PBDEs (that includes BDE100, Law *et al*. 2014), PBDEs in European emissions (Schuster *et al*. 2010) and in marine mammals in the Arctic and North Atlantic since 2000 (Rotander *et al*. 2012). It can be noted that after 2002 a sharp decline in concentrations of PBDEs (as well as PFASs) was observed in blood from newborns in New York state (Ma *et al*. 2013).

Furthermore, both the penta- and octa PBDE mixtures has been globally regulated through the Stockholm convention since 2009.

3.2.23 Perfluorinated alkylated substances (PFAS)

Perfluorinated alkylated substances (PFAS) are organofluorine compounds used as oil-, stain- and water-repellent surfactants and several other products. In this study, PFAS were analysed in cod liver at 10 stations, and in eider blood and eggs at one station (***Table 12***, ***Figure 49***). 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 EU-priority substances

The EQS for PFOS in biota (fish) is 9.1 µg/kg w.w. which applies to whole fish (2013/39/EU). Applying this for blue mussel, all stations were below the EQS. The EQS cannot be directly compared to concentrations found in different tissues of fish. We have in this 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 3.9 µg/kg w.w. in the Inner Oslofjord.

Environmental Quality Standards (EQS) for River Basin Specific Pollutants

The EQS for PFOA is 91.3 µg/kg w.w. in biota (2013/39/EU). Applying this for blue mussel, all stations were below the EQS. Applying this EQS for cod liver, all concentrations were below EQS (see ***Table 11***).

Levels exceeding PROREF

Cod liver from the Inner Oslofjord (st. 30B) exceeded the provisional high reference concentrations (PROREF) for both PFAS and PFOSA in 2017.

Decrease in PROREF factor since 2016

In 2017, cod liver from the Inner Oslofjord exceeded PROREF for both PFAS and PFOSA by a factor of up to two times, while there were no exceedances in 2016.

Downward trends

For both PFOS and PFOSA, both significant downward long- and short-term trends were found in cod liver from Tjøme (st. 36B), Kristiansand harbour (st. 13B), Inner Sørfjord (st. 53B), Austnesfjord (st. 98B1) in Lofoten and Tromsø harbour (st. 43B2). Both significant downward long- and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B) regarding PFOS and at Bømlo (st. 23B) for PFOSA.

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

Levels in eider

In eider at Breøyane (st. 19N) in the Kongsfjord at Svalbard, the concentrations of PFOS were 0.250 µg/kg w.w. in blood and 2.1 µg/kg w.w. in egg. The concentrations of PFOA were <0.5 µg/kg w.w. in blood and <0.5 µg/kg w.w. in egg.

PFOS

The median concentration of perfluorooctonoic sulfonate (PFOS) in cod liver was highest in the Inner Oslofjord (st. 30B, 3.9 µg/kg w.w.) and lowest at Svalbard (st. 19B, 0.200 µg/kg w.w.) (***Table***

15). The concentration found in the Inner Oslofjord had increased from 2.7 µg/kg (w.w.) in 2016 to 3.9 µg/kg (w.w.) in 2017. At Tjøme (st. 36B) the concentrations had increased from 2.1 µg/kg (w.w.) in 2016 to 2.9 µg/kg (w.w.) in 2017.

Significant downward trends for PFOS were dominating in 2017, as in the previous years. Both significant downward long- and short-term trends were found for PFOS from the Inner Oslofjord (st. 30B), Tjøme (st. 36B), Kristiansand harbour (st. 13B), Inner Sørfjord (st. 53B), Austnesfjord (st. 98B1) in Lofoten and Tromsø harbour (st. 43B2).

Cod from the Inner Oslofjord had higher levels of PFOS in liver than all other stations (see also ***Figure 49***).

PFOSA

Perfluorooctane sulfonamide (PFOSA) had a maximum median concentration of 7.8 µg/kg (w.w.) in the Inner Oslofjord (st. 30B), and a minimum level at Svalbard (st. 19B) (<0.1 µg/kg w.w.). The concentration of PFOSA was higher than PFOS in the Inner Oslofjord (***Figure 49***, ***Figure 50***), as in 2016. In 2016, the concentration of PFOSA was higher than PFOS at Tjøme (st. 36B), but not in 2017. PFOSA was significantly higher in cod liver from the Inner Oslofjord than any other station (Tukey-Kramer HSD test)

Both significant downward long- and short-term trends were also found for PFOSA from Kristiansand harbour (st. 13B) and Bømlo (st. 23B).

Both significant downward long- and short-term trends were also found for PFOSA from Tjøme (st. 36B), Kristiansand harbour (st. 13B), the Inner Sørfjord (st. 53B), Bømlo (st. 23B), Austnesfjord (st. 98B1) and Tromsø (st. 43B2).

The median concentrations of the remaining PFASs were mostly below the quantification limits (***Table 15***).

PFNA

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

Inner Oslofjord

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

In this study, cod liver from the Inner Oslofjord had median concentrations of 3.9 µg PFOS/kg (w.w.) and 7.9 µg PFOSA/kg (w.w.) in 2017. Cod liver from a comparable study from the Inner Oslofjord in 2017 had higher mean concentrations of both PFOS (4.2 µg/kg w.w.) and PFOSA (11.4 µg/kg w.w.) (Ruus *et al*. 2018, in prep). The collection of cod in both studies took place during the autumn.

Schøyen and Kringstad (2011) analysed PFAS in cod blood samples from the same individuals as were analysed in the MILKYS programme in 2009 from the Inner Oslofjord (Green *et al*. 2010b – TA-2716/2010). 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 *et al.* 2014) as opposed to what was observed in the present study.

Other studies

In this study, the median concentrations of PFOS (2.1 µg/kg w.w.) and PFOSA (<0.1 µg/kg w.w.) in eider egg from Svalbard were within the same ranges as in another study of eider from three stations in northern Norway and one at Svalbard (mean 3.7±2.3 µg PFOS/kg w.w. and 0.26±0.14 µg PFOSA/kg w.w) (Harju *et al.* 2013).

Median concentrations of PFOS in cod liver from presumed reference stations like Lofoten, Kvænangen/Olderfjord north of Skjervøy and the Varangerfjord indicated that high background concentrations in diffusely contaminated areas might be around 10 µg/kg w.w. (Bakke *et al.* 2007 – TA-2284/2007). All concentrations observed in this present study were lower (maximum 2.7 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 *et al.* 2011a – TA-2810/2011) and from three stations in the Norwegian Sea was 0.75, 0.82 and 11 µg/kg w.w. (Green *et al.* 2012b – TA-2935/2012).

PFAS in freshwater fish was investigated in 2016 (Fjeld *et al.* 2017 – M-807|2017). The concentrations of long-chained compounds, like PFOS and PFOSA, increased with trophic levels with the highest levels in brown trout liver. The mean PFOS-concentrations in liver from brown trout, smelt, charr (*Salvelinus alpinus*) and vendace 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

PFOA has been strictly regulated nationally in consumer products from June 2014[22]. PFOA-data at all stations was inadequate for trend analysis due to concerns about the limit of quantifications.

General, large scale trends

Six of the 10 cod liver stations showed significant downward short-term trends in PFOS (for the period 2008-2017). Significant downward trends for PFOS were dominating in 2013, 2014, 2015, 2016 and 2017, unlike in 2012 when no trends were observed. The observed downward trends could reflect the overall reduction in production and use of PFOS and PFOA for the past 30 years (Nøst *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).

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

Discharges of PFAS (per- and polyfluorinated compounds, SPFAS[23]) to water from land-based industries are shown in ***Figure 49***. The discharges to water had increased to 4 171 g PFAS in 2017 from 1 013 g in 2015.

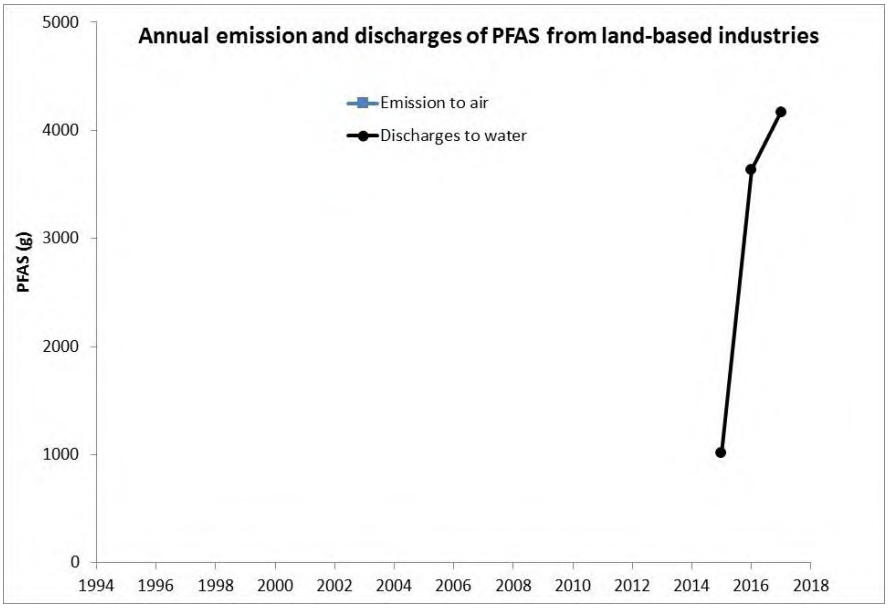


Figure 48. *Annual discharges of PFAS to water from land-based industries for 2015 to 2017 (data from www.norskeutslipp.no, 25. September 2018). No data for emissions to air are reported, and no data for discharges to water are reported for 1994-2014. Note that emissions and discharges from municipal 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.*

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

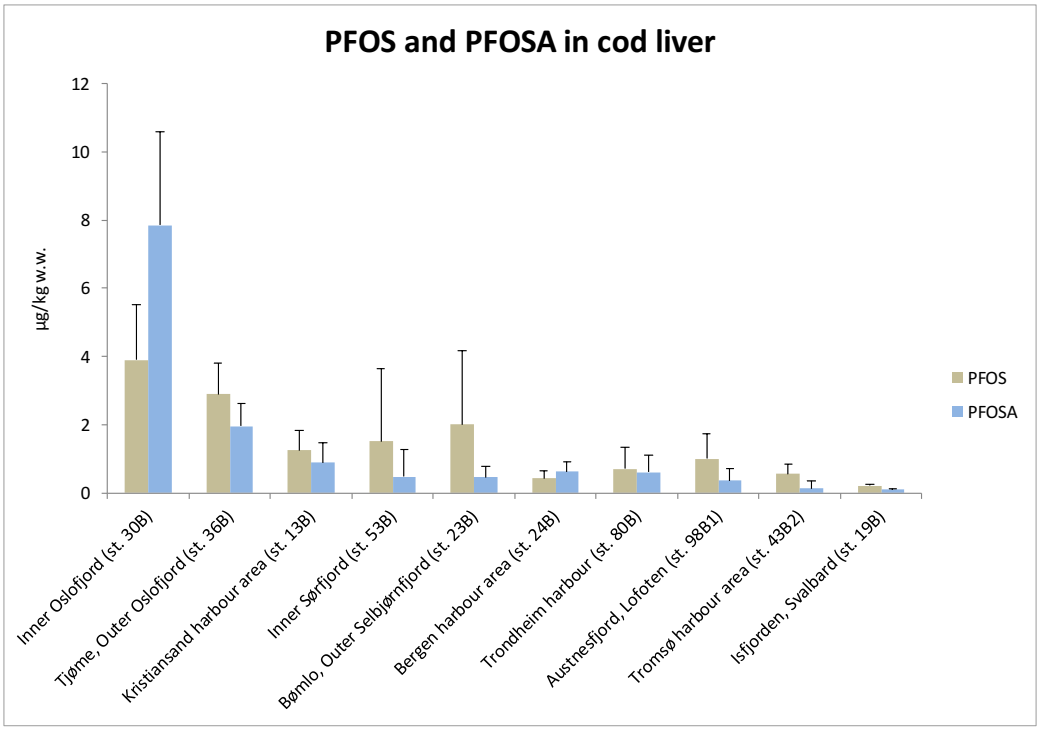


***Figure 49**. Median concentrations (µg/kg w.w.) of two PFAS compounds in cod liver in 2017. The error bar indicates one standard deviation above the median. (See also **Table 15**).*

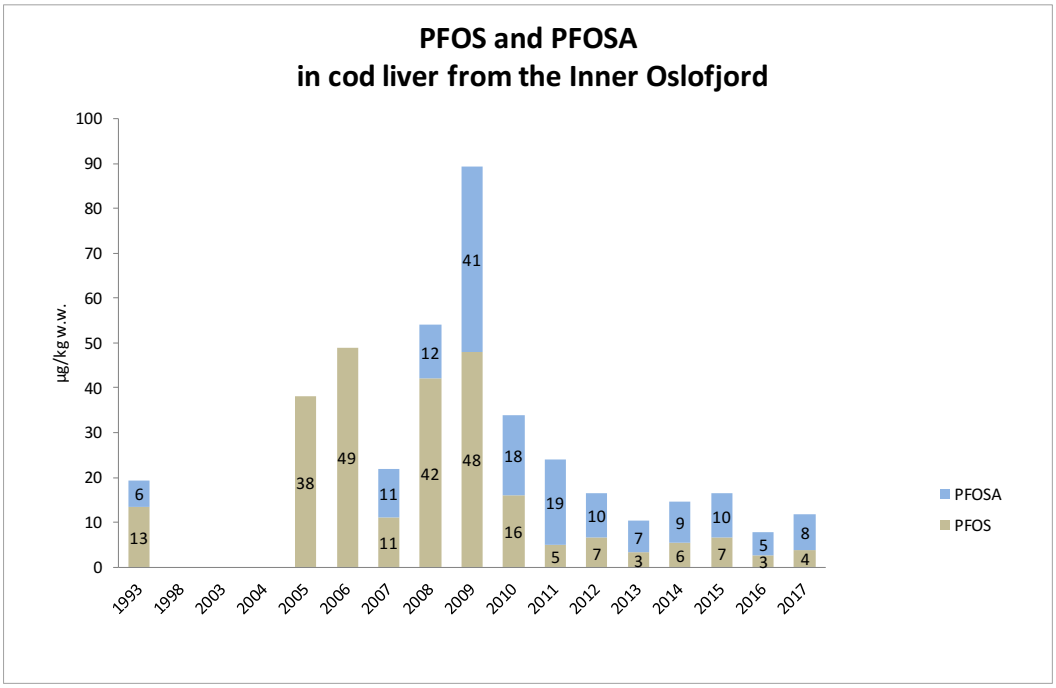


***Figure 50**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2017 in the Inner Oslofjord (st. 30B).*

***Table 15**. Median concentrations (µg/kg w.w.) and standard deviations of the PFAS-compounds analysed in cod liver, and eider blood and eggs in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	PFNA			PFOA			PFOS			PFOSA			PFBS			PFUdA		
Species and sampling locality	2017	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Cod, liver																			
Inner Oslofjord (st. 30B)	12 (8-3)	0.5	0		0.5	0		3.9	1.6278	12[1.7-7.4]	7.85	2.7556	12[3.5-11]	0.2	0.6657	3[0.24-2.5]	1.45	0.4441	12[0.67-2.1]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	0.5	0		0.5	0		2.9	0.9188	10[0.99-4]	1.95	0.6776	10[0.76-3.1]	0.2	0		0.535	0.1541	8[0.49-0.84]
Kristiansand harbour area (st. 13B)	12 (5-2)	0.5	0		0.5	0		1.25	0.587	12[0.82-2.6]	0.89	0.572	12[0.54-2.1]	0.2	0		0.555	0.1555	9[0.43-0.92]
Inner Sørfjord (st. 53B)	15 (3-2)	0.5	0		0.5	0		1.5	2.1383	15[0.18-6.6]	0.47	0.8083	11[0.11-3.1]	0.2	0.3956	2[0.93-1.6]	0.4	0.2759	7[0.41-1.3]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	0.5	0		0.5	0		2	2.1651	13[0.75-7.8]	0.46	0.3093	13[0.1-1.1]	0.37	0.7451	8[0.2-2.3]	0.4	0.2573	6[0.41-1.1]
Bergen harbour area (st. 24B)	15 (4-2)	0.5	0		0.5	0.1549	1[1.]	0.42	0.212	15[0.16-0.88]	0.62	0.2835	15[0.26-1.2]	0.2	0		0.4	0.4084	7[0.44-2]
Trondheim harbour (st. 80B)	15	0.5	0		0.5	0		0.7	0.6453	15[0.27-2.9]	0.61	0.4832	15[0.19-2]	0.2	0		0.49	0.243	9[0.41-1.1]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)	0.5	0		0.5	0		1	0.7467	11[0.32-2.6]	0.35	0.3667	10[0.15-1.2]	0.2	0		0.4	0.1733	5[0.53-0.87]
Tromsø harbour area (st. 43B2)	15	0.5	0		0.5	0		0.56	0.2878	15[0.17-1.2]	0.13	0.2143	10[0.12-0.93]	0.2	0		0.4	0.0485	3[0.51-0.53]
Isfjorden, Svalbard (st. 19B)	15	0.5	0		0.5	0		0.2	0.0413	15[0.12-0.27]	0.1	0.0077	1[0.1]	0.2	0.9514	4[0.25-3.9]	0.4	0.1289	5[0.49-0.85]
Eider, blood																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.5	0		0.5	0		0.25	0.2008	14[0.13-0.89]	0.1	0		0.2	0		0.4	0	
Eider, egg																			
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.63	0.6435	13[0.51-2.5]	0.5	0		2.1	2.2868	15[0.57-8.4]	0.1	0		0.2	0		0.72	0.232	13[0.49-1.1]

3.2.24 Hexabromocyclododecanes (HBCD)

Hexabromocyclododecanes (HBCD) is a persistent pollutant which bioaccumulate and undergo long-range transports. HBCD is one of the substances identified as priority hazardous substances (2013/39/EU) and was globally regulated under the Stockholm convention in 2013. HBCD was analysed in liver of cod from 13 stations, in blue mussel from 12 stations, and in blood and eggs of eider from one station.

Environmental Quality Standards (EQS) for EU-priority substances

When applying the EQS for HBCD (167 µg/kg w.w.), all concentrations in blue mussel and cod liver were below EQS in 2017.

Levels exceeding PROREF

The median concentration of HBCD in blue mussel from Nordnes, Bergen Harbour (st. I241) and Bodø harbour (st. 97A3) exceeded the provisional high reference concentration (PROREF) by a factor of two to five.

The median concentration of HBCD in cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF by a factor of up to two. Maximum concentration of HBCD was 46.8 µg/kg w.w.

Downward trends

There were significant downward long-term and short-term trends for HBCD in cod liver from Stathelle area, Langesundfjord (st. 71B) (***Figure 52 A***). A significant downward short-term trend was also found for HBCD in liver of cod from Tjøme, Outer Oslofjord (st. 36B) (***Figure 52 B***). Significant downward long-term trend was found for HBCD in blue mussel from Gressholmen, Inner Oslofjord (st. 30A) (***Figure 52 C***).

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 51***, ***Table 16***). Median concentration of HBCD in cod liver from the Inner Oslofjord was 8.238 µg/kg w.w.

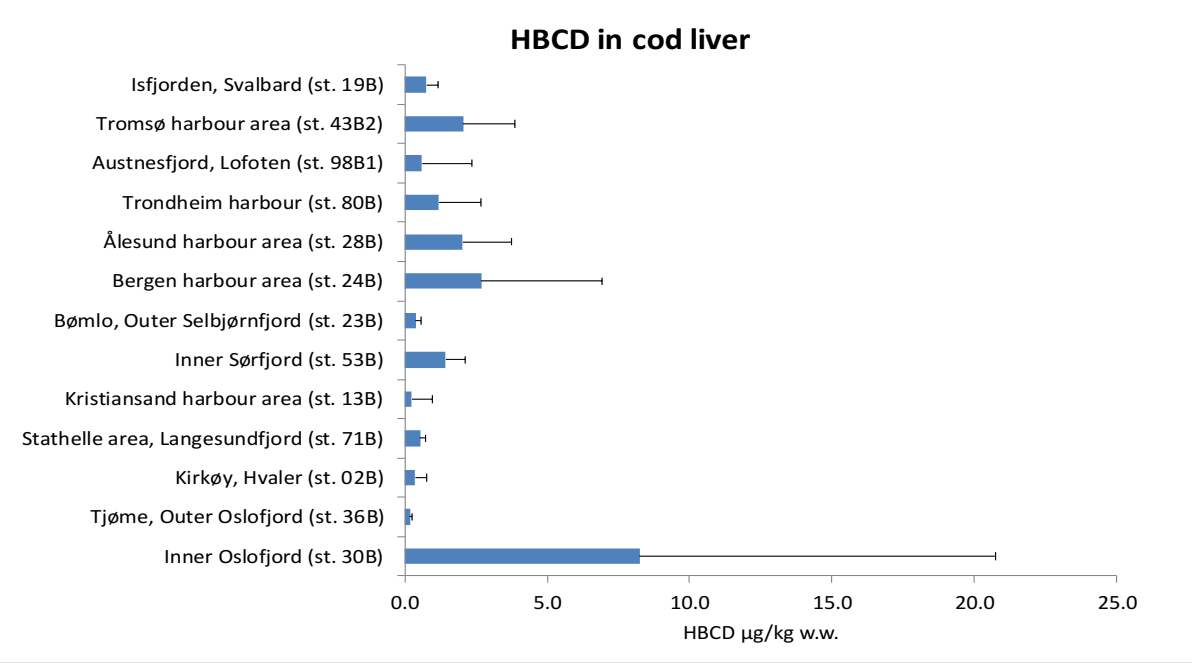
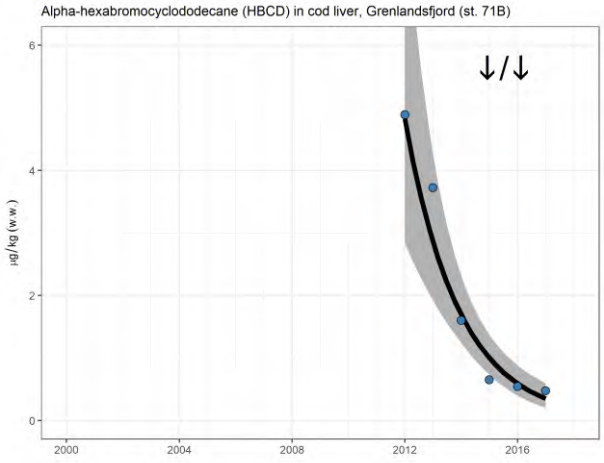
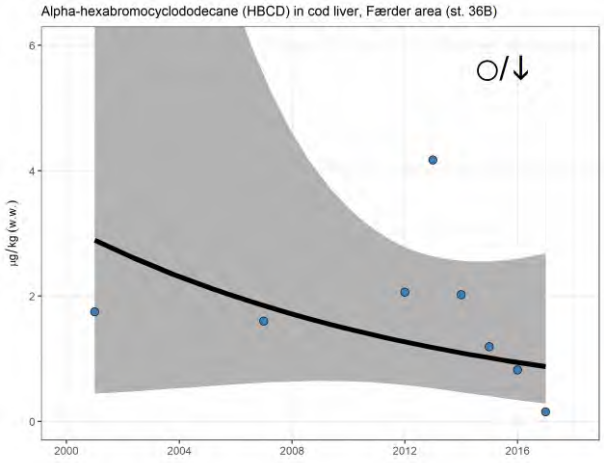


Figure 51*. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver in 2017. The error bar indicates one standard deviation above the median.*

A



B



C

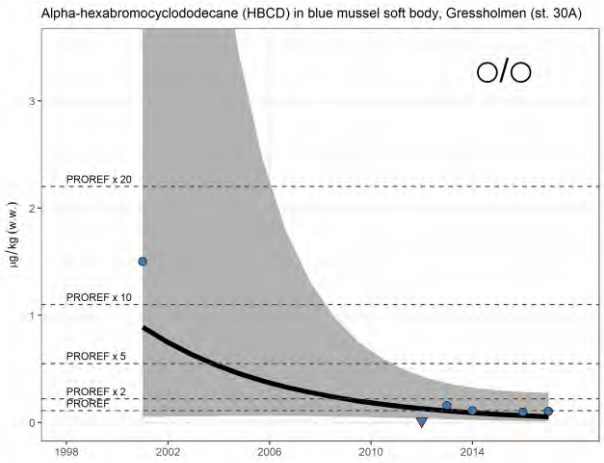


Figure 52. *Median concentrations (mg/kg w.w.) of α–HBCD (HBCDA) in cod liver from 2001 or 2012 to 2017 in Stathelle area, Langesundfjord (st. 71B) (**A**) and Tjøme, Outer Oslofjord (st. 36B) (**B**) and in blue mussel from Gressholmen, Inner Oslofjord (st. 30A) (**C**). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C**).

***Table 16**. Median concentration (µg/kg w.w.) with standard deviation of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver, blue mussel and eider in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	a-HBCD			g-HBCD			b-HBCD			HBCD		
Species and sampling locality	2017	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)	0.106	0.010	3[0.0919-0.111]	0.006	0.000		0.121	0.011	3[0.105-0.1268]	0.009	0.001	3[0.0072-0.0101]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	0.025	0.005	3[0.0176-0.0263]	0.005	0.000		0.040	0.012	3[0.0284-0.0517]	0.009	0.008	2[0.0093-0.0201]
Singlekalven, Hvaler (st. I023)	3 (3-50)	0.016	0.006	3[0.0073-0.0182]	0.005	0.000		0.027	0.006	3[0.0167-0.0282]	0.005	0.000	
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.020	0.000	1[0.019]	0.006	0.000		0.031	0.000	1[0.030]	0.006	0.000	
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	0.046	0.003	3[0.0403-0.0464]	0.006	0.000		0.059	0.004	3[0.0527-0.0601]	0.007	0.001	3[0.0067-0.0078]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	0.245	0.009	3[0.233-0.251]	0.025	0.006	3[0.0161-0.0278]	0.303	0.008	3[0.2896-0.3037]	0.033	0.004	3[0.0288-0.0366]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	0.078	0.011	3[0.0634-0.0845]	0.007	0.001	2[0.0066-0.0078]	0.099	0.012	3[0.0814-0.1047]	0.012	0.002	3[0.0114-0.0148]
Ålesund harbour (st. 28A2)	3 (3-50)	0.066	0.023	3[0.0467-0.093]	0.009	0.004	3[0.009-0.0167]	0.100	0.048	3[0.0843-0.1749]	0.029	0.022	3[0.0245-0.0652]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	0.026	0.004	3[0.0217-0.0291]	0.005	0.000		0.035	0.004	3[0.0313-0.0402]	0.005	0.001	1[0.006]
Bodø harbour (st. 97A3)	3 (3-50)	0.350	0.028	3[0.31-0.364]	0.026	0.002	3[0.0224-0.0269]	0.481	0.024	3[0.4474-0.4948]	0.105	0.006	3[0.104-0.115]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	0.021	0.011	2[0.0208-0.0278]	0.006	0.000		0.033	0.011	2[0.0326-0.0394]	0.006	0.000	
Svolvær airport area (st. 98A2)	3 (3-50)	0.016	0.006	3[0.0114-0.0236]	0.006	0.000		0.028	0.010	3[0.0224-0.0424]	0.007	0.004	2[0.0069-0.0129]
Cod, liver													
Inner Oslofjord (st. 30B)	12 (8-3)	8.105	12.357	12[3.01-46.8]	0.043	0.051	8[0.033-0.185]	8.238	12.510	12[3.1343-47.406]	0.153	0.161	12[0.0525-0.497]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	0.155	0.079	10[0.0726-0.327]	0.006	0.000		0.173	0.078	10[0.09-0.3441]	0.012	0.000	
Kirkøy, Hvaler (st. 02B)	9 (7-2)	0.302	0.393	9[0.0366-1.27]	0.028	0.001		0.361	0.392	9[0.0942-1.3236]	0.028	0.001	
Stathelle area, Langesundfjord (st. 71B)	15 (6-2)	0.474	0.218	15[0.123-0.887]	0.029	0.001		0.532	0.209	15[0.2461-0.9452]	0.029	0.018	4[0.0346-0.0958]
Kristiansand harbour area (st. 13B)	12 (5-2)	0.182	0.701	12[0.0582-2.59]	0.029	0.008	1[0.057]	0.239	0.713	12[0.1158-2.6661]	0.029	0.098	2[0.0473-0.37]
Inner Sørfjord (st. 53B)	15 (3-2)	1.370	0.712	15[0.686-2.96]	0.028	0.005		1.423	0.710	15[0.7454-3.016]	0.028	0.015	1[0.08]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	0.321	0.193	13[0.121-0.78]	0.028	0.004		0.373	0.190	13[0.167-0.8216]	0.028	0.004	
Bergen harbour area (st. 24B)	15 (4-2)	2.630	4.229	15[1.09-16]	0.028	0.001		2.689	4.251	15[1.1528-16.1628]	0.059	0.045	12[0.035-0.152]
Ålesund harbour area (st. 28B)	15 (3-2)	1.910	1.387	15[0.0388-4.46]	0.029	0.014	4[0.0338-0.0726]	2.018	1.739	15[0.106-5.2546]	0.064	0.390	11[0.0495-1.27]
Trondheim harbour (st. 80B)	15	1.130	1.436	14[0.105-5.41]	0.029	0.011		1.201	1.452	15[0.1581-5.5546]	0.047	0.017	9[0.0319-0.078]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)	0.528	1.768	9[0.0881-5.82]	0.030	0.007	1[0.008]	0.603	1.762	9[0.1574-5.8825]	0.040	0.011	2[0.024-0.0674]
Tromsø harbour area (st. 43B2)	15	1.890	1.532	15[0.1-4.97]	0.028	0.001		2.037	1.811	15[0.213-6.2388]	0.082	0.345	11[0.0367-1.24]
Isfjorden, Svalbard (st. 19B)	15	0.645	0.415	15[0.438-2.03]	0.029	0.016		0.760	0.419	15[0.4968-2.0882]	0.029	0.016	
Eider, blood													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.094	0.000		0.089	0.007		0.249	0.007		0.066	0.000	
Eider, egg													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	0.150	0.073	12[0.0961-0.379]	0.089	0.011		0.316	0.071	12[0.2518-0.5347]	0.066	0.000	

Cod liver showed about-100 times higher concentrations than in blue mussel on a wet weight basis (compare ***Figure 53*** and ***Figure 54***). The difference was smaller on a lipid basis. There are some indications of biomagnification for specific diastereomers of HBCD (Haukås 2009).

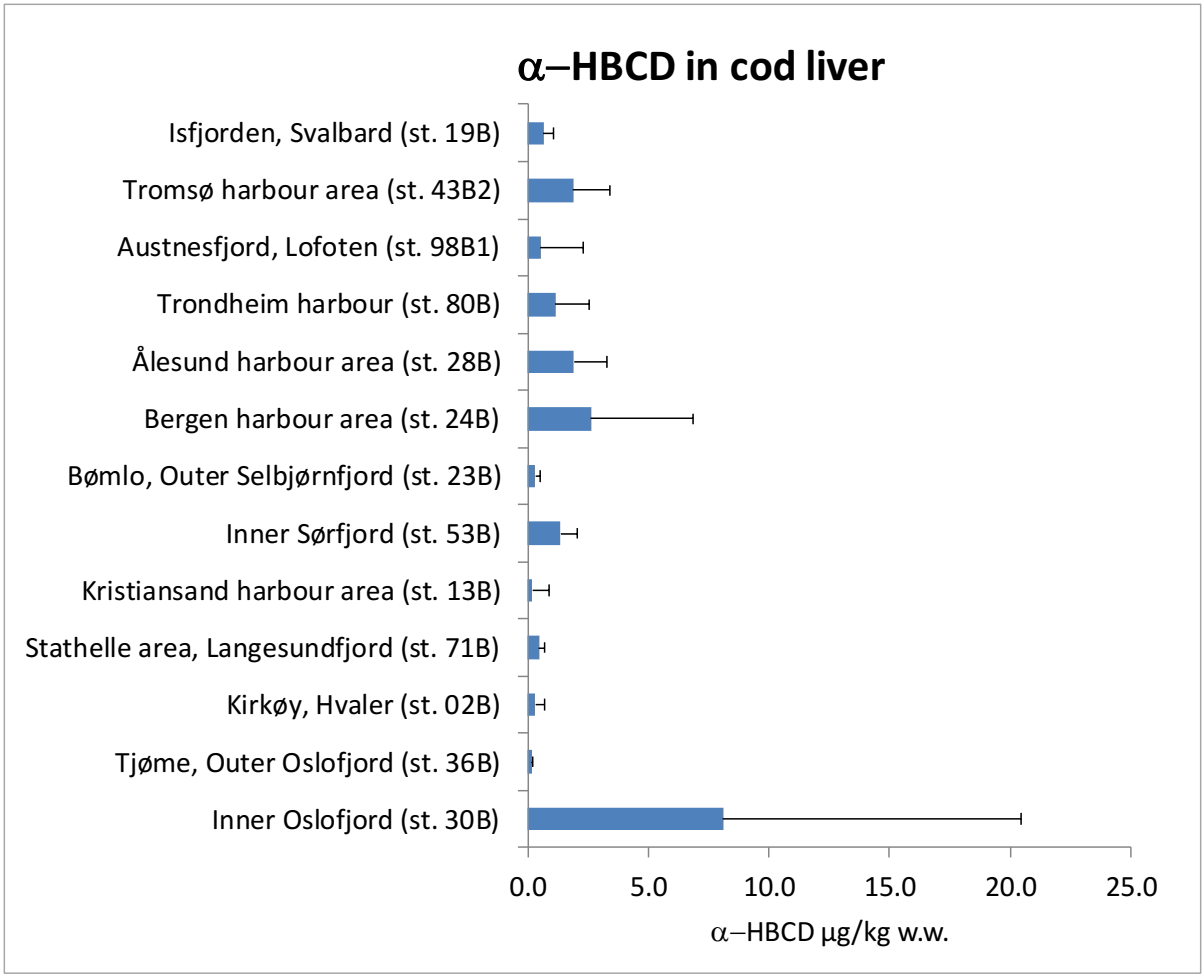


Figure 53*. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2017. The error bar indicates one standard deviation above the mean.*

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 54***).

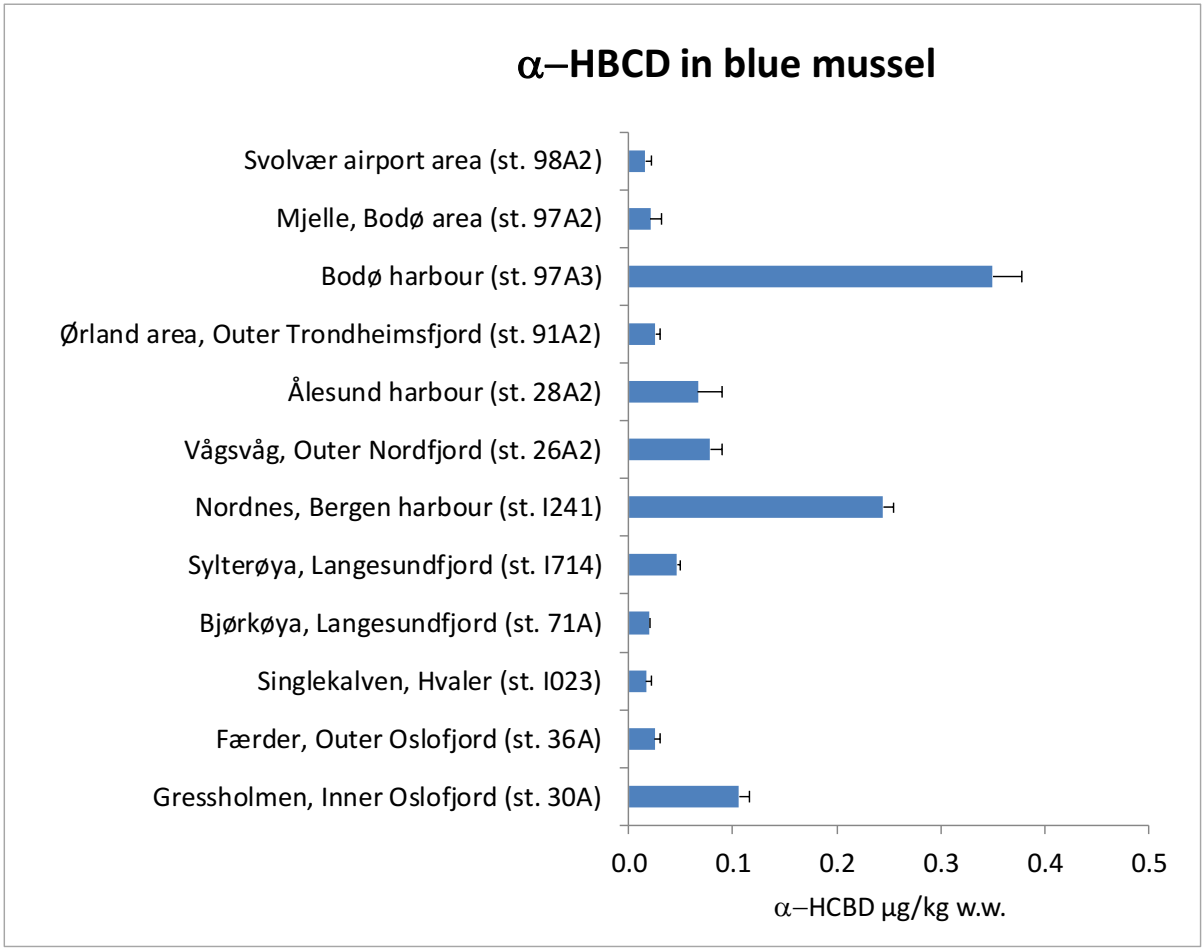


***Figure 54**. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2017. The error bar indicates one standard deviation above the mean.*

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

General, large scale trends

The discharges of HBCD to water from land-based industries showed a decrease from 2004 (12.90 kg HBCD/year) to 2005 (1.50 kg HBCD/year) (***Figure 55***). In 2006, the discharge to water was 0.51 kg and during the following years the discharges have gradually decreased to 0 kg in 2016.

Riverine loads for HBCD isomers for 2016 has 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 – *M-862|2017*).

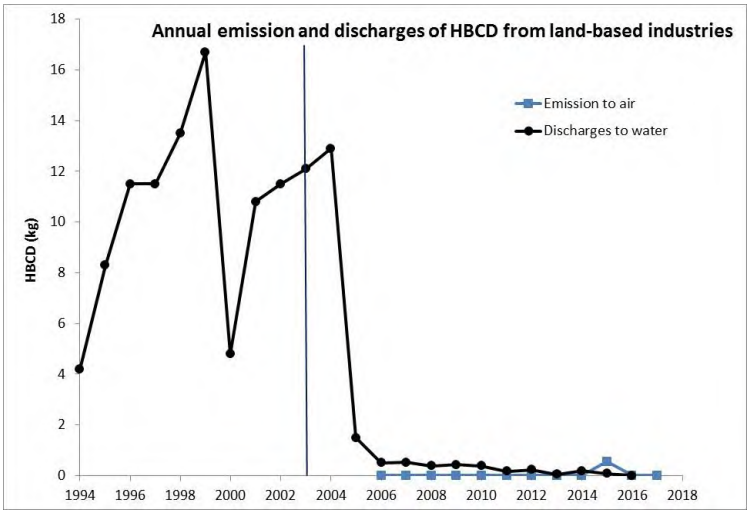


***Figure 55**. Annual emissions of HBCD to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). HBCD has been monitored in this project since 2001 (indicated with a vertical line). No data for emissions to air are reported for 2002-2005. Discharges to water in 2017 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.*

3.2.25 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 will be in place by the end of 2018 through the Stockholm Convention. In the present study, chlorinated paraffins were analysed in liver of cod from 13 stations, in blue mussel from 12 stations, and in blood and eggs of eider from one station.

Chlorinated paraffins are subdivided according to their carbon chain length into short chain chlorinated paraffins (SCCPs, $C_{10\text{-}13}$) and medium chain chlorinated paraffins (MCCPs, $C_{14\text{-}17}$). The EQS for SCCP and MCCP in biota of 6000 and 170 µg/kg w.w., respectively (M-608, 2016). SCCPs and MCCPs are classified as persistent with a high potential for bioaccumulation, and are toxic to aquatic organisms. 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 is used to a limited extent in Norwegian production, but may be found in imported products. There is, however, considerable uncertainty about the quantities in products used in Norway. There is an indication that the discharges from the use of imported products have been reduced by 39 % from 1995 to 2010[1].

Environmental Quality standards (EQS) for EU-priority substances

When applying the EQS for SCCP (6000 µg/kg w.w.) in biota, all concentrations in cod liver and blue mussel were below the EQS.

Environmental Quality Standards (EQS) for River Basin Specific Pollutants

[1] http://www.miljostatus.no/Tema/Kjemikalier/Noen-farlige-kjemikalier/Klorerte-parafiner/

When applying the EQS for MCCP (170 µg/kg w.w.) in biota, median concentrations MCCP in cod liver exceeded EQS for four of the stations. Cod from Ålesund harbour (st. 28B) had highest concentration of MCCPs with median concentration of 842µg/kg w.w., and maximum concentration of 2770 µg/kg w.w. High individual variation was observed (***Figure 60***, ***Table 17***). Cod from the Inner Oslofjord (st. 30B) showed also high concentrations of MCCPs in liver, with median concentration of 498 µg/kg.

Levels exceeding PROREF

The median concentration of SCCP in cod liver ranged from 15.3 to 223 µg/kg w.w., with highest concentrations in cod from Bergen harbour area (st. 24B, ***Figure 58***, ***Table 17***). The median concentration of SCCPs in cod liver from Bergen harbour area exceeded the provisional high reference concentration PROREF by a factor of up to two.

The median concentrations of MCCPs found in liver of cod from Ålesund harbour (st. 28B) and the Inner Oslofjord (st. 30B) exceeded the PROREF by a factor between two and five.

Upward trends

There were significant long-term and short-term upward trends for SCCP in blue mussel from Svolvær airport area (st. 98A2) (***Figure 56 A***), and in addition, SCCP in liver of cod from Austnesfjord, Lofoten (st.98B1) (***Figure 56 B***). There was a significant short-term upward trend for SCCP in liver of cod from the Inner Oslofjord (st. 30B) when using data adjusted for fish length (***Figure 57***).

There were significant short-term and long-term upward trends for MCCP in liver of cod from the Inner Oslofjord (st. 30B). A significant long-term upward trend was found for MCCP in liver of cod from Bømlo, Outer Selbjørnfjord (st. 23B). These trends in cod were also significant when the data was adjusted for fish length.

Downward trends

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

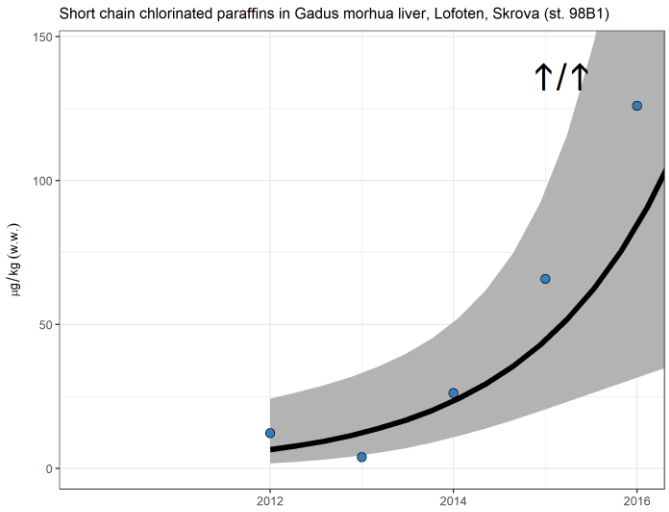
General, large scale trends

The concentration of SCCP in blue mussel ranged from 3.65 to 387 µg/kg w.w. in this study and the highest concentration was found in the samples from Ålesund harbour (st. 28A2, ***Figure 59***).

The concentrations of MCCPs in blue mussel were lower than in cod, and ranged from 4.46 to 52.4 µg/kg w.w. Blue mussel from Bergen harbour (st. I241), Ålesund harbour (st. 28A2) and Bodø harbour (st. 97A3) had the highest concentrations of MCCPs (***Figure 61***).

Median concentration of SCCP was 27 µg/kg w.w. in eider blood, and 31 µg/kg w.w. in eider egg from Kongsfjord, Svalbard (st. 19N). Median concentration of MCCP was 2.5 µg/kg w.w. in eider blood and 8.6 µg/kg w.w. in eider egg from the same station.

A



B

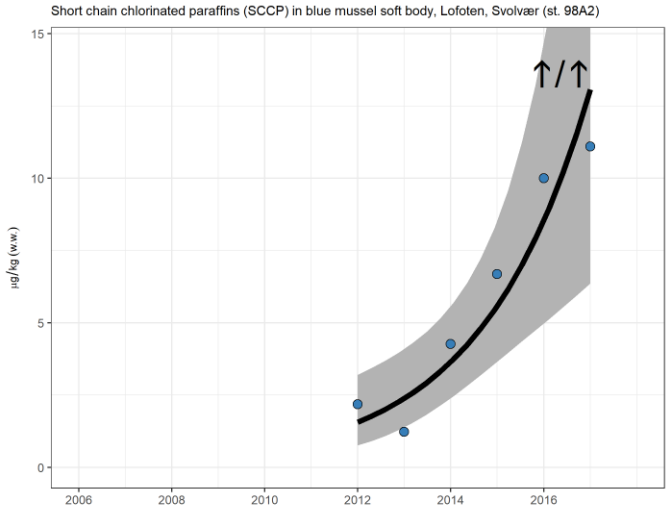


Figure 56. *Median concentrations (mg/kg w.w.) of SCCP in cod liver from 2012 to 2017 in Austnesfjord, Lofoten (st.98B1) (**A**) and in blue mussel from Svolvær airport area (st. 98A2) (**B**). The EQS is indicated with a horizontal red line, and provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see Figure 5 and* **Appendix C***).*

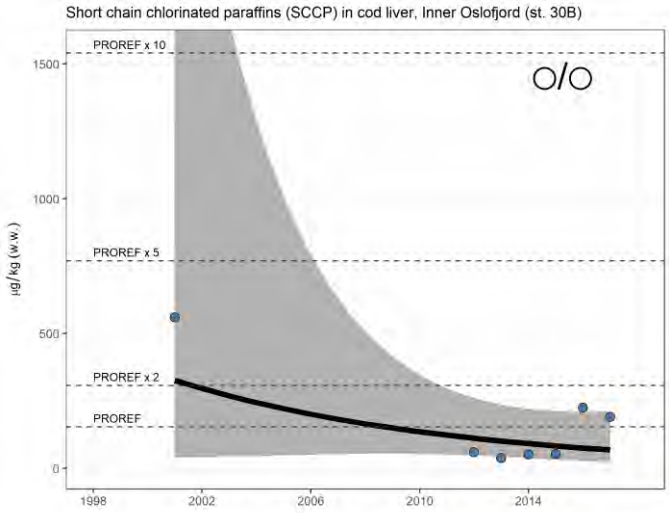
Other studies

Cod from the Inner Oslofjord had median concentration of SCCP in liver of 191 µg/kg w.w., and ranging between 136 to 984 µg/kg w.w. Ruus *et al.* (2018 in prep.) found higher levels of SCCP in cod from the Inner Oslofjord Trend: O/O g w.w.). The concentrations of MCCP in cod liver found by Ruus *et al.* (2018 in prep.) were from 51 to 1051 µg/kg w.w., similar level as in this monitoring programme.

In this study, the median concentration of SCCP (31 µg/kg w.w). in eider egg from Svalbard was higher than in another study of eider from three stations in northern Norway and one at Svalbard (3.2±1.8 µg/kg w.w.) (Harju *et al.* 2013). The same pattern was seen for the median concentration of MCCP (8.6 µg/kg w.w.) in this study compared to the other study (4.2±4.1 µg/kg w.w.).

Riverine loads for SCCPs for 2016 has been estimated to 0.21 kg/year for river Alna (Inner Oslofjord), 9.7 kg/year for river Drammenselva (Mid Oslofjord) and 71 kg/year for river Glomma (Outer Oslofjord) (Skarbøvik *et al.* 2017 – M-862|2017). Riverine loads for MCCPs for 2016 has been estimated to 0.25 kg/year for river Alna, 19 kg/year for river Drammenselva and 420 kg/year for river Glomma.

A



B

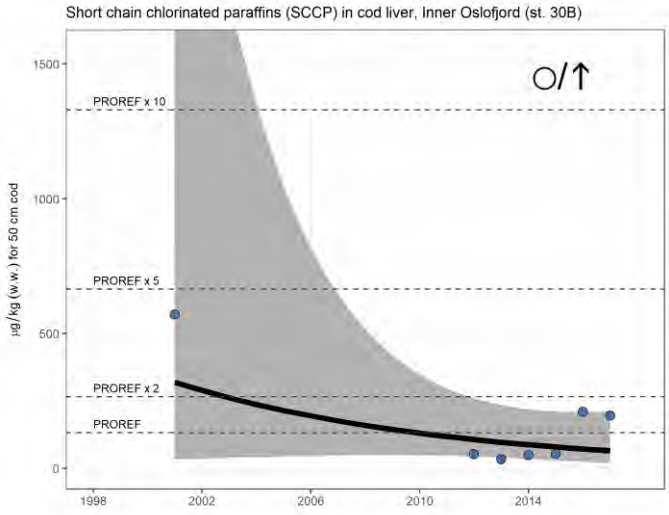


Figure 57. *Median concentrations (mg/kg w.w.) of SCCP in cod liver from 2001 to 2017 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* ***Figure 5*** *and* **Appendix C***). Note that even though the two figures are quite similar, where there is no adjustment for length (***A***) the p-value for the trendanalysis is 0.0592 and where there is an adjusted for length (***B***) the p-values is 0.0379, and hence significant.*

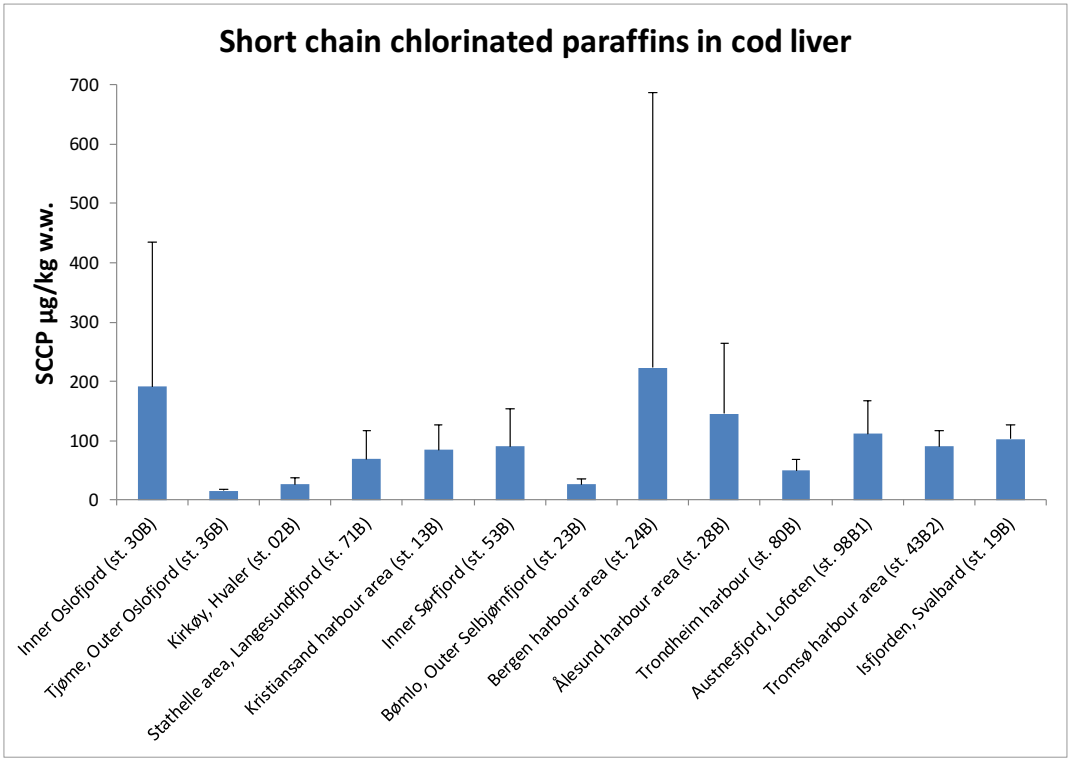


***Figure 58**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in cod liver in 2017. The error bar indicates one standard deviation above the median.*

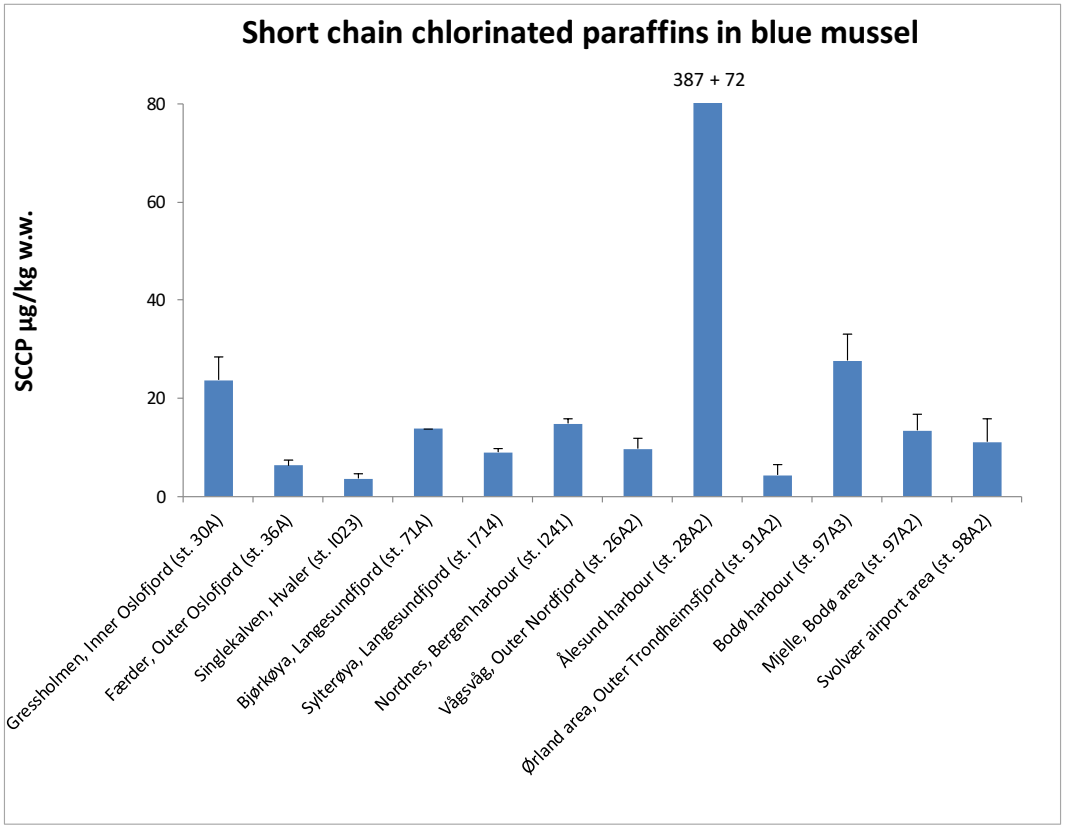


***Figure 59**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in blue mussel in 2017. The error bar indicates one standard deviation above the median.*

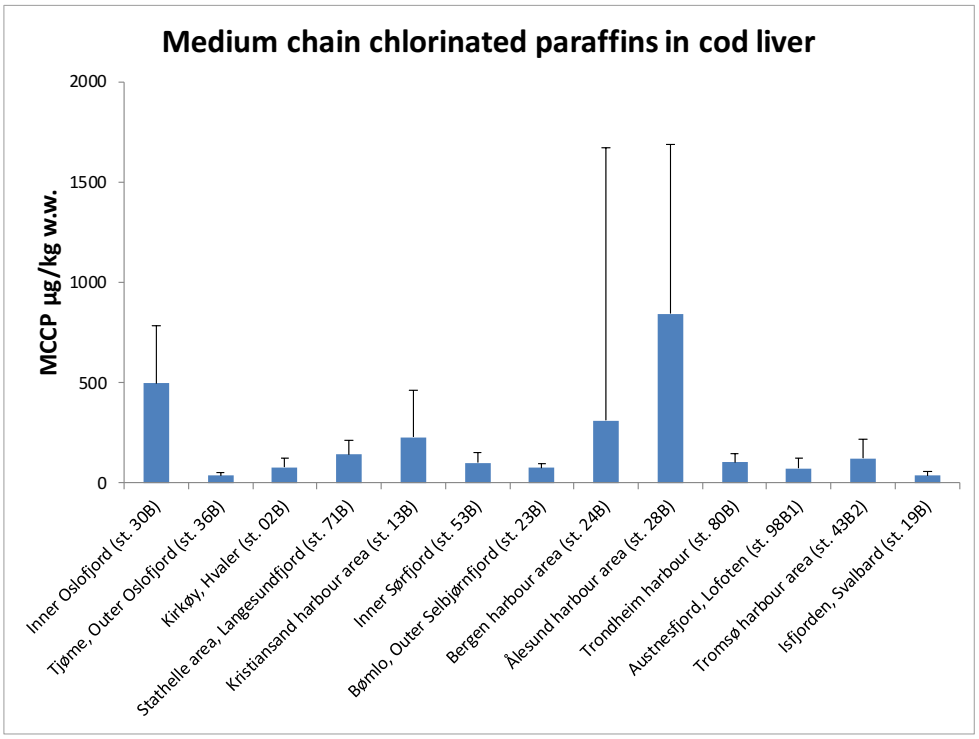


***Figure 60**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in cod liver in 2017. The error bar indicates one standard deviation above the median.*

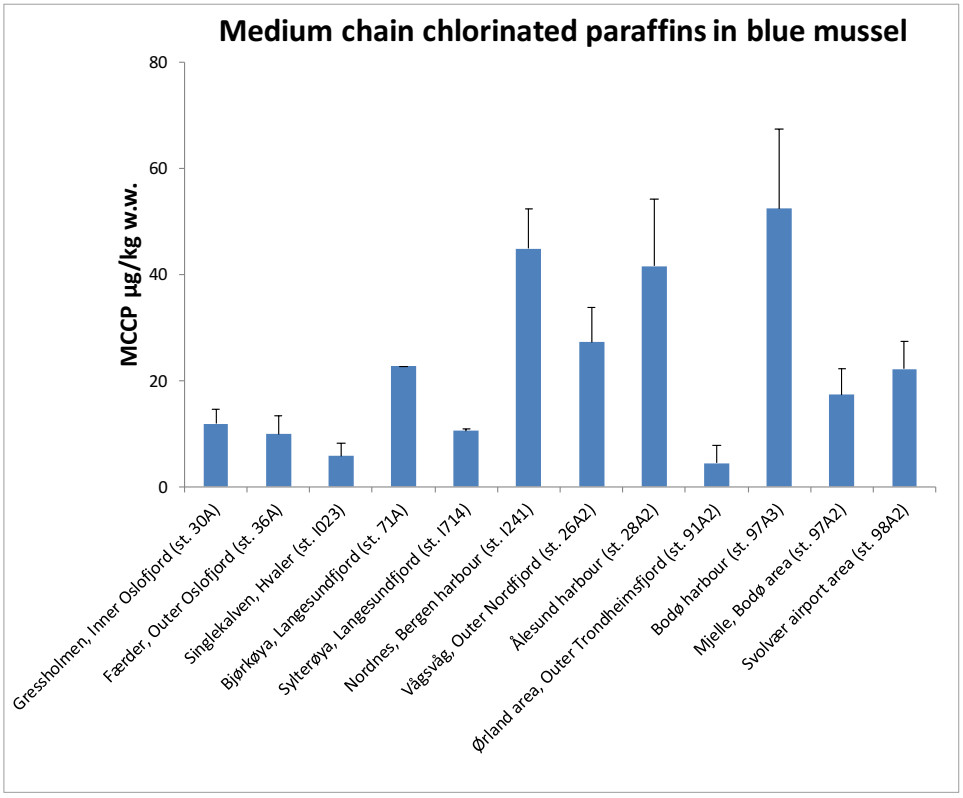


***Figure 61**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in blue mussel in 2017. The error bar indicates one standard deviation above the median.*

***Table 17**. Median concentrations (µg/kg w.w.) with standard deviation of short chain chlorinated paraffins (SCCPs) and medium chain chlorinated paraffins (MCCPs) in blue mussel, cod and eider blood and eggs in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details.).*

Component	Count	SCCP			MCCP		
Species and sampling locality	2017	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel							
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	23.70	4.71	3[22.2-31]	11.90	3	3[11.7-16.6]
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	6.25	1.06	3[4.64-6.65]	9.89	3	3[4.37-10.6]
Singlekalven, Hvaler (st. I023)	3 (3-50)	3.65	1.05	3[3.05-5.1]	5.82	2	3[3.46-8.08]
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	13.70	0.00	1[13.]	22.70	0	1[22.]
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	9.01	0.75	3[8.99-10.3]	10.50	0	3[10.1-10.8]
Nordnes, Bergen harbour (st. I241)	3 (3-50)	14.80	1.11	3[13.9-16.1]	44.90	7	3[42.3-56.3]
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	9.71	2.21	3[9.63-13.5]	27.30	6	3[26.1-37.8]
Ålesund harbour (st. 28A2)	3 (3-50)	387.00	72.38	3[335-478]	41.60	13	3[29.5-55]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	4.27	2.21	3[3.99-7.95]	4.46	3	3[3.72-9.67]
Bodø harbour (st. 97A3)	3 (3-50)	27.60	5.51	3[18.1-27.7]	52.40	15	3[31-60.2]
Mjelle, Bodø area (st. 97A2)	3 (3-50)	13.40	3.31	3[7.71-13.5]	17.30	5	3[13.8-23.7]
Svolvær airport area (st. 98A2)	3 (3-50)	11.10	4.80	3[6.1-15.7]	22.20	5	3[15.7-26]
Cod, liver							
Inner Oslofjord (st. 30B)	12 (8-3)	191.00	243.33	12[136-984]	498.00	288	12[314-1060]
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	15.30	3.07	10[10.5-20.8]	35.15	15	10[22.3-77.3]
Kirkøy, Hvaler (st. 02B)	9 (7-2)	26.00	10.13	9[20.4-48]	77.20	44	9[31.9-164]
Stathelle area, Langesundfjord (st. 71B)	15 (6-2)	68.90	47.80	15[38.3-185]	143.00	71	15[72.5-333]
Kristiansand harbour area (st. 13B)	12 (5-2)	84.45	41.62	12[55.1-180]	226.50	236	12[93.9-799]
Inner Sørfjord (st. 53B)	15 (3-2)	89.90	63.03	15[54.9-308]	100.00	54	15[66.9-225]
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	26.00	8.21	13[21.5-51.8]	74.60	19	13[48.5-105]
Bergen harbour area (st. 24B)	15 (4-2)	223.00	463.34	15[94.9-1520]	310.00	1358	15[111-3790]
Ålesund harbour area (st. 28B)	15 (3-2)	145.00	118.39	15[30.5-441]	842.00	846	15[67.7-2770]
Trondheim harbour (st. 80B)	15	49.00	19.82	15[30.6-83.5]	102.00	42	15[75.3-206]
Austnesfjord, Lofoten (st. 98B1)	11 (4-2)	111.00	56.55	11[37.4-240]	71.60	51	11[38.8-208]
Tromsø harbour area (st. 43B2)	15	89.60	26.81	15[54.8-144]	123.00	97	15[54.4-395]
Isfjorden, Svalbard (st. 19B)	15	103.00	22.87	15[64.6-162]	35.40	19	15[24.1-94.2]
Eider, blood							
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	27.00	143.51	15[7.2-580]	2.50	6	15[0.1-26]
Eider, egg							
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	31.00	7.38	15[20-45]	8.60	11	15[2.7-37]

3.2.26 Bisphenol A (BPA)

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

BPA was analysed in cod liver from three stations, in blue mussel from two stations, and in eider blood and eggs from one station.

The concentrations of BPA in cod liver, blue mussel, and eider (blood and eggs) were below the quantification limits (***Table 18***). Hence, no conclusion can be drawn regarding possible differences between stations.

Table 18. *Median concentrations (µg/kg w.w.) with standard deviation of bisphenol A (BPA) in blue mussel, cod liver, and eider blood and eggs in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any). (See Chapter 2.9 for more details.).*

Component	Count	BPA		
Species and sampling locality	2016	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	1.0	0.0	
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	1.0	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	12 (8-3)	1.0	0.0	
Stathelle area, Langesundfjord (st. 71B)	15 (6-2)	1.0	0.0	
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	1.0	0.0	
Eider, blood				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	5.0	0.0	
Eider, egg				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	30.0	0.0	

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

3.2.27 Tetrabrombisphenol A (TBBPA)

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

Concentrations of TBBPA found in cod liver, blue mussel, and eider (blood and eggs) were generally low. For all the stations the median concentrations were below the limit of quantification (***Table 19***). Only one sample of cod liver from Bømlo, Outer Selbjørnsfjord (st. 23B), had a detectable concentration of TBBPA.

Table 19*. Median concentrations (µg/kg w.w.) with standard deviation of TBBPA in blue mussel and cod liver in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details.)*

Component	Count	TBBPA		
Species and sampling locality	2017	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3 (3-50)	0.0	0.0	
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	0.1	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	12 (8-3)	0.5	0.0	
Stathelle area, Langesundfjord (st. 71B)	15 (6-2)	0.5	0.0	
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	0.5	0.1	1[0.64]
Eider, blood				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	6.0	0.0	
Eider, egg				
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15	20.0	0.0	

3.2.28 Alkylphenols

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

Alkylphenols were analysed in cod liver from 12 stations, in blue mussel from 12 stations and in eider blood and eggs from one station.

Environmental Quality Standards (EQS) for EU-priority substances

When applying the EQS for nonylphenol (3000 µg/kg w.w.) and octylphenol (0.004 µg/kg w.w.) in biota (blue mussel, cod liver, and eider blood and eggs), all concentrations were below the EQS in 2017 (***Table 20***). All the concentrations of nonylphenol were below the EQS. Since the EQS for octylphenol is much lower than the quantification limit, it is not possible to classify this substance correctly.

The concentrations in cod liver, blue mussel, and eider (blood and eggs) were low. All concentrations were below the quantification limits (***Table 20***).

General, large scale

The discharges of phenols from land-based industries to water increased in the period from 2002 to 2008 (4730 kg) and then gradually decreased to 1007 kg in 2017 (***Figure 62***).

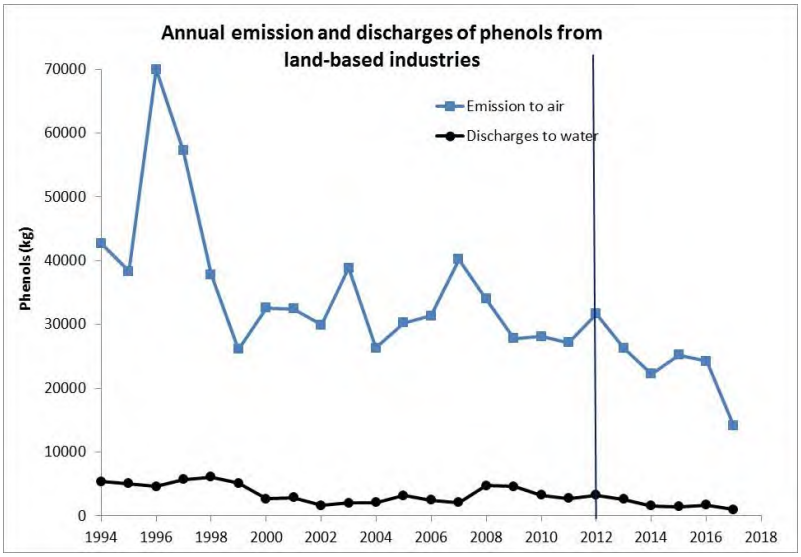


Figure 62. *Annual emissions of phenols to air and discharges to water from land-based industries in the period 1994-2017 (data from www.norskeutslipp.no, 27 June 2018). Phenols have been monitored in this project since 2012 (indicated with a vertical line). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Table 20. *Median concentrations (µg/kg w.w.) with standard deviation of alkylphenols in blue mussel, cod liver, and eider blood and eggs in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was below the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details and* ***Appendix B*** *for description of chemical codes.)*

Component	Count	4-N-NP			4-N-OP			4-T-NP			4-T-OP		
Species and sampling locality	2017	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)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Færder, Outer Oslofjord (st. 36A)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Singlekalven, Hvaler (st. I023)	3 (3-50)	47.0	3.30		47.0	3.30		700.0	0.00		47.0	3.30	
Bjørkøya, Langesundfjord (st. 71A)	1 (1-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Sylterøya, Langesundfjord (st. I714)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Nordnes, Bergen harbour (st. I241)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Vågsvåg, Outer Nordfjord (st. 26A2)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Ålesund harbour (st. 28A2)	3 (3-50)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Ørland area, Outer Trondheimsfjord (st. 91A2)	3 (3-50)	50.2	1.70		50.2	1.70		700.0	0.00		50.2	1.70	
Bodø harbour (st. 97A3)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Mjelle, Bodø area (st. 97A2)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Svolvær airport area (st. 98A2)	3 (3-50)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Cod, liver													
Inner Oslofjord (st. 30B)	12 (8-3)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Tjøme, Outer Oslofjord (st. 36B)	10 (10-3)	10.0	0.00		10.0	0.00		100.0	0.00	1 (100-100)	10.0	0.00	
Kirkøy, Hvaler (st. 02B)	9 (7-2)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Stathelle area, Langesundfjord (st. 71B)	15 (6-2)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Kristiansand harbour area (st. 13B)	12 (5-2)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Inner Sørfjord (st. 53B)	15 (3-2)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Bømlo, Outer Selbjørnfjord (st. 23B)	13 (4-2)	25.0	0.00		25.0	0.00		100.0	0.00	1 (100-100)	25.0	0.00	
Bergen harbour area (st. 24B)	15 (4-2)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Ålesund harbour area (st. 28B)	15 (3-2)	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Trondheim harbour (st. 80B)	15	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Tromsø harbour area (st. 43B2)	15	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Isfjorden, Svalbard (st. 19B)	15	25.0	0.00		25.0	0.00		100.0	0.00		25.0	0.00	
Eider, blood													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15							0.5	0.00		550.0	0.00	
Eider, egg													
Breøyane, Kongsfjorden, Svalbard (st. 19N)	15							4.0	0.00		500.0	0.00	

3.2.29 Siloxanes (D4, D5 and D6)

Siloxanes are chemical compounds consisting of silicon and oxygen substituted with various organic side chains, and they exist both as linear (L) and cyclic (D). Siloxanes are chemicals used as synthetic intermediates in silicone polymer productions, and can be ingredients in cosmetic and personal care products. Siloxanes have properties that affect the consistency of personal care products such as deodorants, skin and hair products to facilitate their use. The chemicals are also used in mechanical fluids and lubricants, biomedical products, cleaning and surface treatment agents, paint, insulation materials and cement.

Siloxanes, i. e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver for the first time at the four stations Inner Oslofjord (st. 30B), Bergen harbour (st. 24B), Tromsø harbour (st. 43B2) and the Isfjord (st. 19B) at Svalbard (***Table 21***, **Figure 63**).

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 four stations (***Table 11***). No individual D5-concentration exceeded EQS (**Table 20**).

The EQS for biota (15 217 µg/kg w.w.) is provided for fish and are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in this 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 2017-samples (see ***Table 11***).

Levels in cod liver

D5 was the most dominant cVMS at all stations. Median D5-concentrations in cod liver were highest in the Inner Oslofjord (1117.6 µg/kg w.w.), and lowest at Svalbard (st. 11.6 µg/kg w.w.). The same patterns were found for D4 and D6.

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 (Miljostatus.no). Estimated emissions of siloxanes have increased gradually from 200 tons in 2000, to 387 tons in 2015.

Other studies

The Inner Oslofjord

Studies of siloxanes in cod from the Inner Oslofjord (st. 30B) have earlier been reported by Powell (2009), Powell *et al.* (2010 and 2018), Ruus *et al.* (2016, 2017a, 2018 in prep.), Schlabach *et al.* (2007) and Schøyen *et al.* (2016). In all studies, D5 were detected as the dominating compound.

In 2017, median D5-concentration in cod liver from the Inner Oslofjord was 1117.6 µg/kg w.w., while the mean D5-concentration was 2518.3 µg/kg w.w. in the study performed by Ruus *et al.* (2018, in prep). In the current study, median concentrations of D4 and D5 in cod liver from the Inner Oslofjord were 4.2 and 127.3 µg/kg w.w., respectively, while the mean concentrations were 175.8 and 274.1 µg/kg w.w., respectively, in the comparable study. Furthermore, Ruus *et al.* (2018, in prep) 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.* 2017a). In 2015, the median D5-concentration was 1083.3 µg/kg w.w. (Ruus *et al.* 2016).

For the period 2011 to 2014, concentrations of D4, D5 and D6 were higher in herring than in cod (both whole fish) from the Inner Oslofjord (st. 30B) (Schøyen *et al*. 2016). There was a positive correlation between lipid content and lipid-normalized D4, D5 and D6 in cod, but a negative correlation in herring. Lipid-normalized concentrations of D4, D5 and D6 were lowest in cod, herring and shrimp compared to the period 2011 to 2013.

In 2008, the mean concentrations of D4, D5 and D6 in cod (whole fish) from the Inner Oslofjord (st. 30B) were 2.6, 61.7 and 4.2 µg/kg w.w., respectively (Powell *et al*. 2010).

In 2006, minimum to maximum concentrations of D4, D5 and D6 in cod liver from the Inner Oslofjord (st. 30B) were 81.2-134.4, 1490.8-1978.5 and 109.1-151.5 µg/kg w.w., respectively (Schlabach *et al*. 2007).

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 (Nordic Council of Ministers 2005).

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, which again flows into the Isfjord. 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.

D5-concentrations varied between 45.5 to 358 µg/kg w. w., D4 was below the detection limit, and D6 varied between 5.3 and 13.8 µg/kg w. w.

Freshwater

The median D5-concentration in cod liver (1117.6 µg/kg w.w.) from the Inner Oslofjord was higher than in trout from Lake Mjøsa in 2016 (17.6 µg/kg w.w.) (Fjeld *et al*. 2017).

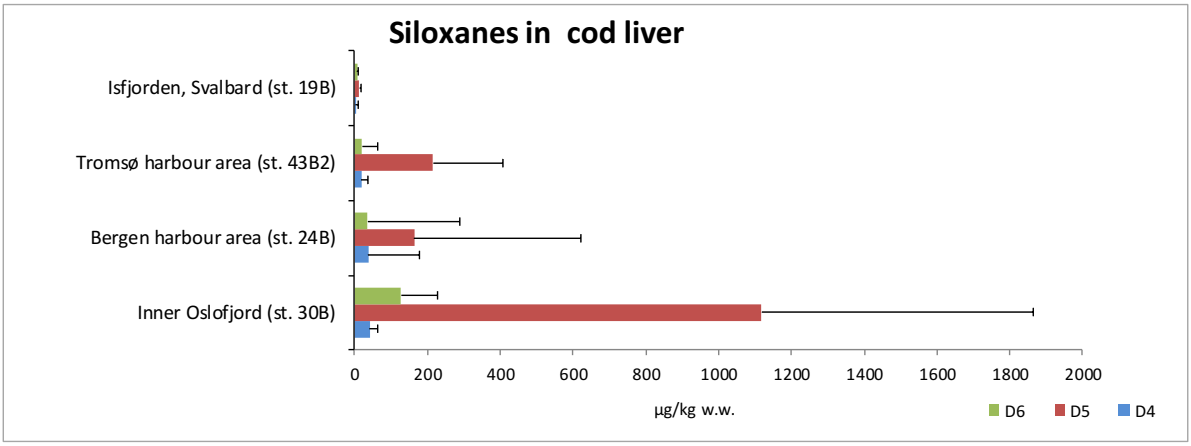


***Figure 63**. Median concentration (µg/kg w.w.) of siloxanes D4, D5 and D6 in cod liver in 2017. The error bar indicates one standard deviation above the median.*

***Table 21**. Median concentrations (µg/kg w.w.) with standard deviation of siloxanes (D4, D5 and D6) in cod liver in 2017. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details.)*

Component	Count	D4			D5			D6		
Species and sampling locality	2017	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.
Cod, liver										
Inner Oslofjord (st. 30B)	12 (8-3)	40.2	21.89	11[29.4966-79.5791]	1117.6	747.81	15[269.9559-2942.2629]	127.3	99.43	15[32.1586-389.6814]
Bergen harbour area (st. 24B)	15 (4-2)	36.4	140.64	14[4.709-571.3281]	163.3	457.47	15[28.927-1395.0601]	36.3	253.01	15[21.1181-1003.5919]
Tromsø harbour area (st. 43B2)	14	18.5	19.41	11 [11.7-59.7]	215.7	192.42	15[55.5618-718.092]	20.5	41.68	14[12.7281-148.8873]
Isfjorden, Svalbard (st. 19B)	12	0.0	0.00	1 [27.4]	11.6	4.09	15[6.8966-23.0016]	6.7	4.22	15[4.8806-18.0066]

3.3 Biological effects methods for cod in the Inner Oslofjord

Biological effect parameters (BEM) are included in the monitoring program to assess the potential pollution effects on organisms. This cannot be done solely on the basis of tissue concentrations of chemicals. There are five BEM methods used (including analyses of degradation products of PAH in bile). Each method is in theory specific for individual or groups of chemicals. One of the advantages of these methods used at the individual level is the ability to integrate biological and chemical endpoints, since both approaches are performed on the same individuals. The results can be seen in relation to newly established reference values (e.g. OSPAR 2013).

3.3.1 OH-pyrene metabolites in bile

Analysis of OH-pyrene in bile is not a measurement of biological effects, per se. It is included here, however, since it is a result of biological transformation (biotransformation) of PAHs, and is thus a marker of exposure. Quantification methods for OH-pyrene have been improved two times since the initiation of these analyses in the CEMP/MILKYS programme. In 1998, the support/normalisation parameter was changed from biliverdine to absorbance at 380 nm. In 2000, the use of single-wavelength fluorescence for quantification of OH-pyrene was replaced with HPLC separation proceeding fluorescence quantification. The single wavelength fluorescence method is much less specific than the HPLC method. Although there is a good correlation between results from the two methods, they cannot be compared directly.

PAH compounds are effectively metabolized in vertebrates. As such, when fish are exposed to and take up PAHs, the compounds are biotransformed into polar metabolites which enhances the efficiency of excretion. It is therefore not suitable to analyse fish tissues for PAH parent compounds as a measure of exposure. However, since the bile is a dominant excretion route of PAH metabolites, and since the metabolites are stored for some time in the gall bladder, the bile is regarded as a suitable matrix for analyses of PAH metabolites as a measure of PAH exposure.

In 2017 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) were significantly higher than in 2016 (Tukey-Kramer HSD test), more than twice as high and the highest median the last 8 years. Median OH-pyrene bile concentration in 2017 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 Skågskjera in Farsund (st. 15B). Furthermore, median OH-pyrene bile concentration in 2017 was slightly above the ICES/OSPAR assessment criterion also at Bømlo on the West coast (st. 23B, reference station), the station where concentrations were lowest. Note that the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380 nm. Also, in the Inner Sørfjord (st. 53B), the median concentration of OH-pyrene metabolites in bile from cod were significantly higher than in 2016 (Tukey-Kramer HSD test), by more than a factor of three, and the highest median since HPLC separation proceeding fluorescence quantification was applied for this parameter. Among the four stations, OH-pyrene concentrations were significantly higher in the Inner Sørfjord (st. 53B) (Tukey-Kramer HSD test) however, no significant short-term trend could be observed in the Sørfjord (st. 53B) (**Appendix F**).

3.3.2 ALA-D in blood cells

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

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

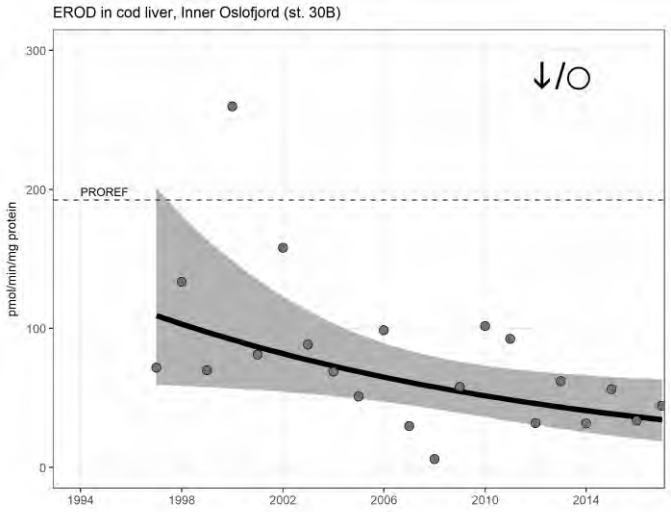
As previously noted, most years up to 2011 the activity of ALA-D in cod was somewhat inhibited in the Inner Oslofjord (st. 30B), compared to reference stations, i.e. Outer Oslofjord (st. 36B; only data to 2001), Bømlo in the Bømlo-Sotra area (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Green *et al*. 2016 – M-618|2016). The median ALA-D activity in the Inner Oslofjord (st. 30B) in 2017 was significantly lower (Tukey-Kramer HSD test) than in in the Bømlo-Sotra area (st. 23B, reference station). Also in the Inner Sørfjord (st. 53B), the median activity of ALA-D was significantly lower than at the reference station (st. 23B) (Tukey-Kramer HSD test). The often 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 2013-2017) indicate the contamination of lead. Higher concentrations of lead in cod liver have generally been observed in the Inner Oslofjord and Inner Sørfjord compared to Bømlo, though with a relatively large individual variation. Median concentrations of lead in cod liver from the Inner Oslofjord (st. 30B) and the Sørfjord (st. 53B) were 0.145 mg/kg and 0.062 mg/kg, respectively, in 2017. In the Bømlo-Sotra area (st. 23B) the concentration was below the limit of detection (<0.03 mg/kg).

3.3.3 EROD-activity

High activity of hepatic cytochrome P4501A activity (EROD-activity) normally occurs as a response to the contaminants indicated in ***Table 5***. It was expected that higher activity would be found at the stations that were presumed to be most impacted by planar PCBs, PCNs, PAHs or dioxins such as the Inner Oslofjord (st. 30B). In 2017, median EROD-activity in liver of cod from Bømlo (st. 23B), the Inner Oslofjord (st. 30B) and the Inner Sørfjord (st. 53B) were about30% higher than in 2016. The median EROD-activity also were somewhat higher in the Oslofjord (st. 30B), than at stations 23B and 53B. 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 2017. Statistically significant downward trends in EROD activity were observed on a long-term basis (whole data series) at Bømlo (st. 23B) and the Inner Oslofjord (st. 30B) (***Figure 64***). Median EROD-activities were below the ICES/OSPAR assessment criterion (background assessment criteria, BAC).

No adjustment for water temperature has been made. Fish are sampled at the same time of year (September-November) when differences between the sexes should be at a minimum. Previous statistical analyses indicated no clear difference in activity between the sexes (Ruus *et al*. 2003 – TA-1948/2003). It has been shown that generally higher activity occurs at more contaminated stations (Ruus *et al*. 2003 – TA-1948/2003). 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

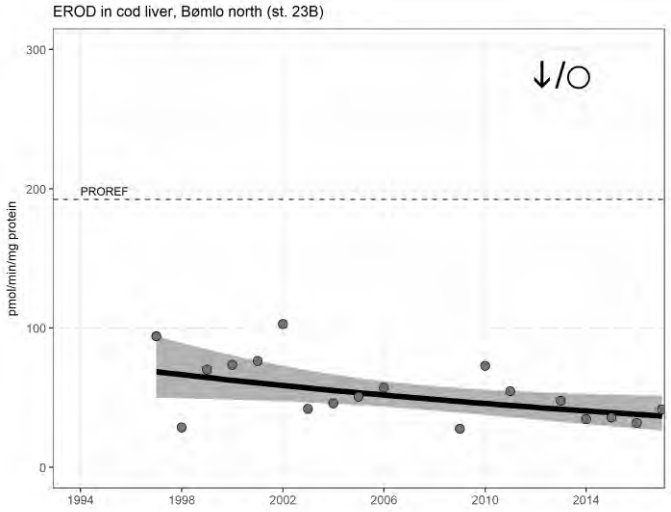


Figure 64. *Median activitet (pmol/min/mg-protein) of EROD in cod liver from 1990 to 2017 in the Inner Oslofjord (st. 30B) (***A***) and from 1997 to 2017 in Bømlo (st. 23B) (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 5** *and* **Appendix C***).*

3.4 Analysis of stable isotopes

3.4.1 General description of method

Stable isotopes of carbon and nitrogen are useful indicators of food origin and trophic levels. $\delta^{13}C$ gives an indication of carbon source in the diet or a food web. For instance, it is in principle possible to detect differences in the importance of autochthonous (native marine) and allochthonous (watershed/origin on land) carbon sources in the food web, since the $\delta^{13}C$ signature of the land-based energy sources is lower (greater negative number) than the autochthonous. Also $\delta^{15}N$ (although to a lesser extent than δ13C) may be lower in allochthonous as compared to autochthonous organic matter (Helland *et al*. 2002), but more important, it increases in organisms with higher trophic level because of a greater retention of the heavier isotope (^{15}N). The relative increase of ^{15}N over ^{14}N ($\delta^{15}N$) is 3-5‰ per trophic level (Layman *et al*. 2012; Post 2002). It thus offers a continuous descriptor of trophic position. As such, it is also the basis for Trophic Magnification Factors (TMFs). TMFs give the factor of increase in concentrations of contaminants per trophic level. If the concentration increase per trophic level can be expressed as:

Log Concentration = $a + b * (\text{Trophic Level})$

Then:

$TMF = 10^b$

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

In the present report, the stable isotope data have merely been reviewed to indicate any possibilities that spatial differences in contaminant concentrations may partially be attributed to different energy sources between stations, or that the same species may inhabit different trophic levels on different stations (***Table* 22**). Analysis of stable isotopes was included in the programme in 2012, thus the database now includes 6 years. Future areas of application for this database may e.g. be to investigate the possible influence of trophic position (baseline normalized) on the short-term concentration time trends, in the same manner as fish length has been included in the models in the recent few years. So far (2012-2016; Green *et al*. 2017 – M-856|2017) the results of the stable isotope analysis have shown a continual geographical pattern, suggesting a spatial trend persistent in time, and the isotopic signatures in mussels thus provide valuable information about the isotopic baselines along the Norwegian coast. This information has e.g. been used to normalize trophic positions of herring gulls, when geographic comparisons have been made (Keilen, 2017).

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

For selected contaminants (BDE-47, -99, -100 and -209, SCCP and MCCP, PFOS and PFOSA), relationships between concentrations and $\delta^{15}N$ have been investigated to examine potential increase in concentration of the specific contaminants with increasing $\delta^{15}N$. Such correlation will give reason for future examination of the potential of the contaminant to increase in concentration with higher level in the food chain (biomagnification). It is previously shown that, for example, the concentration of Hg increases with $\delta^{15}N$ among individuals of the same species (more specifically tusk; *Brosme brosme*) in the Sørfjord (Ruus *et al*. 2013 – M-15|2013). For that reason, also

concentrations of Hg, as well as PCB153 (another compound with known biomagnifying properties), is plotted against $\delta^{15}N$ in cod. The data material for PCB153 and especially Hg is larger, than for the other contaminants. Noteworthy observations from these regressions are referred to, below.

3.4.2 Results and discussion

The results of the stable isotope analysis generally show the same pattern as observed 2012-2016 (Green *et al*. 2017 – M-856|2017), i.e. a continual geographical pattern, suggesting a spatial trend persistent in time. As such, the results still suggest that the different cod populations surveyed can be placed on approximately the same trophic level. As mentioned, an increase in $\delta^{15}N$ of 3 to 5 ‰ represent one full trophic level. Although differences between stations situated at each end of the scale are higher, the same differences can be seen between the mussels from the same areas (***Figure 65***). This indicates that there are geographical differences in the baseline isotopic signatures (see discussion below). It is therefore reasonable to assume that differences in the concentrations of substances between areas are largely due to differences in exposure (either from local sources or through long-range transport). It can be noted, however, that it has previously been shown that differences in e.g. mercury content in tusk from Sørfjord area could be partly attributed to small differences in trophic position (or $\delta^{15}N$) (less than one full trophic level) (Ruus *et al*. 2013 – M-15|2013), indicating that differences in $\delta^{15}N$, corresponding to less than one full trophic level also are of interest in terms of explaining differences in bioaccumulation.

It can be noted that individual cod from the Sørfjord (st. 53B) and Bergen harbour (station 24B; both in Hordaland County) stand out with particularly low $\delta^{15}N$ signature (***Figure 65***); Bergen harbour, station 24B, was introduced in 2015.). The same is shown for mussels from the Sørfjord (stations 51A, 52A, 56A and 57 A, as well as 63A in the Hardangerfjord area), 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 and mussels from the Oslofjord are among the highest observed (***Figure 65***) indicating a high baseline (and not a higher trophic position of the Oslofjord cod). These geographic differences were also observed 2012-2016 (Green *et al*. 2017 – M 856|2017). Interestingly, cod from stations from the North of Norway (Lofoten, 98B1 and Hammerfest, 45B2) show intermediate $\delta^{15}N$ values and low $\delta^{13}C$ values (***Figure 65***). The same can be observed in mussels from Northern Norway (Lofoten, 98A2, and Varanger, 11X). As previously pointed out, the stations generally show very similar patterns from year to year in terms of isotopic signatures, indicating a geographical trend, persistent in time.

Table 22. *Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ in blue mussel, cod and eider, 2016. Statistics shown are count (n), mean and standard deviation.*

		$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$		
Station ID		**n**	**mean**	**st.dev.**	**n**	**mean**	**st.dev.**
Presumed less impacted							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**6**	**-20.47**	**0.88**	**6**	**5.89**	**0.59**
Mølen, Mid Oslofjord (st. 35A)		6	-19.99	0.21	6	6.54	0.57
Færder, Outer Oslofjord (st. 36A)		6	-20.24	0.76	6	7.77	0.25
Singlekalven, Hvaler (st. I023)		6	-19.46	0.32	6	7.57	1.02
Bjørkøya, Langesundfjord (st. 71A)		4	-20.07	0.59	4	4.88	0.73
Gåsøya-Ullerøya, Farsund (st. 15A)		6	-17.70	7.12	6	8.08	0.51
Krossanes, Outer Sørfjord (st. 57A)		6	-20.16	0.20	6	3.11	0.56
Ranaskjer, Ålvik, Hardangerfjord (st. 63A)		6	-19.54	0.32	6	3.62	0.69
Terøya, Outer Hardangerfjord (st. 69A)		6	-21.07	0.23	6	4.20	0.77
Espevær, Outer Bømlafjord (st. 22A)		6	-21.11	0.34	6	6.29	0.44
Vågsvåg, Outer Nordfjord (st. 26A2)		6	-21.17	0.21	6	5.41	0.40
Ørland area, Outer Trondheimsfjord (st. 91A2)		6	-20.25	1.04	6	6.31	0.95
Mjelle, Bodø area (st. 97A2)		6	-21.01	0.19	6	6.44	0.30
Svolvær airport area (st. 98A2)		6	-22.37	0.49	6	6.07	0.37
Brashavn, Outer Varangerfjord (st. 11X)		6	-22.41	0.32	6	6.23	0.77
Atlantic cod (*Gadus morhua*)	**statistics >>**	**27**	**-19.46**	**0.71**	**27**	**14.34**	**0.95**
Tjøme, Outer Oslofjord (st. 36B)		30	-18.73	0.69	30	15.58	1.77
Kirkøy, Hvaler (st. 02B)		25	-18.93	1.06	25	14.72	1.32
Skågskjera, Farsund (st. 15B)		30	-18.30	0.83	30	15.89	0.91
Bømlo, Outer Selbjørnfjord (st. 23B)		30	-18.89	0.72	30	14.17	0.85
Sandnessjøen area (st. 96B)		30	-19.30	0.67	30	13.44	0.78
Austnesfjord, Lofoten (st. 98B1)		30	-20.13	0.80	30	13.70	1.13
Kjøfjord, Outer Varangerfjord (st. 10B)		29	-20.19	0.47	29	13.98	0.61
Isfjorden, Svalbard (st. 19B)		15	-21.20	0.45	15	13.23	0.26
Common eider (*Somateria mossillima*), blood	**statistics >>**	**15**	**-19.61**	**0.83**	**15**	**10.93**	**1.02**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-19.61	0.83	15	10.93	1.02
Common eider (*Somateria mossillima*), egg	**statistics >>**	**15**	**-22.93**	**0.40**	**15**	**10.85**	**0.86**
Breøyane, Kongsfjorden, Svalbard (st. 19N)		15	-22.93	0.40	15	10.85	0.86
Presumed more impacted, summary:							
Blue mussel (*Mytilus edulis*)	**statistics >>**	**5**	**-20.12**	**0.30**	**5**	**6.32**	**0.50**
Gressholmen, Inner Oslofjord (st. 30A)		6	-19.60	0.34	6	7.65	0.48
Gåsøya, Inner Oslofjord (st. I304)		6	-19.38	0.22	6	7.58	0.15
Håøya, Inner Oslofjord (st. I306)		6	-19.26	0.52	6	7.84	0.42
Ramtonholmen, Inner Oslofjord (st. I307)		3	-19.01	0.08	3	7.63	0.33
Kirkøy, Hvaler (st. I024)		3	-20.44	0.50	3	9.95	2.14
Sylterøya, Langesundfjord (st. I714)		6	-20.92	0.21	6	6.18	0.35
Odderøya, Kristiansand harbour (st. I133)		6	-20.76	0.22	6	6.79	0.24
Byrkjenes, Inner Sørfjord (st. 51A)		6	-20.55	0.22	6	2.88	0.55
Eitrheimsneset, Inner Sørfjord (st. 52A)		6	-20.22	0.28	6	3.19	0.80
Kvalnes, Mid Sørfjord (st. 56A)		6	-19.87	0.27	6	2.60	0.66
Nordnes, Bergen harbour (st. I241)		3	-19.99	0.47	3	5.39	0.23
Ålesund harbour (st. 28A2)		3	-19.95	0.37	3	7.51	0.02
Bodø harbour (st. 97A3)		3	-21.66	0.21	3	6.98	0.14
Atlantic cod (*Gadus morhua*)	**statistics >>**	**29**	**-18.75**	**0.85**	**29**	**13.78**	**1.04**
Inner Oslofjord (st. 30B)		30	-18.06	0.98	30	16.73	1.26
Stathelle area, Langesundfjord (st. 71B)		30	-17.90	0.96	30	13.78	1.15
Kristiansand harbour area (st. 13B)		30	-17.86	0.66	30	15.67	1.54
Inner Sørfjord (st. 53B)		30	-18.36	0.74	30	10.69	0.77
Bergen harbour area (st. 24B)		30	-19.44	1.34	30	11.78	1.71
Ålesund harbour area (st. 28B)		23	-19.15	0.59	23	14.12	0.70
Trondheim harbour (st. 80B)		30	-18.58	1.06	30	13.82	0.89
Tromsø harbour area (st. 43B2)		30	-18.87	0.68	30	14.05	0.52
Hammerfest harbour area (st. 45B2)		30	-20.53	0.67	30	13.35	0.84
Average between the two groups for blue mussel	**statistics >>**	**5**	**-20.30**	**0.59**	**5**	**6.11**	**0.55**
Average between the two groups for Atlantic cod	**statistics >>**	**28**	**-19.10**	**0.78**	**28**	**14.06**	**1.00**

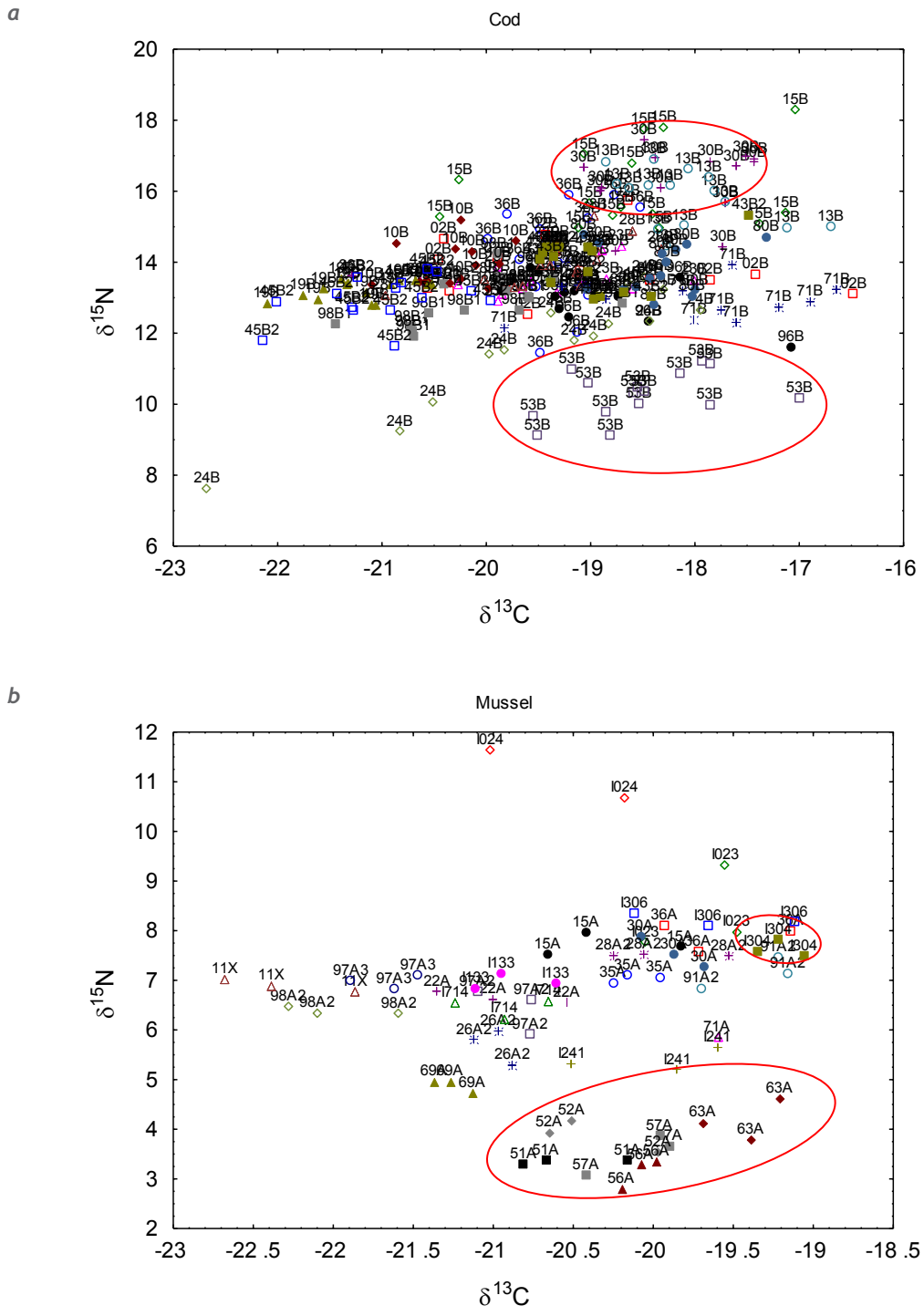


***Figure 65**. $\delta^{13}C$ plotted against $\delta^{15}N$ in for cod (a) and blue mussel (b). Station codes are superimposed. Red ellipses indicate cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.*

The correlation between $\delta^{15}N$ and concentration of Hg in cod could suggest higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[Hg]; $P<0.0050$, with very poor goodness-of-fit; $R^2=0.0309$; ***Figure 66***). However, this is likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations. However, from ***Figure 66***, there are some indications of increasing Hg-concentrations with increasing $\delta^{15}N$ within stations. Linear regressions isolated for each station produced significant positive linear relationships between $\delta^{15}N$ and Log[Hg] for stations 02B, 15B, 23B, 96B, 10B, 19B and 24B.

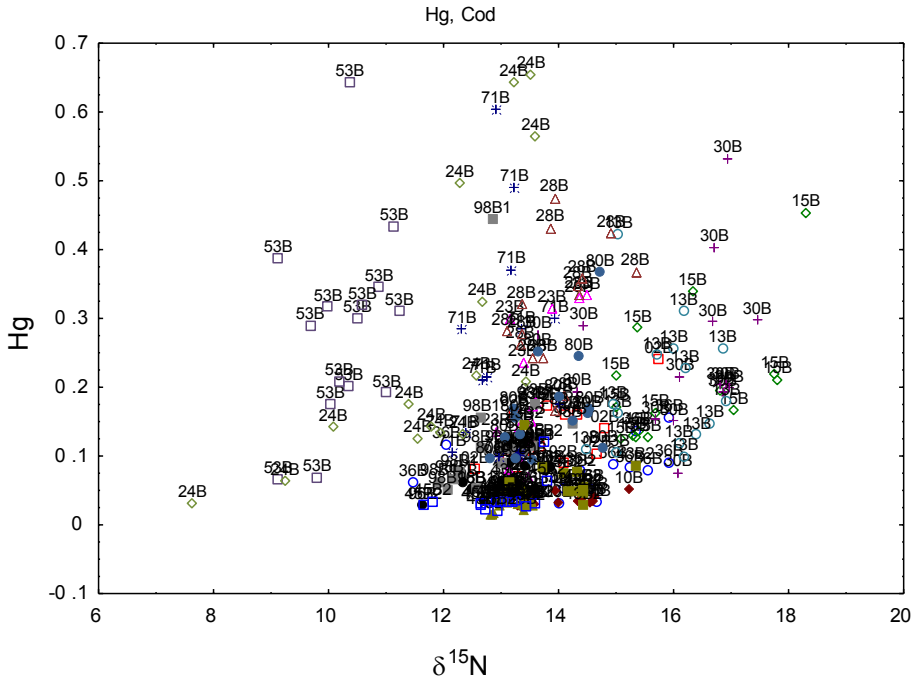


***Figure 66**. $\delta^{15}N$ plotted against the concentration of Hg in cod. Station codes are superimposed.*

As Hg, PCB153 is a compound with known biomagnifying properties (Ruus *et al*. 2016b – M-601|2016). The regression between $\delta^{15}N$ and the concentration of log[PCB153] in cod was not significant, and Bergen harbour (24B), showed high PCB-exposure in combination with low $\delta^{15}N$ (***Figure 67***). Linear regressions isolated for each station produced significant positive linear relationships between $\delta^{15}N$ and Log[PCB153] for stations 36B, 96B and 53B.

Plotting $\delta^{15}N$ against the concentration of PFOS in cod could suggest higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[PFOS]; R^2=0.1000; P=0.0002; ***Figure 68***). However, again this could partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations (e.g. high PFOS-exposure as well as high $\delta^{15}N$ in cod from the Oslofjord). Linear regressions isolated for each station yielded a significant relationship between $\delta^{15}N$ and Log[PFOS] only at station 19B. Similarly, plotting $\delta^{15}N$ against the concentration of PFOSA in cod could suggest higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[PFOSA]; R^2=0.2551; P<0.0001), again largely a result high concentrations combined with high $\delta^{15}N$ in cod from the Oslofjord). Linear regressions isolated for each station yielded no significant relationship between $\delta^{15}N$ and Log[PFOSA].

$\delta^{15}N$ ratio in eiders from Svalbard (blood and egg) showed identical values as 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 $\delta^{13}C$ ratio in the eiders differed between the two matrices (blood and egg). The $\delta^{13}C$ ratio was higher in blood than in eggs likely related to different lipid content. It should be noted that samples were not treated to remove carbonates or lipid before stable isotope analysis. The C:N ratio was measured to 3.41 ± 0.17 in blood and 8.5 ± 0.39 in egg, and a C:N ratio of >3.5 implies the presence of lipids, which may somewhat confound $\delta^{13}C$ interpretation, since lipids are $\delta^{13}C$-depleted relative to proteins (Sweeting *et al*. 2006). The $\delta^{13}C$ ratio in the eiders (egg and blood) was also lower than in pectoral muscle of eider from Svalbard collected in 2007 (Evenset *et al*. 2016).

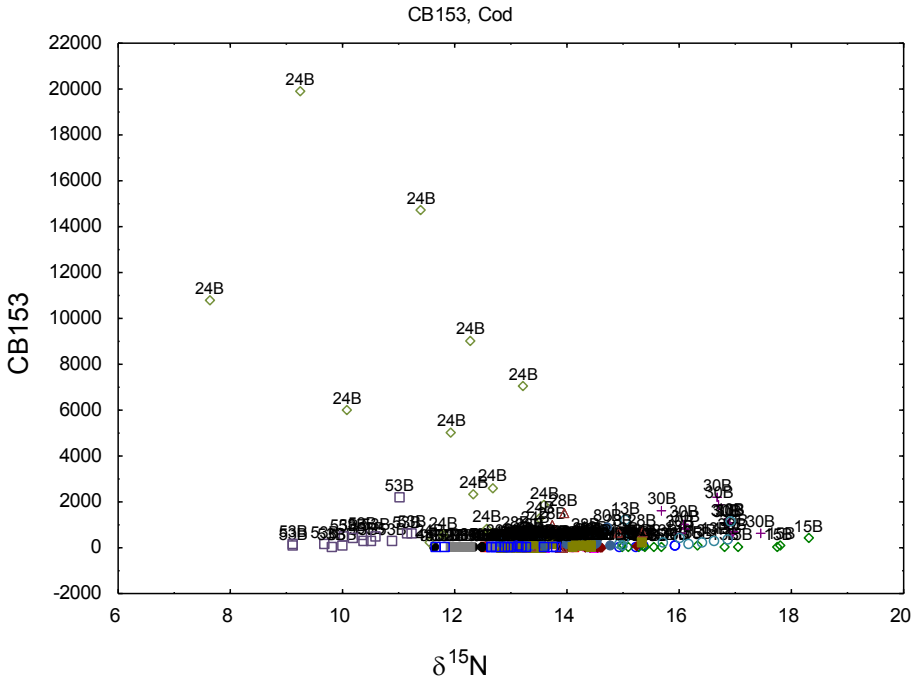


Figure 67. *δ^{15}N plotted against the concentration of PCB153 in cod. Station codes are superimposed.*

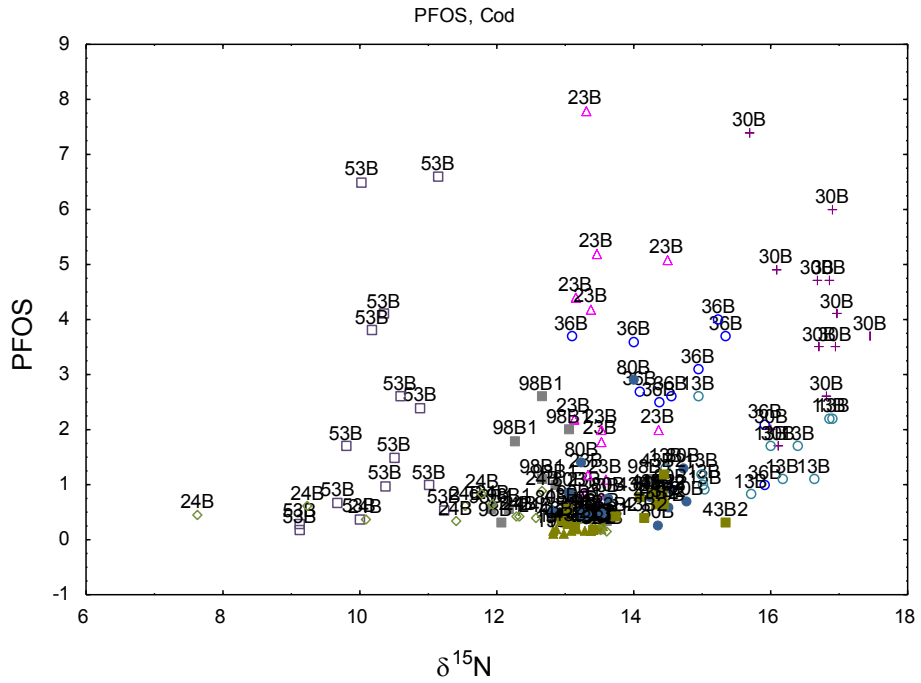


Figure 68. δ^{15}N plotted against the concentration of PFOS in cod. Station codes are superimposed.

3.5 Summary of results from Svalbard

Investigation of contaminants in Svalbard was included for the first time under the MILKYS programme. Samples from two species were used, muscle and liver from cod caught in the Isfjord (st. 19B) and blood and egg from the eider duck found in Kongsfjord (st. 19N) (***Table 23***). The results are reported in the preceeding sections (see chapters 3.2 and 3.3) and summarized here. Where possible, concentrations in cod can be compared to the EQS and PROREF, however for the eider samples, comparison to the EQS was not considered justified and values for PROREF have not yet been established.

Levels in cod

As for most other cod stations, the median concentrations at Svalbard exceeded the EQS for Hg, PCB-7, BDE6S, BDE47, 4-N-OP, 4-T-OP, but were below the EQS for PFOA, PFOS, α–HBCD, SCCP, MCCP, 4-N-NP and 4-T-NP (***Table 11***). Median concentrations of contaminants in cod liver and cod muscle were generally low (below PROREF), the exception being for Cd which exceeded PROREF by a factor of two. (***Table 12***).

Siloxanes, i. e. the cyclic volatile methyl siloxanes (cVMS) octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) were analysed in cod liver for the first time at the four stations, including Svalbard. D5, the most dominant cVMS, as well as D4 and D6 were lowest at Svalbard (**Figure 63**).

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

Levels in eider

Median concentrations of Hg, Pb and As in eider egg from Svalbard were on a similar level (within 60 %) as in a comparable study (Hill 2018). The meidan concentration of PCB-153 in eider blood was below the LOQ, but the LOQ was close (within 40%) to the concentration found in a comparable study in Svalbard (Bustnes 2010).

In this study, the median concentration of PBDE47, PFOS and PFOSA was lower than average concentrations found in another study of eider from three stations in northern Norway and one at Svalbard (Harju *et al*. 2013). However, for SCCP and MCCP, median concentrations were higher (up to ten times) compared to the same study.

The δ^{15}N ratios in eider (blood and egg) from Svalbard were fairly similar to that observed in 2007 (Evenset *et al*. 2016).

***Table 23**. Median concentrations (µg/kg w.w.) of parameters, with standard deviation, measured in cod liver (unless otherwise specified) from the Isfjord (st. 19B) in Svalbard and eider from Breøyane in Kongsfjord (st 19N) in Svalbard in 2017. Units are: percent for fat and dry weight, permille for stabile isotopes, mg/kg for metals and µg/kg for the remaining substances. Count indicates number of samples analysed. The first number within the parentheses indicates the number of pooled samples included. The second number within the parentheses indicates the maximum number of individuals used in one of the pooled samples. Shaded cells indicate that the median was the limit of quantification (LOQ) and value shown in these cells is one half of this limit. The standard deviation (S.d.) is based on all values and where values below the LOQ are taken as half. Detectable data information (D.d.i.) indicates the number of data above the LOQ (if any) and the numbers within the square brackets indicate the minimum and maximum values in this category. (See Chapter 2.9 for more details.).*

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

Table 23. (cont.)

Parameter Code	Gadus morhua, Liver Isfjorden, Svalbard (st. 19B)			Somateria mollissima, Blood Breøyane, Kongsfjorden, Svalbard (st. 19N)			Somateria mollissima, Egg Breøyane, Kongsfjorden, Svalbard (st. 19N)	
	Med.	S.d.	D.d.i.	Med.	S.d.	D.d.i.	Med.	S.d. D.d.i.
4-N-NP	25.000	0.000		0.000	0.000		0.000	0.000
4-N-OP	25.000	0.000		0.000	0.000		0.000	0.000
4-T-NP	100.000	0.000		0.500	0.000		4.000	0.000
4-T-OP	25.000	0.000		550.000	0.000		500.000	0.000
HBCDA	0.645	0.415	15[0.438-2.03]	0.094	0.000		0.150	0.073
HBCDG	0.029	0.016		0.066	0.000		0.066	0.000
HBCDB	0.029	0.016		0.089	0.007		0.089	0.011
HBCDD	0.760	0.419	15[0.4968-2.0882]	0.249	0.007		0.316	0.071
BDESS	3.327	1.094	15[2.5221-6.8778]	0.313	0.089	6[0.3169-0.6242]	0.550	0.496
SCCP	103.000	22.874	15[64.6-162]	27.000	143.510	15[7.2-580]	31.000	7.380
BDE6S	1.170	0.891	15[0.7449-4.119]	0.070	0.000	2[0.0701-0.071]	0.208	0.101
MCCP	35.400	19.408	15[24.1-94.2]	2.500	6.289	15[0.1-26]	8.600	10.888
BDE28	0.053	0.044	15[0.0416-0.2]	0.004	0.000		0.004	0.031
BDE47	0.750	0.658	15[0.501-2.98]	0.032	0.000		0.064	0.038
BDE49	0.187	0.179	15[0.151-0.853]	0.003	0.000		0.005	0.011
BDE66	0.010	0.007	4[0.0101-0.0365]	0.019	0.000		0.019	0.006
BDE71	0.010	0.002	1[0.010]	0.002	0.000		0.002	0.010
BDE77	0.010	0.001		0.001	0.000		0.001	0.000
BDE85	0.020	0.003		0.002	0.000		0.005	0.002
BDE99	0.020	0.001		0.019	0.000		0.027	0.028
BDE100	0.162	0.135	15[0.0959-0.612]	0.005	0.000	1[0.005]	0.042	0.027
BDE119	0.020	0.007	3[0.0231-0.0471]	0.002	0.000		0.004	0.004
BDE126	0.020	0.003	2[0.0208-0.0326]	0.002	0.000		0.003	0.001
BDE138	0.029	0.002		0.006	0.000		0.006	0.000
BDE153	0.029	0.002		0.006	0.000		0.014	0.007
BDE154	0.078	0.061	15[0.0576-0.279]	0.004	0.000	1[0.004]	0.034	0.011
BDE183	0.049	0.003		0.005	0.001	1[0.0]	0.005	0.000
BDE196	0.097	0.005		0.009	0.000		0.009	0.000
BDE209	0.971	0.051		0.134	0.079	3[0.169-0.414]	0.187	0.326
PFAS	0.300	0.042	15[0.22-0.37]	0.350	0.201	14[0.23-0.99]	2.200	2.287
PFDcA	0.500	0.127	1[0.9]	0.500	0.000		0.500	0.081
PFHpA	0.500	0.000		0.500	0.000		0.500	0.000
PFHxA	0.500	0.077	1[0.]	0.500	0.000		0.500	0.000
PFHxS	0.100	0.000		0.110	0.041	8[0.11-0.22]	0.100	0.069
PFNA	0.500	0.000		0.500	0.000		0.630	0.644
PFOA	0.500	0.000		0.500	0.000		0.500	0.000
PFOS	0.200	0.041	15[0.12-0.27]	0.250	0.201	14[0.13-0.89]	2.100	2.287
PFOSA	0.100	0.008	1[0.1]	0.100	0.000		0.100	0.000
PFBS	0.200	0.951	4[0.25-3.9]	0.200	0.000		0.200	0.000
PFUdA	0.400	0.129	5[0.49-0.85]	0.400	0.000		0.720	0.232
D4	3.453	7.002	4[NA-NA]	0.000	0.000		0.000	0.000
D5	11.575	4.087	15[6.8966-23.0016]	0.000	0.000		0.000	0.000
D6	6.730	4.224	15[4.8806-18.0066]	0.000	0.000		0.000	0.000
BPA	0.000	0.000		5.000	0.000		30.000	0.000
TBBPA	0.000	0.000		6.000	0.000		20.000	0.000
C/N (in muscle)	3.350	0.131	15[3.23-3.63]	3.340	0.169	15[3.25-3.88]	8.570	0.392
Delta13C (in muscle)	0.000	0.454	15[-22.11--20.52]	0.000	0.835	15[-20.89--18.16]	0.000	0.398
Delta15N (in muscle)	13.370	0.262	15[12.81-13.54]	10.800	1.021	15[9.58-13.24]	10.800	0.857

3.6 Microplastics in blue mussel

3.6.1 Microplastics in blue mussels

Microplastics (MP) have been identified worldwide throughout the marine environment; beaches, the water surface, the water column and benthic sediment can all contain microplastics. Both terrestrial and marine sources can contribute to the release of microplastics into the marine environment and oceanic currents can facilitate their transport. Estimations on numbers and largest sources of microplastics released into the Norwegian marine environment does exist (Sundt *et al*. 2014), however, it is still in-sufficiently empirical data to support these estimations. The empirical data that does exist from Norwegian microplastic field studies are from WWTP effluent (Magnusson 2014), surface waters (Lusher *et al.*, 2014), sea ice (Bergmann *et al.*, 2017), Atlantic cod (Bråte *et al*. 2016) and mussels (Lusher *et al*. 2017 - M-897|2017, Bråte *et al*. 2018). None of these studies were, however, long-term studies of microplastic occurrence. Since there are many uncertainties behind microplastic measurements, at least for the quantitative side, it is crucial to study temporal trends to see whether the microplastic data obtained are "snap-shot" in time, or if they can be used to support the estimations put forward by Sundt *et al*. (2014).

In 2016, The Norwegian Environment Agency tasked NIVA to investigate methods used for the extraction of microplastics from environmental samples of blue mussels. Following this research, blue mussels were proposed as a suitable indicator of small microplastics (< 1 mm, Lusher *et al.*, 2017 - M-897|2017). NIVA initially assessed 13 stations for the presence of microplastics (Lusher *et al.*, 2017 - M-897|2017) and this led to a total of 15 stations being studied for microplastic content where mussels from only one station (Ørland on the west coast) were found to not contain any microplastics (Bråte *et al.*, 2018). Significant differences in levels and quantitative traits (polymeric composition and shape) of microplastics identified in mussels from stations around the Norwegian coast were found, with two not being identified; Skallneset in connection to the Barents Sea and Akershuskaia from the inner Oslofjord (Bråte *et al*. 2018). The elevated levels in mussels from these stations may be caused by several factors such as hydrographical and atmospheric conditions, including tidal flow and amplitude, ocean currents, freshwater flow, locality to anthropogenic inputs and atmospheric deposition.

All data presented here has been corrected for contamination when identified in corresponding procedural blanks (see 2.6.4). For 2017, suspected plastic particles were identified in mussels from all 17 stations investigated along the Norwegian coast (***Table 24***). In total, 177 out of 319 individuals contained potential plastic particles (56 %). At least one individual per station contained suspected plastic particles (***Figure 69***). The percentage ingestion (number of individuals containing suspected plastic particles) ranged from 15 % to 92 % between stations.

Table 24 *Count of microplastics in blue mussel, 2017. The average number of microplastics (MP) are presented with standard deviation (mean ± SD). All results are presented with raw counts and the corrected values following blank correction where relevant. Blank correction was required when contamination was seen in procedural blanks (5/17 stations). Percent indicates the portion of individuals with microplastics.*

				Average		Corrected	
	Station	n	%	MP/ind. ± SD	MP/g ind. ± SD	MP/ind. ± SD	MP/g ind. ± SD
I023	Singlekalven	20	65 %	1.65 (± 3.07)	0.47 (± 0.89)	-	-
30A	Gressholmen	20	50 %	1.35 (± 2.11)	0.28 (± 0.44)	-	-
I304	Gåsøya	6	33 %	0.50 (± 0.84)	0.16 (± 0.31)	0.27 (± 0.53)	0.09 (± 0.21)
I306	Håøya	20	45 %	0.85 (± 1.18)	0.08 (± 0.12)	-	-
31A	Solbergstrand	20	30 %	0.40 (± 0.68)	0.13 (± 0.23)	-	-
35A	Mølen	20	65 %	1.15 (± 1.60)	0.65 (± 0.97)	-	-
36A	Færder	20	6 5%	0.90 (± 0.97)	1.48 (± 1.93)	-	-
71A	Bjørkøya	13	92 %	3.00 (± 2.80)	2.10 (± 2.47)	1.73 (± 2.60)	1.95 (± 3.82)
65A	Vikingneset	20	50 %	0.80 (± 1.36)	0.85 (± 2.16)	0.64 (± 1.16)	0.73 (± 2.04)
28A	Ålesund	20	15 %	0.15 (± 0.37)	0.11 (± 0.28)	-	-
26A2	Måløy	20	70 %	1.35 (± 1.37)	0.92 (± 0.83)	0.4 (± 0.62)	0.25 (± 0.33)
97A3	Bodø Havn	20	45 %	0.80 (± 1.20)	1.94 (± 3.46)	-	-
97A2	Mjelle	20	65 %	1.10 (± 1.17)	0.35 (± 0.33)	-	-
98A2	Lofoten, Svolvær	20	30 %	0.30 (± 0.47)	0.19 (± 0.30)	-	-
	Tromsø	20	6 5%	1.95 (± 4.11)	2.19 (± 3.18)	-	-
11X	Brashavn	20	65 %	1.05 (± 1.05)	1.31 (± 1.54)	0.84 (± 0.95)	1.04 (± 1.36)
10A2	Skallnes	20	90 %	5.35 (± 3.13)	32.88 (± 29.30)	-	-

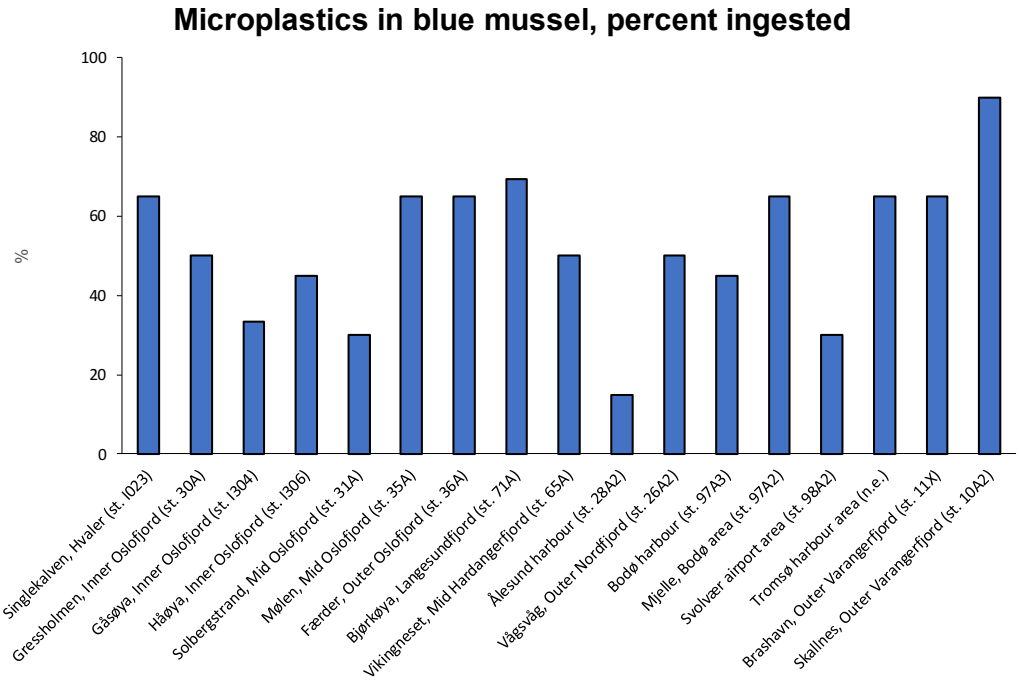


Figure 69*. Percentage microplastic ingestion in blue mussel from 17 stations.*

There was a difference (though this was not tested statistically) in the wet weight of individuals collected at the different stations (***Figure 70***), as also found in Lusher *et al.* (2017 - M-897|2017) and Bråte *et al.* (2018). To account for these differences between the stations, the results are discussed as microplastics per individual (MP indi^{-1}) and microplastics per gram wet weight (MP g w.w^{-1}). Both sets of results show a difference in level of plastic presence between the stations.

Overall the average MP load per individual was 1.40 (± 2.27). The highest level of ingestion was observed at Skallnes (5.35 ± 2.13 MP indi^{-1}) whereas the lowest level of ingestion was observed at Ålesund (0.15 ± 0.37 MP indi-1) (***Figure 71***).

Overall the average MP load per gram w.w. was 2.84 (± 10.84). The highest level of ingestion was observed at Skallnes (32.88 ± 29.30 MP g w.w. $^{-1}$) whereas the lowest level of ingestion was observed at Håøya (0.08 ± 0.12 MP g w.w. $^{-1}$) (***Figure 72***).

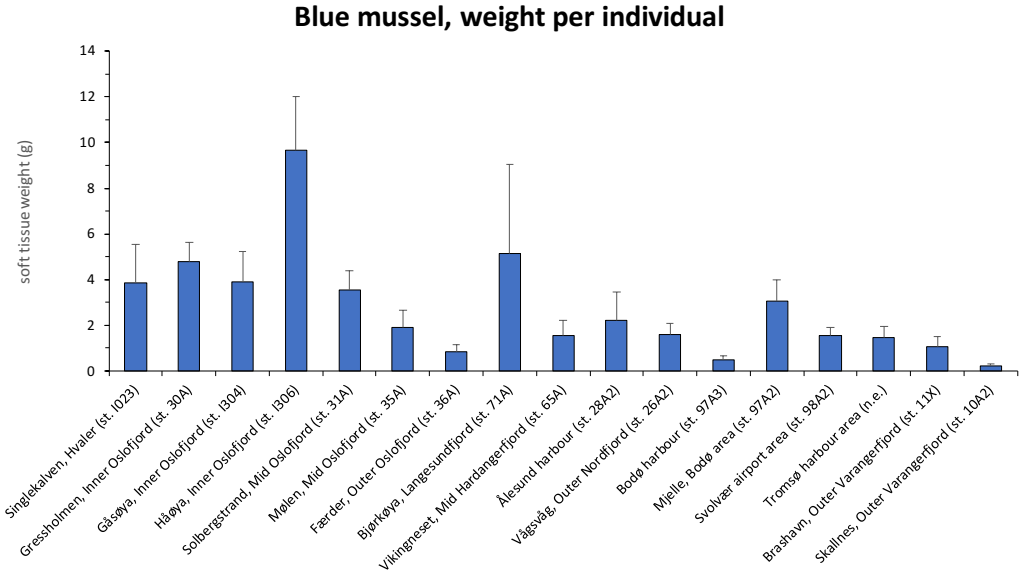


***Figure 70**. Average weights (g w.w.) of blue mussel with one S.D. indicated.*

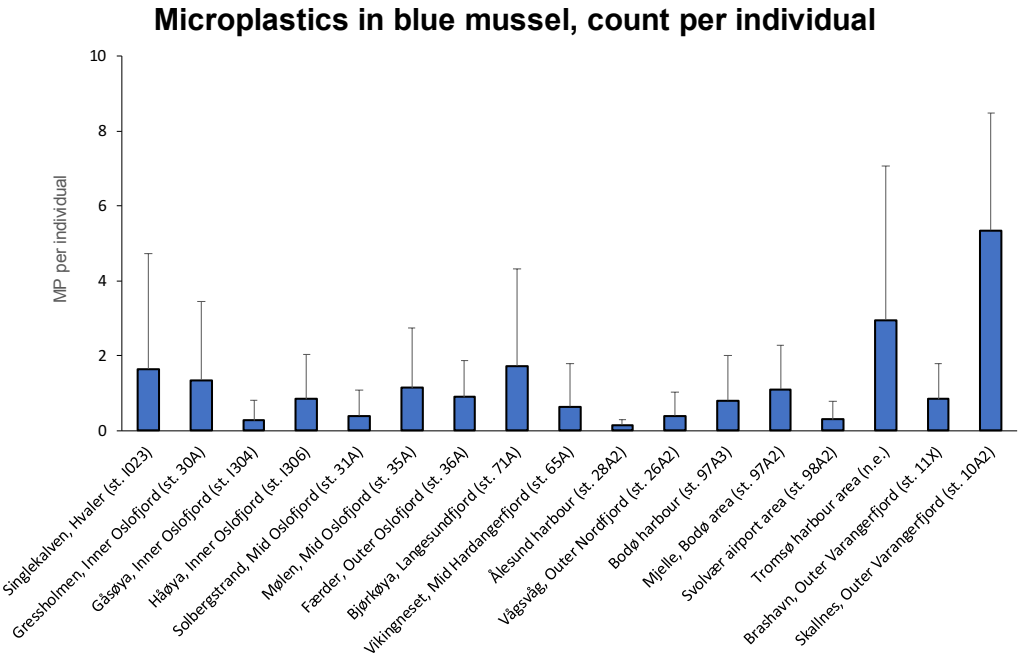


***Figure 71**. Microplastic count per individual blue mussel with one S.D. indicated.*

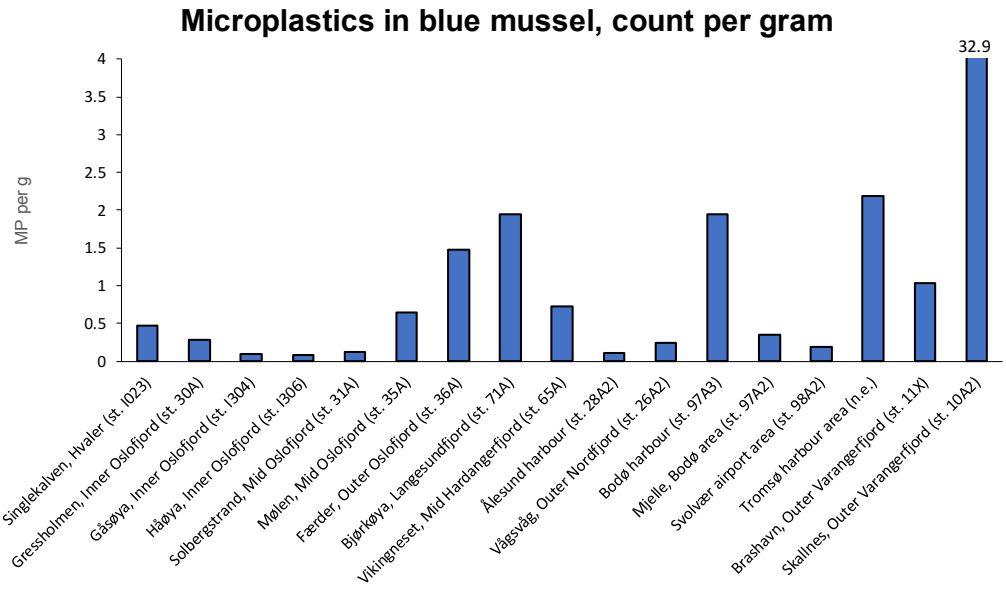


***Figure 72**. Microplastic count per gram (w.w.) blue mussel.*

3.6.2 Quantification of particles

A total number of 445 particles were extracted from mussels (n=319) from 17 stations along the Norwegian coast. Particle size ranged from 0.05 mm (detection limit) to 17.01 mm along their longest dimension. Smaller microplastics (<1mm) accounted for 81.2% of the particles whereas large microplastics (1 – 5 mm) accounted for 18.1% of the particles. The remaining 0.7 % of particles were > 5 mm (***Table 26***).

3.6.3 Chemical identification

A subsample of particles from across the sampling stations were subjected to chemical identification (***Figure 73***). A total number of 169 particles were subjected to FT-IR analysis (41% of all particles). The chemical composition of the representative subsample was dominated by semi-synthetic polymers with a total of 69% pertaining to cellulosic material (48 %), viscose (17 %) and lyocell (Rayon) (4 %) particles. 14 % of the particles would be classified as traditional plastics (including polypropylene polyamide, acrylic, polyvinyl chloride, polyesters and polyethylene).13 % of the particles were rubber like particles including styrene-butadiene rubber (SBR).

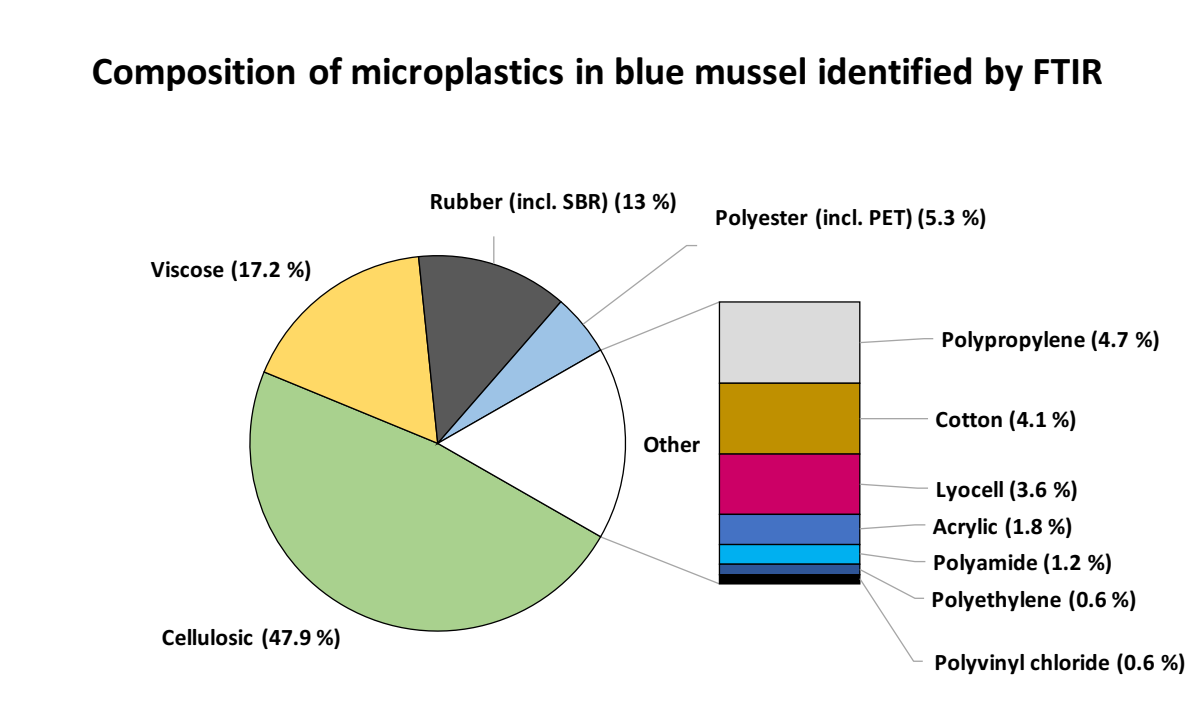


Figure 73. *Composition of 41 % of the microplastic particles in blue mussel as identified by FTIR.*

3.6.4 Comparison of visual and chemical results

The accuracy of NIVA research scientists to visually identify microplastics from biota samples was high (90 %, ***Table 25***). From this subsample, 19 of 182 visually identified plastics were reclassified as non-plastics either because there was no clear match on FTIR or the best match was a non-plastic spectra (such as minerals). Spectra match can be affected in many ways, for example, at Station 92A2, several particles obtain very low matches following FTIR which could be associated with biofilms or environmental contamination from microbes on the particles.

Table 25. *Extract of results from FTIR analysis of 2017 stations where more than 20 % of particles were tested.*

Station	Total identified by FTIR	Not plastic or no match	Confirmed as plastic *	Semi-synthetic **	Rubber ***	Correct ID
I023	18	0	4	5	9	100%
30A	9	1		6	1	89%
I304	1	0		1		100%
I306	7			7		100%
31A	3			3		100%
35A	11	1	1	1	8	91%
36A	8	2	1	5		75%
71A	17		3	14		100%
65A	8		1	7		100%
28A2	3		1	2		100%
26A2	11	1	1	9		91%
97A3	10	3	2	4	1	70%
97A2	15	7*	6	2		53%
98A2 ****	-					n.a
Tromsø	22	1	1	17	3	95%
11X	8		1	7		100%
10A2	31	3	2	25	1	90%
Total	**182**	**19**				**89.6%**

*) Polyamide (PA), Polyehthylene (PE), Polyvinyl chloride (PVC), Polyesters, etc.

**) Celluosic, viscose, Rayon.

***) Ethylene propylene diene terpolymer (EPDM), Styrene-butadine ribber (SBR), Hydrogenated nitrile butadiene rubber (HNBR).

****) Sample had several particles with low match spectra possibly associated with biofilms on the particles.

3.6.5 Comparison to previously published 2016 and 2017 data.

In this report, not all stations were re-investigated across both years. Overall, eight stations were assessed for MP contamination in both 2016 and 2017. Five stations from 2016 were not assessed in 2017 and eleven new stations were added for 2017, giving a total of 19 stations for 2017. Therefore, the microplastic data presented in this report were from mussels all being gathered in 2017, but the data from 2017 do represent a mixture of new data and already analysed data.

Data compiled for both years (***Table 26***) shows that more stations, and more individuals, were investigated in 2017 compared to 2016, although the percentage of individuals containing MPs decreased from 77 % in 2016 to 59 % in 2017.

Based on two years worth of data, the average MP count per individual was similar in 2016 and 2017, although the average number of MP count per g (w.w.) increased. In addition, mussels from Skallneset had by far the highest values of microplastics detected in 2017 (both per individual and per gram). This result was also observed in 2016 (Lusher *et al.*, 2017 - M-897|2017, Bråte *et al.*, 2018). This was a surprising finding in 2016, since this area was considered to be relatively *pristine*. Interestingly, mussels from this station were the smallest sized mussels of all stations. Further investigation in to size effects on mussels is therefore required because elevated levels were observed in small mussels in both 2016 and 2017. For example, small sized mussel may be less efficient in egesting microplastics (Bråte *et al.* 2018).

The particle detection limit in 2016 was 0.07 mm whereas in 2017 it was lowered to 0.03 mm. This has reduced the average size particle size to 0.64 mm and increased the percentage of small microplastics from 66% in 2016 to 82% in 2017. For all stations combined, the shape and polymer composition of particles appears to be comparable between 2016 and 2017, with fibers being the most dominant shape, and cellulosic materials and rubbery-like polymers being the most abundant. Classical polymers, which are often detected in environmental samples (Phuong *et al.* 2016, Li *et al.* 2018), were also detected in mussels in both years, these included polypropylene, polyamide, acrylic, polyvinyl chloride, polyesters and polyethylene. When combining the FT-IR data from all stations, the polymeric compositions of the particles were similar across both years, although this was not tested statistically. It was outside the report's scope to conduct an in-depth investigation of significant differences and similarities between each station over the two years. The comparability between the polymeric composition of microplastic detected in mussels from 2016 and 2017, illustrates that the plastics and microplastics sources to the Norwegian coastal environment probably were similar for the two years. This further supports findings that mussels can be used to qualitatively monitor small microplastics (<1 mm) in coastal environments, and this may be used in the future to track sources of plastics.

***Table 26**. Comparison of microplastic investigations of blue mussel in 2016 (Lusher et al. 2017 - M-897\|2017).*

	2016	2017
Number of stations	13	19
Number of individuals	252	359
Number with potential plastics	193	212
Percentage	76.6%	59.1%
Average MP ind.$^{-1}$ ± SD	1.84 (± 2.06)	1.84 (± 2.80)
Range MP ind.$^{-1}$	0 – 14.67	0 - 21
Average MP g w.w.$^{-1}$± SD	1.85 (± 3.74)	2.61 (± 10.24)
Range MP MP ind.$^{-1}$	0 – 24.45	0 - 120
Number of particles identified	616	655
Particle type		
Fibre	85%	80%
Fragment	11%	18%
Film/foam	4%	2%
Size range		
Average	0.95 (± 0.93)	0.64 (± 0.96)
Min (detection limit)	0.15 mm	0.03 mm
Max	8.01 mm	17.07 mm
% small microplastic (< 1mm)	66%	82%
% large microplastic (1 -5 mm)	32%	17%
% meso/macroplastics (>5 mm)	2%	<1%

3.6.6 Concluding remark

Microplastic contamination is ubiquitous in the marine environment and should be monitored to assess temporal or spatial trends. Microplastics were found in mussels from all stations along the Norwegian coast collected in 2017 as was previously demonstrated in 2016 with the exception from one station. Available data is not sufficient to observe conclusive trends in microplastic presence and composition over the two years of initial monitoring, however one station, Skallnes did stand out for both years. These mussels were the smallest sized mussels analysed, highlighting the requirement to evaluate size as a parameter in microplastic monitoring. Strict standardisation of mussel size on collection may need to be implemented for future microplastic monitoring.

Overall, the composition of particles regarding both shape and polymeric composition appears to be comparable between 2016 and 2017, with fibres dominating and cellulosic materials being the most abundant component of the particles analysed. The comparability between the polymeric composition of microplastic detected in mussels from 2016 and 2017, illustrates that the plastics and microplastics sources to the Norwegian coastal environment probably were similar for the two years. This finding support that mussels can be used to qualitatively monitor small microplastics (<1 mm) in coastal environments, and this may be used in the future to track the sources of this plastic pollution.

4. Conclusions

This programme examines long-term changes for legacy contaminants in biota along the coast of Norway in both polluted areas and areas remote from point sources. In addition, the programme includes supplementary investigations funded by the Ministry of Climate and Environment. As such, the programme provides a basis for assessing the state of the environment for the coastal waters with respect to contaminants and changes over time. In this annual report the primary concern is in relation to environmental quality standards (EQS) and the secondary concern is in relation to a new concept denoted provisional high reference concentrations (PROREF). The main conclusions from the 2017 investigations were (based on wet weight basis):

- Of the 809 median values from 2017 for the 30 selected contaminants, 262 values could be assessed against the EQS of which 157 (59.9 %) were below the EQS.
- Of the 809 median values from 2017 for the 30 selected contaminants, all values could be assessed against the provisional high reference concentration (PROREF) of which 578 (71.4 %) were below PROREF.
- Most temporal trends are downwards, predominantly for metals, including TBT and its effect (imposex), but also PCBs and PFOS downward trends were observed.
- The decrease in TBT can be related to legislation banning the use of this substance.
- For the first time since 1991, the effects of TBT on dogwhelk, the imposex parameter VDSI, were zero at all eight stations.
- Significant upward long-term trend in mercury (Hg) was found in cod fillet from the Inner Oslofjord. Both significant upward long- and short-term trends for Hg were found in the harbours of Kristiansand and Tromsø, while significant upward short-term trends were found at Farsund, Bømlo and in Lofoten. While Hg concentration is strongly linked to fish length, these trends were significant also after adjusting for cod length for Kristiansand harbour, Farsund and Lofoten.
- Highest concentrations of PBDEs, predominantly BDE47, were found in the Bergen harbour and Inner Oslofjord for cod liver, and in the harbours of Bergen (Nordnes) and Bodø for blue mussel.
- Concentrations of PCB-7 in blue mussel at 23 stations had increased PROREF factors since 2016.
- Blue mussel from one station in the Sørfjord had concentrations exceeding PROREF for DDE (degradation product of DDT) by a factor of over 20, presumably related to the earlier use of DDT as pesticide in this orchard district.
- Cod liver from the Inner Oslofjord had significantly higher levels of PFOSA than the nine other stations investigated in the Oslofjord.
- The dominant hexabromocyclododecane (HBCD) in cod liver was α–HBCD. The concentration of α–HBCD was significantly highest in cod liver from in the Inner Oslofjord of all cod stations and in blue mussel from Bodø harbour of all blue mussel stations; probably related to urban activities.
- Short chain chlorinated paraffins (SCCP) were highest in cod liver in Bergen harbour whereas medium chain chlorinated paraffins (MCCP) were highest in Ålesund harbour. SCCP was also highest in blue mussel from Ålesund harbour, whereas MCCP was highest in blue mussel from the Bodø harbour.
- There were both significant upward long- and short-term trends for MCCP in cod liver from the Inner Oslofjord.
- The median concentrations of bisphenol A and alkylphenols were below the quantification limit.
- The median concentrations of tetrabrombisphenol (TBBPA) were generally below the quantification limit.

- For siloxanes in cod liver, D5 was the most dominant, and the levels were highest in the Inner Oslofjord and lowest in the Isfjord at Svalbard. The same patterns were found for D4 and D6.
- Median concentrations of contaminants in cod liver and cod muscle from Svalbard were generally low (below PROREF), the exception being for Cd, which exceeded PROREF by a factor of two.
- Contaminants were analyzed in the blood and egg (homogenate of yolk and albumin) of the eider duck from Svalbard. This was the first time this species was used under the MILKYS programme. Concentrations of Hg, Pb, As, CB153 BDE47, PFOS and PFOSA in egg were in the same level as from comparable studies from the region.
- The ICES/OSPAR Background Assessment Criteria (BAC) for OH-pyrene in cod bile was exceeded at all stations investigated.
- Inhibited ALA-D activity in cod liver from the Inner Oslofjord and Inner Sørfjord indicated exposure to lead.
- EROD activities in cod liver from the Inner Oslofjord suggested exposure to organic contaminants.
- The Inner Oslofjord, and to a lesser degree the harbour areas of Bergen, Kristiansand, Trondheim and Bodø seems all together to be an area where contaminants tend to appear in high concentrations. This is probably caused by a high population in watershed area, a multitude of urban activities, and former and present use of products containing contaminants. A reduced water exchange in the Inner Oslofjord with the outer fjord will also contribute to higher contaminant levels in water and biota.
- High levels of PCBs and Hg in cod are reasons for concern, particularly in the Inner Oslofjord. There is some evidence that elevated concentrations may result from increased fish length due to poor recruitment of cod in recent years in this area. Although the long-term trend for Hg was upward, no trend was observed when adjusted for fish length. No recent-trend was observed, neither for concentrations adjusted for fish length nor for concentrations without such adjustment.
- Results from stabile isotopes indicate that the stations show very similar patterns from 2012 to 2017 in terms of isotopic signatures, indicating a geographical trend, persistent in time.
- Microplastics are found in Norwegian mussels from all stations, and Skallneset in the far north had for the second year the highest levels of microplastics detected, however standardised monitoring is required to identify conclusive trends both quantitatively and qualitatively.

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Appendix A
Quality assurance programme

Information on Quality Assurance

The laboratories (NIVA and subcontractor Eurofins) have participated in the QUASIMEME international intercalibration exercises and other proficiency testing programmes relevant to chemical and imposex analyses.

The quality assurance programme is corresponding to the 2015 programme (cf. Green *et al*. 2016 – M-618|2016). The results for QUASIMEME round 2016-1, FAPAS 1275 and FAPAS 1281 apply to the 2017 samples. The results are acceptable.

NIVA participated in the last round of QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" performed in June-August 2012. Shell height, penis-length-male, penis-length-female, average-shell-height and female-male-ratio were measured. NIVA got the score satisfactory for all parameters except number of females for one sample, which got the score questionable. The score for VDSI was satisfactory for both samples tested.

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

Accreditation
The laboratories used for the chemical testing are accredited according to ISO/IEC 17025:2005, except for the PFASs.

Summary of quality control results
Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly (***Table 27***). Fish protein (DORM-4 and DOLT-5) was used as SRM for the control of the determination of metals. The reference material for determination of BDEs and HBCDDs in blue mussel was Folkehelse RM, an internal reference (fish oil) and SRM2974, a CRM (organics in freeze-dried mussel tissue) produced by NIST (National Institute of Standards and Technology). For determination of PCBs, DDTs and PAHs in blue mussel, as well as HBCDDs, PCBs, DDTs and BDEs in liver, Quasimeme biota samples with known true value was applied in addition to an in-house reference material (HSD-1) created by Eurofins from spiked fish liver. For TBBPA, spiked fish oil was used for quality assurance, and for chlorinated paraffins and octyl/nonylphenols, spiked fish meal was used.

Table 27. *Summary of the quality control of results for the 2017 biota samples analysed in 2017-2018. The Standard Reference Materials (SRM) was DORM-4* (fish protein) for blue mussel, fish liver and fish fillet. The in-house reference materials were QUASIMEME samples QOR110BT (mussel tissue), QBC032BT and QOR108BT (fish liver) and QPH065BT (shellfish tissue). In addition, spiked fish oil, spiked fish meal and spiked internal reference material were analysed. The SRMs and in-house reference materials and quality assurance standards were analysed in series with the MILKYS samples, and measured several times (N) over a number of weeks (W). The values are reported in the following units: metals (mg/kg), BDE (pg/g), PCB (µg/kg), DDTs (µg/kg), HBCDDs (ng/g), PAH (µg/kg), TBBPA (ng/sample), BPA (µg/kg), SCCP/MCCP (ng/sample) octyl/nonylphenol (ng/sample) and PFASs (% recovery). Tissue types were: mussel soft body (SB), fish liver (LI) and fish fillet (MU).*

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
Ag	**Silver**	SB/LI	DOLT-5	2.05 ± 0.08	41	9	1,67	0,110
As	**Arsenic**	SB/LI	DORM-4	6,80±0,64	51	17	6,47	0,250
Cd	**Cadmium**	SB/LI	DORM-4	0,306±0,015	51	17	0,31	0,013
Cr	**Chromium**	SB/LI	DORM-4	1,87±0,16	51	17	1,79	0,160
Co	**Cobalt**	SB/LI	DOLT-5	0.267 ± 0.026	41	9	0,23	0,012
Cu	**Copper**	SB/LI	DORM-4	15,9±0,9	51	17	14,45	0,740
Hg	**Mercury**	SB/MU	DORM-4	0,41±0,055	72	18	0,415	0,035
Ni	**Nickel**	SB/LI	DORM-4	1,36±0,22	51	17	1,22	0,110
Pb	**Lead**	SB/LI	DORM-4	0,416±0,053	51	17	0,4	0,025
Zn	**Zinc**	SB/LI	DORM-4	52,2±3,2	51	17	50,06	2,410
Sn	**Tin**	SB/LI	DOLT-5	0.069 ± 0.036	41	9	0,09	0,020
BDE-28	**2,2,4' Tribromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	84,34	2,23
BDE-47	**2,2',4,4',-Tetrabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	1573,00	23,35
BDE-100	**2,2',4,4',6-Pentabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	329,31	23,89
BDE-99	**2,2',4,4',5-Pentabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	248,14	13,73
BDE-154	**2,2',4,4',5,6'-Hexabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	192,55	37,98
BDE-153	**2,2',4,4'5,5'-Hexabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	59,66	3,51
BDE-183	**2,2',3,4,4,5',6-Heptabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	-	-
BDE-196	**2,2',3,3',4,4',5,6-Octabromodiphenyleter**	SB/LI	Internal RM (fish oil)		12	10	-	-
BDE-209	**Decabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	160,41	68,37
BDE-17	**2,2',4-Tribromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	16,35	3,16
BDE-49	**2,2',4,5'-tetrabromodiphenyleter**	SB/LI	Internal RM (fish oil)		12	10	433,07	14,41
BDE-66	**2,3',4,4'-Tetrabromodiphenyleter**	SB/LI	Internal RM (fish oil)		12	10	63,76	3,53
BDE-71	**2,3',4',6-Tetrabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	4,56	3,96
BDE-77	**3,3',4',4-Tetrabde**	SB/LI	Internal RM (fish oil)		12	10	5,36	0,45
BDE-85	**2,2',3,4',4-PentaBDE**	SB/LI	Internal RM (fish oil)		12	10	0,00	0,00
BDE-119	**2,3',4,4',6-Pentabromodiphenyl ether**	SB/LI	Internal RM (fish oil)		12	10	34,08	2,34
BDE-126	**3,3',4,4',5-Pentabromodiphenylether**	SB/LI	Internal RM (fish oil)		12	10	12,10	3,52
BDE-138	**2,2',3,4,4',5'-HexaBDE**	SB/LI	Internal RM (fish oil)		12	10	0,00	0,00
PCB 81	**PCB congener CB-81**	SB/LI	Internal RM (fishmeal)	0,208 ± 0,169	34	13	0,45	0,26
PCB 77	**PCB congener CB-77**	SB/LI	Internal RM (fishmeal)	9,68 ± 4,22	34	13	9,14	2,42
PCB 52	**PCB congener CB-52**	SB/LI	Internal RM (fishmeal)	256 ± 29	34	13	267	24
PCB 28	**PCB congener CB-28**	SB/LI	Internal RM (fishmeal)	112 ± 47	34	13	107	23
PCB 189	**PCB congener CB-189**	SB/LI	Internal RM (fishmeal)	6,06 ± 1,22	34	13	6,42	0,49
PCB 180	**PCB congener CB-180**	SB/LI	Internal RM (fishmeal)	430 ± 41	34	13	480	60
PCB 169	**PCB congener CB-169**	SB/LI	Internal RM (fishmeal)	0,791 ± 0,184	34	13	0,81	0,1
PCB 167	**PCB congener CB-167**	SB/LI	Internal RM (fishmeal)	30,5 ± 7,3	34	13	30,9	4,34
PCB 157	**PCB congener CB-157**	SB/LI	Internal RM (fishmeal)	13,9 ± 1,1	34	13	14,2	0,96

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
PCB 156	PCB congener CB-156	SB/LI	Internal RM (fishmeal)	48,7 ± 3,3	34	13	50,4	4,08
PCB 153	PCB congener CB-153	SB/LI	Internal RM (fishmeal)	1410 ± 170	34	13	1540	175
PCB 138	PCB congener CB-138	SB/LI	Internal RM (fishmeal)	846 ± 139	34	13	944	121
PCB 126	PCB congener CB-126	SB/LI	Internal RM (fishmeal)	3,19 ± 0,42	34	13	3,00	0,24
PCB 123	PCB congener CB-123	SB/LI	Internal RM (fishmeal)	3,94 ± 1,5	34	13	4,65	1,1
PCB 118	PCB congener CB-118	SB/LI	Internal RM (fishmeal)	446 ± 30	34	13	468	41
PCB 114	PCB congener CB-114	SB/LI	Internal RM (fishmeal)	7,02 ± 2,21	34	13	7,73	0,87
PCB 105	PCB congener CB-105	SB/LI	Internal RM (fishmeal)	134 ± 11	34	13	142	11
PCB 101	PCB congener CB-101	SB/LI	Internal RM (fishmeal)	605 ± 65	34	13	644	71
DDEOP	o,p'-DDE	SB/LI	Pool_107 (fishmeal)	0,06 ± 0,012	20	16	0,062	0,008
TDEOP	o,p'-DDD	SB/LI	Pool_107 (fishmeal)	0,16 ± 0,032	20	16	0,16	0,018
DDTOP	o,p'-DDT	SB/LI	Pool_107 (fishmeal)	0,082 ± 0,016	20	16	0,084	0,014
DDEPP	p,p'-DDE	SB/LI	Pool_107 (fishmeal)	1,94 ± 0,39	20	16	1,99	0,20
TDEPP	p,p'-DDD	SB/LI	Pool_107 (fishmeal)	0,75 ± 0,15	20	16	0,80	0,106
DDTPP	p,p'-DDT	SB/LI	Pool_107 (fishmeal)	0,40 ± 0,08	20	16	0,39	0,036
α-HBCDD	α-Hexabromocyclododecane	SB/LI	Internal RM (fish oil)		7	3	950,87	84,38
ß-HBCDD	ß- Hexabromocyclododecane	SB/LI	Internal RM (fish oil)		7	3	52,56	11,15
γ-HBCDD	γ- Hexabromocyclododecane	SB/LI	Internal RM (fish oil)		7	3	285,28	33,97
BGHIP	Benzo[ghi]perylene	SB/LI	Pool_107 (fishmeal)	0,59 ± 0,15	10	24	0,53	0,19
ICDP	Indeno[1,2,3-cd]pyrene	SB/LI	Pool_107 (fishmeal)	0,46 ± 0,11	10	24	0,42	0,08
BBJF	Benzo[b+j]fluoranthene	SB/LI	Pool_107 (fishmeal)	1,20 ± 0,30	10	24	1,14	0,22
DBA3A	Dibenzo[ac,ah]anthracene	SB/LI	Pool_107 (fishmeal)	-	-	-	-	-
BKF	Benzo[k]fluoranthene	SB/LI	Pool_107 (fishmeal)	0,32 ± 0,08	10	24	0,29	0,07
ACNLE	Acenaphthylene	SB/LI	Pool_107 (fishmeal)	1,92 ± 0,48	7	24	1,69	0,43
ANT	Anthracene	SB/LI	Pool_107 (fishmeal)	1,08 ± 0,27	9	24	0,97	0,22
BAA	Benzo[a]anthracene	SB/LI	Pool_107 (fishmeal)	1,06 ± 0,26	10	24	1,04	0,19
BAP	Benzo[a]pyrene	SB/LI	Pool_107 (fishmeal)	0,66 ± 0,17	10	24	0,56	0,11
CHR	Chrysene	SB/LI	Pool_107 (fishmeal)	1,23 ± 0,31	10	24	1,03	0,24
FLU	Fluoranthene	SB/LI	Pool_107 (fishmeal)	3,76 ± 0,94	10	24	3,30	0,77
FLE	Fluorene	SB/LI	Pool_107 (fishmeal)	-	-	-	-	-
NAP	Naphthalene	SB/LI	Pool_107 (fishmeal)	-	-	-	-	-
PA	Phenanthrene	SB/LI	Pool_107 (fishmeal)	9,58 ± 2,40	10	24	8,81	1,99
PYR	Pyrene	SB/LI	Pool_107 (fishmeal)	4,10 ± 1,03	10	24	3,57	1,00
ACNE	Acenaphthene	SB/LI	Pool_107 (fishmeal)	-	-	-	-	-
TBBPA	Tetrabromobisphenol-A	SB/LI	Internal RM (spiked fishoil)	-	4	4	1220,90	113,90
BPA	Bisphenol-A	SB/LI	Olive oil REFBP007	50.2 ± 28.2	52	-	51,3	6,3
BPA	Bisphenol-A	SB/LI	Peach, canned REFBP008	4.11 ± 1.35	37	-	4,39	0,48
BPA	Bisphenol-A	SB/LI	REFBP005 Liqur 2	22.2 ± 10.8	77	-	23	2,6
APO	4-tert-oktylfenol	LI/SB	Internal RM (spiked blank)		12	14	54886,56	21982,41
APO	4-Nonylfenol	LI/SB	Internal RM (spiked blank)		12	14	64473,36	37167,59
APO	4-n-oktylfenol	LI/SB	Internal RM (spiked blank)		12	14	61395,85	20999,74
APO	4-n-nonylfenol	LI/SB	Internal RM (spiked blank)		12	14	64960,69	22448,25
MOT	Monooktyltinn (MOT)	LI/SB	-	-	-	-	-	
MBT	Monobutyltinn (MBT)	LI/SB	ZRM 81 (mussel tissue)	1,50 ± 0,56	20	12	1,72	0,17
DBT	Dibutyltinn (DBT)	LI/SB	ZRM 81 (mussel tissue)	1,54 ± 0,5	15	12	1,21	0,13
TBT	Tributyltinn (TBT)	LI/SB	ZRM 81 (mussel tissue)	2,20 ± 0,38	20	12	1,91	0,22
TTBT	Tetrabutyltinn (TTBT)	LI/SB	-	-	-	-	-	
DOT	Dioktyltinn (DOT)	LI/SB	-	-	-	-	-	
TPhT	Trifenyltinn (TPhT)	LI/SB	ZRM 81 (mussel tissue)	1,31 ± 0,24	16	12	1,43	0,24

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
TCyT	**Trisykloheksyltinn (TCyT)**	LI/SB	-	-	-	-	-	
PFBS	**Perfluorobutane sulphonate**	LI		100%[1)]	10		92	7,3%
PFHxA	**Perfluorohexane acid**	LI		100%[1)]	10		103	5,1%
PFHpA	**Perfluoroheptane acid**	LI		100%[1)]	10		101	3,9%
PFOA	**Perfluorooctane acid**	LI		100%[1)]	10		98	3,1%
PFNA	**Perfluorononane acid**	LI		100%[1)]	10		99	7,0%
PFOS	**Perfluorooctane sulphonate**	LI		100%[1)]	10		104	2,5%
PFOSA	**Perfluorooctane sulphone amide**	LI		100%[1)]	10		102	3,4%
PFHxS	**Perfluorohexane sulphonate**	LI		100%[1)]	10		93	2,2%
PFDA	**Perfluorodecanoic acid**	LI		100%[1)]	10		96	6,1
PFUDA	**Perfluoroundecanoic acid**	LI		100%[1)]	10		111	10,0%
PFDS	**Perfluorodecanesulphonate**	LI		100%[1)]	10		85	10,0%

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

** BCR, Community Bureau of Reference, Commission of the European Communities.

1) Not certified value.

2) Recovery of spiked control sample

Appendix B
Abbreviations

(Includes all abbreviations used in MILKYS and forerunner programmes,
and not just those used in this report.)

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

Abbreviation[1]	English	*Norwegian*	Param. group
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
BBJF [3, 4]	benzo[*j*]fluoranthene	*benzo[j]fluoranten*	PAH
BBJKF [3, 4]	benzo[*b,j,k*]fluoranthene	*benzo[b,j,k]fluoranten*	PAH
BBJKF [3, 4]	benzo[b+j,k]fluoranthene	*benzo[b+j,k]fluoranten*	PAH
BBKF [3, 4]	benzo[*b+k*]fluoranthene	*benzo[b+k]fluoranten*	PAH
BEP	benzo[*e*]pyrene	*benzo[e]pyren*	PAH
BGHIP [3]	benzo[*ghi*]perylene	*benzo[ghi]perylen*	PAH
BIPN [2]	biphenyl	*bifenyl*	PAH
BJKF [3, 4]	benzo[*j,k*]fluoranthene	*benzo[j,k]fluorantren*	PAH
BKF [3, 4]	benzo[*k*]fluoranthene	*benzo[k]fluorantren*	PAH
CHR [3, 4]	chrysene	*chrysen*	PAH
CHRTR [3, 4]	chrysene+triphenylene	*chrysen+trifenylen*	PAH
COR	coronene	*coronen*	PAH
DBAHA [3, 4]	dibenz[*a,h*]anthracene	*dibenz[a,h]anthracen*	PAH
DBA3A [3, 4]	dibenz[*a,c/a,h*]anthracene	*dibenz[a,c/a,h]antracen*	PAH
DBP [4, 6]	dibenzopyrenes	*dibenzopyren*	PAH
DBT	dibenzothiophene	*dibenzothiofen*	PAH
DBTC1	C_1-dibenzothiophenes	*C_1-dibenzotiofen*	PAH
DBTC2	C_2-dibenzothiophenes	*C_2-dibenzotiofen*	PAH
DBTC3	C_3-dibenzothiophenes	*C_3-dibenzotiofen*	PAH
FLE [3]	fluorene	*fluoren*	PAH
FLU [3]	fluoranthene	*fluoranten*	PAH
ICDP [3, 4]	indeno[*1,2,3-cd*]pyrene	*indeno[1,2,3-cd]pyren*	PAH
NAP [2, 4]	naphthalene	*naftalen*	PAH
NAPC1 [2]	C_1-naphthalenes	*C_1-naftalen*	PAH
NAPC2 [2]	C_2-naphthalenes	*C_2-naftalen*	PAH
NAPC3 [2]	C_3-naphthalenes	*C_3-naftalen*	PAH
NAP1M [2]	1-methylnaphthalene	*1-metylnaftalen*	PAH
NAP2M [2]	2-methylnaphthalene	*2-metylnaftalen*	PAH
NAPD2 [2]	1,6-dimethylnaphthalene	*1,6-dimetylnaftalen*	PAH
NAPD3 [2]	1,5-dimethylnaphthalene	*1,5-dimetylnaftalen*	PAH
NAPDI [2]	2,6-dimethylnaphthalene	*2,6-dimetylnaftalen*	PAH
NAPT2 [2]	2,3,6-trimethylnaphthalene	*2,3,6-trimetylnaftalen*	PAH
NAPT3 [2]	1,2,4-trimethylnaphthalene	*1,2,4-trimetylnaftalen*	PAH
NAPT4 [2]	1,2,3-trimethylnaphthalene	*1,2,3-trimetylnaftalen*	PAH
NAPTM [2]	2,3,5-trimethylnaphthalene	*2,3,5-trimetylnaftalen*	PAH
NPD	collective term for naphthalenes, phenanthrenes and dibenzothiophenes	*Samme betegnelse for naftalen, fenantren og dibenzotiofens*	PAH
PA [3]	phenanthrene	*fenantren*	PAH
PAC1	C_1-phenanthrenes	*C_1-fenantren*	PAH
PAC2	C_2-phenanthrenes	*C_2-fenantren*	PAH
PAC3	C_3-phenanthrenes	*C_3-fenantren*	PAH
PAM1	1-methylphenanthrene	*1-metylfenantren*	PAH

Abbreviation[1]	English	*Norwegian*	Param. group
PAM2	2-methylphenanthrene	*2-metylfenantren*	PAH
PADM1	3,6-dimethylphenanthrene	*3,6-dimetylfenantren*	PAH
PADM2	9,10-dimethylphenanthrene	*9,10-dimetylfenantren*	PAH
PER	perylene	*perylen*	PAH
PYR [3]	pyrene	*pyren*	PAH
DI-Σn	sum of "n" dicyclic "PAH"s (footnote 2)	*sum "n" disykliske "PAH" (fotnote 2)*	
P-Σn/P_S	sum "n" PAH (DI-Σn not included, footnote 3)	*sum "n" PAH (DI-Σn ikke inkludert, fotnote 3)*	
PK-Σn/PK_S	sum carcinogen PAHs (footnote 4)	*sum kreftfremkallende PAH (fotnote 4)*	
PAHΣΣ	dI-Σn + P-Σn etc.	*dI-Σn + P-Σn mm.*	
SPAH	"total" PAH, specific compounds not quantified (outdated analytical method)	*"total" PAH, spesifikke forbindelser ikke kvantifisert (foreldet metode)*	
BAP_P	% BAP of PAHΣΣ	*% BAP av PAHΣΣ*	
BAPPP	% BAP of P-Σn	*% BAP av P-Σn*	
BPK_P	% BAP of PK_Sn	*% BAP av PK_Sn*	
PKn_P	% PK_Sn of PAHΣΣ	*% PK_Sn av PAHΣΣ*	
PKnPP	% PK_Sn of P-Σn	*% PK_Sn av P-Σn*	
PCBs			
PCB	**polychlorinated biphenyls**	***polyklorerte bifenyler***	
CB	individual chlorobiphenyls (CB)	*enkelte klorobifenyl*	
CB28	CB28 (IUPAC)	*CB28 (IUPAC)*	OC-CB
CB31	CB31 (IUPAC)	*CB31 (IUPAC)*	OC-CB
CB44	CB44 (IUPAC)	*CB44 (IUPAC)*	OC-CB
CB52	CB52 (IUPAC)	*CB52 (IUPAC)*	OC-CB
CB77 [5]	CB77 (IUPAC)	*CB77 (IUPAC)*	OC-CB
CB81 [5]	CB81 (IUPAC)	*CB81 (IUPAC)*	OC-CB
CB95	CB95 (IUPAC)	*CB95 (IUPAC)*	OC-CB
CB101	CB101 (IUPAC)	*CB101 (IUPAC)*	OC-CB
CB105	CB105 (IUPAC)	*CB105 (IUPAC)*	OC-CB
CB110	CB110 (IUPAC)	*CB110 (IUPAC)*	OC-CB
CB118	CB118 (IUPAC)	*CB118 (IUPAC)*	OC-CB
CB126 [5]	CB126 (IUPAC)	*CB126 (IUPAC)*	OC-CB
CB128	CB128 (IUPAC)	*CB128 (IUPAC)*	OC-CB
CB138	CB138 (IUPAC)	*CB138 (IUPAC)*	OC-CB
CB149	CB149 (IUPAC)	*CB149 (IUPAC)*	OC-CB
CB153	CB153 (IUPAC)	*CB153 (IUPAC)*	OC-CB
CB156	CB156 (IUPAC)	*CB156 (IUPAC)*	OC-CB
CB169 [5]	CB169 (IUPAC)	*CB169 (IUPAC)*	OC-CB
CB170	CB170 (IUPAC)	*CB170 (IUPAC)*	OC-CB
CB180	CB180 (IUPAC)	*CB180 (IUPAC)*	OC-CB
CB194	CB194 (IUPAC)	*CB194 (IUPAC)*	OC-CB
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*	

Abbreviation[1]	English	*Norwegian*	Param. group
CB-ΣΣ	sum of PCBs, includes PCB-Σ7	*sum PCBer, inkluderer PCB-Σ7*	
TECBW	sum of PCB-toxicity equivalents after WHO model, see **TEQ**	*sum PCB- toksisitets ekvivalenter etter WHO modell, se **TEQ***	
TECBS	sum of PCB-toxicity equivalents after SAFE model, see **TEQ**	*sum PCB-toksisitets ekvivalenter etter SAFE modell, se **TEQ***	
PCN	polychlorinated naphthalenes	*polyklorerte naftalen*	
DIOXINs			
TCDD	2, 3, 7, 8-tetrachloro-dibenzo dioxin	*2, 3, 7, 8-tetrakloro-dibenzo dioksin*	OC-DX
CDDST	sum of tetrachloro-dibenzo dioxins	*sum tetrakloro-dibenzo dioksiner*	
CDD1N	1, 2, 3, 7, 8-pentachloro-dibenzo dioxin	*1, 2, 3, 7, 8-pentakloro-dibenzo dioksin*	OC-DX
CDDSN	sum of pentachloro-dibenzo dioxins	*sum pentakloro-dibenzo dioksiner*	
CDD4X	1, 2, 3, 4, 7, 8-hexachloro-dibenzo dioxin	*1, 2, 3, 4, 7, 8-heksakloro-dibenzo dioksin*	OC-DX
CDD6X	1, 2, 3, 6, 7, 8-hexachloro-dibenzo dioxin	*1, 2, 3, 6, 7, 8-heksakloro-dibenzo dioksin*	OC-DX
CDD9X	1, 2, 3, 7, 8, 9-hexachloro-dibenzo dioxin	*1, 2, 3, 7, 8, 9-heksakloro-dibenzo dioksin*	OC-DX
CDDSX	sum of hexachloro-dibenzo dioxins	*sum heksakloro-dibenzo dioksiner*	
CDD6P	1, 2, 3, 4, 6, 7, 8-heptachloro-dibenzo dioxin	*1, 2, 3, 4, 6, 7, 8-heptakloro-dibenzo dioksin*	OC-DX
CDDSP	sum of heptachloro-dibenzo dioxins	*sum heptakloro-dibenzo dioksiner*	
CDDO	Octachloro-dibenzo dioxin	*Oktakloro-dibenzo dioksin*	OC-DX
PCDD	sum of polychlorinated dibenzo-p-dioxins	*sum polyklorinaterte-dibenzo-p-dioksiner*	
CDF2T	2, 3, 7, 8-tetrachloro-dibenzofuran	*2, 3, 7, 8-tetrakloro-dibenzofuran*	OC-DX
CDFST	sum of tetrachloro-dibenzofurans	*sum tetrakloro-dibenzofuraner*	
CDFDN	1, 2, 3, 7, 8/1, 2, 3, 4, 8-pentachloro-dibenzofuran	*1, 2, 3, 7, 8/1, 2, 3, 4, 8-pentakloro-dibenzofuran*	OC-DX
CDF2N	2, 3, 4, 7, 8-pentachloro-dibenzofuran	*2, 3, 4, 7, 8-pentakloro-dibenzofuran*	OC-DX
CDFSN	sum of pentachloro-dibenzofurans	*sum pentakloro-dibenzofuraner*	
CDFDX	1, 2, 3, 4, 7, 8/1, 2, 3, 4, 7, 9-hexachloro-dibenzofuran	*1, 2, 3, 4, 7, 8/1, 2, 3, 4, 7, 9-heksakloro-dibenzofuran*	OC-DX
CDF6X	1, 2, 3, 6, 7, 8-hexachloro-dibenzofuran	*1, 2, 3, 6, 7, 8-heksakloro-dibenzofuran*	OC-DX

Abbreviation[1]	English	*Norwegian*	Param. group
CDF9X	1, 2, 3, 7, 8, 9-hexachloro-dibenzofuran	*1, 2, 3, 7, 8, 9-heksakloro-dibenzofuran*	OC-DX
CDF4X	2, 3, 4, 6, 7, 8-hexachloro-dibenzofuran	*2, 3, 4, 6, 7, 8-heksakloro-dibenzofuran*	OC-DX
CDFSX	sum of hexachloro-dibenzofurans	*sum heksakloro-dibenzofuraner*	
CDF6P	1, 2, 3, 4, 6, 7, 8-heptachloro-dibenzofuran	*1, 2, 3, 4, 6, 7, 8-heptakloro-dibenzofuran*	OC-DX
CDF9P	1, 2, 3, 4, 7, 8, 9-heptachloro-dibenzofuran	*1, 2, 3, 4, 7, 8, 9-heptakloro-dibenzofuran*	OC-DX
CDFSP	sum of heptachloro-dibenzofurans	*sum heptakloro-dibenzofuraner*	OC-DX
CDFO	octachloro-dibenzofurans	*octakloro-dibenzofuran*	OC-DX
PCDF	sum of polychlorinated dibenzo-furans	*sum polyklorinated dibenzo-furaner*	
CDDFS	sum of PCDD and PCDF	*sum PCDD og PCDF*	
TCDDN	sum of TCDD-toxicity equivalents after Nordic model, see **TEQ**	*sum TCDD- toksisitets ekvivalenter etter Nordisk modell, se **TEQ***	
TCDDI	sum of TCDD-toxicity equivalents after international model, see **TEQ**	*sum TCDD-toksisitets ekvivalenter etter internasjonale modell, se **TEQ***	
BIOICIDES			
ALD	aldrin	*aldrin*	OC-DN
DIELD	dieldrin	*dieldrin*	OC-DN
ENDA	endrin	*endrin*	OC-DN
CCDAN	cis-chlordane (=α-chlordane)	*cis-klordan (=α-klordan)*	OC-DN
TCDAN	trans-chlordane (=γ-chlordane)	*trans-klordan (=γ-klordan)*	OC-DN
OCDAN	oxy-chlordane	*oksy-klordan*	OC-DN
TNONC	trans-nonachlor	*trans-nonaklor*	OC-DN
TCDAN	trans-chlordane	*trans-klordan*	OC-DN
Triclosan	5-chloro-2-2,4-dichlorophenoxy)phenol	*5-kloro-2-2,4-diklorofenoxy)fenol*	OC-CL
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	*3-(3,4-diklorofenyl)-1,1-dimetylurea*	OC-CL
Irgarol	a triazine (nitrogen containing heterocycle)	*en triazin (nitrogen holdig heterosykle)*	
OCS	octachlorostyrene	*oktaklorstyren*	OC-CL
QCB	pentachlorobenzene	*pentaklorbenzen*	OC-CL
DDD	dichlorodiphenyldichloroethane 1,1-dichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyldikloretan 1,1-dikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDE	dichlorodiphenyldichloroethylene (principle metabolite of DDT) 1,1-*bis*-(4-chlorophenyl)-2,2-dichloroethene*	*diklordifenyldikloretylen (hovedmetabolitt av DDT) 1,1-bis-(4-klorofenyl)-2,2-dikloroeten*	OC-DD

Abbreviation[1]	English	*Norwegian*	Param. group
DDT	dichlorodiphenyltrichloroethane 1,1,1-trichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyltrikloretan* *1,1,1-trikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDEOP	o,p'-DDE	*o,p'-DDE*	OC-DD
DDEPP	p,p'-DDE	*p,p'-DDE*	OC-DD
DDTOP	o,p'-DDT	*o,p'-DDT*	OC-DD
DDTPP	p,p'-DDT	*p,p'-DDT*	OC-DD
TDEPP	p,p'-DDD	*p,p'-DDD*	OC-DD
DDTEP	p,p'-DDE + p,p'-DDT	*p,p'-DDE + p,p'-DDT*	OC-DD
DD-nΣ	sum of DDT and metabolites, n = number of compounds	*sum DDT og metabolitter, n = antall forbindelser*	OC-DD
HCB	hexachlorobenzene	*heksaklorbenzen*	OC-CL
HCHG	Lindane γ HCH = gamma hexachlorocyclohexane (γ BHC = gamma benzenehexachloride, outdated synonym)	*Lindan* *γ HCH = gamma heksaklorsykloheksan* *(γ BHC = gamma benzenheksaklorid, foreldet betegnelse)*	OC-HC
HCHA	α HCH = alpha HCH	*α HCH = alpha HCH*	OC-HC
HCHB	β HCH = beta HCH	*β HCH = beta HCH*	OC-HC
HC-nΣ	sum of HCHs, n = count	*sum av HCHs, n = antall*	
EOCl	extractable organically bound chlorine	*ekstraherbart organisk bundet klor*	OC-CL
EPOCl	extractable persistent organically bound chlorine	*ekstraherbart persistent organisk bundet klor*	OC-CL
PBDEs			
PBDE	**polybrominated diphenyl ethers**	***polybromerte difenyletere***	OC-BR
BDE	brominated diphenyl ethers		OC-BR
BDE28	2,4,4'-tribromodiphenyl ether	*2,4,4'-tribromdifenyleter*	OC-BR
BDE47	2,2',4,4'-tetrabromodiphenyl ether	*2,2',4,4'-tetrabromdifenyleter*	OC-BR
BDE49*	2,2',4,5'- tetrabromodiphenyl ether	*2,2',4,5'- tetrabromdifenyleter*	OC-BR
BDE66*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE71*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE77	3,3',4,4'-tetrabromodiphenyl ether	*3,3',4,4'-tetrabromdifenyleter*	OC-BR
BDE85	2,2',3,4,4'-pentabromodiphenyl ether	*2,2',3,4,4'-pentabromdifenyleter*	OC-BR
BDE99	2,2',4,4',5-pentabromodiphenyl ether	*2,2',4,4',5-pentabromdifenyleter*	OC-BR
BDE100	2,2',4,4',6-pentabromodiphenyl ether	*2,2',4,4',6-pentabromdifenyleter*	OC-BR
BDE119	2,3',4,4',6-pentabromodiphenyl ether	*2,3',4,4',6-pentabromdifenyleter*	OC-BR

Abbreviation[1]	English	*Norwegian*	Param. group
BDE126	3,3',4,4',5'-pentabromodiphenyl ether	*3,3',4,4',5'-pentabromdifenyleter*	OC-BR
BDE138	2,2',3,4,4',5'-hexabromodiphenyl ether	*2,2',3,4,4',5'-heksabromdifenyleter*	OC-BR
BDE153	2,2',4,4',5,5'-hexabromodiphenyl ether	*2,2',4,4',5,5'-heksabromdifenyleter*	OC-BR
BDE154	2,2',4,4',5,6'-hexabromodiphenyl ether	*2,2',4,4',5,6'-heksabromdifenyleter*	OC-BR
BDE183	2,2',3,4,4',5',6-heptabromodiphenyl ether	*2,2',3,4,4',5',6-heptabromdifenyleter*	OC-BR
BDE196	2,2',3,3',4,4',5',6-octabromodiphenyl ether	*2,2',3,3',4,4',5',6-octabromdifenyleter*	OC-BR
BDE205	2,2',3,3',4,4',5,5',6'-nonabromodiphenyl ether	*2,2',3,3',4,4',5,5',6'-nonabromdifenyleter*	OC-BR
BDE209	decabromodiphenyl ether	*Dekabromdifenyleter*	OC-BR
BDE4S	sum of BDE -85, -99, -100, -119	*sum av BDE -85, -99, -100, -119*	OC-BR
BDE6S	sum of BDE -28, -47, -99, -100, -153, -154	*sum av BDE -28, -47, -99, -100, -153, -154*	OC-BR
BDESS	sum of all BDEs	*sum av alle BDEer*	OC-BR
HBCDD	hexabromocyclododecane (1 2 5 6 9 10 hexabromocyclododecane)	*heksabromsyklododekan (1 2 5 6 9 10 heksabromsyklododekan)*	OC-BR
HBCDA	α–hexabromocyclododecane	*α–heksabromsyklododekan*	OC-BR
HBCDB	β-hexabromocyclododecane	*β-heksabromsyklododekan*	OC-BR
HBCDG	γ-hexabromocyclododecane	*γ-heksabromsyklododekan*	OC-BR
TBBPA	tetrabrombisphenol A	*tetrabrombisfenol A*	OC-CP
BPA	bisphenol A	*bisfenol A*	OC-CP
HCBD	hexachlorobutadiene	*heksaklorobutadien*	OC-CL
PFAS	**perfluorinated alkylated substances**	***Perfluoralkylerte stoffer***	
PFBS	perfluorobutane sulfonate	*perfluorbutan sulfonat*	PFAS
PFDCA	perfluorodecanoic acid	*perfluordekansyre*	PFAS
PFDCS	ammonium henicosafluorodecanesulphonate	*ammonium henikosafluordekansulfonat*	PFAS
PFHxA	perfluorohexanoic acid	*perfluorhexansyre*	PFAS
PFHpA	perfluoroheptanoic acid	*perfluorheptansyre*	PFAS
PFOA	perfluorooctanoic acid	*perfluoroktansyre*	PFAS
PFNA	perfluorononanoic acid	*perfluornonansyre*	PFAS
PFOS	Perfluorooctanesulfonic acid	*Perfluorooktansulfonatsyre*	PFAS
PFOSA	perfluorooctanesulfonamide	*perfluorooktansulfonamid*	PFAS
PFUDA	perfluoroundecanoic acid	*perfluorundekansyre*	PFAS
SCCP	short chain chlorinated paraffins, C_{10-13}	*kortkjedete klorerte parafiner, C_{10-13}*	

Abbreviation[1]	English	*Norwegian*	Param. group
MCCP	medium chain chlorinated, C_{14-17} paraffins	*mediumkjedete klorerte parafiner, C_{14-17}*	
Alkylphenols	**phenols/chlorophenols**	***fenoler/klorfenoler***	
4-n-NP	4-n-nonylphenol	*4-n-nonylfenol*	
4-n-OP	4-n-octylphenol	*4-n-oktylfenol*	
4-t-NP	4-tert-nonylphenol	*4-tert-nonylfenol*	
4-t-OP	4-tert-octylphenol	*4-tert-oktylfenol*	
	stable isotopes	***stabile isotoper***	
C/N	$\delta^{13}C$ /$\delta^{15}N$	$\delta^{13}C$ /$\delta^{15}N$	
Delta15N	$\delta^{15}N$	$\delta^{15}N$	
Delta13C	$\delta^{13}C$	$\delta^{13}C$	
	phthalates/organic esters	***phtalater/organiske estere***	
BBP	benzylbutylphthalate	*benzylbutylftalat*	
DBP[6]	dibutylphthalate	*dibutylftalat*	
DBPA	dibutyladipat	*dibutyladipat*	
DEHA	diethylhexcyladipate	*dietylheksyladipat*	
DEHP	di(2-ethylhexyl)-phthalate	*di(2-etylhexyl)-ftalat*	
DEP	dietylphthale	*dietylftalat*	
DEPA	diethyladipat	*dietyladipat*	
DIBP	diisobutylphthalate	*diisobutylftalat*	
DIDP	diisodectylyphthalate	*diisodekylftalat*	
DIHP	diisoheptylphthalate	*diisoheptylftalat*	
DINCH	1,2-Cyclohexane dicarboxylic acid diisononyl ester	*1,2-sykloheksan dikarboksyl syre diisononyl ester*	
DIPA	diisobutyl adipate	*diisobutyladipat*	
DMP	dimethylphthalate	*dimetylftalat*	
DNOP	di-n-octylphthalte	*di-n-oktylftalt*	
DPF	diphenylphthalate	*difenylftalat*	
SDD	dinonylphthalte+diisononylphthalate	*dinonylftalat+diisononylftalat*	
TBP	tributylphosphate	*tributylfosfat*	
TOA	tributyl-o-acetylcitrate	*tributyl-o-acetylcitrate*	
Triclosan	triclosan	*triklosan*	
[not defined]	dodecylfenol	*dodecylfenol*	
Diuron	Duiron	*Durion*	
Irgarol	Irgarol	*Irgarol*	
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			

Abbreviation[1]	English	*Norwegian*	Param. group
ALAD	δ-aminolevulinic acid dehydrase inhibition	*δ-aminolevulinsyre dehydrase*	BEM
CYP1A	cytochrome P450 1A-protein	*cytokrom P450 1A-protein*	BEM
EROD-activity	Cytochrome P4501A-activity (CYP1A/P4501A1, EROD)	*cytokrom P450 1A-aktivitet*	BEM
OH-pyrene	Pyrene metabolite	*pyren metabolitt*	BEM
VDSI	Vas Deferens Sequence Index		BEM
INSTITUTES			
EFDH	Eurofins [DK]	*Eurofins [DK]*	
EFNO	Eurofins [N, Moss]	*Eurofins [N, Moss]*	
EFGFA	Eurofins [DE, GFA]	*Eurofins [DE, GFA]*	
EFSofia	Eurofins [DE, Sofia]	*Eurofins [DE, Sofia]*	
FIER	Institute for Nutrition, Fisheries Directorate	*Fiskeridirektoratets Ernæringsinstitutt*	
FORC	FORCE Institutes, Div. for Isotope Technique and Analysis [DK]	*FORCE Institutterne, Div. for Isotopteknik og Analyse [DK]*	
GALG	GALAB Laboratories Gmbh [D]	*GALAB Laboratories Gmbh [D]*	
IFEN	Institute for Energy Technology	*Institutt for energiteknikk*	
IMRN	Institute of Marine Research (IMR)	*Havforskningsinstituttet*	
NACE	Nordic Analytical Center	*Nordisk Analyse Center*	
NILU	Norwegian Institute for Air Research	*Norsk institutt for luftforskning*	
NIVA	Norwegian Institute for Water Research	*Norsk institutt for vannforskning*	
SERI	Swedish Environmental Research Institute	*Institutionen för vatten- och luftvårdsforskning*	
SIIF	Fondation for Scientific and Industrial Research at the Norwegian Institute of Technology-SINTEF (a division, previously: Center for Industrial Research SI)	*Stiftelsen for industriell og teknisk forskning ved Norges tekniske høgskole- SINTEF (en avdeling, tidligere: Senter for industriforskning SI)*	
VETN	Norwegian Veterinary Institute	*Veterinærinstituttet*	
VKID	Water Quality Institute [DK]	*Vannkvalitetsintitutt [DK]*	

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

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

3) Indicates the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 (often called PAH-16) minus naphthalene (dicyclic), so that the Norwegian Environmental Agency classification system can be applied

4) Indicates PAH compounds potentially cancerogenic for humans according to IARC (1987, updated 14 August 2007 at http://monographs.iarc.fr/ENG/Classification/crthgr01.php), i.e., categories 1, 2A, and 2B (are, possibly and probably carcinogenic). NB.: the update includes Chrysene as cancerogenic.

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

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

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

Other abbreviations *andre forkortelser*

	English	*Norwegian*
TEQ	"Toxicity equivalency factors" for the most toxic compounds within the following groups:	*"Toxisitetsekvivalentfaktorer" for de giftigste forbindelsene innen følgende grupper.*
	• polychlorinated dibenzo-p-dioxins and dibenzofurans (**PCDD/PCDFs**). Equivalents calculated after Nordic model (Ahlborg 1989) [1] or international model (Int./EPA, cf. Van den Berg *et al.* 1998) [2]	• *polyklorerte dibenzo-p-dioksiner og dibenzofuraner (**PCDD/PCDF**). Ekvivalentberegning etter nordisk modell (Ahlborg 1989) [1] eller etter internasjonal modell (Int./EPA, cf. Van den Berg et al. 1998) [2]*
	• non-ortho and mono-ortho substituted chlorobiphenyls after WHO model (Ahlborg *et al.* 1994) [3] or Safe (1994, cf. NILU pers. comm.)	• *non-orto og mono-orto substituerte klorobifenyler etter WHO modell (Ahlborg et al. 1994) [3] eller Safe (1994, cf. NILU pers. medd.)*
ppm	parts per million, mg/kg	*deler pr. milliondeler, mg/kg*
ppb	parts per billion, μg/kg	*deler pr. milliarddeler, μg/kg*
ppp	parts per trillion, ng/kg	*deler pr. tusen-milliarddeler, ng/kg*
d.w.	dry weight basis	*tørrvekt basis*
w.w.	wet weight or fresh weight basis	*våtvekt eller friskvekt basis*

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

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

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

Appendix C
Provisional high reference concentrations (PROREF)

***Table 28**. Provisional high reference concentrations* (PROREF) for contaminants in blue mussel (*Mytilus edulis*), perwinkle (*Littorina littorea*), dogwhelk (*Nucella lapillus)* and Atlantic cod (*Gadus* morhua) for whole soft body, liver and muscle based on MILYKYS data (see section 2.7). All values are on a wet weight basis. The stations, count and total number of values used to determine PROREF are indicated. Also indicated for comparison are the upper limits to Class I from the system (cf. Molvær *et al. 1997)* used in previous annual MILKYS reports and the risk-based standards (e.g. EU EQS and Water Region Specific Substances) used in this report (cf. Miljødirektorat 2016 – M-608|2016). The yellow and green cells indicate where PROREF is below the corresponding limits from the two systems, and the orange and red cells indicate where PROREF is above the corresponding limits from the two systems.

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
CD	Mytilus edulis	Soft body	I241, 26A2, I969	3	106	M	**0.18**	0.4	*2.222*		
CR	Mytilus edulis	Soft body	52A, 15A, 26A2, I131A, 64A	5	100	M	**0.36**	0.6	*1.667*		
CU	Mytilus edulis	Soft body	I307, I712, 63A, I306, I304, 57A, B11, 51A, B6, 64A, I023, 56A, B10	13	517	M	**1.42**	2	*1.408*		
HG	Mytilus edulis	Soft body	36A, 46A, 10A2	3	137	M	**0.01**	0.04	*4.000*	0.02	*2.000*
NI	Mytilus edulis	Soft body	I241, I131A, 52A, 57A, 26A2	5	101	M	**0.29**	1	*3.448*		
PB	Mytilus edulis	Soft body	11X, 48A	2	75	M	**0.2**	0.6	*3.000*		
AG	Mytilus edulis	Soft body	26A2, 63A, 65A, 97A2, I023, I131A, I306, I712, I241, 22A, I304	11	232	M	**0.01**	0.06	*6.000*		
CO	Mytilus edulis	Soft body	26A2, I241	2	34	M	**0.08**				
ZN	Mytilus edulis	Soft body	43A, I712, 48A	3	49	M	**17.7**	40	*2.265*		
AS	Mytilus edulis	Soft body	31A, B5, I301, I023, B2, 30A	6	204	M	**3.32**	2	*0.602*		
MO	Mytilus edulis	Soft body	B7, B11, B2, B3, B6, B10, 35A, B5	8	207	M	**0.22**				
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	M	**0.3**				
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	U	**0.12**				
CB52	Mytilus edulis	Soft body	10A2, 11X, 15A, 26A2, 41A, 43A, 64A, 65A, 69A, 84A, 97A2, 98A2	12	480	U	**0.2**				
CB101	Mytilus edulis	Soft body	43A, 48A, 98A2, 97A2, 10A2, 64A, 26A2, 11X, 41A	9	245	U	**0.2**				
CB105	Mytilus edulis	Soft body	10A2, 11X, 15A, 41A, 43A, 46A, 48A	7	208	U	**0.15**				
CB118	Mytilus edulis	Soft body	43A	1	15	U	**0.07**				
CB138	Mytilus edulis	Soft body	43A, 10A2, 11X, 41A	4	153	U	**0.2**				
CB153	Mytilus edulis	Soft body	43A, 11X, 10A2, 41A	4	153	U	**0.26**				
CB156	Mytilus edulis	Soft body	10A2, 11X, 15A, 22A, 35A, 36A, 41A, 43A, 44A, 46A, 48A	11	399	U	**0.15**				
CB180	Mytilus edulis	Soft body	10A2, 11X, 15A, 22A, 26A2	5	282	U	**0.1**				
CB_S7	Mytilus edulis	Soft body	11X, 10A2	2	96	U	**0.93**	4	*4.301*	0.6	*0.645*
DDEPP	Mytilus edulis	Soft body	43A, 41A, 10A2, 11X	4	147	U	**0.22**	2	*9.091*	610	*2772.727*
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	U	**0.6**				
HCB	Mytilus edulis	Soft body	22A, 11X, 43A, 48A, 10A2, 15A, 30A, 31A, 36A, 41A, 44A, 46A	12	517	U	**0.1**	0.1	*1.000*	10	*100.000*
NAP	Mytilus edulis	Soft body	98A2, I023, 71A	3	47	U	**17.3**			2400	*138.728*
ACNLE	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A, I132, I133	7	266	U	**1**				
ACNE	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A	5	177	U	**0.8**				
FLE	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A, I304, I306, I307, I915	9	364	U	**1.6**				
PA	Mytilus edulis	Soft body	98A2, I023, 71A	3	47	U	**2.28**				
ANT	Mytilus edulis	Soft body	30A, 71A, 98A2, I023	4	112	U	**1.1**			2400	*2181.818*
FLU	Mytilus edulis	Soft body	98A2, I023	2	32	U	**5.35**			30	*5.607*
PYR	Mytilus edulis	Soft body	98A2	1	17	U	**1.02**				
BAA	Mytilus edulis	Soft body	98A2, I023	2	32	U	**1.49**			304	*204.027*
CHR	Mytilus edulis	Soft body	98A2	1	17	U	**0.52**				
BBJF	Mytilus edulis	Soft body	98A2, I023, I304, I306, I307	5	107	U	**6.24**				
BBJKF	Mytilus edulis	Soft body	I304, I306, I307, 30A	4	96	U	**3.93**				
BKF	Mytilus edulis	Soft body	30A, 98A2, I023, I304, I306, I307, I913	7	167	U	**1.5**				
BAP	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A	5	177	U	**1.3**	1	*0.769*	5	*3.846*
ICDP	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A	5	176	U	**1.73**				
DBA3A	Mytilus edulis	Soft body	30A, I131A	2	117	U	**0.5**				
BGHIP	Mytilus edulis	Soft body	98A2, I023, I304, I306, I307, I913, 71A	7	254	U	**2.07**				
P_S	Mytilus edulis	Soft body	98A2	1	17	U	**6.04**	50	*8.284*		
CB77	Mytilus edulis	Soft body	76A	1	18	U	**0.01**				
CB81	Mytilus edulis	Soft body	76A	1	18	U	**0**				

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
CB126	Mytilus edulis	Soft body	76A	1	18	U	**0**				
CB169	Mytilus edulis	Soft body	76A	1	18	U	**0**				
MBTIN	Mytilus edulis	Soft body	22A	1	14	U	**0.86**				
DBTIN	Mytilus edulis	Soft body	30A, I131A, I201, I205, I304, I306, I307	7	317	U	**4.77**				
BDE47	Mytilus edulis	Soft body	98A2, 26A2, I023, 71A, 91A2	5	79	U	**0.14**			0.009	*0.061*
BDE99	Mytilus edulis	Soft body	98A2, 91A2, 26A2, I023	4	61	U	**0.06**				
BDE100	Mytilus edulis	Soft body	98A2, 26A2, I023, 91A2, 71A	5	79	U	**0.05**				
BDE126	Mytilus edulis	Soft body	71A, 97A2, 26A2, I023, 91A2	5	75	U	**0.05**				
BDE153	Mytilus edulis	Soft body	97A2, 26A2, I023, 91A2, 71A, 98A2, 30A	7	109	U	**0.05**				
BDE154	Mytilus edulis	Soft body	97A2, 26A2, I023, 91A2, 71A, 98A2, 30A	7	109	U	**0.05**				
BDE183	Mytilus edulis	Soft body	71A, 97A2, 26A2, I023, 91A2, 98A2	6	92	U	**0.3**				
BDE196	Mytilus edulis	Soft body	71A, 97A2, 26A2, I023, 91A2	5	75	U	**0.3**				
BDE209	Mytilus edulis	Soft body	71A, 97A2, 91A2, I023, 26A2	5	75	U	**1.29**				
BDE6S	Mytilus edulis	Soft body	98A2, 26A2, 71A, 91A2, I023	5	79	U	**0.19**			0.009	*0.044*
BDESS	Mytilus edulis	Soft body	98A2	1	16	U	**0.19**				
HBCDA	Mytilus edulis	Soft body	I023, 97A2, 91A2	3	44	U	**0.11**			167	*1518.182*
HBCDG	Mytilus edulis	Soft body	I023, 97A2, 91A2	3	44	U	**0.03**				
HBCDB	Mytilus edulis	Soft body	I023, 97A2, 91A2	3	44	U	**0.02**				
HBCDD	Mytilus edulis	Soft body	I023, 97A2, 91A2	3	44	U	**0.15**				
SCCP	Mytilus edulis	Soft body	I023, 71A, 91A2, 97A2, 26A2, 30A	6	90	U	**20.3**			6000	*296.150*
MCCP	Mytilus edulis	Soft body	I023, 26A2, 71A, 91A2, 97A2, 30A	6	89	U	**87.6**			170	*1.941*
TBT	Mytilus edulis	Soft body	11X	1	20	U	**7.11**	20	*2.813*	150	*21.097*
TCHT	Mytilus edulis	Soft body	I301, I133, 22A, 30A	4	65	U	**2**				
TDEPP	Mytilus edulis	Soft body	41A, 43A, 44A, 46A, 48A, 92A1	6	93	U	**0.1**				
TBEP	Mytilus edulis	Soft body	26A2, I023, 91A2, 97A2, 30A	5	71	U	**11.3**				
TBP	Mytilus edulis	Soft body	30A, I023, 97A2, 26A2, 91A2	5	71	U	**5.96**				
TCEP	Mytilus edulis	Soft body	26A2, I023, 91A2, 97A2, 30A	5	71	U	**55.5**				
TCPP	Mytilus edulis	Soft body	30A, 26A2, 97A2, 91A2	4	56	U	**40.3**				
TDCP	Mytilus edulis	Soft body	26A2, 91A2, 97A2, I023, 30A	5	71	U	**8.93**				
TEHP	Mytilus edulis	Soft body	26A2, I023, 91A2, 97A2, 30A	5	71	U	**24**				
TIBP	Mytilus edulis	Soft body	30A, I023, 26A2, 97A2, 91A2	5	71	U	**9.9**				
EHDPP	Mytilus edulis	Soft body	30A, 26A2, I023, 91A2, 97A2	5	71	U	**11.1**				
BPA	Mytilus edulis	Soft body	30A, 97A2, I023	3	45	U	**7.45**				
TBBPA	Mytilus edulis	Soft body	30A, 97A2, 26A2, I023, 71A, 91A2	6	87	U	**0.27**				
C/N	Mytilus edulis	Soft body	15A, 71A, I304, 22A, 30A, I023, 97A2, 56A	8	120	PERCENTW_W	**4.98**				
Delta13C	Mytilus edulis	Soft body	97A2, 22A, 26A2, 15A	4	60	NONE	**20.5**				
Delta15N	Mytilus edulis	Soft body	56A, 51A	2	30	NONE	**3.77**				
DOT	Mytilus edulis	Soft body	I301, I133, 22A, 30A	4	65	U	**0.99**				
MOT	Mytilus edulis	Soft body	I301, I133, 22A, 30A	4	65	U	**0.99**				
DDTEP	Mytilus edulis	Soft body	84A, 36A, 71A, 31A	4	107	U	**3**				
KPAH	Mytilus edulis	Soft body	98A2	1	17	U	**0.62**				
PAH16	Mytilus edulis	Soft body	98A2, I023	2	32	U	**30.1**				
TTBT	Nucella lapillus	Soft body	15G, 76G, 22G, 131G, 36G, 11G, 227G	7	35	U	**1.01**				
MBTIN	Nucella lapillus	Soft body	22G, 98G, 36G, 11G, 15G, 76G, 131G, 227G1	8	47	U	**2.18**				
DBTIN	Nucella lapillus	Soft body	11G, 131G, 15G, 98G, 36G, 22G, 76G	7	42	U	**1.2**				
MPTIN	Nucella lapillus	Soft body	71G	1	5	U	**2.62**				
DPTIN	Nucella lapillus	Soft body	71G	1	5	U	**1.94**				
TPTIN	Nucella lapillus	Soft body	71G	1	6	U	**1.65**				
TBT	Nucella lapillus	Soft body	11G, 131G, 15G, 98G	4	66	U	**23.5**			150	*6.372*
TCHT	Nucella lapillus	Soft body	76G, 22G, 131G, 11G, 36G, 15G, 98G, 227G1	8	55	U	**2.33**				
VDSI	Nucella lapillus	Soft body	11G, 15G, 131G, 76G	4	63	%	**3.68**				
DOT	Nucella lapillus	Soft body	76G, 22G, 131G, 36G, 15G, 11G, 98G, 227G1	8	55	U	**1.2**				
MOT	Nucella lapillus	Soft body	76G, 22G, 131G, 36G, 15G, 11G, 98G, 227G1	8	55	U	**1.2**				
CD	Gadus morhua	Liver	80B, 67B, 15B, 23B	4	1655	M	**0.14**	0.3	*2.143*		
CR	Gadus morhua	Liver	10B, 15B, 71B, 43B2, 80B, 13B, 36B, 30B, 98B1	9	1176	M	**0.4**				
CU	Gadus morhua	Liver	10B, 15B, 80B	3	1101	M	**14**	20	*1.429*		
HG	Gadus morhua	Fillet	10B	1	504	M	**0.06**	0.1	*1.667*	0.02	*0.333*

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
NI	Gadus morhua	Liver	15B, 23B, 43B2, 10B, 71B, 80B, 53B, 36B	8	973	M	**0.65**				
PB	Gadus morhua	Liver	10B, 36B, 67B, 92B, 15B, 43B, 98B1, 13B, 23B, 43B2	10	3616	M	**0.05**	0.1	*2.000*		
AG	Gadus morhua	Liver	80B, 10B	2	229	M	**0.93**				
CO	Gadus morhua	Liver	43B2	1	145	M	**0.06**				
ZN	Gadus morhua	Liver	98B1, 10B, 92B, 43B2, 80B	5	1351	M	**35**	30	*0.857*		
AS	Gadus morhua	Liver	10B, 13B, 80B, 43B2, 71B, 15B	6	721	M	**12.8**				
SN	Gadus morhua	Liver	10B, 15B, 23B, 36B, 43B2, 53B, 71B, 80B, 13B, 98B1, 30B	11	1381	M	**0.3**				
CB28	Gadus morhua	Liver	80B, 98B1, 23B, 67B, 10B, 43B, 92B, 53B, 43B2	9	3039	U	**8**				
CB52	Gadus morhua	Liver	67B, 23B, 98B1	3	1385	U	**16**				
CB101	Gadus morhua	Liver	23B	1	554	U	**32.4**				
CB118	Gadus morhua	Liver	98B1, 23B, 10B, 92B, 43B, 67B, 80B	7	2359	U	**100**				
CB138	Gadus morhua	Liver	98B1, 10B, 43B, 92B	4	1282	U	**158**				
CB153	Gadus morhua	Liver	98B1, 10B, 92B, 43B	4	1282	U	**190**				
CB180	Gadus morhua	Liver	98B1, 10B, 92B	3	1165	U	**45.8**				
CB_S7	Gadus morhua	Liver	98B1, 10B, 92B, 43B	4	1229	U	**614**	500	*0.814*	0.6	*0.001*
DDEPP	Gadus morhua	Liver	23B, 10B, 98B1	3	1498	U	**161**	200	*1.244*	610	*3.795*
DDTPP	Gadus morhua	Liver	10B, 23B, 36B, 98B1	4	885	U	**13**				
HCHA	Gadus morhua	Liver	53B, 15B, 36B, 10B, 23B, 30B, 67B, 92B, 43B, 98B1	10	4071	U	**8**				
HCHG	Gadus morhua	Liver	53B, 36B, 10B, 15B, 30B, 43B, 92B, 23B, 67B, 98B1	10	4074	U	**12**			61	*5.083*
HCB	Gadus morhua	Liver	36B, 53B	2	1079	U	**14**	20	*1.429*	10	*0.714*
4-N-NP	Gadus morhua	Liver	80B, 43B2	2	135	U	**131**			3000	*22.901*
4-N-OP	Gadus morhua	Liver	43B2, 80B	2	135	U	**23.5**			0.004	*0.0002*
4-T-NP	Gadus morhua	Liver	43B2, 80B	2	135	U	**241**			3000	*12.453*
4-T-OP	Gadus morhua	Liver	80B, 43B2	2	135	U	**20**			0.004	*0.0002*
CYP1A	Gadus morhua	Liver	23B, 53B	2	487	ABS	**2.07**				
ALAD	Gadus morhua	Blood	53B	1	395	ng/min/mg protein	**34.9**				
EROD	Gadus morhua	Liver	23B, 53B, 36B, 30B	4	1303	pmol/min/mg protein	**192**				
BAP3O	Gadus morhua	Bile	30B, 15B	2	305	ug/kg/ABS 380 nm	**2.78**				
PA1O	Gadus morhua	Bile	23B, 15B, 30B, 53B	4	800	ug/kg/ABS 380 nm	**6.15**				
PYR1O	Gadus morhua	Bile	23B	1	398	ug/kg/ABS 380 nm	**15.8**				
BDE28	Gadus morhua	Liver	36B, 13B, 98B1, 23B, 43B2	5	701	U	**1.4**				
BDE47	Gadus morhua	Liver	98B1, 36B, 23B	3	557	U	**16**			0.009	*0.001*
BDE49	Gadus morhua	Liver	23B, 98B1	2	266	U	**3.95**				
BDE66	Gadus morhua	Liver	23B, 98B1	2	266	U	**0.6**				
BDE71	Gadus morhua	Liver	98B1, 23B, 53B, 30B	4	553	U	**0.4**				
BDE77	Gadus morhua	Liver	30B	1	122	U	**1.69**				
BDE85	Gadus morhua	Liver	98B1, 53B, 23B, 30B	4	536	U	**1.73**				
BDE99	Gadus morhua	Liver	13B, 23B	2	363	U	**0.75**				
BDE100	Gadus morhua	Liver	98B1	1	173	U	**2.6**				
BDE126	Gadus morhua	Liver	13B, 23B, 30B, 36B, 43B2, 80B	6	419	U	**0.1**				
BDE138	Gadus morhua	Liver	30B, 23B, 53B, 98B1	4	561	U	**0.3**				
BDE153	Gadus morhua	Liver	13B, 23B	2	363	U	**0.15**				
BDE154	Gadus morhua	Liver	98B1, 36B	2	323	U	**1.5**				
BDE183	Gadus morhua	Liver	13B, 23B, 30B, 36B, 43B2, 53B, 80B, 98B1	8	1360	U	**0.6**				
BDE196	Gadus morhua	Liver	13B, 23B, 30B, 36B, 43B2, 53B, 80B, 98B1	8	1142	U	**1**				
BDE205	Gadus morhua	Liver	23B, 30B, 98B1, 53B	4	559	U	**1.5**				
BDE209	Gadus morhua	Liver	13B	1	131	U	**2**				
BDE6S	Gadus morhua	Liver	98B1	1	173	U	**19.8**			0.009	*0.0004*
BDESS	Gadus morhua	Liver	98B1	1	173	U	**19.8**	50	*2.528*		
HBCDA	Gadus morhua	Liver	43B2	1	65	U	**7**			167	*23.857*
HBCDG	Gadus morhua	Liver	43B2, 80B	2	135	U	**0.89**				
HBCDB	Gadus morhua	Liver	43B2, 80B	2	135	U	**0.4**				

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
HBCDD	Gadus morhua	Liver	43B2	1	65	U	**7.18**				
PFBS	Gadus morhua	Liver	13B, 36B, 43B2, 53B, 80B, 23B, 30B, 98B1	8	1316	U	**8**				
PFNA	Gadus morhua	Liver	13B, 23B, 30B, 36B, 43B2, 80B, 98B1, 53B	8	1315	U	**5**				
PFOA	Gadus morhua	Liver	13B, 43B2, 80B, 53B, 23B, 36B, 30B, 98B1	8	1289	U	**10**			91.3	*9.130*
PFOS	Gadus morhua	Liver	43B2, 80B	2	251	U	**10.3**	50	*4.878*	9.1	*0.888*
PFOSA	Gadus morhua	Liver	43B2, 98B1, 53B, 80B, 23B	5	718	U	**6.24**	10	*1.603*		
PFAS	Gadus morhua	Liver	43B2, 80B	2	251	U	**11**				
SCCP	Gadus morhua	Liver	23B, 43B2, 80B	3	245	U	**154**			6000	*38.961*
MCCP	Gadus morhua	Liver	23B, 43B2	2	174	U	**393**			170	*0.433*
TDEPP	Gadus morhua	Liver	23B, 92B, 36B	3	1303	U	**32**				
TBEP	Gadus morhua	Liver	43B2	1	65	U	**135**				
TBP	Gadus morhua	Liver	43B2	1	65	U	**135**				
TCEP	Gadus morhua	Liver	43B2	1	65	U	**477**				
TCPP	Gadus morhua	Liver	43B2	1	65	U	**67.6**				
TDCP	Gadus morhua	Liver	43B2	1	65	U	**71.1**				
TEHP	Gadus morhua	Liver	43B2	1	64	U	**334**				
TIBP	Gadus morhua	Liver	43B2	1	65	U	**135**				
EHDPP	Gadus morhua	Liver	43B2	1	65	U	**66.4**				
BPA	Gadus morhua	Liver	43B2, 80B	2	134	U	**2**				
TBBPA	Gadus morhua	Liver	80B, 43B2	2	135	U	**0.57**				

Appendix D
Maps of stations

Nominel station positions 1981-2017
(cf. Appendix E)

Appendix D (cont.) Map of stations

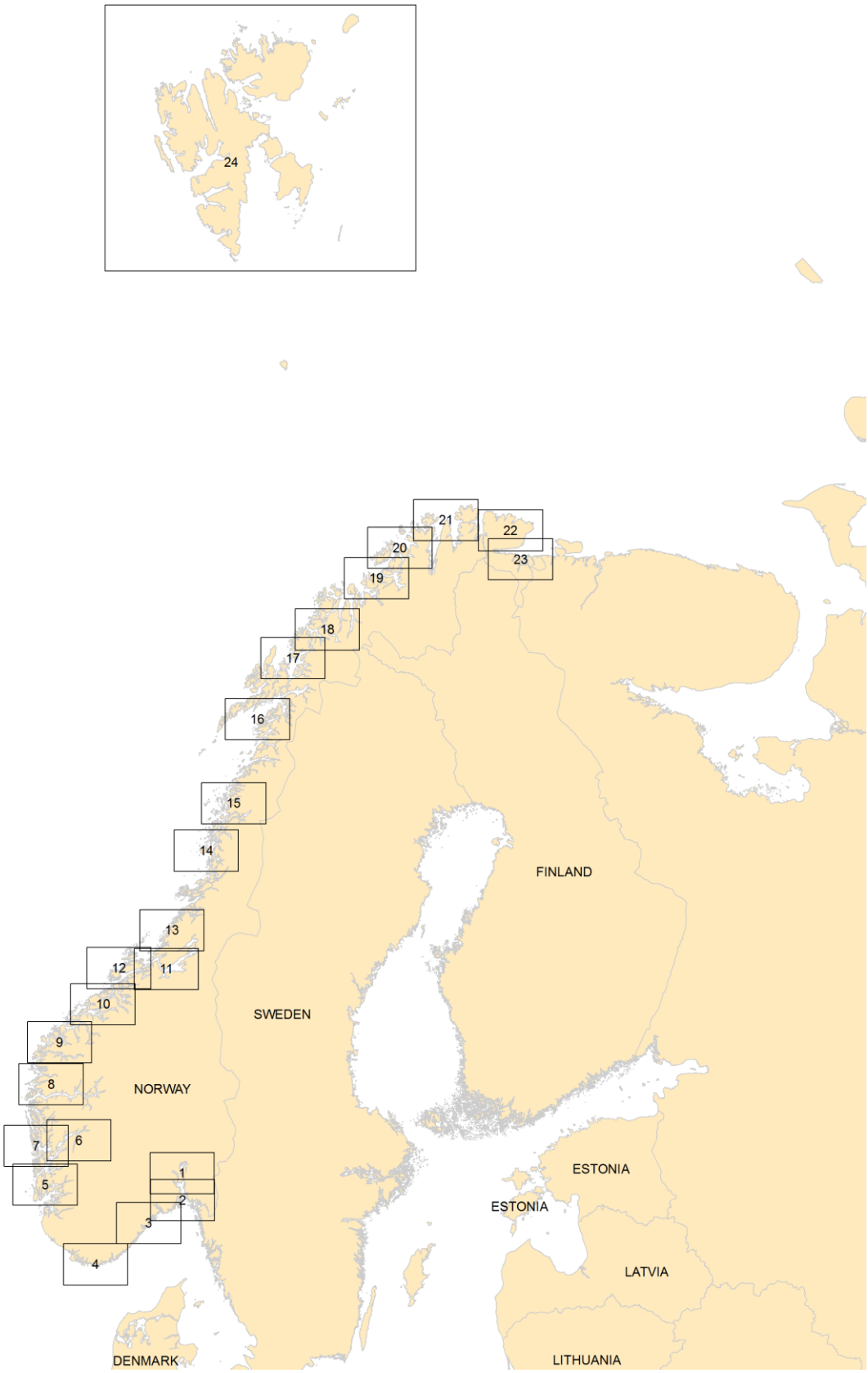
NOTES

The station's nominal position is plotted, and not the specific positions that may have differed from one year to another. The maps are generated using ArcGIS version 9.1.

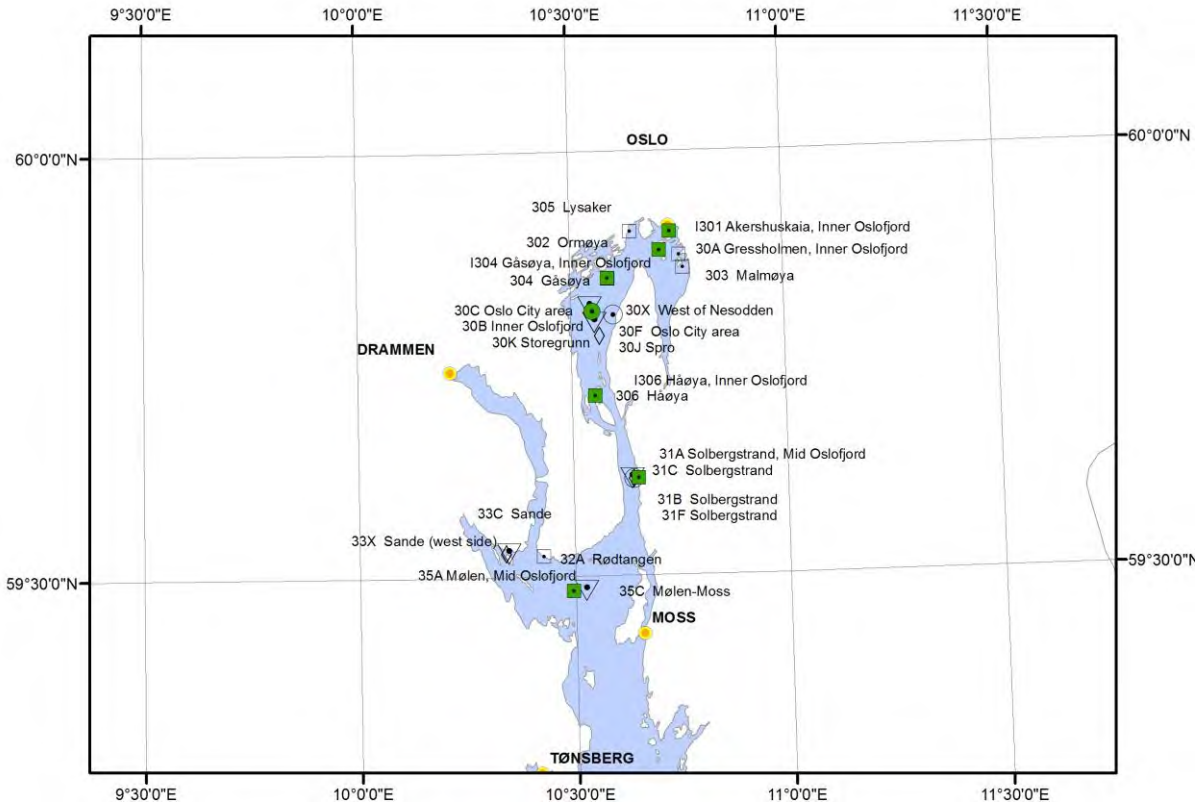
The following symbols and codes apply:

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

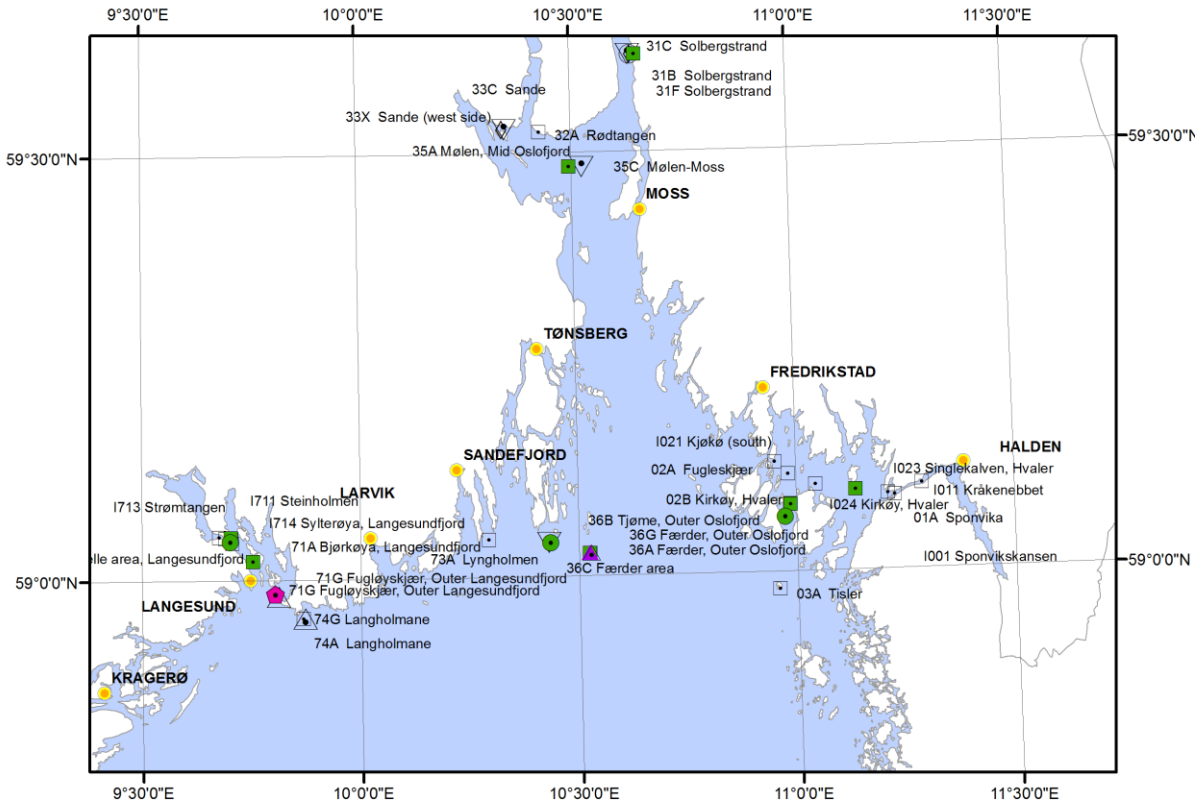
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (cf. Green *et al.* 2011b – TA-2862/2011).



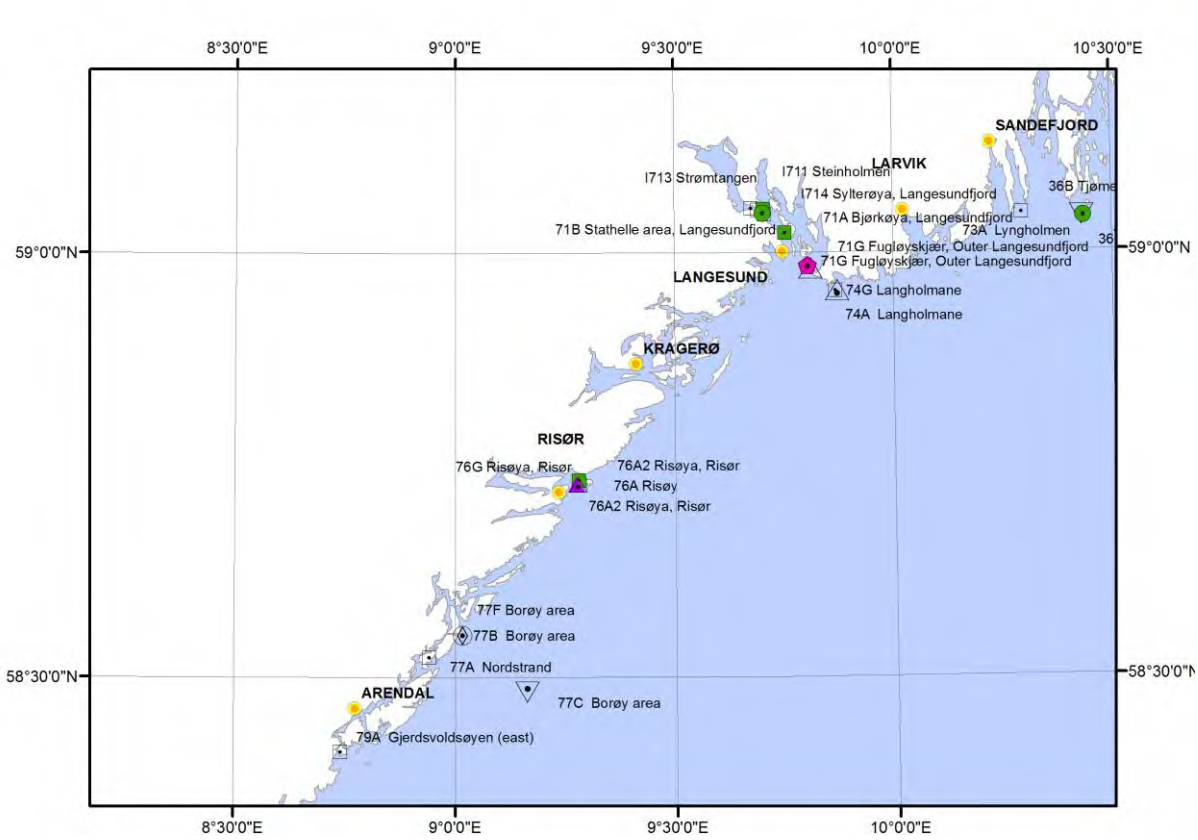
Maps presenting MILKYS stations in Norway. Numbers refer to map references that follow. Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


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

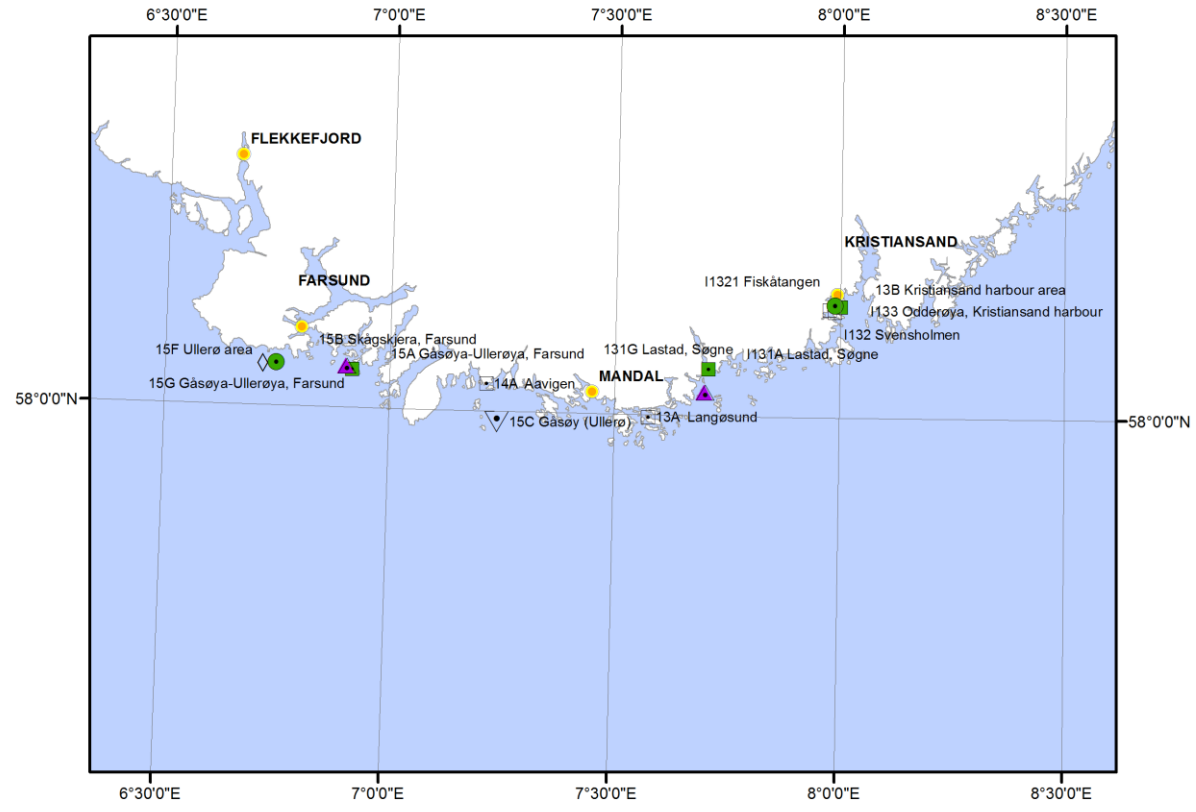
MAP 1


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

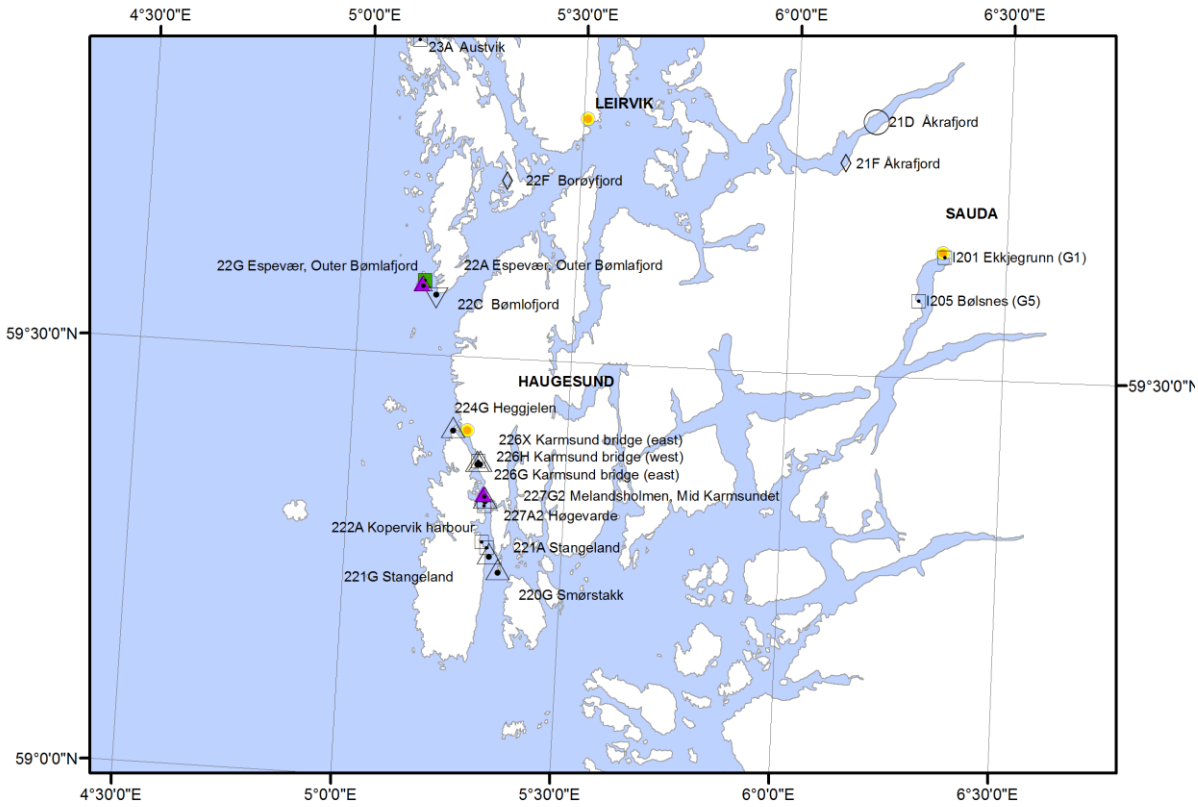
MAP 2


8°30'0"E
9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
59°0'0"N
58°30'0"N
SANDEFJORD
LARVIK
I713 Strømtangen
I711 Steinholmen
I714 Sylterøya, Langesundfjord
71A Bjørkøya, Langesundfjord
73A Lyngholmen
36B Tjøme
71B Stathelle area, Langesundfjord
71G Fugløyskjær, Outer Langesundfjord
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ
RISØR
76G Risøya, Risør
76A2 Risøya, Risør
76A Risøy
77F Borøy area
77B Borøy area
77A Nordstrand
ARENDAL
77C Borøy area
79A Gjerdsvoldsøyen (east)

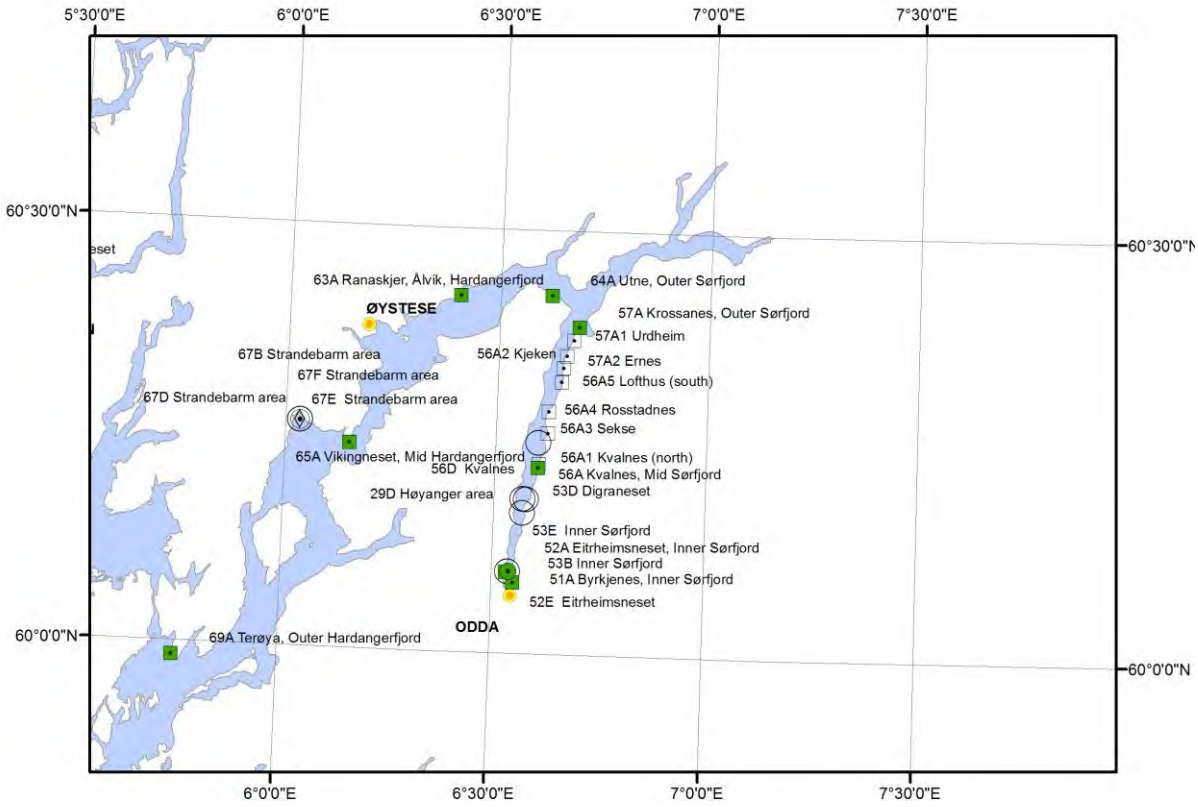
MAP 3


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
58°0'0"N
FLEKKEFJORD
KRISTIANSAND
FARSUND
I1321 Fiskåtangen
13B Kristiansand harbour area
I133 Odderøya, Kristiansand harbour
I132 Svensholmen
15B Skagskjera, Farsund
15F Ullerø area
15A Gåsøya-Ullerøya, Farsund
131G Lastad, Søgne
I131A Lastad, Søgne
15G Gåsøya-Ullerøya, Farsund
14A Aavigen
MANDAL
15C Gåsøy (Ullerø)
13A Langøsund

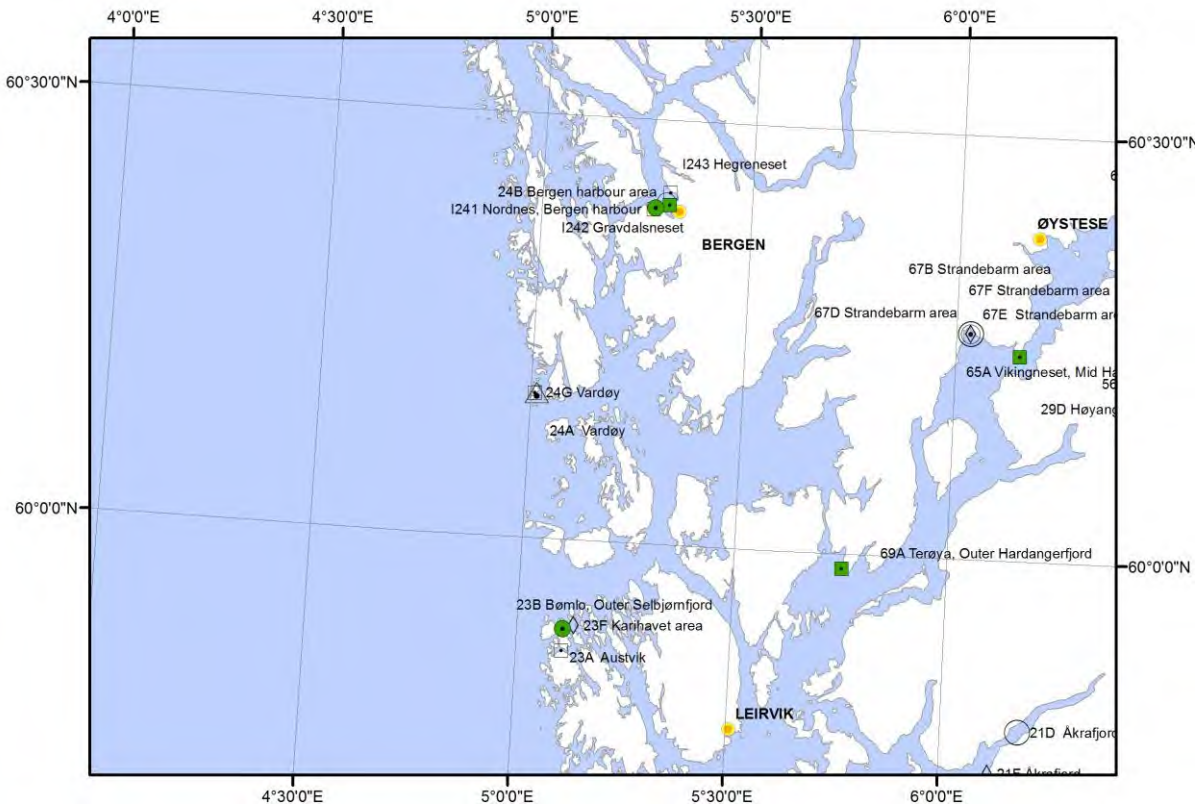
MAP 4


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
59°30'0"N
59°0'0"N
23A Austvik
LEIRVIK
21D Åkrafjord
21F Åkrafjord
22F Borøyfjord
SAUDA
22G Espevær, Outer Bømlafjord
22A Espevær, Outer Bømlafjord
I201 Ekkjegrunn (G1)
22C Bømlofjord
I205 Bølsnes (G5)
HAUGESUND
224G Heggjelen
226X Karmsund bridge (east)
226H Karmsund bridge (west)
226G Karmsund bridge (east)
227G2 Melandsholmen, Mid Karmsundet
227A2 Høgevarde
222A Kopervik harbour
221A Stangeland
221G Stangeland
220G Smørstakk

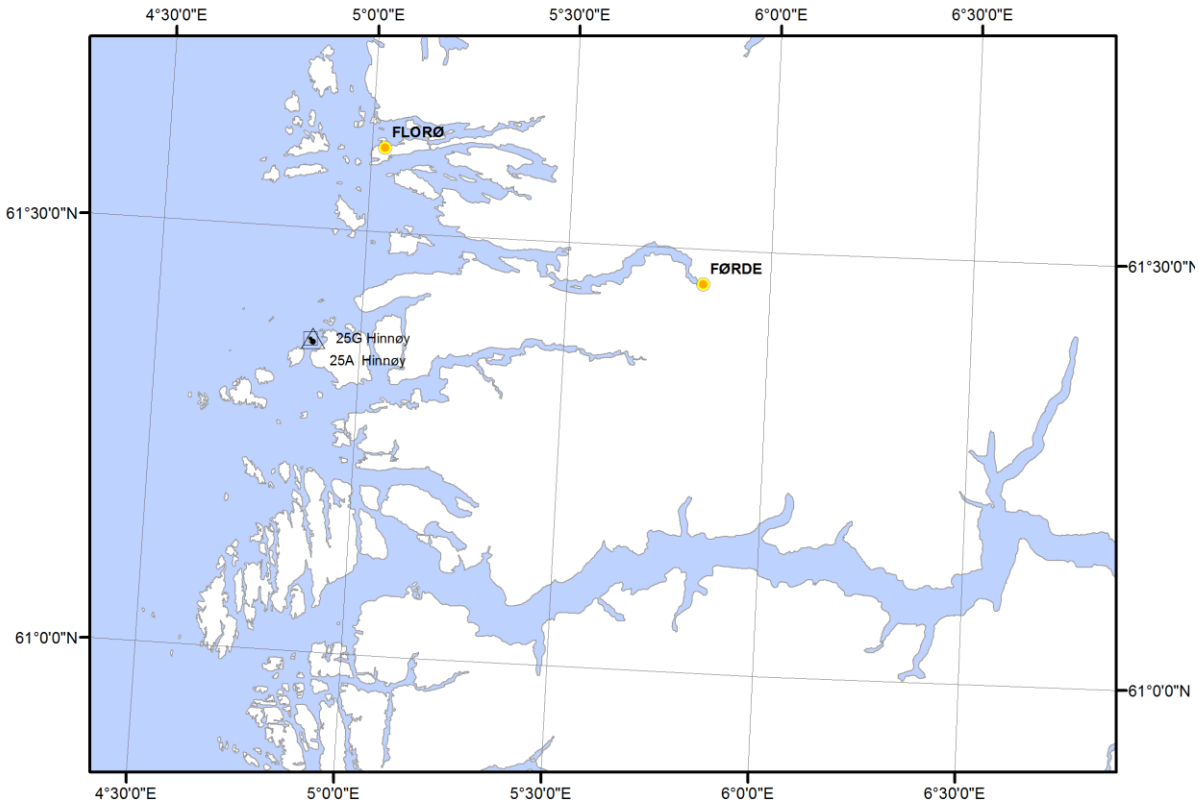
MAP 5


5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E
7°30'0"E
60°30'0"N
60°0'0"N
63A Ranaskjer, Ålvik, Hardangerfjord
64A Utne, Outer Sørfjord
ØYSTESE
57A Krossanes, Outer Sørfjord
57A1 Urdheim
67B Strandebarm area
56A2 Kjeken
57A2 Ernes
67F Strandebarm area
56A5 Lofthus (south)
67D Strandebarm area
67E Strandebarm area
56A4 Rosstadnes
56A3 Sekse
65A Vikingneset, Mid Hardangerfjord
56A1 Kvalnes (north)
56D Kvalnes
56A Kvalnes, Mid Sørfjord
29D Høyanger area
53D Digraneset
53E Inner Sørfjord
52A Eitrheimsneset, Inner Sørfjord
53B Inner Sørfjord
51A Byrkjenes, Inner Sørfjord
52E Eitrheimsneset
ODDA
69A Terøya, Outer Hardangerfjord

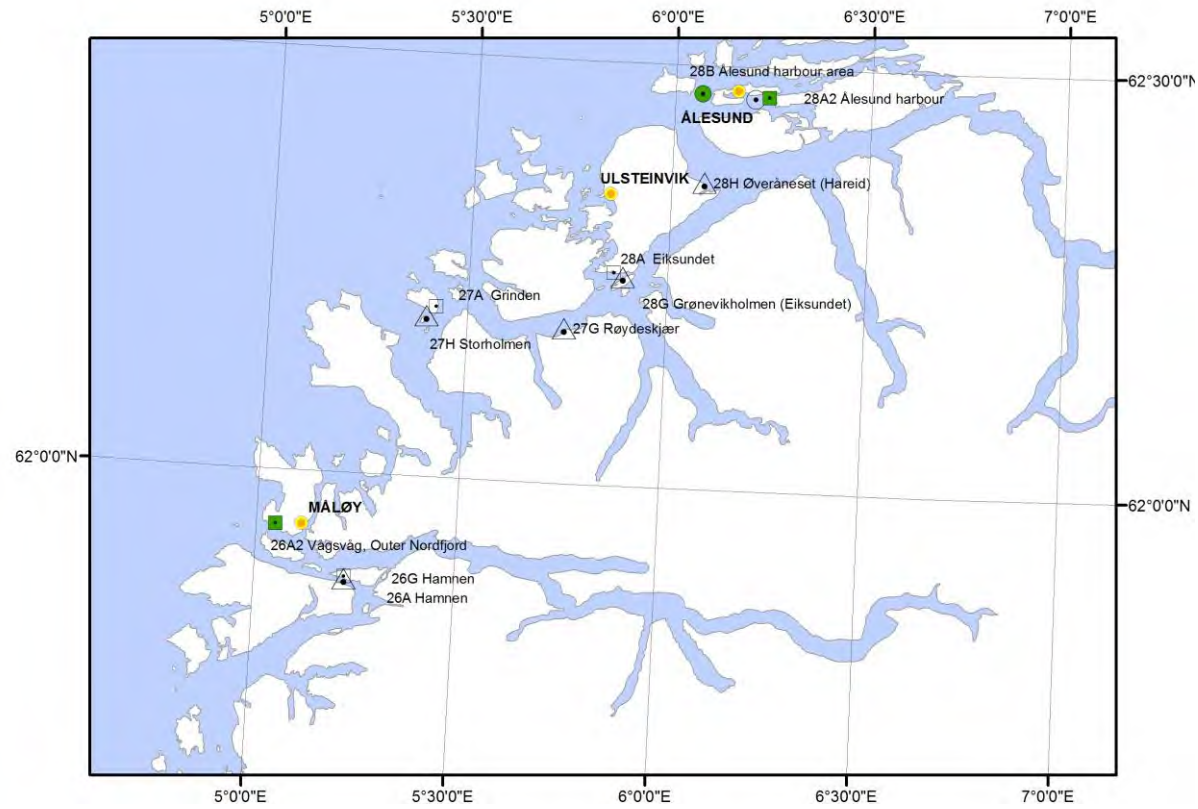
MAP 6


4°0'0"E
4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
60°30'0"N
60°0'0"N
I243 Hegreneset
24B Bergen harbour area
I241 Nordnes, Bergen harbour
I242 Gravdalsneset
BERGEN
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

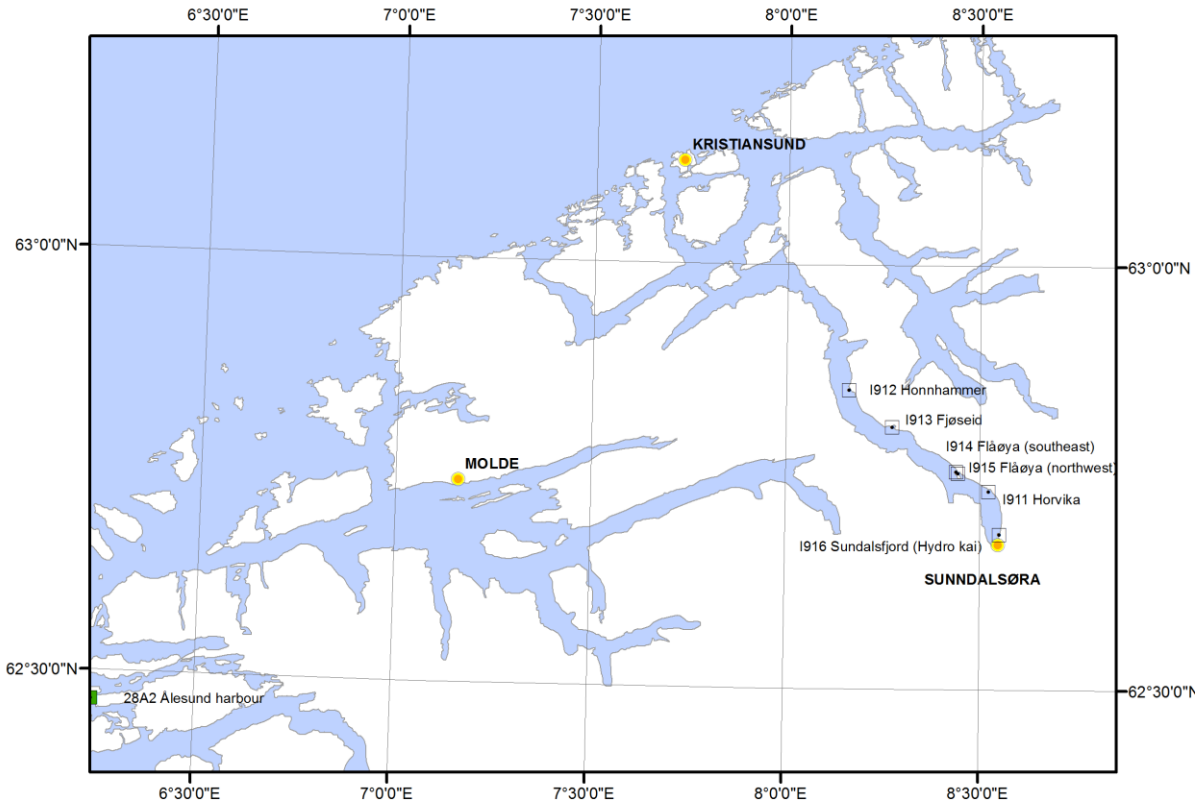
MAP 7


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
26G Hinnøy
25A Hinnøy

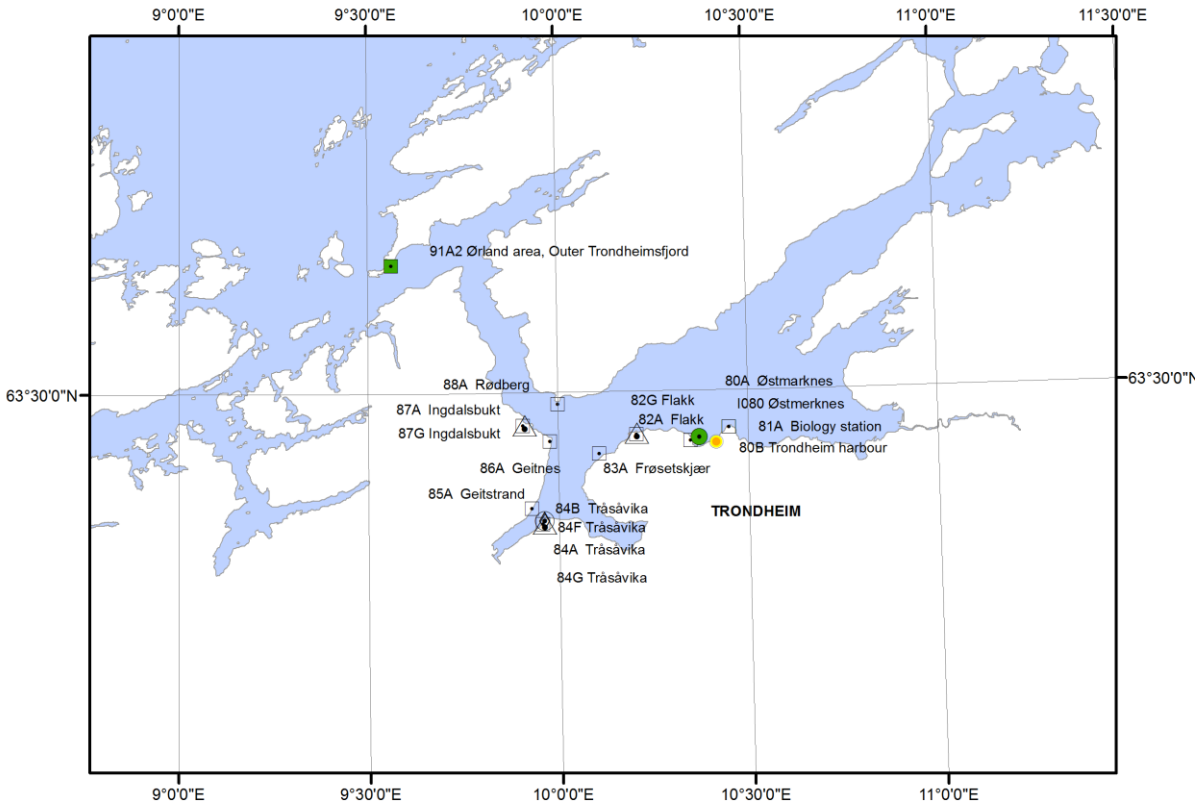
MAP 8


5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
7°0'0"E
62°30'0"N
62°0'0"N
28B Ålesund harbour area
28A2 Ålesund harbour
ÅLESUND
ULSTEINVIK
28H Øveråneset (Hareid)
28A Eiksundet
27A Grinden
28G Grønevikholmen (Eiksundet)
27G Røydeskjær
27H Storholmen
MÅLØY
26A2 Vågsvåg, Outer Nordfjord
26G Hamnen
26A Hamnen

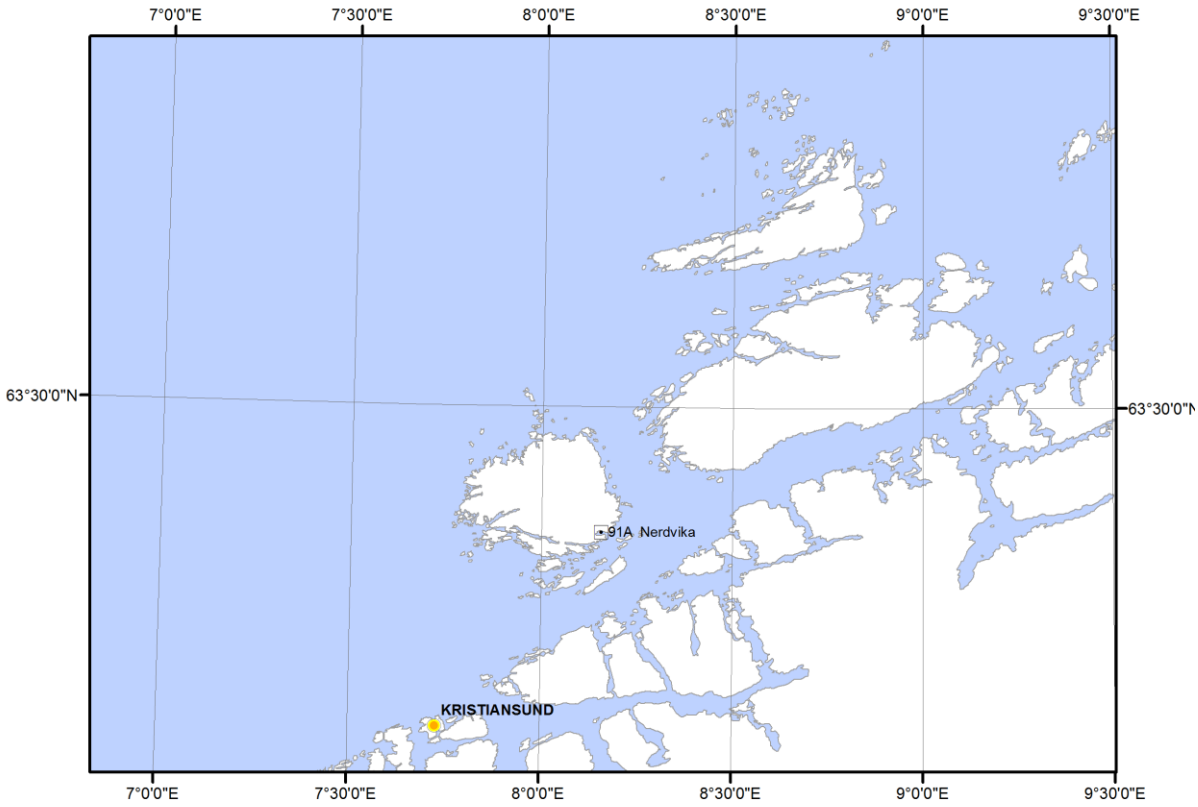
MAP 9


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
63°0'0"N
62°30'0"N
KRISTIANSUND
MOLDE
I912 Honnhammer
I913 Fjøseid
I914 Flåøya (southeast)
I915 Flåøya (northwest)
I911 Horvika
I916 Sundalsfjord (Hydro kai)
SUNNDALSØRA
28A2 Ålesund harbour

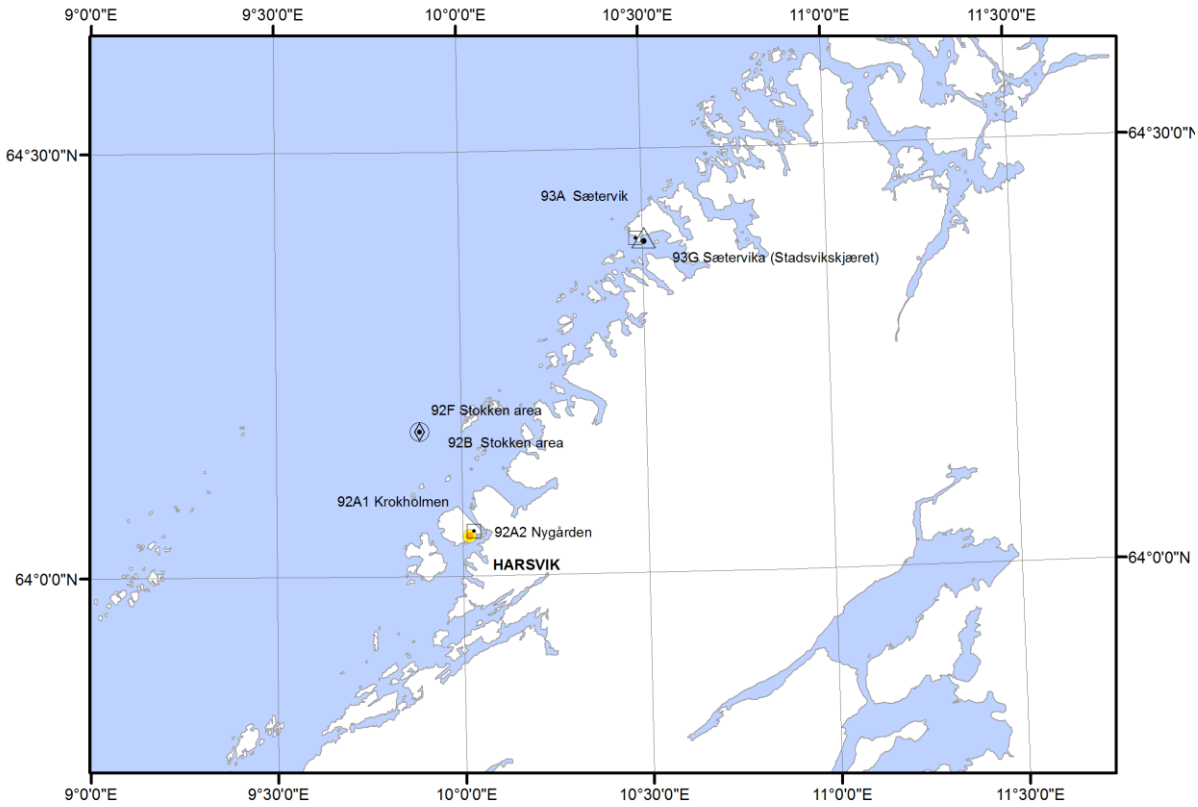
MAP 10


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

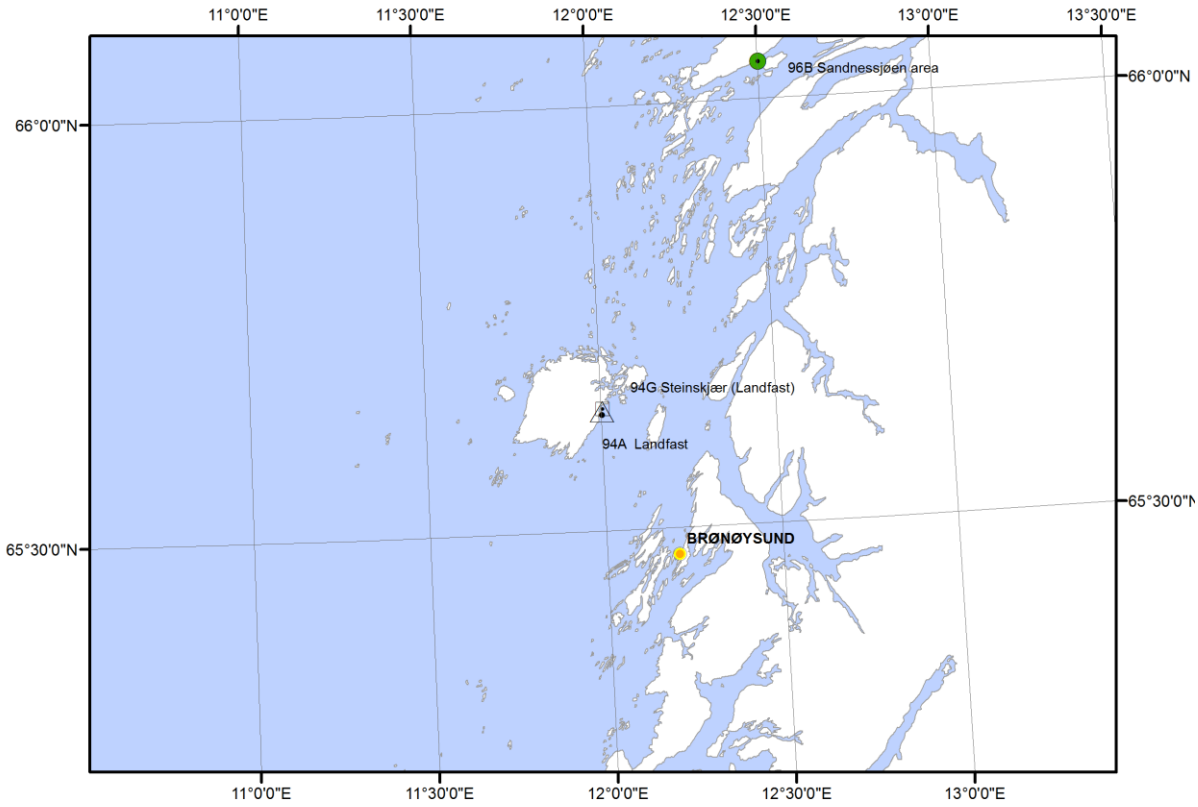
MAP 11


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

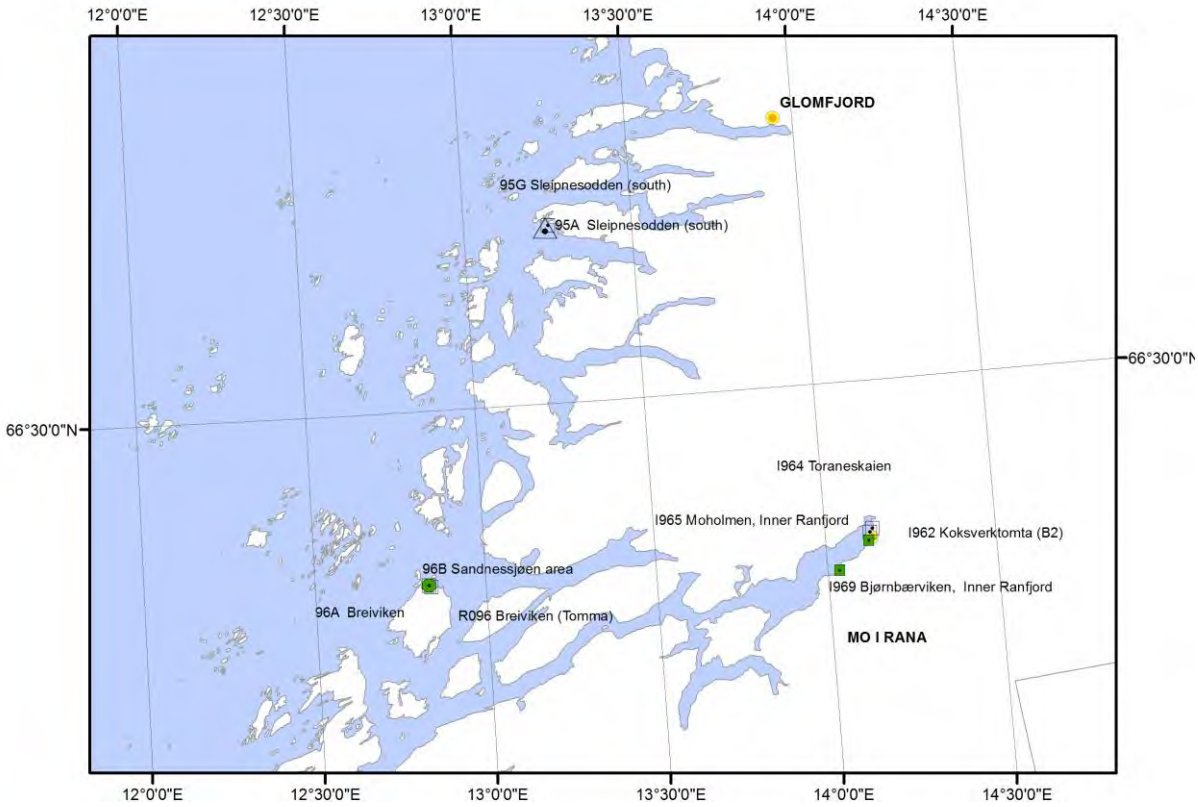
MAP 12


9°0'0"E
9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
64°30'0"N
64°0'0"N
93A Sætervik
93G Sætervika (Stadsvikskjæret)
92F Stokken area
92B Stokken area
92A1 Krokhölmen
92A2 Nygården
HARSVIK

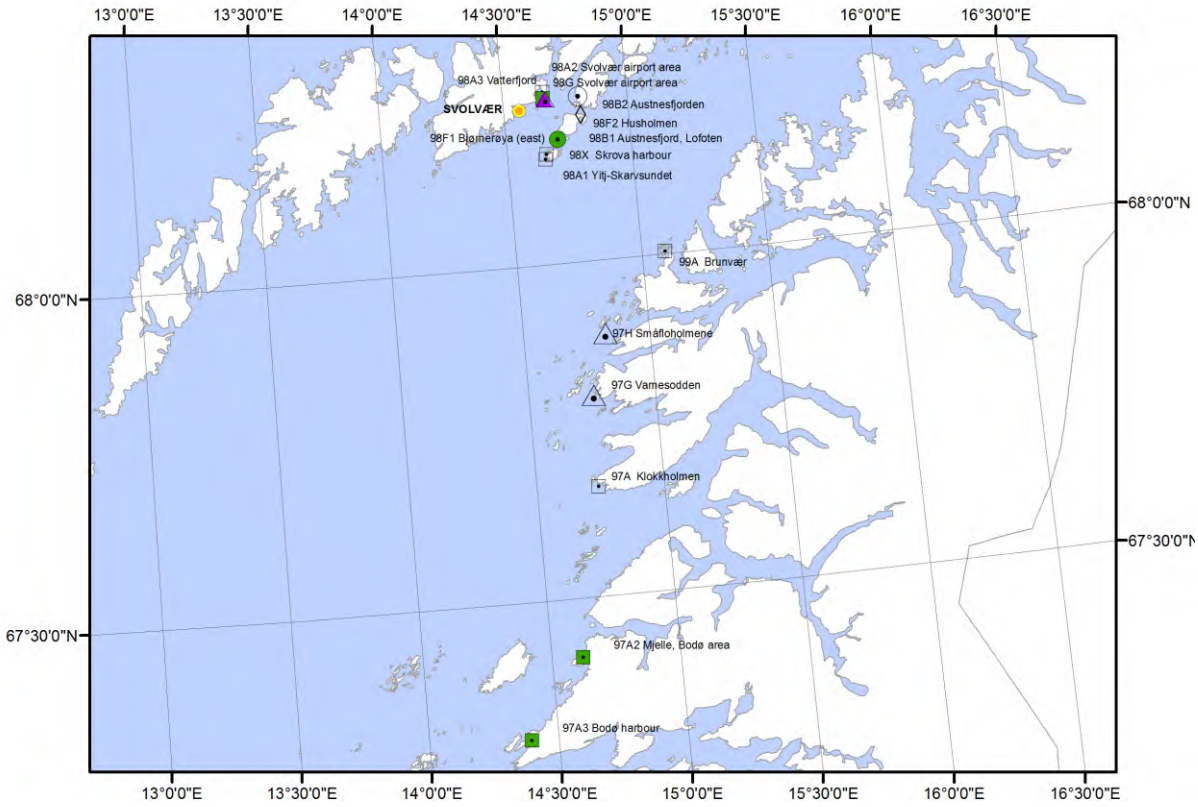
MAP 13


11°0'0"E
11°30'0"E
12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
66°0'0"N
65°30'0"N
96B Sandnessjøen area
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

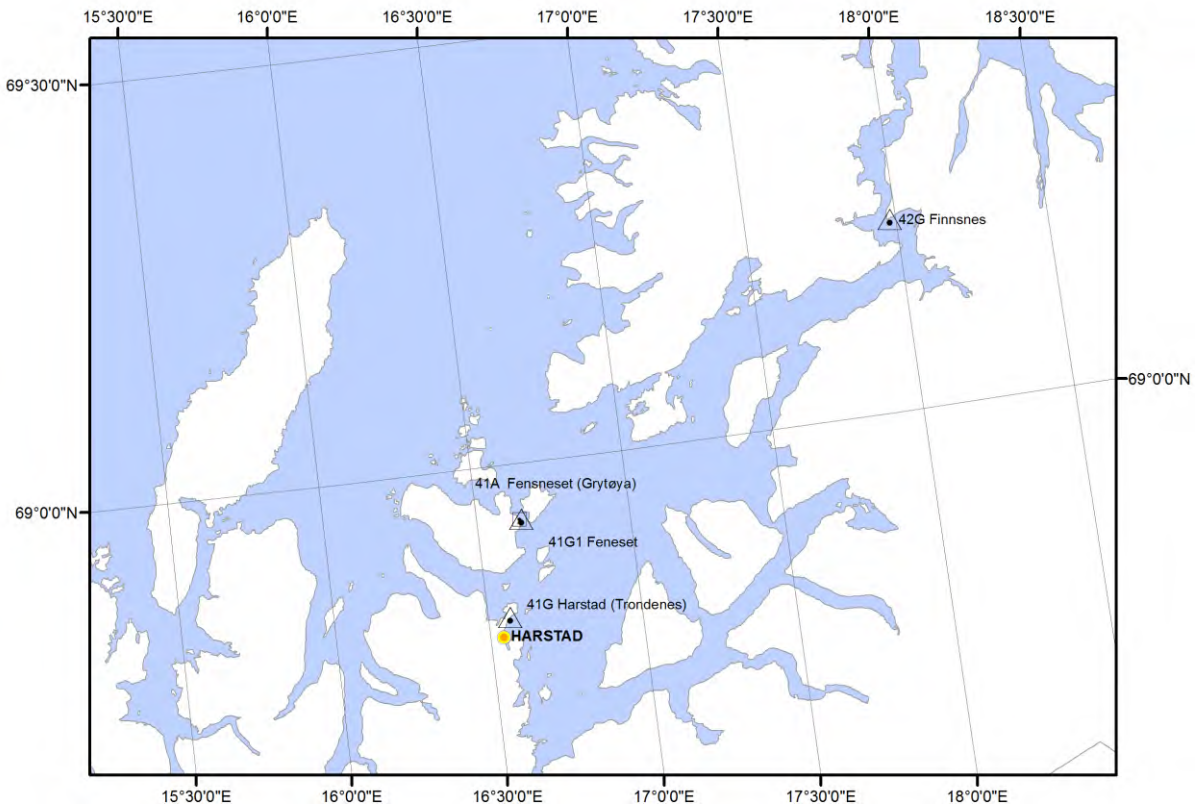
MAP 14


12°0'0"E
12°30'0"E
13°0'0"E
13°30'0"E
14°0'0"E
14°30'0"E
66°30'0"N
GLOMFJORD
95G Sleipnesodden (south)
95A Sleipnesodden (south)
I964 Toraneskaien
I965 Moholmen, Inner Ranfjord
I962 Koksverktomta (B2)
I969 Bjørnbærviken, Inner Ranfjord
96B Sandnessjøen area
96A Breiviken
R096 Breiviken (Tomma)
MO I RANA

MAP 15


13°0'0"E
13°30'0"E
14°0'0"E
14°30'0"E
15°0'0"E
15°30'0"E
16°0'0"E
16°30'0"E
68°0'0"N
67°30'0"N
98A2 Svolvær airport area
98A3 Vatterfjord
98G Svolvær airport area
SVOLVÆR
98B2 Austnesfjorden
98F2 Husholmen
98F1 Bjørneøya (east)
98B1 Austnesfjord, Lofoten
98X Skrova harbour
98A1 Yttj-Skarvsundet
99A Brunvær
97H Småfloholmene
97G Vamesodden
97A Klokkholmen
97A2 Mjelle, Bodø area
97A3 Bodø harbour

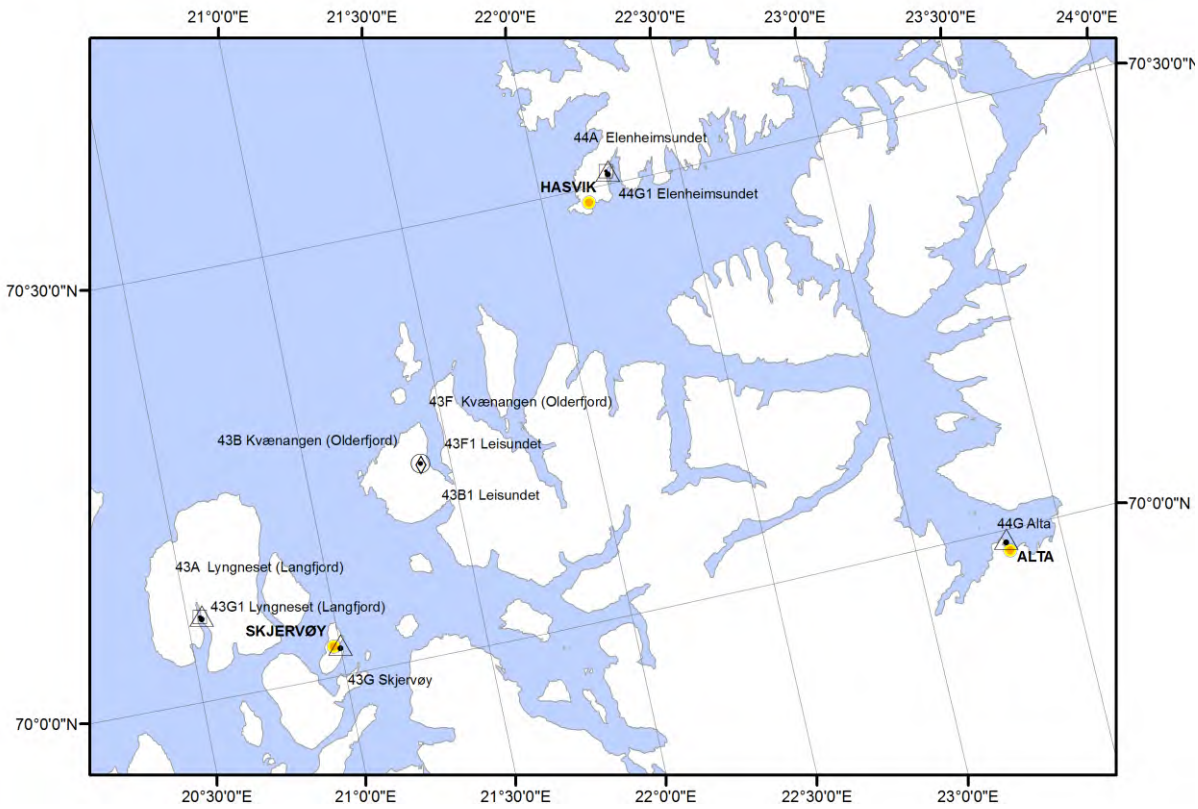
MAP 16


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

MAP 17


17°30'0"E
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

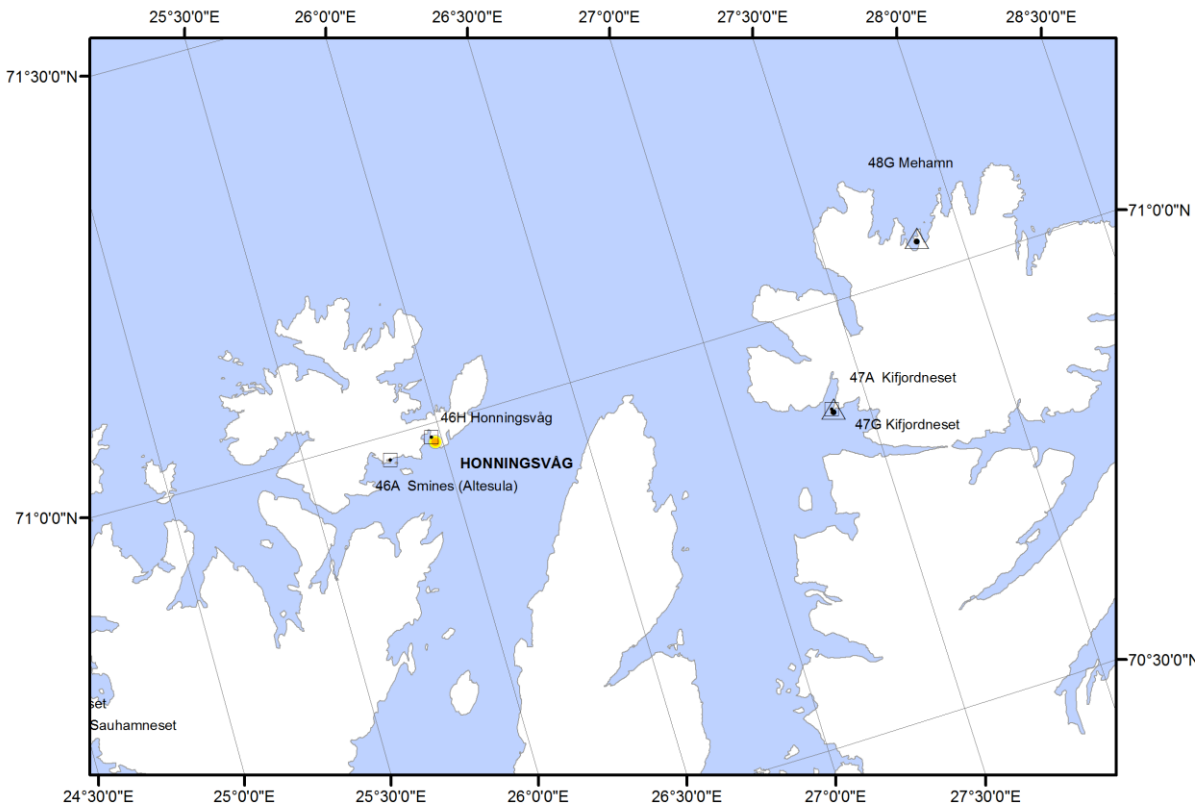
MAP 18


21°0'0"E
21°30'0"E
22°0'0"E
22°30'0"E
23°0'0"E
23°30'0"E
24°0'0"E
70°30'0"N
70°0'0"N
20°30'0"E
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet
43F Kvænangen (Olderfjord)
43B Kvænangen (Olderfjord)
43F1 Leisundet
43B1 Leisundet
44G Alta
ALTA
43A Lyngneset (Langfjord)
43G1 Lyngneset (Langfjord)
SKJERVØY
43G Skjervøy

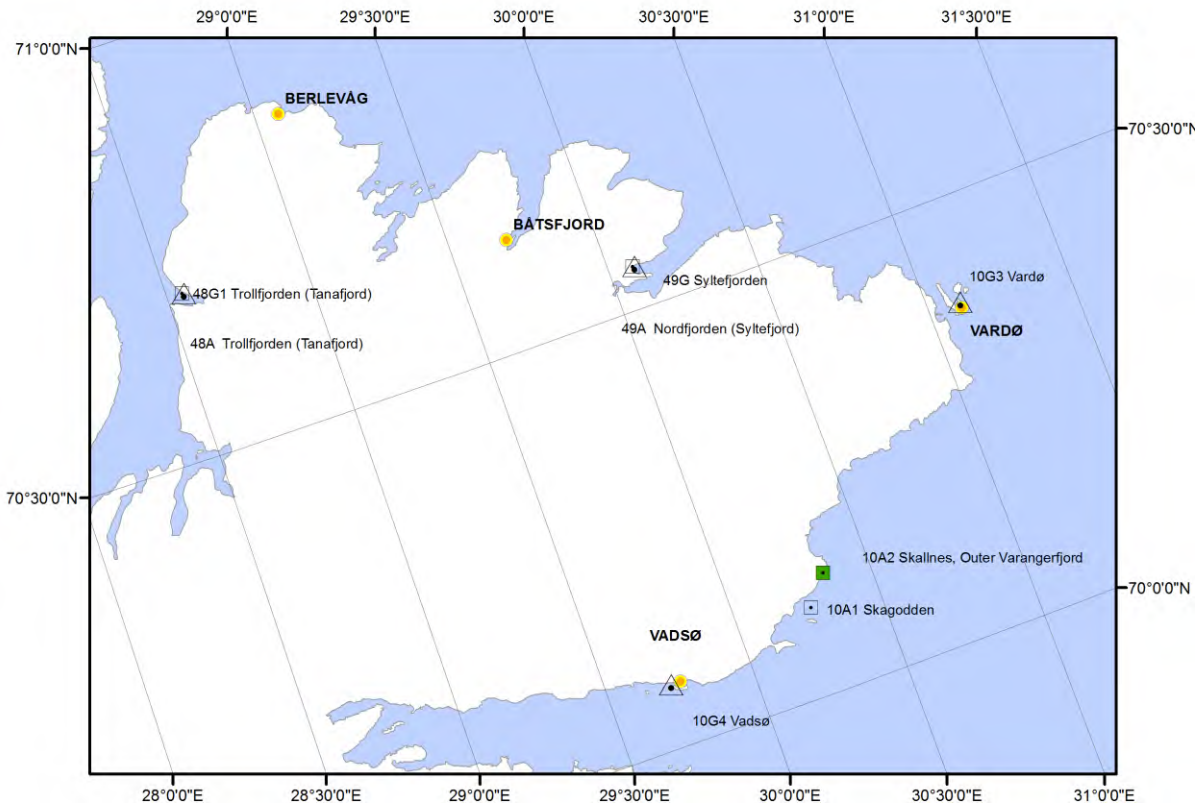
MAP 19


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

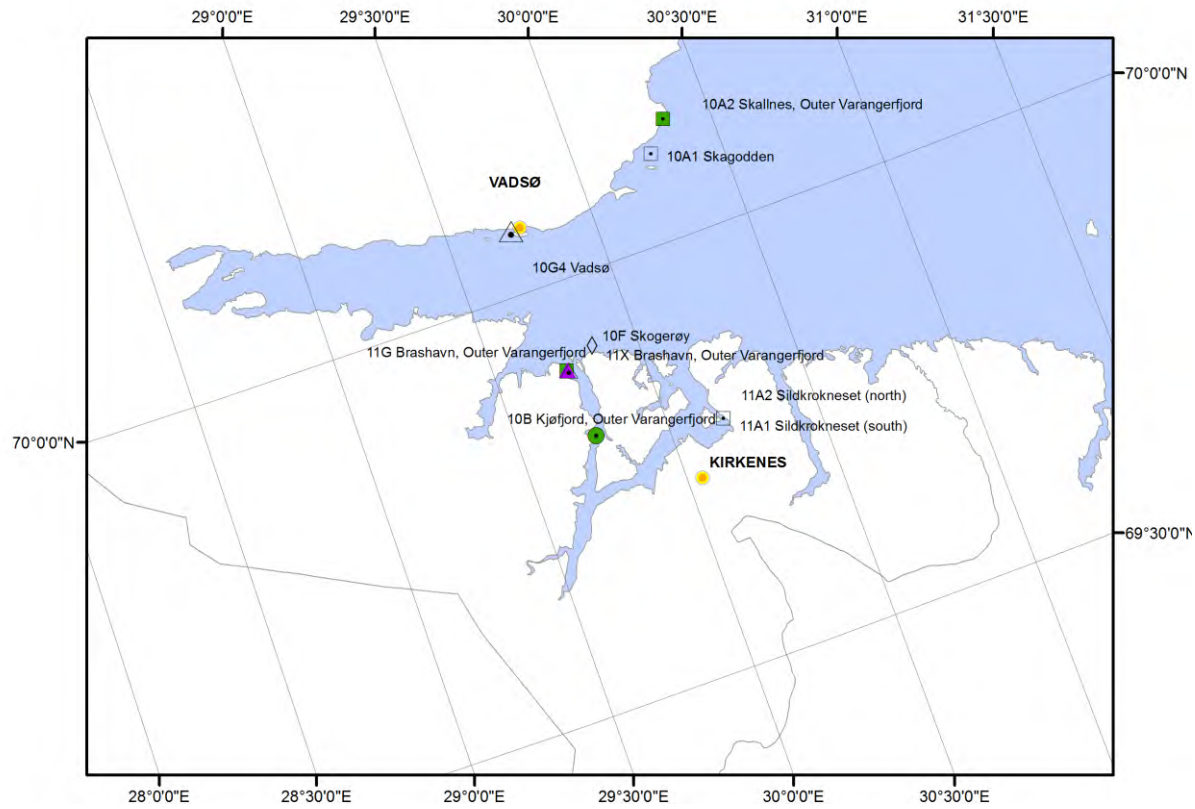
MAP 20


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

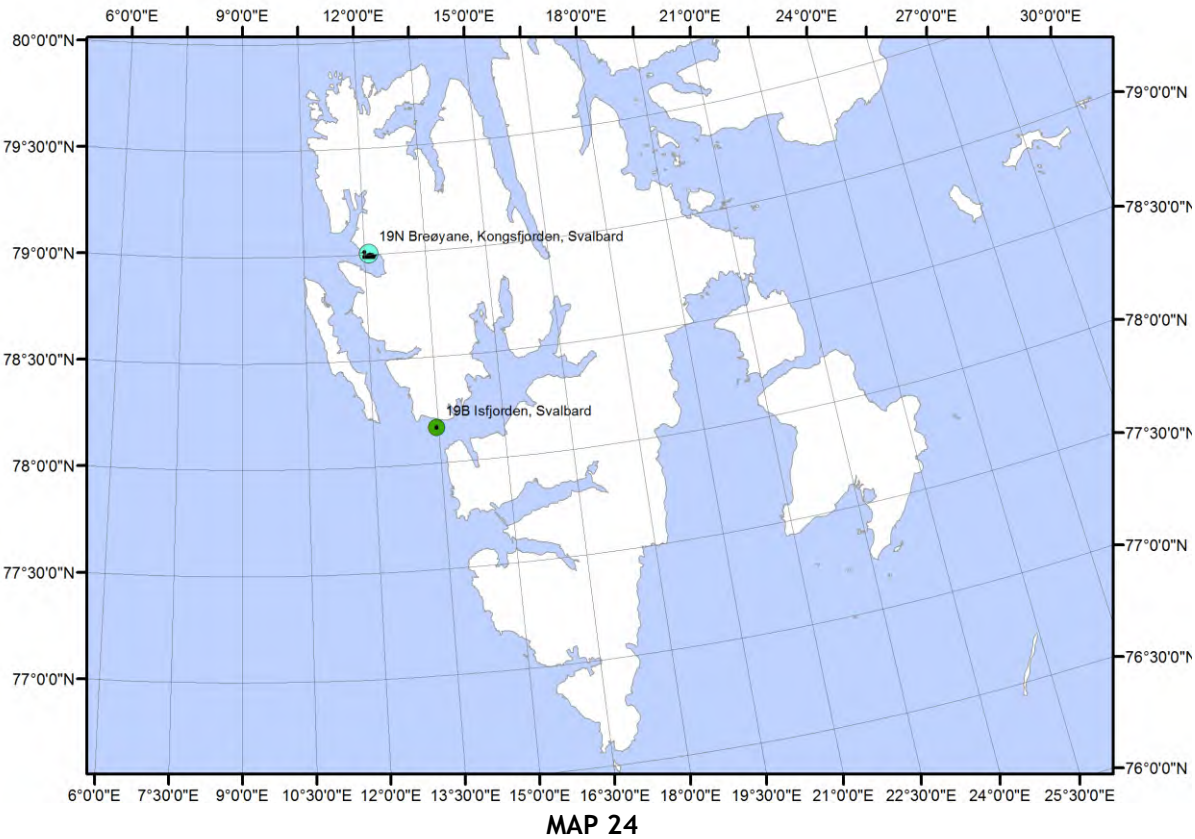
MAP 21


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

MAP 22


29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
31°0'0"E
31°30'0"E
70°0'0"N
69°30'0"N
10A2 Skallnes, Outer Varangerfjord
10A1 Skagodden
VADSØ
10G4 Vadsø
10F Skogerøy
11G Brashavn, Outer Varangerfjord
11X Brashavn, Outer Varangerfjord
11A2 Sildkrokneset (north)
10B Kjøfjord, Outer Varangerfjord
11A1 Sildkrokneset (south)
KIRKENES
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 2016-2017

Nominal station positions are shown on maps in Appendix D

Year:
2016t - samples taken in 2016
2017p – samples planned in 2017
2017t – samples taken in 2017

Species:
Atlantic cod (*Gadus morhua***)**
Blue Mussel (*Mytilus edulis***)**
Dogwhelk (*Nucella lapillus***)**
Periwinkle (*Littorina littorea)*
Common eider duck (*Somateria mollissima*)

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

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

Overview follows on next page

Parameter-group codes (see **Appendix B** for descriptions of codes) 2016-2017:

code	Description	Me-SB	Nl/Ll-SB	Gm-BI	Gm-BL	Gm-Ll	Gm-MU	Sm-BL	Sm-Eg
I-MET	metals [1)]	x				X			
I-MET	Hg	x					X	X	X
ISOTO	$\delta^{15}N$ and $\delta^{13}C$	x					X	X	X
O-BR	PBDEs [2)]	x				X		X	X
OC-CB	PCBs [3)]	x				X			
OC-CL	HCB	x				X		X	X
OC-CP	SCCP, MCCP	x				X		X	X
OC-DD	DDT, DDE, DDD	x				X			
OC-HC	α-, γ-HCH	x				X			
O-FL	PFAS [4)]					X		X	X
O-PAH	PAHs [5)]	x				X			
O-MET	TBT [6)]	x	x						
O-FTA	Phthalates [7)]					X			
O-PHE	Phenols [8)]	x				X		X	X
PHC	PHCs [9)]	x	x			X		X	X
SLX	Siloxanes[10)]					X			
BEM	Biological effects met.[11)]		Imposex	OH-pyrene	ALA-D	EROD-activity, CYP1A [12)]			

[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, TPTIN.

[7)] O-FTA Phthalates, includes: BBP, DBPA, DEHA, DEHP, DEP, DEPA, DIBP, DIDP, DIHP, DINCH, DIPA, DMP, DNOP, DPF.

[8)] O-PHE phenols (octa non), includes: 4-n-NP, 4-n-OP, 4-t-NP, 4-t-OP.

[9)] PHC – phenols including BPA, TBBPA.

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

[11)] Biological effects methods.

[12)] Cod only, CYP1A was not measured for 2017 samples.

***Appendix E**. Sampling and analyses for 2016-2017 – biota.*

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM	SLX
2016t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3			3						
2017p	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3		3						
2017t	**Mytilus edulis**	Whole soft body	**Akershuskaia, Inner Oslofjord (st. I301)**	59.90533	10.73633	3	3		3	3		3	3		3						
2016t	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3			3	3	3	3	3		
2017p	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3	3	3	3		3	3		
2017t	**Mytilus edulis**	Whole soft body	**Gressholmen, Inner Oslofjord (st. 30A)**	59.88362	10.71100	3	3	3	3	3	3	3	3	3	3	3		3	3		
2016t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3			3				3		
2017p	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3		3				3		
2017t	**Mytilus edulis**	Whole soft body	**Gåsøya, Inner Oslofjord (st. I304)**	59.85133	10.58900	3	3		3	3		3	3		3				3		
2016t	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	3			3										3		
2017p	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	3			3										3		
2017t	**Mytilus edulis**	Whole soft body	**Håøya, Inner Oslofjord (st. I306)**	59.71333	10.55517	3			3										3		
2016t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3									
2017p	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3								
2017t	**Mytilus edulis**	Whole soft body	**Solbergstrand, Mid Oslofjord (st. 31A)**	59.61550	10.65150	3	3		3	3		3	3								
2016t	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	3			3										3		
2017p	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	3			3										3		
2017t	**Mytilus edulis**	Whole soft body	**Mølen, Mid Oslofjord (st. 35A)**	59.48359	10.49499	3			3										3		
2016t	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3						3	3		
2017p	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3	3		3			3		
2017t	**Mytilus edulis**	Whole soft body	**Færder, Outer Oslofjord (st. 36A)**	59.02740	10.52500	3	3	3	3	3	3	3	3	3		3			3		
2016t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3				3	3	3	3	3		
2017p	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3				3	3			3		
2017t	**Mytilus edulis**	Whole soft body	**Singlekalven, Hvaler (st. I023)**	59.09511	11.13678	3		3	3		3				3	3			3		
2016t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	2			2										2		
2017p	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	3			3										3		

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM	SLX
2017t	**Mytilus edulis**	Whole soft body	**Kirkøy, Hvaler (st. I024)**	59.07905	10.98734	2			2										2		
2016t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	1		1	0	1	1	1			1	1	1	1	1		
2017p	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	3		3		3	3	3	3		3	3		3	3		
2017t	**Mytilus edulis**	Whole soft body	**Bjørkøya, Langesundfjord (st. 71A)**	59.02333	9.75367	1		1		1	1	1	1		1	1		1	1		
2016t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3	0	3	3	3			3			3	3		
2017p	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3		3	3			3		
2017t	**Mytilus edulis**	Whole soft body	**Sylterøya, Langesundfjord (st. I714)**	59.05140	9.70384	3		3		3	3	3	3		3	3			3		
2016t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3									
2017p	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3								
2017t	**Mytilus edulis**	Whole soft body	**Risøya, Risør (st. 76A2)**	58.73270	9.28104	3			3	3		3	3								
2016t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3									3						
2017p	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3									3						
2017t	**Mytilus edulis**	Whole soft body	**Lastad, Søgne (st. I131A)**	58.05557	7.70830	3									3						
2016t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3						3		
2017t	**Mytilus edulis**	Whole soft body	**Odderøya, Kristiansand harbour (st. I133)**	58.13167	8.00167	3	3		3	3		3	3						3		
2016t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3										3		
2017p	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3										3		
2017t	**Mytilus edulis**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15A)**	58.04605	6.91590	3			3										3		
2016t	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	3			3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	3			3	3		3	3	3					3		
2017t	**Mytilus edulis**	Whole soft body	**Byrkjenes, Inner Sørfjord (st. 51A)**	60.08429	6.55095	3			3	3		3	3	3					3		
2016t	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3	3						3		
2017t	**Mytilus edulis**	Whole soft body	**Eitrheimsneset, Inner Sørfjord (st. 52A)**	60.09677	6.53293	3			3	3		3	3						3		
2016t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3						3		

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM	SLX
2017t	**Mytilus edulis**	Whole soft body	**Kvalnes, Mid Sørfjord (st. 56A)**	60.22050	6.60200	3			3	3		3	3						3		
2016t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3						3		
2017t	**Mytilus edulis**	Whole soft body	**Krossanes, Outer Sørfjord (st. 57A)**	60.38707	6.68952	3			3	3		3	3						3		
2016t	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	3			3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	3			3	3		3	3						3		
2017t	**Mytilus edulis**	Whole soft body	**Ranaskjer, Ålvik, Hardangerfjord (st. 63A)**	60.42096	6.40502	3			3	3		3	3						3		
2016t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3									
2017p	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3									
2017t	**Mytilus edulis**	Whole soft body	**Utne, Outer Sørfjord (st. 64A)**	60.42390	6.62230	3			3			3									
2016t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3									
2017p	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3								
2017t	**Mytilus edulis**	Whole soft body	**Vikingneset, Mid Hardangerfjord (st. 65A)**	60.24233	6.15267	3			3	3		3	3								
2016t	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	3			3										3		
2017p	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	3			3										3		
2017t	**Mytilus edulis**	Whole soft body	**Terøya, Outer Hardangerfjord (st. 69A)**	59.98400	5.75450	3			3										3		
2016t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3							3		
2017p	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3	3					3		
2017t	**Mytilus edulis**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22A)**	59.58711	5.15203	3	3		3	3		3	3	3					3		
2016t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3					3	3	3			
2017p	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3			3		3			3		
2017t	**Mytilus edulis**	Whole soft body	**Nordnes, Bergen harbour (st. I241)**	60.40077	5.30396	3		3	3		3			3		3			3		
2016t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3					3	3	3	3		
2017p	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3					3			3		
2017t	**Mytilus edulis**	Whole soft body	**Vågsvåg, Outer Nordfjord (st. 26A2)**	61.93622	5.04878	3		3	3		3					3			3		
2017p	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3			3		3			3		
2017t	**Mytilus edulis**	Whole soft body	**Ålesund harbour (st. 28A2)**	62.46585	6.23960	3		3	3		3			3		3			3		

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM	SLX
2016t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3					3	3	3	3		
2017p	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3					3			3		
2017t	**Mytilus edulis**	Whole soft body	**Ørland area, Outer Trondheimsfjord (st. 91A2)**	63.65144	9.56386	3		3	3		3					3			3		
2017p	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3					3			3		
2017t	**Mytilus edulis**	Whole soft body	**Bodø harbour (st. 97A3)**	67.29631	14.39564	3		3	3		3					3			3		
2016t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3					3	3	3	3		
2017p	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3					3			3		
2017t	**Mytilus edulis**	Whole soft body	**Mjelle, Bodø area (st. 97A2)**	67.41271	14.62193	3		3	3		3					3			3		
2016t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3				3	3	3	3	3		
2017p	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3			3	3	3			3		
2017t	**Mytilus edulis**	Whole soft body	**Svolvær airport area (st. 98A2)**	68.24917	14.66270	3		3	3		3			3	3	3			3		
2016t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	**3**		**3**							3		
2017p	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	**3**		**3**	3						3		
2017t	**Mytilus edulis**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11X)**	69.89930	29.74100	3			3	**3**		**3**	3						3		
2016t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	**3**		**3**									
2017p	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	**3**		**3**	3								
2017t	**Mytilus edulis**	Whole soft body	**Skallnes, Outer Varangerfjord (st. 10A2)**	70.13728	30.34175	3			3	**3**		**3**	3								
2016t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1													0	
2017p	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1													1	
2017t	**Littorina littorea**	Whole soft body	**Fugløyskjær, Outer Langesundfjord (st. 71G)**	58.98496	9.80458		1														
2016t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Færder, Outer Oslofjord (st. 36G)**	59.02776	10.52560		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Risøya, Risør (st. 76G)**	58.72800	9.27550		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1													1	

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2017p	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Lastad, Søgne (st. 131G)**	58.02843	7.69902		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Gåsøya-Ullerøya, Farsund (st. 15G)**	58.04933	6.90117		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Melandsholmen, Mid Karmsundet (st. 227G2)**	59.33960	5.31220		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Espevær, Outer Bømlafjord (st. 22G)**	59.58367	5.14450		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Svolvær airport area (st. 98G)**	68.24699	14.66641		1													1	
2016t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1													1	
2017p	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1													1	
2017t	**Nucella lapillus**	Whole soft body	**Brashavn, Outer Varangerfjord (st. 11G)**	69.89953	29.74190		1													1	
2016t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	12		12	12	**12**	12	**12**		12		12	12	12		12	
2017p	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15		15	15	**15**	15	**15**	15	15		15		15		15	15
2017t	**Gadus morhua**	Liver	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	12		12	12	**12**	12	**12**	12	12		12		12		12	12
2016t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	10		10	10	**10**	10	**10**		10		10	10	0			
2017p	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15		15	15	**15**	15	**15**	15	15		15					
2017t	**Gadus morhua**	Liver	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	10		10	10	**10**	10	**10**	10	10		10					
2016t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	9		9	9		9					9	9	9			
2017p	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15		15	15		15					15					
2017t	**Gadus morhua**	Liver	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	9		9	9		9					9					
2016t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15		15			15					15	15	15			

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2017p	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15		15			15					15		15			
2017t	**Gadus morhua**	Liver	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15		15			15					15		15			
2016t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	12		12	12		12			12		12	12	12			
2017p	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15		15	15		15			15		15					
2017t	**Gadus morhua**	Liver	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	12		12	12		12			12		12					
2016t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15									
2017p	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15								
2017t	**Gadus morhua**	Liver	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15			15	15		15	15								
2016t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15		15		15	15	15		15	
2017p	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15	15		15				15	
2017t	**Gadus morhua**	Liver	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15		15	15	15	15	15	15	15		15				15	
2016t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		13	13	13	13	13	13	13		13	13	13		13	
2017p	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		15	15	15	15	15	15	15		15		15		15	
2017t	**Gadus morhua**	Liver	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	13		13	13	13	13	13	13	13		13		13		13	
2016t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15			15		15	15	15			
2017p	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15			15		15					15
2017t	**Gadus morhua**	Liver	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15		15	15		15			15		15					15
2016t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15					15	15	15			
2017p	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15					15					
2017t	**Gadus morhua**	Liver	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15		15	15		15					15					
2016t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15			15		15	15	15			
2017p	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15			15		15					
2017t	**Gadus morhua**	Liver	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15		15	15		15			15		15					
2016t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15												
2017p	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15												
2017t	**Gadus morhua**	Liver	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15			15												
2016t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	11		11	11	11	11	11		11							

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2017p	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15		15	15	**15**	15	**15**	15	15							
2017t	**Gadus morhua**	Liver	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	11		11	11	**11**	11	**11**	11	11							
2016t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			15		15	15	15			
2017p	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			15		15					15
2017t	**Gadus morhua**	Liver	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15		15	15		15			15		15					15
2016t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	14			14												
2017p	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	14			14												
2017t	**Gadus morhua**	Liver	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	14			14												
2016t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	**15**		**15**									
2017p	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	**15**		**15**	15								
2017t	**Gadus morhua**	Liver	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15			15	**15**		**15**	15								
2017p	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15			15		15					15
2017t	**Gadus morhua**	Liver	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15		15	15		15			15		15					15
2016t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15													15		
2017p	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15													15		
2017t	**Gadus morhua**	Muscle	**Inner Oslofjord (st. 30B)**	59.81265	10.55183	15													15		
2016t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15													15		
2017p	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15													15		
2017t	**Gadus morhua**	Muscle	**Tjøme, Outer Oslofjord (st. 36B)**	59.04050	10.43583	15													15		
2016t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15													15		
2017p	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15													15		
2017t	**Gadus morhua**	Muscle	**Kirkøy, Hvaler (st. 02B)**	59.06482	10.97354	15													15		
2016t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15													15		
2017p	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15													15		
2017t	**Gadus morhua**	Muscle	**Stathelle area, Langesundfjord (st. 71B)**	59.04650	9.70275	15													15		
2016t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15													15		
2017p	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15													15		

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2017t	**Gadus morhua**	Muscle	**Kristiansand harbour area (st. 13B)**	58.13283	7.98850	15													15		
2016t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15													15		
2017p	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15													15		
2017t	**Gadus morhua**	Muscle	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690	15													15		
2016t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15													15		
2017p	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15													15		
2017t	**Gadus morhua**	Muscle	**Inner Sørfjord (st. 53B)**	60.09727	6.53972	15													15		
2016t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15													15		
2017p	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15													15		
2017t	**Gadus morhua**	Muscle	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857	15													15		
2016t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15													15		
2017p	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15													15		
2017t	**Gadus morhua**	Muscle	**Bergen harbour area (st. 24B)**	60.39664	5.27069	15													15		
2016t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15													15		
2017p	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15													15		
2017t	**Gadus morhua**	Muscle	**Ålesund harbour area (st. 28B)**	62.46778	6.06862	15													15		
2016t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15													15		
2017p	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15													15		
2017t	**Gadus morhua**	Muscle	**Trondheim harbour (st. 80B)**	63.44562	10.37173	15													15		
2016t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15													15		
2017p	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15													15		
2017t	**Gadus morhua**	Muscle	**Sandnessjøen area (st. 96B)**	66.04437	12.50355	15													15		
2016t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15													15		
2017p	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15													15		
2017t	**Gadus morhua**	Muscle	**Austnesfjord, Lofoten (st. 98B1)**	68.18577	14.70814	15													15		
2016t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15													15		
2017p	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15													15		

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2017t	**Gadus morhua**	Muscle	**Tromsø harbour area (st. 43B2)**	69.65300	18.97400	15													15		
2016t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15													15		
2017p	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15													15		
2017t	**Gadus morhua**	Muscle	**Hammerfest harbour area (st. 45B2)**	70.65000	23.63333	15													15		
2016t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15													15		
2017p	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15													15		
2017t	**Gadus morhua**	Muscle	**Kjøfjord, Outer Varangerfjord (st. 10B)**	69.81623	29.76020	15													15		
2017p	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15													15		
2017t	**Gadus morhua**	Muscle	**Isfjorden, Svalbard (st. 19B)**	78.17000	13.46000	15													15		
2016t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183															15	
2017p	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183															15	
2017t	**Gadus morhua**	Bile	**Inner Oslofjord (st. 30B)**	59.81265	10.55183															15	
2016t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690															15	
2017p	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690															15	
2017t	**Gadus morhua**	Bile	**Skågskjera, Farsund (st. 15B)**	58.05138	6.74690															15	
2016t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972															15	
2017p	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972															15	
2017t	**Gadus morhua**	Bile	**Inner Sørfjord (st. 53B)**	60.09727	6.53972															15	
2016t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857															15	
2017p	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857															15	
2017t	**Gadus morhua**	Bile	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857															15	
2016t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183															15	
2017p	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183															15	
2017t	**Gadus morhua**	Blood	**Inner Oslofjord (st. 30B)**	59.81265	10.55183															15	
2016t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972															15	
2017p	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972															15	
2017t	**Gadus morhua**	Blood	**Inner Sørfjord (st. 53B)**	60.09727	6.53972															15	

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM	SLX
2016t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857															15	
2017p	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857															15	
2017t	**Gadus morhua**	Blood	**Bømlo, Outer Selbjørnfjord (st. 23B)**	59.89562	5.10857															15	
2017p	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15	15		
2017t	**Somateria mollissima**	Blood	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15	15		
2017p	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15	15		
2017t	**Somateria mollissima**	Egg	**Breøyane, Kongsfjorden, Svalbard (st. 19N)**	79.00400	12.11000	15		15	15	15	15			15		15		15	15		

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2017

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 2016 or 2017 is shown. The column headings are as follows:

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

Species:
- **MYTI EDU**-Blue Mussel (*Mytilus edulis*)
- **LITT LIT**-Common periwinkle (*Littorina littorea*)
- **NUCE LAP**-Dogwhelk (*Nucella lapillus*)
- **GADU MOR**-Atlantic cod (*Gadus morhua*)
- **SOMA MOL**-Common eider (*Somateria mollissima*)

Tissue:
- **SB**-Soft body tissue
- **LI**-Liver tissue
- **MU**-Muscle tissue
- **BL**-Blood
- **BI**-Bile
- **EG**-Egg-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: Provisional high reference concentration
Yr_[Year columns]: median value for years 1981-2017. The gray-shade coding refers to relation to exceedences to provisional high reference concentration (PROREF): below PROREF (clear) or exceeding PROREF by a factor of: 1-2, 2-5, 5-10, 10-20 or greater than 2
EQS [Year columns]: median value for years 1981-2016 with indication of relation to Environmental Quality Standards (2013/39/EU) and other risk-based standards developed nationally (Arp *et al*. 2014 – M-241|2014, Miljødirektoratet 2016 – M-608|2016). Both of these standards are referred to collectively in this report as Environmental Quality Standards (EQS). Green-filled circle indicates no exceedences and red-filled circle indicates exceedences of the quality standard.
Sample count [year]: number of samples analysed The first number within the parentheses indicates the number of pooled samples included. The second number within the

parentheses indicates for mussels the total number of individuals used in all pooled samples and for cod the number individuals in each pooled sample.
SD [year]: standard deviation.
PROREF [year]: exceedences to provisional high reference concentration (PROREF): below PROREF (1) or exceeding PROREF by a factor of: 1-2 (2), 2-5 (3), 5-10 (4), 10-20 (5) or greater than 20 (6) (see **Appendix C**).
EQS [year]: below (1) or above (2) EU Environmental Quality Standard (EQS). Note: the EU EQRs are based on the whole organism whereas monitoring of fish in MILKYS is on a particular tissue. Hence, comparison is only relevant if it is assumed that the concentration found is the same for all tissues in the fish.
EQS threshold
Trend p(long)[year]: The statistical significance (p)[year] of the trend for the entire time series.
Detectable % change(long)[year]: the percent change that can be detected with 90 % confidence.
First Year(long)[year]: first year in time series.
Last Year(long)[year]: last year in time series.
Number of Years(long)[year]: number of years with data.

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

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

TREND_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
PROREF_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.
EQS_CHANGE_[year]-[year]: indicates the difference (if any) between the year-before-last results and the last year's results.

Note on quantification limit in trend analyses: half of the limit is used, however if a substance is included as part of a sum (e.g. PCB-7) then null is used. Note, that the number of such cases and position in a times series may affect whether or not a trend analyses can be applied (see Chapter 2.8).

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The Norwegian Environment Agency is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are a government agency under the Ministry of Climate and Environment and have 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.