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Contaminants in coastal waters of Norway 2016

Miljøgifter i norske kystområder 2016

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 2016, 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 2016 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 2016-investigation included analyses of 104 different contaminants or biological effect parameters in five types of samples (blue mussel, dog whelk, common periwinkle and cod). 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), phosphorus flame retardants (PFRs), bisphenol A (BPA), tetrabrombisphenol A (TBBPA) and alkyphenols. 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 800 time series (last 10 years). Of these there were statistically significant trends in 135 cases: 107 were downwards and 28 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 2016-medians for all 800 time series, there were 403 cases that could be classified against EQS, of which 254 (63 %) were below the EQS and 149 (37 %) were above the EQS. All of the 2016-medians from the 800 time series could be classified using a new concept denoted provisional high reference concentrations (PROREF). Of these 594 were below PROREF and 206 exceeded PROREF: 124 by a factor of less than two, 59 by a factor between two and five, 11 by a factor between five and 10, six by a factor between 10 and 20, and six by a factor greater than 20. Some cases warrant special concern, such as high concentrations of several organic pollutants 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.

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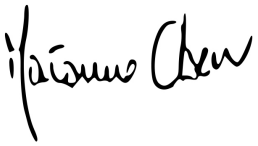

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English summary

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 seems to be the area where contaminants tend to appear in relatively high concentrations and hence warrant special concern. For example, the investigation found an upward long-term trend for mercury (Hg) in cod (*Gadus morhua*) fillet and high polychlorinated biphenyls (PCB), polybrominated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS) and alpha-hexabromocyclododecane (α–HBCD) in cod liver. No short-term trend for Hg in code fillet was detected in the Oslofjord.

Monitoring contaminants and associated parameters along the Norwegian coast contributes to OSPAR’s Coordinated Environmental Monitoring Programme (CEMP). The 2016-investigation monitored blue mussel (*Mytilus edulis*) at 34 stations, dog whelk (*Nucella lapillus*) at eight stations, common periwinkle (*Littorina littorea*) at one station, and Atlantic cod (*Gadus morhua*) at 16 stations. 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 2016 included analyses of metals (mercury (Hg), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), arsenic (As), nickel (Ni), chromium (Cr), cobalt (Co)), tributyltin (TBT), polychlorinated biphenyls (PCBs), pesticides (DDE), polycyclic aromatic hydrocarbons (PAHs), polybromated diphenyl ethers (PBDEs), perfluorinated alkylated substances (PFAS), hexabromocyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP and MCCP), organophosphorus flame retardants (PFRs), bisphenol A (BPA), tetrabrombisphenol A (TBBPA), alkylphenols as well as biological effects parameters.

The results from 2016 supplied data for a total of 2148 data sets (contaminant-station-species) on 112 different contaminants. Thirty representative contaminants and biological effect parameters were chosen for presentation in this report. This selection had 801 time series of which there were statistically significant time (2007-2016) related trends in 127 cases: 100 were downwards and 27 upwards. The downward trends were largely associated with concentrations of metals (42 %) 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 (92.6 %), primarily mercury (22.2 %).

Of the 801 time series, 252 cases could be classified against Environmental Quality Standard (EQS) for EU priority pollutants and Water region specific substances, of which 171 (68%) were below the EQS.

All 801 time series could be compared to a new concept denoted provisional high reference concentration (PROREF), and of these 608 (75.9 %) were below PROREF, and 193 (24.1 %) exceeded PROREF: 117 (14.6 %) by a factor of less than two, 53 (6.6 %) by a factor between two and five, 11 (1.4 %) by a factor between five and 10, four (0.5 %) by a factor between 10 and 20, and eight (1 %) 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 is severely polluted with pesticides (DDE).

Concentrations of contaminants in fish

Cod fillet from the Inner Oslofjord exceeded PROREF for mercury by a factor of five to 10, and a significant upward long term trend was found for the period 1984-2016 using the OSPAR method which targets specific length-groups. When adjusting concentrations to expected concentrations for 50 cm cod using the method taking into considerations fish-length, the cod fillet from the Inner Oslofjord exceeded PROREF for mercury by a factor of two to five, and the upward long-term trend (1984-2016) was still significant. Cod fillet from the Outer Oslofjord exceeded PROREF for mercury by a factor of two to five, and upward short-term trends (2007-2016) were found by using both the OSPAR method and after adjusting for fish length effects.

Cod liver from the Inner Oslofjord exceeded both EQS and PROREF, the latter by a factor over 10, with PCBs. Contamination of cod was otherwise generally low (insignificantly or moderately polluted). The high concentrations of PCBs observed in cod liver in the Inner Oslofjord are probably related to urban activities in the past in combination with little water exchange with the outer fjord.

PBDEs have been investigated in cod liver for several fjords since 2005. In 2016, the two highest median concentrations of sum PBDEs were found in Bergen harbour and Inner Oslofjord, and lowest at Færder. BDE47 was the dominant congener in all samples and significantly higher in the Bergen harbour and Inner Oslofjord than the other stations. As for PCB, the high concentrations of PBDEs are probably related to urban activities and water exchange conditions.

PFAS has been investigated in cod liver 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 lowest concentration of PFOS and PFOSA was found in the Tromsø harbour and Inner Sørfjord, respectively. 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.

Of the hexabromocyclododecanes, α–HBCD was the most abundant component. Cod liver from the Inner Oslofjord had significantly higher median concentration of HBCD than the other stations. The high concentrations of HBCD are probably related to urban activities, as well as a reduced water exchange with the outer fjord.

Concentrations of short chain chlorinated paraffins (SCCP) in cod liver were highest in cod from Bergen harbour. Medium chlorinated paraffins (MCCP) in cod liver was highest in Langesundfjord.

Most concentrations of organophosphorus flame retardants (PFRs) in cod were predominantly below the detection limits in cod, hence no conclusions could be drawn regarding the differences among the stations.

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

Concentrations of contaminants in blue mussel

Blue mussel from three stations in the Mid and Outer Sørfjord area exceeded PROREF for DDE by a factor of greater than 20. Three other stations in this area exceeded PROREF for DDE by a factor

between 5 and 10. Contamination of this substance is related to earlier use of DDT as pesticide in orchards along the fjords (ca. 1945-1970).

Median concentrations of PCB-7, α-HBCD and SCCP were highest at Nordnes in Bergen harbour area. KPAH and PBDEs (sum of six compounds – BDE6S) were highest at one station in the Inner Oslofjord.

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

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 2016 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) was about half of that in 2015, i.e. at approximately the same level as in 2013-2014.

The ALA-D activity in the the Inner Sørfjord in 2016 showed lower activity than at Bømlo. Reduced activities of ALA-D reflect higher exposure to lead.

The median EROD activity in the Inner Oslofjord was similar to that observed in 2014 (i.e. approximately half of that in 2013 and 2015). The EROD activities were below the ICES/OSPARs BAC. Concentrations over BAC would indicate possible impact by planar PCBs, PCNs, PAHs or dioxins. The median amount of CYP1A in the liver of cod from the Oslofjord appeared higher than in liver of cod from Sørfjorden and the Bømlo area.

The effects of TBT on dog whelk were relatively low (VDSI<0.828) at all eight stations. There were significant downward trends for all stations, except for Brashavn in the Varangerfjord where no significant trend could be seen and previous VDSI-levels were low. The results indicate that the legislation banning the use of TBT has been effective.

Stable isotopes

The stabile isotope δ^{15}N is analysed as a measure of trophic position. Results showed very relative similar isotopic signatures among the stations in 2016 as in 2012-2015, 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. The geographical differences in the baseline isotopic signatures must be taken into consideration when interpreting accumulation of contaminants in relation to trophic position. The δ^{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, concentrations of mercury and PCB-153 (contaminants with well-known biomagnifying properties) increased with higher δ^{15}N, i.e. higher concentrations in individuals with slightly higher trophic position.

Time trends for contaminants in cod taking length into account

The statistical analyses of time trends (increase/decrease) of contaminant concentrations in cod uses the median value (for each contaminant and station), and does not normally take into account

[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.

length of the sampled cod, as the aim of the sampling strategy is to spread samples equally over several length groups. However, for several reasons, the actual cod used in sampling may differ from this ideal situation. For most stations, adjusting concentrations for fish length (using the expected concentration for 50 cm fish) led to different conclusions about time trends for about 5-15% of the time series. Of these 5-15%, the most common situation was that time series that had no significant time trend using unadjusted concentrations changed to a significant downward trend when fish length was taken into account. Contaminant concentrations statistically adjusted to a standard cod-length can help explain some observed trends, however it also introduces an extra level of uncertainty especially where sampling has been inconsistent.

Sammendrag

I programmet "Miljøgifter i norske kystområder – MILKYS", gjøres det overvåking av nivåer, trender og effekter av miljøgifter langs norskekysten. Overvåkingsprogrammet gir datagrunnlag for å vurdere miljøtilstanden for kystområdene.

Hovedkonklusjon for overvåkingsprogrammet er at nivåene av mange miljøgifter er nedadgående. Det var flest nedadgående trender for konsentrasjoner av miljøgifter i marine organismer. I indre Oslofjord er det relativt høye konsentrasjoner av flere miljøgifter. Det er påvist oppadgående langtidstrend for kvikksølv i filét av torsk (*Gadus morhua*), ganske høye nivåer av polyklorerte bifeynler (PCB), polybromerte difenyletere (PBDE), perfluorerte alkylforbindelser (PFAS) og alfa-heksabromsyklododekan (□□HBCD) i torskelever.

Undersøkelsen inngår som en del av OSPARs koordinerte miljøovervåkingsprogram Coordinated Environmental Monitoring Programme (CEMP). I 2016 omfattet overvåkingen miljøgifter i blåskjell (*Mytilus edulis*) ved 34 stasjoner, purpursnegl (*Nucella lapillus*) ved 8 stasjoner, strandsnegl (*Littorina littorea*) ved én stasjon og torsk ved 16 stasjoner. Stasjonene er plassert både 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. Undersøkelsen i 2016 omfattet overvåking av metaller (kvikksølv (Hg), kadmium (Cd), bly (Pb), kobber (Cu), sink (Zn), sølv (Ag), arsen (As), nikkel (Ni), krom (Cr) og kobolt (Co)), tributyltinn (TBT), polyklorerte bifenyler (PCB), pestisider (DDE), polybromerte difenyletere (PBDE), perfluoralkylerte stoffer (PFAS), heksabromsyklododekan (HBCD), korte- og mellomkjedete klorparafiner (SCCP og MCCP), fosfororganiske flammehemmere (PFR), bisfenol A (BPA), tetrabrombisfenol A (TBBPA), alkyfenoler, samt biologiske effekt parametre.

2016-resultatene omfatter totalt 2148 datasett (miljøgifter-stasjoner-arter) for 112 forskjellige miljøgifter. Et utvalg på 30 representative miljøgifter og biologiske effektparametere presenteres i denne rapporten. Dette utvalget består av 801 tidsserier hvorav 127 viste statistisk signifikante trender for perioden 2007 til 2016: 100 var nedadgående og 27 var oppadgående. De nedadgående trendene omfattet metaller (42 %) 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 metaller (92.6 %), og da primært kvikksølv.

Av de 801 tidsseriene kunne 252 av dem klassifiseres i henhold til miljøkvalitetsstandarder (EQS-verdier) for EUs prioriterte miljøgifter og vannregionspesifikke stoffer, og 171 (68 %) av disse var lavere enn EQS-verdiene.

Alle de 801 tidsseriene ble vurdert i forhold til et nytt begrep kalt provisorisk høy referansekonsentrasjon (PROREF). Av disse var 608 (75.9 %) lavere enn PROREF og 193 (24.1 %) overskred PROREF. Overskridelsene av PROREF for 117 (14,6 %) av tidsseriene var en faktor lavere enn to, for 53 (6.6 %) av tidsseriene en faktor mellom to og fem, for 11 (1.4 %) av tidsseriene en faktor mellom fem og 10, for fire (0.5 %) av tidsseriene en faktor mellom 10 og 20, og for åtte (1 %) av tidsseriene en faktor høyere enn 20. Selv om de fleste konsentrasjonene var under eller oversteg PROREF med en faktor lavere enn to, bør ikke tilfellene som overstiger PROREF ignoreres. Et eksempel på dette er blåskjell i Sørfjorden som var sterkt forurenset av pesticider (DDE).

Konsentrasjoner av miljøgifter i fisk
Torsk fra indre Oslofjord hadde konsentrasjon av kvikksølv i filéten som var fem til 10 ganger

høyere enn PROREF, og det var signifikant oppadgående langtidsstrend for perioden 1984 til 2016. Langtidstrend var 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, og det var også signifikant oppadgående langtidstrend (1984-2016). Torsk fra ytre Oslofjord hadde konsentrasjon av kvikksølv i filéten tilsvarende to til fem ganger høyere enn PROREF, og det var signifikante korttidstrender (2007-2016) ved beregning med OSPAR-metoden og ved justering for fiskelengde.

Torskelever fra indre Oslofjord hadde konsentrasjon av PCB-forbindelser som overskred både EQS og PROREF (den siste med en faktor på over 10). Torsk fra andre områder var ellers generelt lite forurenset (ubetydelig eller moderat forurenset) av disse forbindelsene. De høye konsentrasjonene av PCBer som ble observert i torskelever fra indre Oslofjord har trolig sammenheng med urban påvirkning i kombinasjon med lav vannutskifting med ytre fjord.

PBDEer er undersøkt i torskelever fra flere fjorder siden 2005. I 2016 var de høyeste nivåene av PBDEer i torskelever fra indre Oslofjord og fra Bergen havn, og lavest nivå i torsk fra Færder. BDE47 var den dominerende PBDE-forbindelsen i alle prøvene. 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, en PFAS-forbindelse, var høyest i torskelever fra indre Oslofjord og lavest i Bergen. PFOSA, også en PFAS-forbindelse, var høyest i indre Oslofjord og lavest i Tromsø havn. 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.

Av heksabromsyklododekaner var α-HBCD den mest dominerende diastereomeren. Torskelever fra indre Oslofjord hadde den høyeste median-konsentrasjonen av HBCD. De høye HBCD-konsentrasjonene er sannsynligvis relatert til urban påvirkning, samt lav vannutskifting med ytre fjord.

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

De aller fleste konsentrasjonene av fosfororganiske flammehemmere (PFRer) i torsk var under deteksjonsgrensene. Nivåene anses derfor som generelt lave, men ingen konklusjoner kan trekkes når det gjelder forskjeller mellom stasjonene.

Bisfenol A, TBBPA og alkylfenol ble i hovedsak ikke påvist i torsk.

Konsentrasjoner av miljøgifter i blåskjell

Blåskjell fra tre stasjoner i midtre -og ytre del av Sørfjorden hadde konsentrasjon av DDE som var mer enn 20 ganger høyrere enn PROREF. Tre 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 i frukthager langs fjordene (ca. 1945-1970).

Blåskjell fra Nordnes i Bergen havn hadde de høyeste mediankonsentrasjonene av PCB-7, α-HBCD og SCCP. Det var høyest nivå av KPAH og PBDEs (sum av 6 BDE-forbindelser) i blåskjell fra én av stasjonene i indre Oslofjord.

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

Biologiske effekter
ICES/OSPARs vurderingskriterium for bakgrunnsnivå[1] («background assessment criteria», BAC) for OH-pyren i torskegalle ble overskredet på alle undersøkte stasjoner (indre Oslofjord, Farsund-området og indre Sørfjorden), inkludert referansestasjonen (Bømlo-Sotra området) i 2016, og dette viser at fisken har vært eksponert for PAH. Median-konsentrasjonen av OH-pyren metabolitter i galle i torsk fra indre Oslofjord var omtrent halvparten av nivået som ble påvist i 2015.. Med andre ord var det en tilsynelatende lavere PAH-eksponering, og omtrent samme nivå som i 2013-2014.

ALA-D aktivitet i torsk fra indre Oslofjord og indre Sørfjorden i 2016 var lavere enn ved Bømlo. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly.

Median EROD-aktivitet i indre Oslofjord var omtrent på samme nivå som observert i 2015 (altså omtrent halvparten av i 2013 og 2015). Konsentrasjonen var fortsatt under ICES/OSPARs BAC. Konsentrasjoner over BAC indikerer mulig effekt av plane PCBer, PCNer, PAHer eller dioksiner. Mediankonsentrasjonen av CYP1A i lever av torsk fra Oslofjorden var høyere enn i torsk fra Sørfjorden og Bømloområdet.

Effektene av TBT på purpursnegl var relativt lave (VDSI <0.828) på alle de åtte stasjonene. Det var signifikant nedadgående trender på alle stasjonene bortsett fra ved Brashavn i Varangerfjorden der ingen signifikant trend kunne påvises og tidligere VDSI-nivåer har vært lave. 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 2016 som i årene 2012-2015. 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.

Tidstrender for miljøgifter i torsk og betrakninger i forhold til fiskelengde
I de statistiske analysene av tidstrender (økning/nedgang) for konsentrasjoner av miljøgifter er det brukt medianverdier (for hver miljøgift og stasjon), og det er ikke tatt hensyn til lengden av den undersøkte torsken. Miljøgiftkonsentrasjoner kan justeres til å gjelde for en standard fiskelengde, og dette førte i en del tilfeller til endringer i tidstrend, spesielt fra ikke-signifikant trend til nedadgående trend over tid.

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

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.

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 also 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.

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[1]) 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 Tronheimfjord, 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 moderately elevated concentrations of mercury in cod fillet. Cod liver in the Inner Oslofjord also revealed the highest median concentration of α–HBCD in 2014. Investigations of the Sørfjord/Hardangerfjord have shown elevated levels of 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

[1] Norwegian Environment Agency monitoring report.

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[1], **Appendix C**). In this report, the results were assessed primarily in relation to EU's Environmental Quality Standards (EQS) as well as national water-region specific standards for hazardous substances (Miljødirektorat, 2016 – M-608|2016). 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 2.5).

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 for specificity as to which contaminants impact the parameter and robustness.

The state of contamination is divided into three issues of concern: levels, trends and effects. Different monitoring strategies are used, in particular with regard to the selection of indicator media (blue mussel, snail, cod liver etc.) and selection of chemical analyses. Sample frequency is annual for biota. The programme underwent an extensive revision in 2012, both in regard to stations and chemical analyses. Monitoring of flatfish was discontinued but three more cod-stations were added and a fourth added in 2015 bringing the total to 16. The blue mussel stations were reduced from 38 to 26. Choice of chemical analyses for each station has changed considerably after 2011 (**Appendix E**). Pesticide and dioxin analyses were discontinued except for DDTs at some stations in the Sørfjord/Hardangerfjord. However, many new 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 and stabile isotopes. The Norwegian Pollution and Reference Indices (cf. Green *et al*. 2011b – TA-2862/2011, 2012a –

[1] Norwegian Environment Agency monitoring report.

TA-2974/2012) are not included in the revised programme but passive sampling of contaminants in water has been added.

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). 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*. This additional funding 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 micropollutants. 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)) and Environmental Contaminants in an Urban Fjord (*Miljøgifter i en urban fjord*). These three programmes are operated by NIVA on behalf of Norwegian Environment Agency.

1.2 Purpose

An aim of the Norwegian Environment Agency is to obtain an overview of the status and trends of the environment as well as to assess the importance of various sources of pollution. The Norwegian Environment Agency seeks to develop a 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 2020. 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's 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's EQSD. The results from MILKYS can also be useful in addressing aspects of the EU's 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).

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 to the Russian border in the north (***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), dog whelk at eight stations (nine were planned), periwinkle at one station and cod at 16 stations. Note that the station names have been updated to provide a better description as to where the station is located. The station codes have not been changed.

Samples were collected during 2016 and analysed according to OSPAR guidelines (OSPAR 2003, 2012)[1]. 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*), dog whelk (*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 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.

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).

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

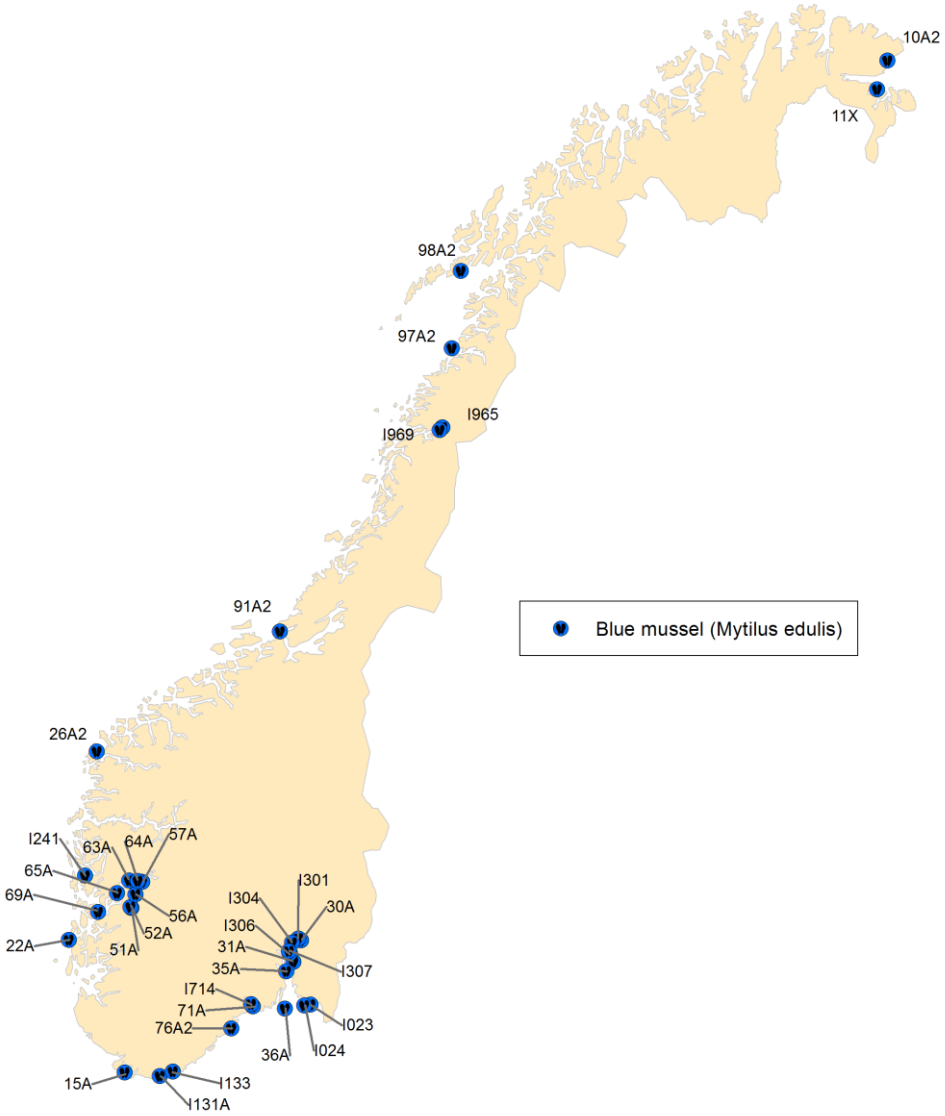


***Figure 1**. Stations where blue mussel were sampled in 2016. See also station information in detailed maps in **Appendix D**.*

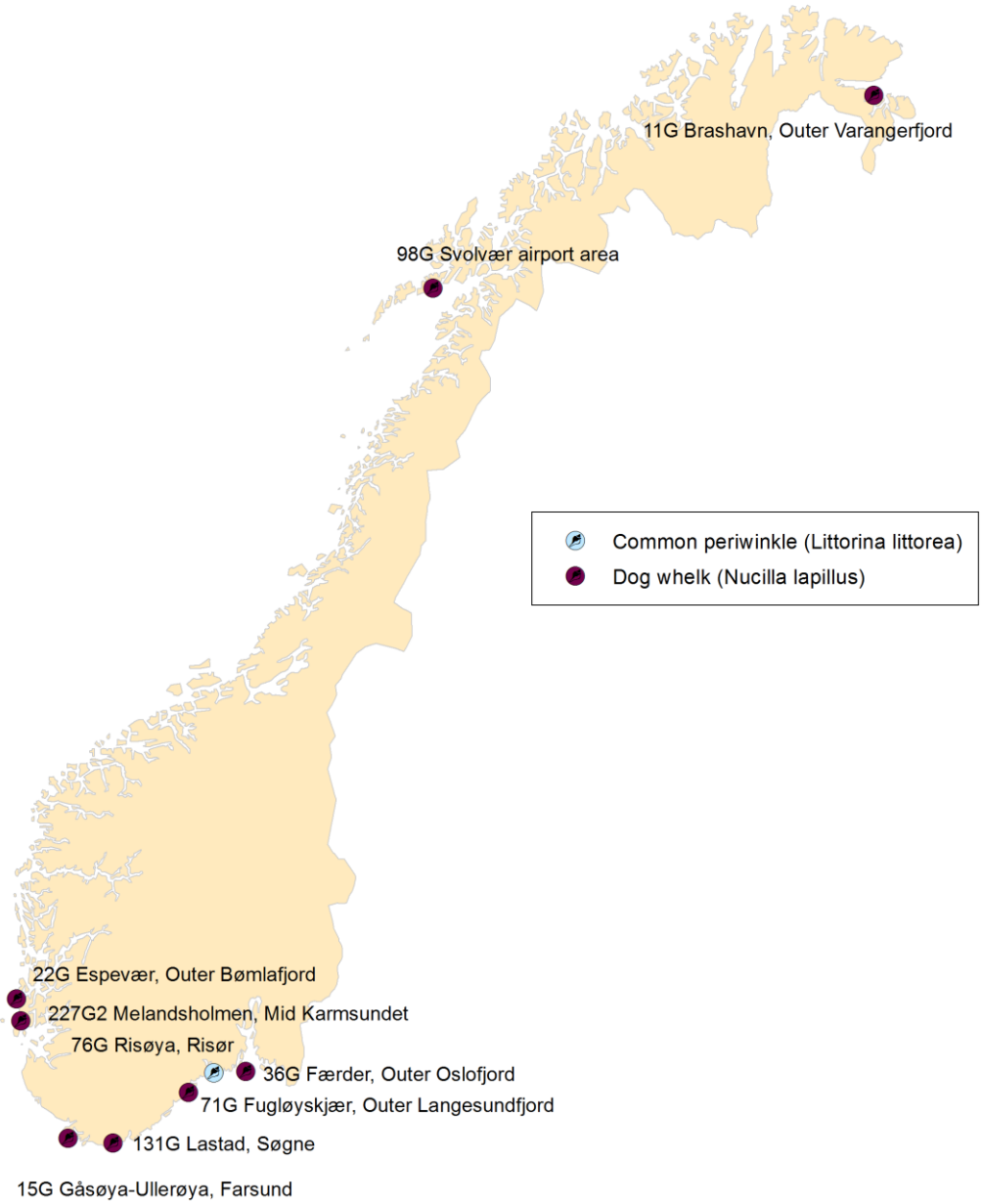


***Figure 2**. Stations where dog whelk and periwinkle were sampled in 2016. See also station information in detailed maps in **Appendix D**.*

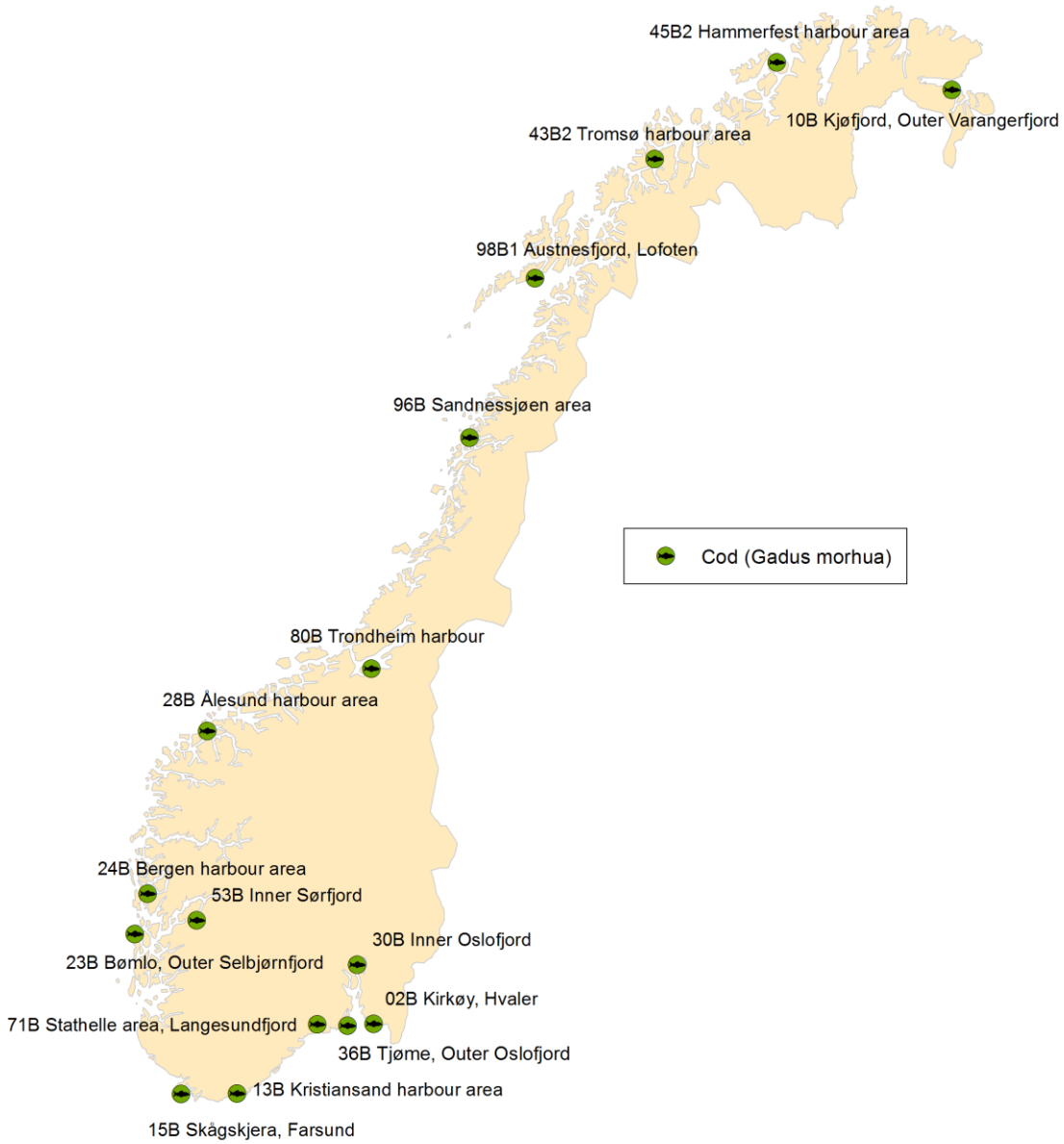


***Figure 3**. Stations where cod were sampled in 2016. Note that biological effects methods were applied to cod samples from the Inner Oslofjord. See also station information in detailed maps in **Appendix D**.*

2.1.2 Blue mussel

A sufficient number of individuals for three pooled samples of blue mussel were found at 33 stations of the 34 stations, including the eight stations funded directly by the Ministry of Climate and Environment). One station (Færder st. 36A) had only two samples. 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 locations 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 not taken into account in the interpretations of the results for this investigation.

The blue mussel samples were collected from 17th August to 14th November 2016.

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

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 Dog whelk and periwinkle

Concentrations and effects of organotin on dog whelk 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 dog whelks, 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 dog whelk 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 dog whelk collected in Lofoten and in the Varangerfjord. The snail samples were collected from 6th September to 13th October 2016.

2.1.4 Atlantic cod

Fifteen individuals of Atlantic cod were to be sampled for each station. This was accomplished at 14 stations, whereas at Hvaler (st. 02B) and Ålesund harbour (28B) (***Figure 3***) only 10 and 8 individuals were caught, respectively.

The cod were sampled from 16th August to 20th December 2016. 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 using 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**). The Skågskjera near Farsund (st. 15B), Bømlo in the Outer Selbjørnfjord (st. 23B) and Austnesfjord in the Lofoten area (st. 98B1) were the three 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.

2.2 Chemical analyses of biological samples

2.2.1 Choice of chemical analyses and target species/tissues

An overview of chemical analyses performed on 2016-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 2016. 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	Dog whelk	Common periwinkle	Cod liver	Cod fillet
Metals Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobalt (Co) and tin (Sn)	32 (8)			16	
Mercury (total Hg)	34 (8)				16
Organotin (MBT, DBT, TBT, TPT)	7 (7)	8	1		
PCB-7 (PCB-28, 52, 101, 118, 138, 153, and 180**)**	31 (8)			15	
HCB, OCS, 5CS**	0 (8)			0 (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	
Hexabromocyclododecane (HBCDs: α-, ß-, γ-HBCD**)**	9			12	
Perfluorinated alkylated substances (PFAS) PFNA, PFOA, PFHpA, PFHxA, PFHxS, PFOS, PFBS, PFOSA				9	
Chlorinated paraffins (SCCP (C10-C13) and MCCP (C14-C17)**)**	10			12	
Phosphorus flame retardants (PFRs) TIBP, TBP, TCEP, TCPP, TDCP, TBEP, TPhP, EHDPP, V6, DBPhP, BdPhP, TEHP, ToCrP, TCrP	8			12	
Alkylphenoln (Octylphenol, nonylphenol**)**	8			11	
Tetrabrombisphenol A (TBBPA)	10			11	
Bisphenol A (BPA)	10			11	

*) 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 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.

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 12)***. 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. uncertainty	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
copper (Cu)	7440-50-8	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	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
zinc (Zn)	7440-66-6	**NIVA/EFM**	0.5 mg/kg	20 %	Standard method NS EN ISO 17294-2	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
arsenic (As)	7440-38-2	**NIVA/EFM**	0.03 mg/kg	20 %	Standard method NS EN ISO 17294-2	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
nickel (Ni)	7440-02-0	**NIVA/EFM**	0.04 mg/kg	20 %	Standard method NS EN ISO 17294-2	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
tin (Sn)	7440-31-5	**NIVA/EFM**	0.1 mg/kg	20 %	Standard method NS EN ISO 17294-2	ISO 17025, accredited
Total-Hg	7439-9-76	**NIVA/EFM**	0.005 mg/kg	25 %	Standard method	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-52	35693-99-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-101	37680-73-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-118	31508-00-6	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-138	35065-28-2	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	30 %	Internal method	ISO 17025
PCB-153	35065-27-1	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
PCB-180	35065-29-3	**NIVA/EFM**	0.05 µg/kg low fat. 1 µg/kg high fat	40 %	Internal method	ISO 17025
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
BDE99	60348-60-9	**NIVA/EFM**	0.01 µg/kg mussels. 0.1 µg/kg high fat	40 %	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
BDE126*	366791-32-4	**NIVA/EFM**	0.01 µg/kg mussels	50 %	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
BDE154	207122-15-4	**NIVA/EFM**	0.02 µg/kg mussels. 0.1 µg/kg high fat	40 %	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
BDE196	32536-52-0	**NIVA/EFM**	0.05 µg/kg mussels. 0.3 µg/kg high fat	40 %	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
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
Tetrabrombisphenol A (TBBPA)	79-94-7	**EF-GFA**	0.5 ng/g	40 %	Internal method, validated	ISO 17025
Bisphenol A (BPA)	80-05-7	**EF-GFA**	1-5 ng/g	40 %	Internal method, validated	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

Name	[CAS-number]	Lab.	LOQ	Est. uncertainty	Standard or internal method	Accreditation status
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			0.4 µg/kg			
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
MCCP (C14-C17)	85535-85-9	**EF-GFA**	5-10 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
Phenols						
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
4-nonylphenol	104-40-5 (25154-52-3, 84852-15-3)	**EF-GFA**	10-50 ng/g	40 %	Internal method, validated	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
PFRs						
tri-iso-butylphosphate (TIBP)*	126-71-6	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tributylphosphate (TBP)	126-73-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(2-chlorethyl)phosphate (TCEP)	115-96-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(1-chlor-2-propyl) phosphate (TCPP)	13674-84-5	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(1,3-dichlor-2-propyl) phosphate (TDCP)	13674-87-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tri(2-butoxyethyl) phosphate (TBEP)	78-51-3	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
triphenylphosphate (TPhP)	115-86-6	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
2-ethylhexsyl-di-phenylphosphate (EHDPP)*	1241-94-7	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tetra is-(2-chloroethyl)dichlorisopentyldiphosphate (V6)		**EF-GFA**	100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
dibutylfenylphosphate (DBPhP)**	2528-36-1	**EF-GFA**	100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
butyldifenylphosphate (BdPhP)**	2752-95-6	**EF-GFA**	100-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tris(2-etylheksyl)phosphate (TEHP)*	78-42-2	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025
tris-o-kresylphosphate (ToCrP)*	78-30-8	**EF-GFA**	20-200 ng/1 g fat	40 %	Internal method, under development	ISO 17025

Name	[CAS-number]	Lab.	LOQ	Est. uncertainty	Standard or internal method	Accreditation status
trikresylphosphate (TCrP)	1330-78-5	**EF-GFA**	200-1000 ng/1 g fat	40 %	Internal method, under development	ISO 17025
Phthalates						
Dibutylphthalate (DBP)	84-74-2	**EF-Sofia**	500 µg/kg	40 %		Not accredited
Dibutyladipat (DBPA)		**EF-Sofia**	500 µg/kg	40 %		Not accredited
Diethylhexcyladipate (DEHA)		**EF-Sofia**	2000 µg/kg	40 %		Not accredited
Di(2-ethylhexyl)-phthalate (DEHP)	117-81-7	**EF-Sofia**	1000 µg/kg	40 %		Not accredited
Dietylphthalate (DEP)		**EF-Sofia**	500 µg/kg	40 %		Not accredited
Diethyladipat (DEPA)	85-68-7	**EF-Sofia**	500 µg/kg	40 %		Not accredited
Benzylbutylphthalate (BBP)		**EF-Sofia**	300 µg/kg	40 %		Not accredited
Diisobutylphthalate (DIBP)	84-69-5	**EF-Sofia**	500 µg/kg	40 %		Not accredited
Diisodectylyphthalate (DIDP)		**EF-Sofia**	5000 µg/kg	40 %		Not accredited
Diisoheptylphthalate (DIHP)		**EF-Sofia**	5000 µg/kg	40 %		Not accredited
1,2-Cyclohexane dicarboxylic acid diisononyl ester (DINCH)		**EF-Sofia**	500 µg/kg	40 %		Not accredited
Diisobutyl adipate (DIPA)		**EF-Sofia**	300 µg/kg	40 %		Not accredited
Dimethylphthalate (DMP)		**EF-Sofia**	500 µg/kg	40 %		Not accredited
Di-n-octylphthalte (DNOP)		**EF-Sofia**	500 µg/kg	40 %		Not accredited
Diphenylphthalate (DPF)		**EF-Sofia**	500 µg/kg	40 %		Not accredited
Dinonylphthalte+diisononylphthalate (SDD)		**EF-Sofia**	n.a.	40 %		Not accredited
Tributyl-o-acetylcitrate (TOA)		**EF-Sofia**	n.a.	40 %		Not accredited
BEM						
VDSI		**NIVA**		10-20%	ICES 1999	Not accredited
EROD		**NIVA**		10-20%	ICES 1991	Not accredited
CYP1A		**NIVA**		10-20%	ICES 1998	Not accredited
ALA-D		**NIVA**		20 %	ICES 2004	Not accredited

2.2.2 Laboratories and brief method descriptions

The 2016 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**). NIVA was responsible for the 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).

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. Among the individual PCBs quantified, seven (ΣPCB-7) are commonly used for interpretation of the results[1] (***Table 4***).

Table 4*. The seven suggested PCB-congeners (the sum is denoted as PCB-7), which according to ICES (1986) 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. 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 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**).

Organic tin compounds were analysed at Eurofins GFA in 2016/2017 using GC-MS quantification.

Analyses of polybrominated diphenylether (PBDE) in cod liver were done at Eurofins Moss in 2016/2017. Results are given based on the total extractable fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

Analysis of perfluorinated alkylated substances (PFAS) in cod liver 2016 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). From 2013 LC-qTOF (liquid chromatography quadropole time of flight) has been used for detection and

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

quantification. The limit of quantification has improved for analyses of the 2016-samples 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.

The new analyses introduced in 2012/2013 were done by Eurofins. Chlorinated paraffins (SCCP (C10-C13), MCCP (C14-C17)), phosphorus flame retardants (PFRs) 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, β, γ-HBCD) were determined by LC-MS-MS also by Eurofins GFA.

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 individual were 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 is measured. On a bulk basis the total shell weight, total soft tissue weight, dry weight and % fat content is measured. These measurements are stored in the database and published periodically.

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

2.3 Biological effects analysis

Five 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 and CYP1A 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 (CYP1A/P4501A1, EROD)	fish liver	planar PCB/PCNs, PAHs, dioxins
CYP1A	Relative amount of cytochrome P450 1A-protein	fish liver	Supporting parameter for EROD-activity
TBT	Imposex/Intersex	whole body	organotin

BEM-sampling requires that the target fish is kept alive until just prior to tissue or blood sampling. Sampling for BEM-analyses is performed by trained personnel, most often under field conditions. 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 dog whelk) and Intersex analysis (on the common periwinkle) are a measure of effects of TBT and are usually performed on fresh samples unless for practical purposes the samples had to be frozen until analysis.

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 locations 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.

Biological effect methods were first included in the programme in 1997. There have been some modifications since then 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 2016 included five biological effects methods (BEM) (cf. ***Table 5***). Measures of OH-pyrene, EROD-activity and CYP1A 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 dog whelks and common periwinkles. This impact is assessed when dog whelks and the common periwinkles are analysed for imposex and intersex[1], respectively see ***Table 3***).

2.4 Information on quality assurance

2.4.1 International intercalibrations

The laboratories (NIVA and subcontractor Eurofins) have participated in the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME) international intercalibration exercises and other proficiency testing relevant to chemical and imposex analyses. For chemical analyses, round 2016-1 apply to the 2016-samples. The results are acceptable. These QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this

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

programme. The quality assurance programme is corresponding to the analyses of the 2015 samples (cf. Green *et al.* 2016 – M-618|2016).

NIVA participated in the QUASIMEME Laboratory Performance Studies "imposex and intersex in Marine Snails BE1" 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.

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 PFCs.

2.5 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's 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 apply to concentrations in biota (***Table 10*** and ***Table 11***). There is a provision in this daughter directive which allows a country to develop their own EQS for 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 for substances not otherwise accounted for by the EU directives (Arp *et al.* 2014 – M-241|2014, Miljødirektoratet 2016 – M-608|2016). 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 two 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. 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).

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 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.

This report of the 2016-investigations addresses the principle cases primarily where median concentrations exceeded EQS and secondarily where median concentrations exceeded PROREF were (***Table 10*** and ***Table 11***). Exceedances of PROREF (x) were grouped in 6 factor-intervals: <x, 1-2x, 2-5x, 5-10x, 10-20x and >20x.

The EQS and PROREF as well as time trend analyses use wet weight concentrations. The choice of base follows the OSPAR approach aimed at meeting several considerations: scientific validity, uniformity for groups of contaminants for particular tissues and a minimum loss of data. As to the latter, the choice of base 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.

The results can also be useful as part of the implementation of The Water Framework Directive (WFD) (2000/60/EC) ratified by Norway in 2009, and the Marine Strategy Directive (MSFD) (2008/56/EC), which by late 2017 has not yet been ratified by Norway. These two directives together concern all waters out to territorial borders. They are the main policies at the EU level designed to achieve good "ecological" (WFD) or "environmental and chemical" (MSFD) status, herein termed GES, in the European marine environment, by the year 2016 (2021 for Norway) and 2020 at the latest. The directives also set out to ensure the continued protection and preservation of the environment and the prevention of deterioration. The Norwegian framework regulation on water management (the Water Regulation) was adopted on December 15th 2006, and incorporates the WFD into Norwegian law. The Environmental Quality Standards (EQS) for 45 priority substances or groups of substances have been outlined in the EQS Directive (EQSD) (2013/39/EU replacing directive 2008/105/EC). Several of these substances are monitored by MILKYS. The EQS apply to concentrations in water, and for fifteen substances biota (***Table 10*** and ***Table 11***).

2.5.1 Derivation of provisional high reference concentrations - PROREF

The purpose of provisional high reference concentrations (PROREF) was to define a set of contaminant concentrations that are low relative to concentrations registered under the MILKYS programme. The derivation of PROREF is based entirely on MILKYS data. The MILKYS programme (and its forerunners) have monitored an extensive list of contaminants along the coast in both impacted and less impacted areas. Though a wide variety of species have been monitored since the programme was initiated in the early 1980s, most of the measurements have been in blue mussel and cod liver or cod muscle (for mercury).

The derivation of PROREF has two basic steps: the selection of stations to be used and the calculation of PROREF. The following outlines the approach:

1. Selection of 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 considered as at their 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 50 cm.

An overview of the PROREF applied in this report is shown in **Appendix C**, and a summary comparing PROREF with the existing EQS and the national classification system used in previous reports is shown in ***Table 6***. For this report, 174 PROREF values are defined based on 1 to 29 stations and 5 to 4074 values. For example, only one station was used to determine PROREF for TBT and KPAH among others in blue mussel and Hg, PCB7, BDE6S, HBCDA, PYR10, ALAD among others 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 from 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 which has a PROREF of 2.07 µg/kg w.w., whereas the PROREF for the sum of carcinogen PAHs (KPAH) is 0.622 µg/kg w.w.

Thirtyone PROREF values could be compared to 23 EQS. PROREF was lower 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[1] polluted) in the national system used in previous reports (***Table 6***), and was lower in four cases.

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

This is the first time PROREF values have been applied and these values should be periodically reviewed in the light of results from reference localities and introduction of new analytical methods, and/or units.

Table 6. Overview of provisional high reference concentration (PROREF) used in this report the stations from which PROREF was derived. Also shown are the Environmental Quality Standards (EQS) for "biota" [1)] (2013/39/EU) and national quality standards[1] (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. (see complete list of PROREF used in this report in **Appendix C**).

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	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 [2 3]	Gadus morhua	Liver	98B1, 10B, 92B, 43B	4	1229	U	**614**	500	*0.814*	1	*0.002*
DDEPP [4]	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 [6]	Gadus morhua	Liver	98B1, 36B, 23B	3	557	U	**16**			0.009	*0.001*
BDE6S [7]	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*
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 [2 3]	Mytilus edulis	Soft body	11X, 10A2	2	96	U	**0.93**	4	*4.301*	1	*1.075*
DDEPP [4]	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[5]	Mytilus edulis	Soft body	98A2, I023, 71A	3	47	U	**17.3**			2400	*138.728*
ANT[5]	Mytilus edulis	Soft body	30A, 71A, 98A2, I023	4	112	U	**1.1**			2400	*2181.82*
FLU[5]	Mytilus edulis	Soft body	98A2, I023	2	32	U	**5.35**			30	*5.607*
BAA[5]	Mytilus edulis	Soft body	98A2, I023	2	32	U	**1.49**			304	*204.03*
BAP[5]	Mytilus edulis	Soft body	30A, 71A, 98A2, I023, I131A	5	177	U	**1.3**	1	*0.769*	5	*3.846*
P_S [5]	Mytilus edulis	Soft body	98A2	1	17	U	**6.04**	50	*8.284*		
BDE47 [6]	Mytilus edulis	Soft body	98A2, 26A2, I023, 71A, 91A2	5	79	U	**0.14**			0.009	*0.061*
BDE6S [7]	Mytilus edulis	Soft body	98A2, 26A2, 71A, 91A2, I023	5	79	U	**0.19**			0.009	*0.044*

[1] The contaminants for which the national quality standards apply are termed in the EU system as "river basin specific".

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	Class I / Q95	EQS	EQS / Q95
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 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) Sum of PCB congeners 28, 52, 101, 118, 138, 153 og 180.
3) In report M-608 (Miljødirektorat, 2016 - M-608|2016) the EQS is 1 µg/kg wet weight, but this was adjusted down to be in line with Arp *et al.* (2014 - M-241|2014) (Miljødirektorat, pers. comm. 16th June 2017, ref. TA-2013/10729).
4) For this study the same limit was applied to p,p DDE.
5) 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).
6) Not official EQS for BDE47, but this PBDE is often the most dominant BDE.
7) 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 and OH-pyrene and VDSI (OSPAR 2013) were used to assess the results (***Table 7***).

Table 7*. Assessment criteria for biological effects measurements using background assessment 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	dog whelk	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.

2.6 Statistical time trend analysis

2.6.1 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 quantification limit can vary within and among sets of samples and comparisons of quantification limits should be made with caution.

Dominance of values below the limit of quantification 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.

2.6.2 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 4***. It should be noted that this robust method has been developed so that it could provide a rough guide to possible trends in the OSPAR region. Further investigation is necessary to better understand the factors affecting a particular trend. This may lead to different conclusions. As an exercise in this respect the times series for mercury in cod filet from the Inner Oslofjord was examined more closely (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 in that a linear trend for the whole time series period was tested whereas OSPAR currently tests the 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 2016.

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 signicant and not-significant trends is not always readily discernable in a figure. A case in point is shown for MCCP *where in with no adjustment for length (**Figure 39a**) the p-value for the trendanalysis is 0.0512 and where there is an adjusted for length (**Figure 39b**) the p-values is 0.0423, 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.

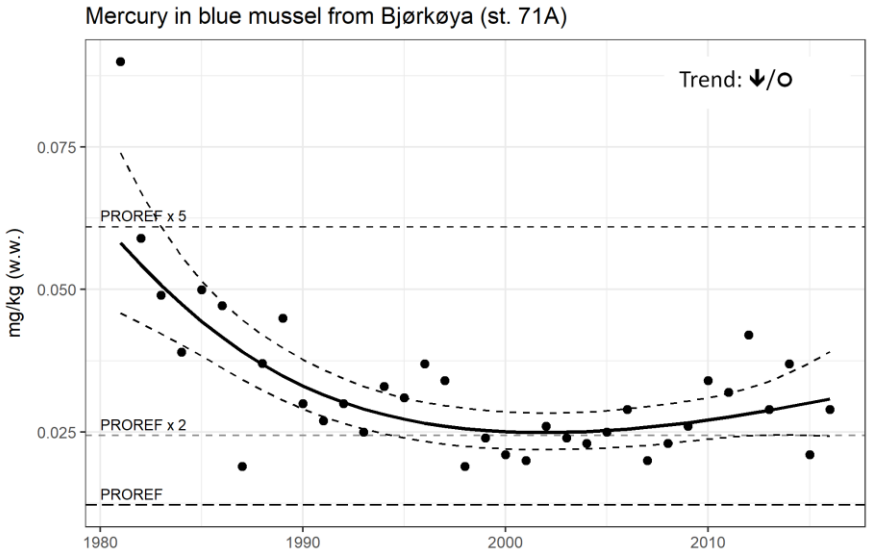


***Figure 4**. Example of time series that show the median concentration (black dots), running mean of median values (Loess smoother – thick black line) and 95 % confidence intervals surrounding the running mean (grey dashed lines). The horizontal dashed grey lines indicate the lower boundaries relative to PROREF[1]; 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 24**). 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 2007-2016 (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. Note that scales for the x axis and y axis can vary from figure to figure.*

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

2.7 Note on presentation of contaminant tables

Summaries of the results for some organic contaminants are presented in **Table 12** to **Table 19**. These tables provide some extensive details and warrant explanation. Some of the analyses, especially of the "New" contaminants (e.g. HBCD, SCCP/MCCP, PFR, 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 12** is shown below in **Table 8**. With respect to "Count" the first number indicates the number of individuals or pooled samples that were analysed. For example, for blue mussel from Færder three samples were analysed and all three were pooled samples and the maximum number of individual mussels that went into the pooled sample was 20. For cod liver from the Inner Oslofjord there were 15 samples whereof two were pooled with a maximum of two fish livers in each pool. This means that analyses were done on 13 individual cod (15-2=13) was analysed on its own. 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 Færder is blank and indicates that none of the three values were above LOQ, whereas for cod liver from Inner Oslofjord indicates that all 15 samples had concentrations of BDE47 above LOQ and these ranged from 8.3 to 87 µg/kg w.w. Only one of the values was above LOQ for blue mussel from Svolvær airport area. Note that when a dataset contains values below LOQ the median takes these as half the LOQ (see chapter 2.6.1). 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 8**. Example table – extract from **Table 12**. 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	BDE47		
Species and sampling locality	2016	Med.	S.d.	D.d.i
Blue mussel				
Færder, Outer Oslofjord (st. 36A)	3(3-20)	0.050	0.000	
Svolvær airport area (st. 98A2)	3(3-120)	0.050	0.000	1[0.05]
Cod, liver				
Inner Oslofjord (st. 30B)	15(2-2)	28.000	24.131	15[8.3 - 87]
Tromsø harbour area (st. 43B2)	12(3-2)	8.850	3.888	12[5.6 - 17]

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, dog whelk and periwinkle along the coast of Norway in 2016 is shown in ***Table 10*** and ***Table 11***. More details on trend analyses for the entire monitored period that include results from either 2015 or 2016 are shown in **Appendix F**. The results from 2016 present data for a total of 2148 data sets (contaminant[1]-station-species-tissue) on 112 different contaminants. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period[2], whereas a short-term trend refers to the analysis on data for the last 10 years, i.e. 2007-2016 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 or their effect (VDSI), and totalled 801 data series[3] for the 2016 data (***Table 9***). Of the 801 cases, 252 cases could be classified against EQS, of which 171 (68 %) were below the EQS and 81 (32.1 %) were above the EQS. All 801 cases could be compared to PROREF, and of these 608 (75.9 %) were below PROREF. Of the 801 cases 193 (24.1 %) exceeded PROREF: 117 (14.6 %) by a factor of less than two, 53 (6.6 %) by a factor between two and five, 11 (1.4 %) by a factor between five and 10, fire (0.5 %) by a factor between 10 and 20, and åtte (1 %) by a factor greater than 20 (***Figure 5A***). Of the 801 data series recent and significant trends were registered in 127 cases: 100 (12.5 %) were downwards trends and 27 (3.4 %) were upwards (***Figure 5B***). The downward trends were primarily associated with metals (42 %), tributyltin (TBT, 12 %) and Vas Deferens Sequence Index (VDSI) (the effect of TBT) (4 %) (***Figure 6A***). The upward trends were also mainly associated with metals (92.6 %), primarily Hg (22.2 %).

Primary focus was on those cases where median concentrations in 2016 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 2016 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).

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

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

[2] This can be as early as 1984 but can vary depending on the station, species-tissue and contaminant.

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

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

Contaminant /BEM	Description	Blue mussel	Dog whelk, periwinkle	Cod, liver	Cod fillet	TOTAL
Ag	Silver	32*		16		**48**
As	Arsenic	32*		16		**48**
Cd	Cadmium	32*		16		**48**
Co	Cobalt	32*		16		**48**
Cr	Chromium	32*		16		**48**
Cu	Copper	32*		16		**48**
Hg	Mercury	34*			16	**50**
Ni	Nickel	32*		16		**48**
Pb	Lead	32*		16		**48**
Zn	Zinc	32*		16		**48**
PCB-7 (CB_S7)	sum of PCB congeners 28+52+101+118+138+153+180	31*		15		**46**
ppDDE (DDEpp)	p,p'-DDE (a DDT metabolite)	19*		7*		**26**
HBCDa	α—hexabromocyclododecane	9		12		**21**
SCCP	short chain chlorinated paraffin (C10-C13)	10		12		**22**
MCCP	medium chain chlorinated paraffin (C14-C17)	10		12		**22**
BDE47	Tetrabromdiphenylether	10		10		**20**
BDE100	Pentabromdiphenylether	10		10		**20**
BDE209	Decabromdiphenylether	10		10		**20**
PAHs (P_S)	sum nondicyclic PAHs	10				**10**
KPAHs (PK_S)	sum carcinogen PAHs	10				**10**
BKF	benzo[k]fluoranthene	10				**10**
B[ghi]P	benzo[ghi]perylene	10				**10**
ICDP	Indeno[1,2,3-cd]pyrene	10				**10**
B[a]P	benzo[a]pyrene	10				**10**
FLU	Fluoranthene	10				**10**
PFOS	perfluorooctanoic sulfonate			9		**9**
PFOSA	perfluorooctylsulfonate acid amide			9		**9**
PFBS	Potassium perfluorobutanesulfonat			9		**9**
TBT	tributyltin (formulation basis)	7*	9			**16**
VDSI	Vas Deferens Sequence Index		9			**9**
TOTAL		**508**	**18**	**259**	**16**	**801**

1) 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 for blue mussel stations: 35A, 52A, 57A, 63A, 69A, I133, I306, I307.

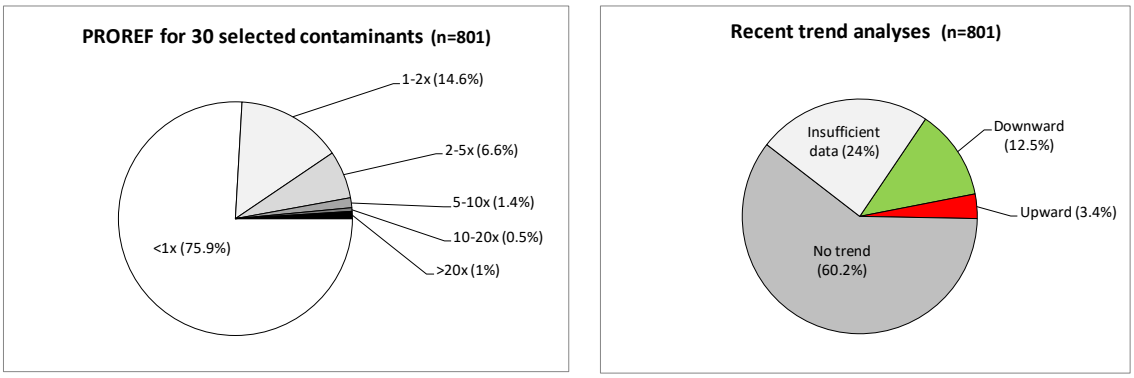


Figure 5. *Summary of frequency of exceedance to provisional high reference concentration (PROREF) (A) and the results from short-term trend analyses (**B**) and for 30 selected contaminants (cf. **Table 9**). Grey-shade coding in Figure B refers to relation to PROREF[1] (cf. **Table 24**).*

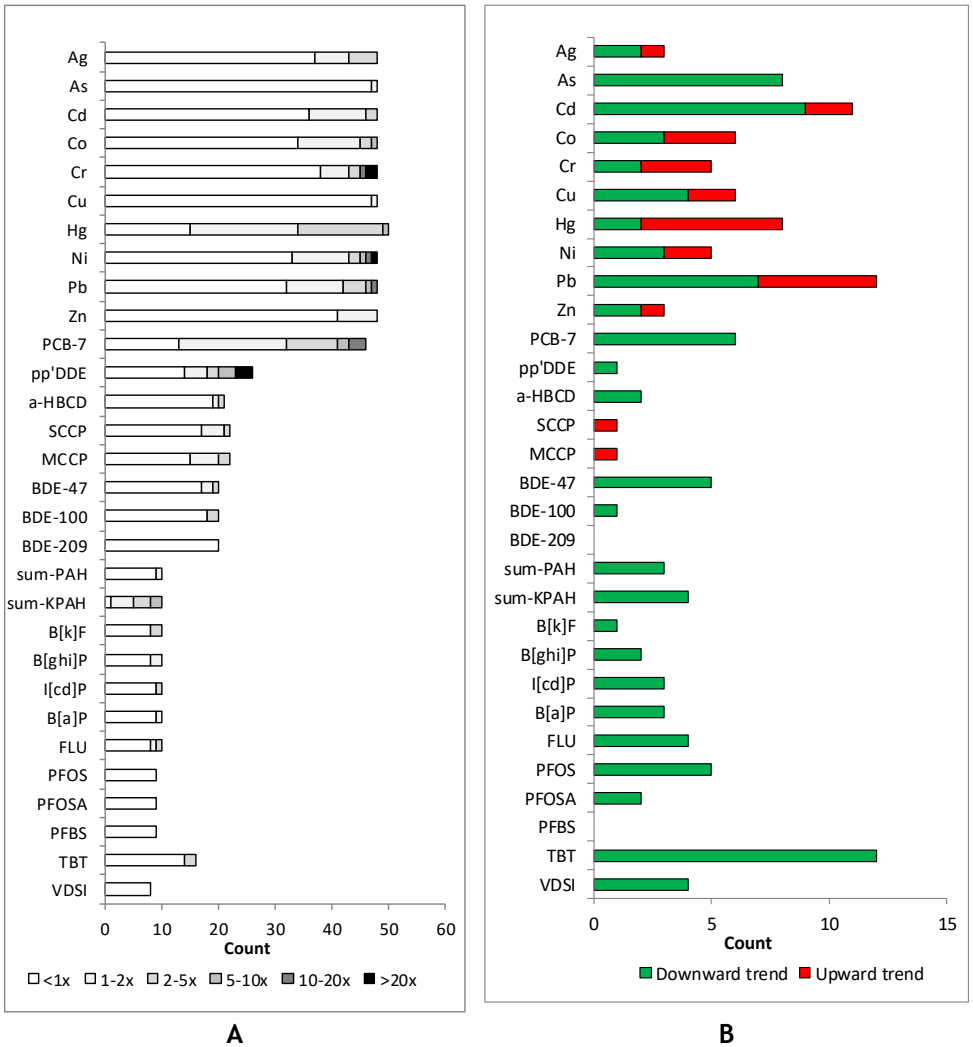


Figure 6. *Summary of frequency of exceedance to provisional high reference concentration (PROREF) (A) and short-term trends (**B**) and for each of the 30 selected contaminants (cf. **Table 9**, (see **Appendix B** for description of chemical codes). Grey-shade coding in Figure B refers to relation to PROREF (cf. **Table 24**).*

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

***Table 10**. Assessment of levels of median concentrations of contaminants with respect to EQS (EU-priority pollutants* and Water region specific substances**) and PROREF in samples collected in 2016 in four species: blue mussel, dog whelk, common periwinkle and cod. Tissues: soft body (for blue musse, dog whelk and periwinkle), liver (cod except for Hg) and fillet (cod, mercury. 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**). *Green-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	Station name	Species	HG*	TBT*	TPTIN	PCB7**	DDEPP*	ANT*	BAP*	FLU*	NAP*	BAA**	BDE6S*	BDE47	PFOA**	PFOS*	HBCDA*	SCCP*	4-N-NP*	MCCP**	4-T-NP*	4-N-OP*	4-T-OP*
I301	Akershuskaia, Inner Oslofjord	Blue mussel	●	●	●	●	●	●	●	●	●	●											
30A	Gressholmen, Inner Oslofjord	Blue mussel	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●
I304	Gåsøya, Inner Oslofjord	Blue mussel	●	●	●	●	●	●	●	●	●	●											
I306	Håøya, Inner Oslofjord	Blue mussel	●			●																	
I307	Ramtonholmen, Inner Oslofjord	Blue mussel	●			●																	
31A	Solbergstrand, Mid Oslofjord	Blue mussel	●	●	●	●	●																
35A	Mølen, Mid Oslofjord	Blue mussel	●			●																	
36A	Færder, Outer Oslofjord	Blue mussel	●	●	●	●	●						●	●			●	●		●			
I023	Singlekalven, Hvaler	Blue mussel	●			●		●	●	●	●	●	●	●			●	●	●	●	●	●	●
I024	Kirkøy, Hvaler	Blue mussel	●			●																	
71A	Bjørkøya, Langesundfjord	Blue mussel	●			●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●
I714	Sylterøya, Langesundfjord	Blue mussel	●			●	●	●	●	●	●	●	●	●			●	●		●			
76A2	Risøya, Risør	Blue mussel	●			●	●																
I131A	Lastad, Søgne	Blue mussel	●					●	●	●	●	●											
I133	Odderøya, Kristiansand harbour	Blue mussel	●	●	●	●	●																
15A	Gåsøya-Ullerøya, Farsund	Blue mussel	●			●																	
51A	Byrkjenes, Inner Sørfjord	Blue mussel	●			●	●																
52A	Eitrheimsneset, Inner Sørfjord	Blue mussel	●			●	●																
56A	Kvalnes, Mid Sørfjord	Blue mussel	●			●	●																
57A	Krossanes, Outer Sørfjord	Blue mussel	●			●	●																
63A	Ranaskjer, Ålvik, Hardangerfjord	Blue mussel	●			●	●																
64A	Utne, Outer Sørfjord	Blue mussel	●			●	●																
65A	Vikingneset, Mid Hardangerfjord	Blue mussel	●			●	●																

Station	Station name	Species	HG*	TBT*	TPTIN	PCB7**	DDEPP*	ANT*	BAP*	FLU*	NAP*	BAA**	BDE6S*	BDE47	PFOA**	PFOS*	HBCDA*	SCCP*	4-N-NP*	MCCP**	4-T-NP*	4-N-OP*	4-T-OP*
69A	Terøya, Outer Hardangerfjord	Blue mussel	●			●																	
22A	Espevær, Outer Bømlafjord	Blue mussel	●	●	●	●	●																
I241	Nordnes, Bergen harbour	Blue mussel	●			●							●	●			●	●	●	●	●	●	●
26A2	Vågsvåg, Outer Nordfjord	Blue mussel	●			●							●	●				●	●	●	●	●	●
91A2	Ørland area, Outer Trondheimsfjord	Blue mussel	●			●							●	●			●	●	●	●	●	●	●
I965	Moholmen, Inner Ranfjord	Blue mussel	●					●	●	●	●	●											
I969	Bjørnbærviken, Inner Ranfjord	Blue mussel	●					●	●	●	●	●											
97A2	Mjelle, Bodø area	Blue mussel	●			●							●	●			●	●	●	●	●	●	●
98A2	Svolvær airport area	Blue mussel	●			●		●	●	●	●	●	●	●			●	●	●	●	●	●	●
10A2	Skallnes, Outer Varangerfjord	Blue mussel	●			●	●																
11X	Brashavn, Outer Varangerfjord	Blue mussel	●			●	●																
30B	Inner Oslofjord	Cod	●			●	●						●	●	●	●	●	●	●	●	●	●	●
36B	Tjøme, Outer Oslofjord	Cod	●			●	●						●	●	●	●	●	●	●	●	●	●	●
02B	Kirkøy, Hvaler	Cod	●			●											●	●	●	●	●	●	●
71B	Stathelle area, Langesundfjord	Cod	●														●	●	●	●	●	●	●
13B	Kristiansand harbour area	Cod	●			●							●	●	●	●	●	●	●	●	●	●	●
15B	Skågskjera, Farsund	Cod	●			●	●																
53B	Inner Sørfjord	Cod	●			●	●						●	●	●	●	●	●	●	●	●	●	●
23B	Bømlo, Outer Selbjørnfjord	Cod	●			●	●						●	●	●	●	●	●	●	●	●	●	●
24B	Bergen harbour area	Cod	●			●							●	●	●	●	●	●	●	●	●	●	●
28B	Ålesund harbour area	Cod	●			●							●	●			●	●	●	●	●	●	●
80B	Trondheim harbour	Cod	●			●							●	●	●	●	●	●	●	●	●	●	●
96B	Sandnessjøen area	Cod	●			●																	
98B1	Austnesfjord, Lofoten	Cod	●			●	●						●	●	●	●	●	●		●			
43B2	Tromsø harbour area	Cod	●			●							●	●	●	●	●	●	●	●	●	●	●
45B2	Hammerfest harbour area	Cod	●			●																	
10B	Kjøfjord, Outer Varangerfjord	Cod	●			●	●																
30B	Inner Oslofjord	Cod	●																				
71G	Fugløyskjær, Outer Langesundfjord	Common periwinkle		●	●																		
36G	Færder, Outer Oslofjord	Dog whelk		●	●																		

Station	Station name	Species	HG*	TBT*	TPTIN	PCB7**	DDEPP*	ANT*	BAP*	FLU*	NAP*	BAA**	BDE6S*	BDE47	PFOA**	PFOS*	HBCDA*	SCCP*	4-N-NP*	MCCP**	4-T-NP*	4-N-OP*	4-T-OP*
76G	Risøya, Risør	Dog whelk		●	●																		
131G	Lastad, Søgne	Dog whelk		●	●																		
15G	Gåsøya-Ullerøya, Farsund	Dog whelk		●	●																		
227G2	Melandsholmen, Mid Karmsundet	Dog whelk		●	●																		
22G	Espevær, Outer Bømlafjord	Dog whelk		●	●																		
98G	Svolvær airport area	Dog whelk		●	●																		
11G	Brashavn, Outer Varangerfjord	Dog whelk		●	●																		

***Table 11**. Assessment of levels and trends of median concentrations of contaminants with respect to PROREF in samples collected in 2016 with indication of levels and trends in four species: blue mussel, dog whelk, common periwinkle and cod.* Tissues: soft body (for blue musse, dog whelk 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	Station_name	Species	HG	CD	PB	CU	ZN	AG	AS	CO	CR	NI	TBT	TPTIN	CB_S7	DDEPP	BDE47	BDE100	BDE209	PFOS	PFOSA	P_S	KPAH	BAP	FLU	NAP	BKF	BGHIP	ICDP	HBCDA	SCCP	MCCP	VDSI
I301	Akershuskaia, Inner Oslofjord	Blue mussel	🡅/O	O/O	🡇/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	🡇/🡇	▪/▪	🡇/O	🡇/O	▪/▪	▪/▪	▪/▪			🡇/O	O/🡇	🡇/🡇	🡇/O	🡇/★	🡇/🡇	🡇/🡇	🡇/🡇				
30A	Gressholmen, Inner Oslofjord	Blue mussel	O/O	O/🡇	🡅/O	O/O	🡇/O	O/O	🡇/🡇	🡅/🡅	🡅/🡅	🡅/🡅	🡇/🡇	▪/▪	🡇/O	🡇/O	🡇/★	O/★	▪/▪			🡇/🡇	🡇/🡇	★/★	🡇/🡇	🡇/O	O/O	O/O	🡇/★	O/▪	O/O	O/O	
I304	Gåsøya, Inner Oslofjord	Blue mussel	O/🡅	🡅/🡅	O/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	▪/▪	▪/▪	🡇/🡇	O/O	▪/▪	▪/▪	▪/▪			O/O	★/★	★/★	🡇/🡇	🡇/★	★/★	O/★	★/★				
I306	Håøya, Inner Oslofjord	Blue mussel	O/🡅	O/🡅	O/O	🡇/O	🡇/O	★/★	O/O	O/O	O/O	O/O			🡇/O	O/O						O/O	★/★	★/★	O/O	★/★	★/★	O/★	★/★				
I307	Ramtonholmen, Inner Oslofjord	Blue mussel	🡅/🡅	🡅/O	🡅/🡅	🡇/🡇	🡇/O	O/O	O/O	O/O	O/O	O/O			🡇/🡇	O/O	▪/▪	▪/▪				O/O	★/★	★/★	O/O	O/★	★/★	O/★	★/★				
31A	Solbergstrand, Mid Oslofjord	Blue mussel	🡇/🡇	🡇/🡇	🡇/O	O/O	O/O	O/O	O/O	O/O	O/O	O/O	▪/▪	▪/▪	🡇/O	🡇/O	▪/▪	▪/▪	▪/▪						▪/▪	▪/▪							
35A	Mølen, Mid Oslofjord	Blue mussel	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	★/★	★/★	★/★	★/★				
36A	Færder, Outer Oslofjord	Blue mussel	🡇/O	🡇/▪	O/▪	O/▪	O/▪	▪/▪	▪/▪	▪/▪	▪/▪	O/▪	🡇/🡇	▪/▪	🡇/O	O/O	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	
I023	Singlekalven, Hvaler	Blue mussel	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	
I024	Kirkøy, Hvaler	Blue mussel	O/O	O/O	O/O	🡇/O	O/O	★/★	O/O	O/O	O/O	O/O			🡇/O	🡇/▪																	
71A	Bjørkøya, Langesundfjord	Blue mussel	🡇/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	
I714	Sylterøya, Langesundfjord	Blue mussel	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	
76A2	Risøya, Risør	Blue mussel	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪																	
I131A	Lastad, Søgne	Blue mussel	O/O	O/O	O/O	O/O	🡇/O	★/★	O/O	🡇/🡇	🡇/🡇	O/O	▪/▪		🡇/▪	O/O						O/O	O/O	★/★	O/O	🡇/★	O/O	🡇/O	🡇/★				
I133	Odderøya, Kristiansand harbour	Blue mussel	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				
15A	Gåsøya-Ullerøya, Farsund	Blue mussel	O/O	O/O	O/O	O/O	O/O	O/O	🡇/🡇	O/O	O/O	O/O	🡇/O		O/O	O/O																	
51A	Byrkjenes, Inner Sørfjord	Blue mussel	🡇/O	🡇/O	🡇/O	🡇/▪	🡇/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			🡇/O	O/O																	
52A	Eitrheimsneset, Inner Sørfjord	Blue mussel	🡇/O	🡇/O	🡇/O	🡇/O	🡇/O	O/O	O/O	O/O	O/O	O/O			🡇/O	O/O	▪/▪	▪/▪															
56A	Kvalnes, Mid Sørfjord	Blue mussel	🡇/O	🡇/O	🡇/O	🡇/O	🡇/O	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			🡇/O	🡅/O						▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪				
57A	Krossanes, Outer Sørfjord	Blue mussel	🡇/O	🡇/🡇	🡇/O	🡇/O	🡇/O	O/O	O/O	O/O	O/O	O/O			🡇/O	O/O																	
63A	Ranaskjer, Ålvik, Hardangerfjord	Blue mussel	🡇/O	🡇/🡇	🡇/🡇	🡇/O	🡇/O	★/★	O/O	🡇/🡇	O/O	O/O			★/O	O/O						▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪				
64A	Utne, Outer Sørfjord	Blue mussel	O/O	O/O	O/O	O/O	O/O	★/★	O/O	O/O	O/O	O/O			O/O	O/O																	
65A	Vikingneset, Mid Hardangerfjord	Blue mussel	O/O	🡇/🡇	🡇/O	🡇/O	🡇/O	O/O	O/O	🡇/🡇	O/O	O/O			★/★	O/O																	
69A	Terøya, Outer Hardangerfjord	Blue mussel	O/🡇	🡇/🡇	🡇/🡇	O/O	🡇/🡇	O/O	O/O	O/O	🡅/🡅	O/O			★/★	O/O						▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪				
22A	Espevær, Outer Bømlafjord	Blue mussel	O/O	O/O	🡇/🡇	O/🡇	🡇/O	O/O	O/O	O/O	O/O	O/O	🡇/🡇	▪/▪	🡇/O	O/O	▪/▪	▪/▪															
I241	Nordnes, Bergen harbour	Blue mussel	O/O	O/O	🡇/🡇	O/O	O/O	★/★	O/O	O/O	O/O	O/O			🡇/O	O/O	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	
26A2	Vågsvåg, Outer Nordfjord	Blue mussel	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	
91A2	Ørland area, Outer Trondheimsfjord	Blue mussel	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	
I965	Moholmen, Inner Ranfjord	Blue mussel	🡇/O	🡇/🡇	🡇/🡇	O/O	O/O	O/O	🡇/O	O/O	O/O	🡇/🡇										🡇/🡇	🡇/🡇	🡇/🡇	O/🡇	🡇/O	O/O	🡇/🡇	🡇/🡇				
I969	Bjørnbærviken, Inner Ranfjord	Blue mussel	O/O	O/O	🡇/🡇	O/O	O/🡇	O/O	O/O	🡅/🡅	O/O	O/O										🡇/🡇	🡇/🡇	🡇/🡇	O/🡇	O/O	O/O	🡇/O	🡇/🡇				
97A2	Mjelle, Bodø area	Blue mussel	O/O	O/O	O/O	🡇/🡇	O/O	★/★	O/O	O/O	O/O	🡇/🡇			🡇/🡇		O/O	★/★	★/★											★/★	O/O	O/O	
98A2	Svolvær airport area	Blue mussel	🡇/O	O/O	🡇/O	O/O	O/O	O/O	🡇/🡇	O/O	O/O	O/O	🡇/O		★/★	O/★	🡇/O	O/★	★/★			O/🡇	★/★	★/★	★/★	★/★	★/★	★/★	★/★	🡇/🡇	🡅/🡅	O/O	
10A2	Skallnes, Outer Varangerfjord	Blue mussel	🡇/O	O/O	🡇/🡇	O/O	O/O	🡇/🡇	🡇/🡇	O/O	O/O	O/O	▪/▪		★/O	🡇/O	▪/▪	▪/▪				▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪				
11X	Brashavn, Outer Varangerfjord	Blue mussel	O/O	O/O	🡇/O	O/O	O/O	🡇/🡇	🡇/🡇	O/O	🡅/🡅	🡅/🡅	★/★		🡇/🡇	🡇/O	▪/▪	▪/▪				▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪				
30B	Inner Oslofjord	Cod	🡅/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	
36B	Tjøme, Outer Oslofjord	Cod	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	
02B	Kirkøy, Hvaler	Cod	O/O	O/O	★/★	O/O	O/O	O/O	O/O	O/O	O/O	O/O			O/O															O/O	O/O	🡅/🡅	
71B	Stathelle area, Langesundfjord	Cod	O/O	🡇/🡇	★/★	🡅/🡅	O/O	O/O	O/O	O/O	O/O	O/O																		🡇/🡇	O/O	O/O	
13B	Kristiansand harbour area	Cod	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	

Station	Station_name	Species	HG	CD	PB	CU	ZN	AG	AS	CO	CR	NI	TBT	TPTIN	CB_S7	DDEPP	BDE47	BDE100	BDE209	PFOS	PFOSA	P_S	KPAH	BAP	FLU	NAP	BKF	BGHIP	ICDP	HBCDA	SCCP	MCCP	VDSI
15B	Skågskjera, Farsund	Cod	O/↑	O/O	↓/↑	O/↑	O/↑	O/O	O/O	O/O	O/O	O/O	▪/▪		↓/O	↓/↓	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪									▪/▪			
53B	Inner Sørfjord	Cod	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	
23B	Bømlo, Outer Selbjørnfjord	Cod	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	
24B	Bergen harbour area	Cod	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪									▪/▪	▪/▪	▪/▪	
28B	Ålesund harbour area	Cod	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪		▪/▪	▪/▪	▪/▪											▪/▪	▪/▪	▪/▪	
80B	Trondheim harbour	Cod	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	
96B	Sandnessjøen area	Cod	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪																		
98B1	Austnesfjord, Lofoten	Cod	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/O	
43B2	Tromsø harbour area	Cod	↑/↑	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	
45B2	Hammerfest harbour area	Cod	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪																		
10B	Kjøfjord, Outer Varangerfjord	Cod	↓/O	↓/O	O/O	↓/O	↓/O	O/O	O/O	O/O	O/O	O/O	▪/▪		↓/O	↓/O	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪									▪/▪			
30B	Inner Oslofjord	Cod	↑/O												▪/▪	▪/▪	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪				
71G	Fugløyskjær, Outer Langesundfjord	Common periwinkle											O/O	▪/▪																			▪/▪
36G	Færder, Outer Oslofjord	Dog whelk											↓/↓	▪/▪																			↓/↓
76G	Risøya, Risør	Dog whelk											↓/↓	▪/▪																			↓/O
131G	Lastad, Søgne	Dog whelk											↓/↓	▪/▪																			↓/O
15G	Gåsøya-Ullerøya, Farsund	Dog whelk											↓/↓	▪/▪																			↓/O
227G2	Melandsholmen, Mid Karmsundet	Dog whelk																															
22G	Espevær, Outer Bømlafjord	Dog whelk											↓/↓	▪/▪																			↓/↓
98G	Svolvær airport area	Dog whelk											↓/↓	▪/▪																			↓/↓
11G	Brashavn, Outer Varangerfjord	Dog whelk											★/★	▪/▪																			O/O

3.2 Levels and trends in contaminants

3.2.1 Mercury (Hg)

Mercury (Hg) is found naturally in the earth's crust and is liberated to the environment by industrial processes. In gas form, the toxic substance can be transported over long distances and end up in the environment in completely different parts of the globe than where it is released. Hg can be organic, inorganic or elemental and has toxic effects on the nerve system. Hg was analysed in blue mussel at 34 stations and in cod fillet at 16 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

EU has provided EQS of 0.02 mg/kg w.w. in biota (cf. ***Table 6***). Applying this EQS for blue mussel, concentrations of Hg were above or at the EQS at Akershuskaia (st. I301, 0.02 mg/kg w.w.) in the Inner Oslofjord and at Bjørkøya (st. 71A, 0.029 mg/kg w.w.) in the Grenlandfjord-area. Concentrations of Hg above or at the EQS was also observed at Odderøya (st. I133, 0.021 mg/kg w.w.) in the Kristiansandfjord. This was also the case at Byrkjenes (st. 51A, 0.039 mg/kg w.w.), Eitrheimsneset (st. 52A, 0.034 mg/kg w.w.), Kvalnes (st. 56A, 0.041 mg/kg w.w.), Krossanes (st. 57A, 0.028 mg/kg w.w.) and Utne (st. 64A, 0.02 mg/kg w.w.) in the Sørfjord, and in the Hardangerfjord at Ranaskjer (st. 63A, 0.022 mg/kg w.w.) and Vikingneset (st. 65A, 0.024 mg/kg w.w.).

The EQS for biota is provided for fish and are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in certain tissues of fish. We have in 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 2016-samples (except for the Varangerfjord st. 10B where the concentration was 0.018 mg/kg w.w., see ***Table 10***).

Levels exceeding PROREF

Blue mussel exceeded provisional high reference concentration (PROREF) by a factor between two and five times at Bjørkøya in the Langesundfjord (st. 71A) and in the Sørfjord at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A). The exceedances were a factor of up to two in the Oslofjord at Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Ramtonholmen (st. I307), Håøya (st. I306), Mølen (st. 35A), Kirkøy (st. I024) and Singlekalven (st. I023). This was also the result at Sylterøya (st. I714) in the Langesundfjord and at Odderøya (st. I133) in the Kristiansandfjord. This was also the case at the western part of Norway at Utne (st. 64A), 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), and in the northern part at Mjelle in the Bodø area (st. 97A2).

Except for in Hammerfest (st. 45B2) and in Kjøfjord, Outer Varangerfjord (st. 10B), Hg in cod fillet exceeded the PROREF at all stations (***Table 11***). Cod fillet exceeded PROREF by a factor between five and 10 times in the Inner Oslofjord (st. 30B). The exceedances were a factor between two and five at Tjøme (st. 36B), Kirkøy at Hvaler (st. 02B), Stathelle area in the Grenlandfjord (st. 71B), Kristiansand harbour area (st. 13B), Skågskjera in Farsund (st. 15B), the Inner Sørfjord (st. 53B), Bømlo (st. 23B), Bergen harbour (st. 24B), Ålesund (st. 28B) and Austnesfjord in Lofoten (st. 98B1).

The exceedances a factor up to two at the areas of Trondheim harbour (st. 80B), Sandnessjøen (st. 96B) and Tromsø harbour (st. 43B2).

Increase in PROREF factor since 2015

Cod fillet from the Inner Oslofjord (st. 30B) in 2016 exceeded the PROREF by a factor between five to 10 and between two to five in 2015. The median concentration of Hg in the Inner Oslofjord (st. 30B) had increased from 0.227 mg/kg w.w. in 2015 to 0.3640 mg/kg w.w. in 2016.

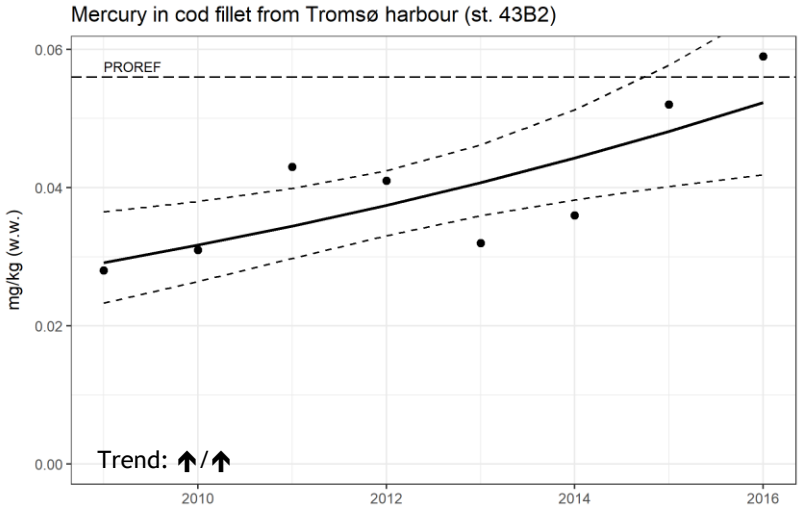
Blue mussel at Bjørkøya (st. 71A) exceeded provisional high reference concentration PROREF by a factor between five and 10 in 2016 and between two to five in 2015.

Upward trends

In the Inner Oslofjord a significant upward long-term trend was found in mussels from Akershuskaia (st. I301). Significant upward short-term trends were found at Gåsøya (st. I304), Ramtonholmen (st. I307) and Håøya (st. I306) in the Inner Oslofjord.

Both significant upward long- and short-term trends were found in cod fillet from Tromsø harbour (st. 43B2, ***Figure 7a***). Cod fillet from the Inner Oslofjord (st. 30B) showed significant upward long-term trends (***Table 11***, ***Figure 8***) in 2016 and 2015 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 also showed a significant upward long-term trend, whereas no trend was detected in cod fillet from Tromsø harbour when fish-length was taken into account (***Figure 7b***, see also section 3.5). A significant upward short-term trend was found at Tjøme (st. 36B) in the Outer Oslofjord and Skågskjera in Farsund (st. 15B) in both 2016 and 2015.

A



B

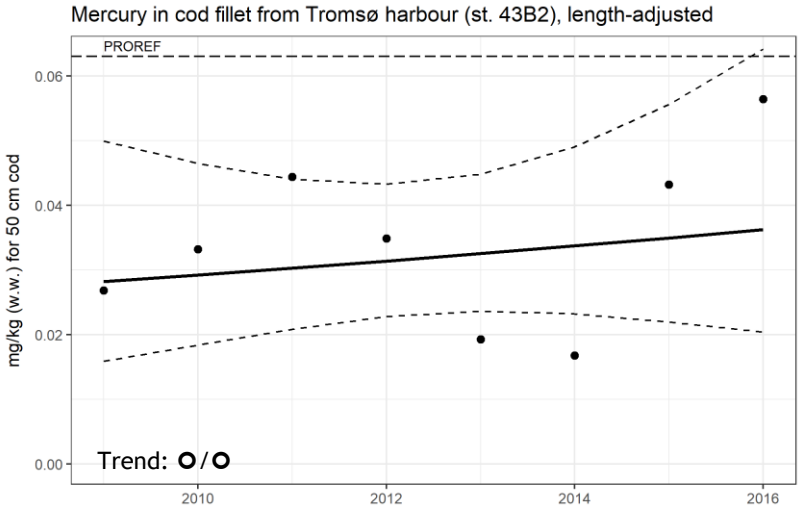
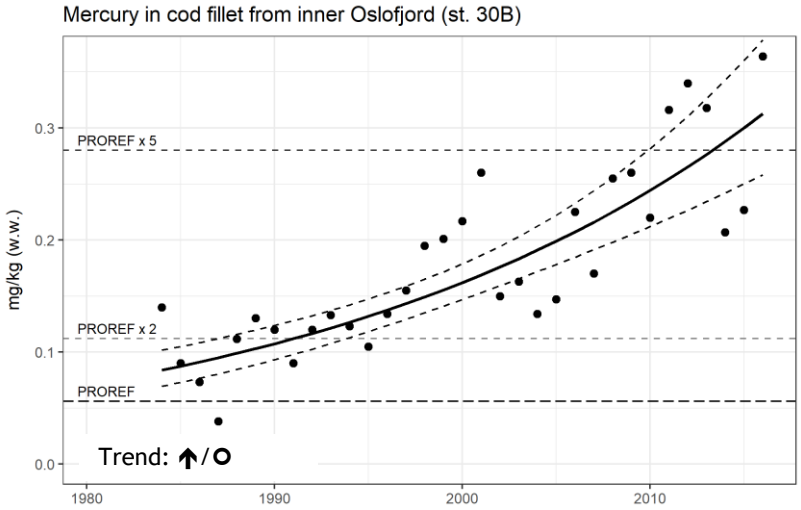


Figure 7. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from 2009 to 2016 in the Tromsø harbour (st. 43B2); no adjustment for length (***A***) and adjusted for length (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

A



B

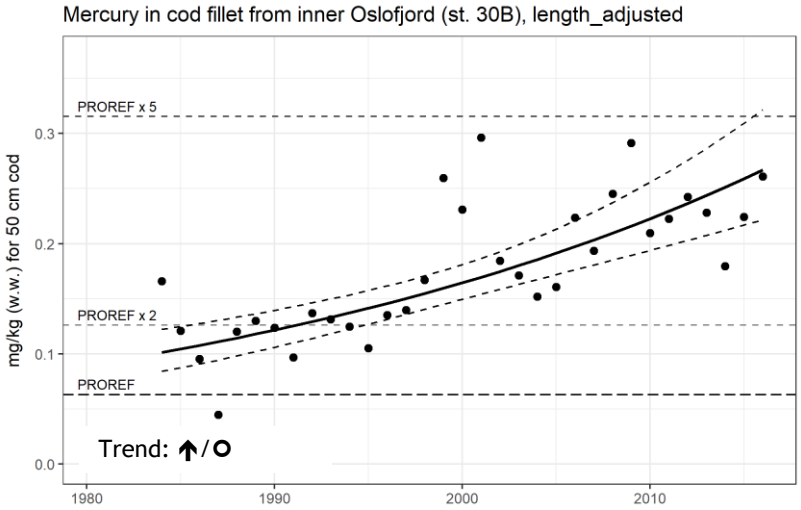


Figure 8. *Median concentrations (mg/kg w.w.) of mercury (Hg) in cod fillet from 1984 to 2016 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

Decrease in PROREF factor since 2015

Cod fillet from Ålesund (st. 28B) exceeded PROREF by a factor between two and five in 2016 and between five to 10 in 2015.

Blue mussel at Byrkjenes (st. 51A) exceeded PROREF by a factor between two and five in 2016 and between five to 10 in 2015. The exceedances at Kirkøy at Hvaler (st. I024), Sylterøya in the Langesundfjord (st. I714) and Ranaskjer (st. 63A) in the Hardangerfjord, exceeded PROREF by a factor of up to two in 2016 and between two to five in 2015.

Downward trends

In blue mussel, both significant downward long- and short-term trends were found at Solbergstrand (st. 31A) in the Mid Oslofjord. Significant downward long-term trends were found at Færder (st. 36A) in the Oslofjord and Bjørkøya (st. 71A) in the Langesundfjord. This was also observed in Sørfjorden at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A), Kvalnes (st. 56A) and Krossanes (st. 57A), and in the Hardangerfjord at Ranaskjer (st. 63A). The same result was seen at Svolvær airport (st. 98A2), in Moholmen (st. I965) in the Ranfjord, and in the Varangerfjord at Skallnes (st. 10A2). A significant downward short-term trend was found at Terøya (st. 69A) in the Outer Hardangerfjord.

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

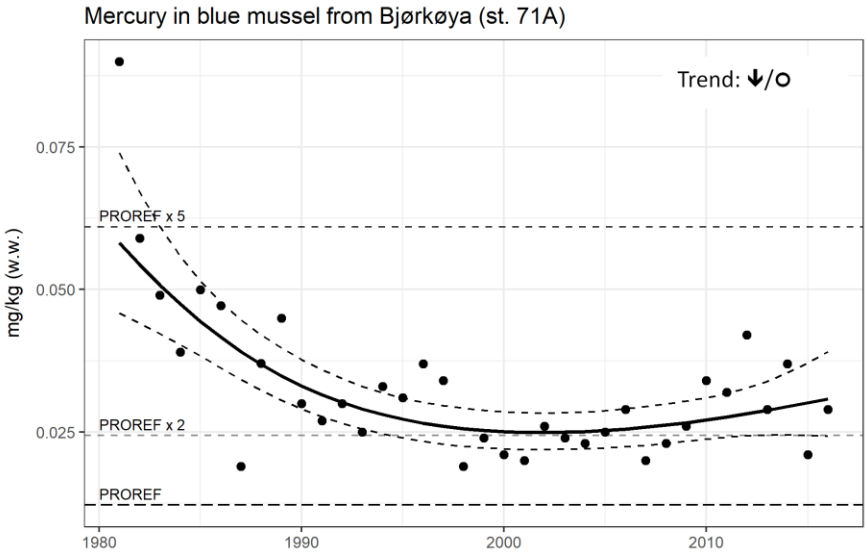


Figure 9. *Median concentrations (mg/kg w.w.) of mercury (Hg) in blue mussel from 1981 to 2015 at Bjørkøya (st. 71A) in the Grenlandfjord area. The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

Other studies

Another recent survey actuated due to operational monitoring in compliance with the EU Water Framework Directive showed that blue mussel from Langøya in the Holmestrandfjord in 2016 exceeded EQS for Hg at five of six stations (Gitmark *et al.* 2017). Blue mussel at Mølen (st. 35 A) was below EQS.

In the Ranfjord, blue mussel had concentrations below EQS for Hg at Toraneskaia, Bjørnbærviken and Moholmen in the Ranfjord in 2016 (Øxnevad *et al.* 2017).

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. 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, one downward long-term trend was found in cod fillet from the Varangerfjord, while two upward long-term trends were found in cod fillet from the Inner Oslofjord and Tromsø harbour.

Total riverine input of Hg in Norway has been 178 kg in 2015 (Skarbøvik *et al*. 2016 – M-634|2016). The riverine inputs of Hg to different seawater were 71 kg to Skagerrak, 45 kg to the North Sea, 41 kg to the Norwegian Sea and 21 kg to the Barents Sea, indicating higher input in the southern part of Norway. Total Hg load dropped 42 % to 178 kg in 2015 compared to the mean for the period 1990-2014 (308 kg). In addition to riverine inputs was the contribution by direct discharges from sewage (6 kg) and industrial (15 kg) effluents amounting to 21 kg or about 11 % of the total (199 kg).

When considering the total of 55 possible recent short-term (2007-2016) trends for both cod and blue mussel, significant trends are limited to upwards at 5 stations and downwards at 1 station (***Table 11***, ***Figure 10***).

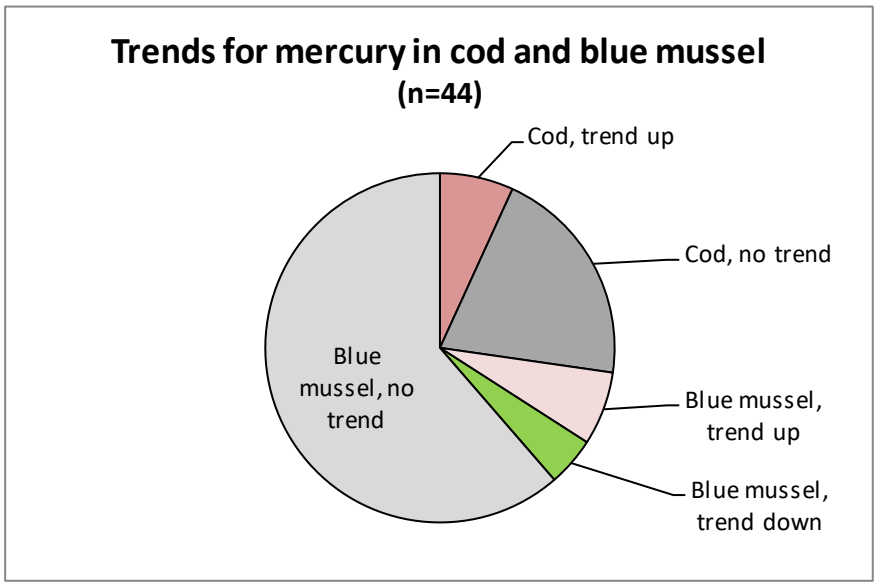


Figure 10. *Frequency of short-term (recent) trends (2007-2016) for Hg in cod fillet and blue mussel.*

In the present study, there were upward long-term trends in blue mussel at Akershuskaia and cod fillet from the Inner Oslofjord. Furthermore, upward short-term trends in blue mussel at Gåsøya, Ramtonholmen and Håøya, and cod fillet from Tjøme in the Oslofjord were registered as well as a short-term trend in cod fillet from Skågskjera in Farsund. 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 is the only contaminant, 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.

Ruus *et al.* (2017) showed that most of the upward trends in Hg-concentrations in cod fillet from the Inner Oslofjord could be attributed to the sampling of larger fish. 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 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 is 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). The riverine input to the Inner Oslofjord from Alna river was 0.06 kg Hg in 2015 (Skarbøvik *et al.* 2016 – M-634|2016). VEAS sewage treatment plant reported a discharge of 0.33 kg Hg in 2016 to the Inner Oslofjord (VEAS 2017).

Emissions of Hg to air from land-based industries showed essentially a decrease from 2002 (257 kg Hg/year) to 2009 (104 kg Hg/year), and the emission was 116 kg Hg/year in 2016 (***Figure 11***). The emissions to air varied between 260 kg Hg/year in 2004 to 86 kg Hg/year in 2015 for the period 2002-2016.

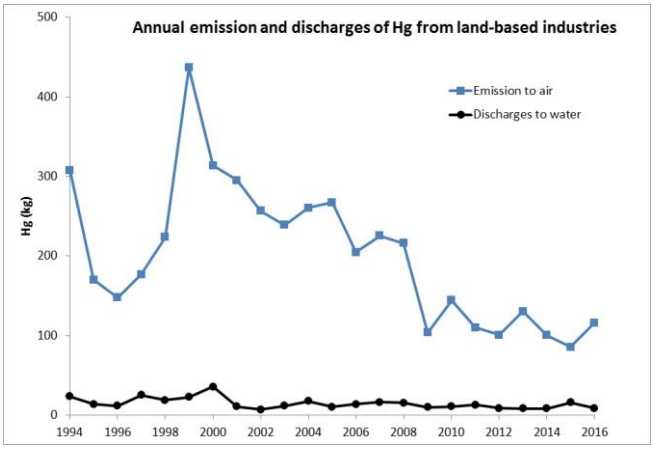


Figure 11. *Annual emissions of Hg to air and discharges to water from land-based industries for the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

Other studies
Cod fillet samples from the 2016 MILKYS programme from Inner Oslofjord had higher concentration (median 0.364 mg/kg Hg w.w.) as in a comparable study in the Inner Oslofjord in 2016 (mean 0.225 mg/kg Hg w.w.) (Ruus *et al*. 2017 – M-812|2017, in press).

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*. 2016 – M-548|2016). 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).

Garmo *et al*. (2017) found that the Hg-level 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.

Fifty years of measurements show that freshwater fish has less Hg 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).

3.2.2 Cadmium (Cd)
Cadmium (Cd) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF
Blue mussel at Eitrheimsneset (st. 52A) in the Inner Sørfjord exceeded the PROREF by a factor between two and five (***Table 11***). Blue mussel at nine other stations exceeded the PROREF by a factor of up to two. These blue mussel stations were located in the Oslofjord at Akershuskaia (st. I301), Gåsøya (st. I304), Ramtonholmen (st. I307), Håøya (st. I306) and Mølen (st. 35A). A similar exceedance was also observed at Odderøya (st. I133) in the Kristiansandfjord, Krossanes (st. 57A) in the Outer Sørfjord, and in the Varangerfjord at Skallnes (st. 10A2) and Brashavn (st. 11X).

Cod liver at Tromsø harbour area (st. 43B2) exceeded the PROREF by a factor between two and five, while the exceedance was up to two at Hammerfest harbour area (st. 45B2).

Increase in PROREF factor since 2015
Blue mussel at Håøya (st. I306) in the Oslofjord at Odderøya (st. I133) in the Kristiansandfjord, were both below PROREF in 2015, but exceeded this limit by a factor of up to two in 2016.

Cod liver from Tromsø harbour (st. 43B2) exceeded PROREF by a factor of up to two in 2015 and between two to five in 2016.

Upward trends
There were both significant upward long-term and short-term trends in blue mussel at Gåsøya (st. I304) in the Inner Oslofjord. A long-term upward trend in blue mussel at Ramtonholmen (st. I307) and a short-term upward trend at Håøya (st. I306) were also observed in the Inner Oslofjord (***Table 11***).

Downward trends

In blue mussel, there were both significant downward long- and short-term trends at Solbergstrand (st. 31A) in the Inner Oslofjord, in 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 Moholmen (st. I965) in the Ranfjord. There were 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 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 in the Langesundfjord (st. 71B), and long-term trends at Tjøme (st. 36B), and in Kjøfjord in the Varangerfjord (st. 10B). A significant downward short-term trend was found in the Inner Sørfjord.

Other studies

Cod liver samples from the 2016 MILKYS programme from the Inner Oslofjord had lower concentration (median 0.03 mg/kg Cd w.w.) than in a comparable study in the Inner Oslofjord in 2016 (mean 0.102 mg/kg Cd w.w.) (Ruus *et al*. 2017 – M-812|2017, in press). 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 2016 (228 kg Cd/year) (***Figure 12***). The emission of Cd to air showed a gradually decrease from 1999 (560 kg Cd/year) to 2016 (60 kg Cd/year).

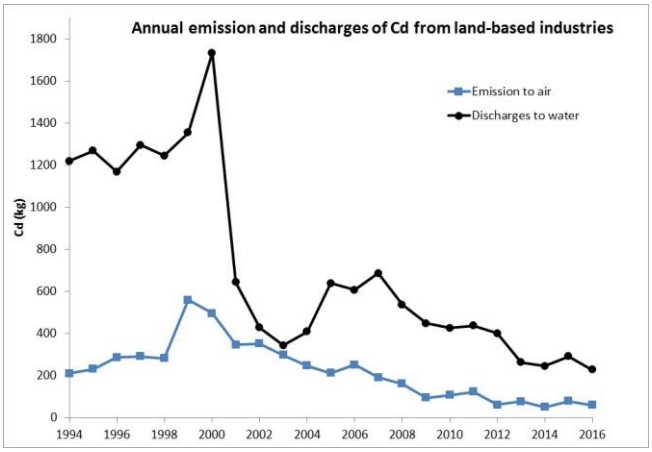


Figure 12. *Annual emissions of Cd to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 increased from 31.2 kg/year in 2014 to 46.8 kg/year in 2015, and then decreased to 28.19 kg/year in 2016 (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 in both 2015 and 2016.

Total riverine input of Cd in Norway has been estimated to be 2.17 tonnes in 2015 (Skarbøvik *et al*. 2016 – M-634|2016). While the total riverine inputs of Cd in different seawaters were 1.1 tonnes to Skagerrak, 0.61 tonnes to the North Sea, 0.2 tonnes to the Norwegian Sea and 0.3 tonnes to the Barents Sea, indicating higher input in the southern part of Norway. Total Cd load dropped 41 % to 2.2 tonnes in 2015 compared to the mean for the period 1990-2014 (3.7 tonnes). In addition to riverine inputs, direct discharges from sewage (0.02 tonnes) and industrial (0.11) effluents contribute, amounting to 0.13 tonnes or about 6.5 % of the total (2 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.005 tonnes Cd in 2015. VEAS sewage treatment plant reported a discharge of 5.0 kg Cd to the Inner Oslofjord in 2016 (VEAS 2017).

3.2.3 Lead (Pb)

Lead (Pb) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at Eitrheimsneset (st. 52A) exceeded PROREF for Pb by a factor between 10 to 20. The exceedance was by a factor between five and 10 at Odderøya (st. I133), and between two and five times at Gressholmen (st. 30A) in the Inner Oslofjord, Krossanes (st. 57A) in the Outer Sørfjord, Nordnes (st. I241) in the Bergen harbour area and Moholmen (st. I965) in the Ranfjord. Blue mussel exceeded PROREF by a factor of up to two at nine stations (***Table 11***). These stations were Akershuskaia (st. I301), Gåsøya (st. I304) and Ramtonholmen (st. I307) in the Inner 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) and Ranaskjer (st. 63A) in Hardanger, and at Mjelle in Bodø area (st. 97A2).

Cod liver from the Inner Sørfjord (st. 53B) exceeded PROREF of Pb by a factor of up to two (***Table 11***).

Increase in PROREF factor since 2015

Blue mussel at Eitrheimsneset (st. 52A) exceeded PROREF in 2016 by a factor of between 10 and 20 in 2016, and between five and 10 in 2015.

Upward trends

There were both significant upward long- and short-term trends in blue mussel from Ramtonholmen (st. I307), and a significant upward long-term trend at Gressholmen (st. 30A).

There were both significant upward long- and short-term trends in cod liver at Tromsø harbour (st. 43B2). There were significant upward short-term trends in cod liver from Tjøme (st. 36B), Skågskjera in Farsund (st. 15B), Bømlo (st. 23B) and Tromsø harbour (st. 43B2).

Downward trends

Of the trend analysis performed for blue mussel, fifteen revealed significant downward long-term trends (***Table 11***). 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 and at Espevær (st. 22A) on the west coast. Similar trends were also observed at and Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Ranfjord, and at Skallnes (st. 10A2) in the Varangerfjord. Significant downward long-term trends were found at Akershuskaia (st. I301), Solbergstrand (st. 31A) and Mølen (st. 35A) 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.

In cod liver, significant downward long-term trends were found in the Inner Oslofjord (st. 30B), Tjøme (st. 36B), Skågskjera in Farsund (st. 15B), Inner Sørfjord (st. 53B) and Bømlo (st. 23B).

Other studies

Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord showed concentration (median 0.033 mg/kg Pb w.w.) almost at the same level as observed in a comparable study (mean 0.065 mg/kg Pb w.w.) in the Inner Oslofjord in 2016 (Ruus et *al*. 2017 – M-812|2017, in press). The collection of cod in both studies took place during the autumn.

General, large scale trends

There were low levels of Pb in cod liver even in the vicinity of highly populated areas such as Oslo. 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 44.3 tonnes in 2015 (Skarbøvik *et al*. 2016 – M-634|2016), the riverine inputs of Pb in different areas were 24.7 tonnes to Skagerrak, 12.3 tonnes to the North Sea, 3.1 tonnes to the Norwegian Sea and 4.3 tonnes to the Barents Sea, indicating higher input in the southern part of Norway. Total Pb load dropped 15 % to 44 tonnes in 2015 compared to the mean for the period 1990-2014 (52 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (0.3 tonnes) and industrial (1.1 tonnes) effluents amounting to 1.4 tonnes or about 3 % of the total (46 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.120 tonnes Pb in 2015. VEAS sewage treatment plant reported a discharge of 49 kg Pb in 2015 (VEAS 2016).

Discharges of Pb to water from land-based industries in Norway showed a decrease from 2010 (6841 kg Pb/year) to 2016 (1015 kg Pb/year) (***Figure 13***).

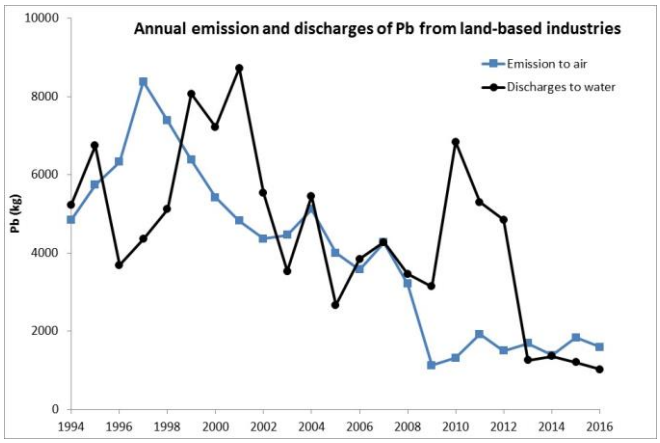


Figure 13. *Annual emissions of Pb to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.4 Copper (Cu)

Copper (Cu) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at Gressholmen (st. 30A) was the only station where the concentration exceeded the PROREF, but in this case, less than a factor of two.

Upward trends

In cod liver from Stahelle in the Langesundfjord (st. 71B), both significant upward long- and short-term trends were found. A significant upward short-term trend was found at Skågskjera in Farsund (st. 15B).

Downward trends

There were both significant downward short- and long-term trends in mussel from Ramtonholmen (st. I307) in the Inner Oslofjord, at Bjørkøya (st. 71A) in the Langesundfjord, and in Mjelle in the Bodø area (97A2). Significant downward long-term trends were observed at 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, at Ranaskjer (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord. At Espevær (st. 22A) on the west coast, a significant downward short-term trend was found.

Cod liver from Tjøme (st. 36B) in the Outer Oslofjord and Kjøfjord (st. 10B) in the Outer Varangerfjord had significant downward long-term trends.

Other studies

Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord had lower concentration (median 2.9 mg/kg Cu w.w.) than in a comparable study in the Inner Oslofjord in 2016 (mean 6.608 mg/kg Cu w.w.) (Ruus *et al*. 2017 – M-812|2017, in press). 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 2016 (31 293 kg Cu/year) (***Figure 14***).

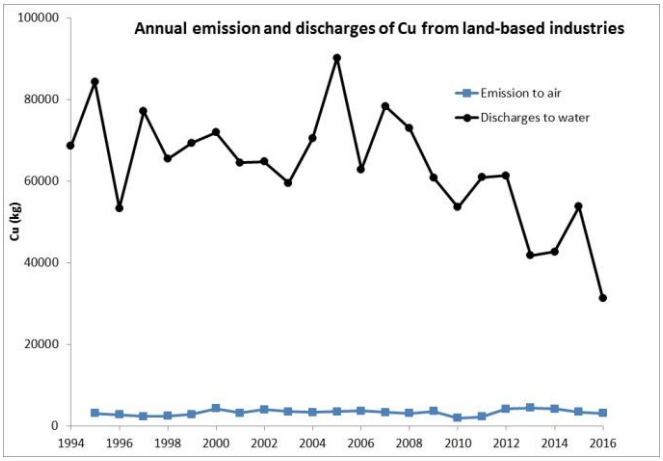


Figure 14. *Annual emissions of Cu to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 198 tonnes in 2015 (Skarbøvik *et al*. 2016 – M-634|2016). The total riverine inputs of Cu were 77 tonnes to Skagerrak, 27 tonnes to the North Sea, 30 tonnes to the Norwegian Sea and 64 tonnes to the Barents Sea. Total Cu load in Norway decreased 10 % to 198 tonnes in 2015 compared to the mean for the period 1990-2014 (221 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (4 tonnes) and industrial (5 tonnes) effluents and fish farming (978) amounting to 987 tonnes or about 83 % of the total (1185 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.288 kg Cu in 2015. VEAS sewage treatment plant reported a discharge of 552 kg Cu in 2016 (VEAS 2017).

3.2.5 Zinc (Zn)

Zinc (Zn) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel from seven stations exceeded PROREF, but by less than a factor of two. These stations were Gåsøya (st. I304) in the Inner Oslofjord, Odderøya (st. I133) in the Kristiansandfjord, Espevær (s. 22A) at the west coast, Nordnes (st. I241) in Bergen harbour area, Vågsvåg (st. 26A2) in the Outer Nordfjord, Moholmen (st. I965), in the Ranfjord and Skallnes (st. 10A2) in the Outer Varangerfjord.

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).

Downward trends

In blue mussel, both significant downward long- and short-term trends were found at Terøya (st. 69A) in the Outer Hardangerfjord. Downward long-term trends were found at Gressholmen (st. 30A), Ramtonholmen (st. I307) 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), and in the Hardangerfjord at Ranaskjer (st. 63A) and Vikingneset (st. 65A). A downward long-term trend was also observed at Espevær (st. 22A) on the west coast. A significant downward short-term trend was found at Bjørnbærviken (st. I969) in the Inner Ranfjord.

In cod liver, significant downward long-term trends were found at Tjøme (st. 36B) in the Outer Oslofjord and Kjøfjord (st. 10B) in the Outer Varangerfjord.

Other studies

Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord had lower concentration (median 12 mg/kg Zn w.w.) than in a comparable study in the Inner Oslofjord in 2016 (mean 22.943 mg/kg Zn w.w.) (Ruus *et al*. 2017 – M-812|2017, in press). 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 2016 (70 669 kg Zn/year) (***Figure 15***).

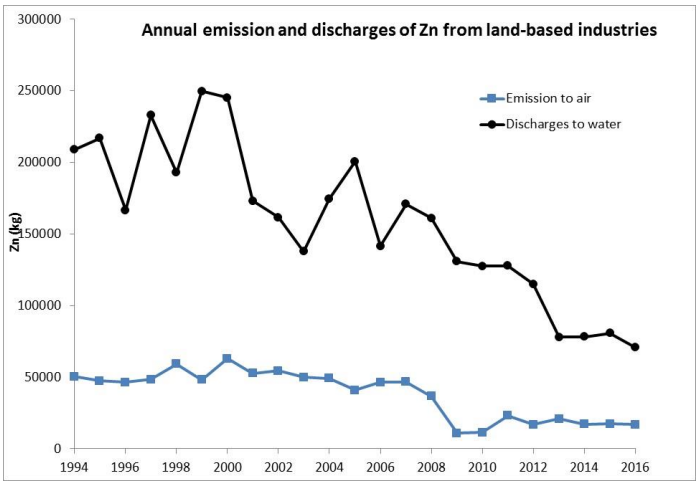


Figure 15. *Annual emissions of Zn to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 696 tonnes in 2015 (Skarbøvik *et al*. 2016 – M-634|2016). Total riverine inputs of Zn were 442 tonnes to Skagerrak, 150 tonnes to the North Sea, 71 tonnes to the Norwegian Sea and 33 tonnes to the Barents Sea, indicating higher input in the southern part of Norway. Total Zn load increased 5 % to 696 tonnes in 2015 compared to the mean for the period 1990-2014 (732 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (12 tonnes) and industrial (17 tonnes) effluents amounting to 29 tonnes or about 4 % of the total (725 tonnes). The riverine input to the Inner Oslofjord from Alna river was 1.186 kg Zn in 2015. VEAS sewage treatment plant reported a discharge of 1933 kg Zn in 2016 (VEAS 2017).

3.2.6 Silver (Ag)

Silver (Ag) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at four stations exceeded PROREF by a factor between two and five. These stations were located at Gressholmen (st. 30A) and Ramtonholmen (st. I307) in the Inner Oslofjord, at Bjørkøya (st. 71A) in the Langesundfjord and at Utne (st. 64A) in the Outer Sørfjord. Blue mussel exceeded PROREF by a factor of up to two at Akershuskaia (st. I301) and Færder (st. 36A) in the Oslofjord, at Eitrheimsneset (st. 52A) in the Inner Sørfjord, at Svolvær airport area (st. 98A2) in Lofoten, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF by a factor between two and five.

Increase in PROREF factor since 2015

The Ag-concentration in blue mussel had increased from being below the PROREF at Ramtonholmen (st. I307) in the Inner Oslofjord in 2015 (<0.004 mg/kg w.w.), to exceed the level by a factor between two to five in 2016 (0.024 mg/kg w.w.). The Ag-concentration in blue mussel had increased from exceeding the PROREF by a factor of up to two in 2015, to between two to five in

2016 at Gressholmen (st. 30A) in the Inner Oslofjord, at Bjørkøya (st. 71A) in the Langesundfjord, and at Utne (st. 64A) in the Outer Sørfjord.

Decrease in PROREF factor since 2015

The Ag-concentration in blue mussel had decreased from exceeding the PROREF by a factor between two to five in 2015, to less than two in 2016 at Eitrheimsneset (st. 52A) in the Sørfjord, and Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

The Ag-concentration in cod liver in the Inner Oslofjord (st. 30B) had decreased from exceeding the PROREF by a factor between five and 10 in 2015, to between two and five in 2016.

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 16a*** and ***b***, respectively). The unadjusted median concentration in 2016 was 0.915 mg Ag/kg.

Downward trends

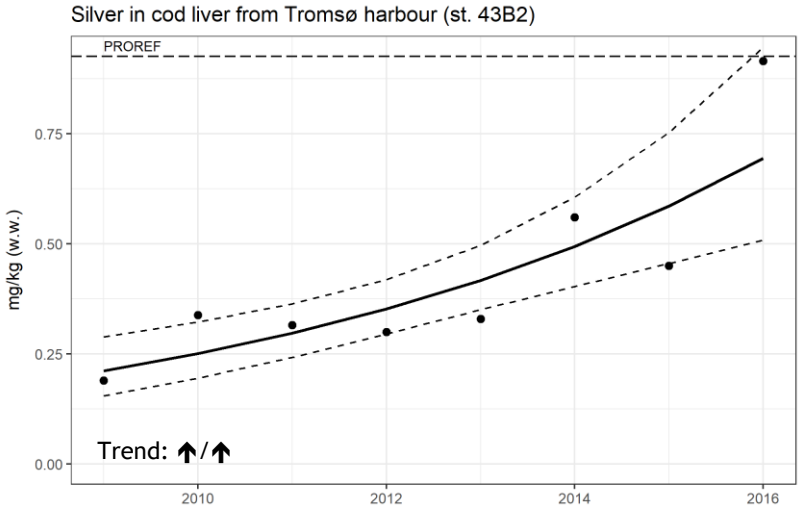
There were both significant downward long- and short-term trends in blue mussel from Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord.

Other studies

The highest Ag-concentrations in this study were found in cod liver from the Inner Oslofjord in 2016 (2.4 mg/kg w.w.), as in 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 2016 revealed a median concentration of 2.4 mg/kg Ag (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2016 showed higher mean concentration (4.067 mg/kg Ag w.w.) (Ruus *et al.* 2017 – M-812|2017, in press). Ag displayed statistically significant positive relationships between (log) concentrations and trophic position in the Inner Oslofjord in both 2015 and 2016 (Ruus *et al.* 2017 – M-812|2017, in press). The collection of cod in both studies took place during the autumn.

A



B

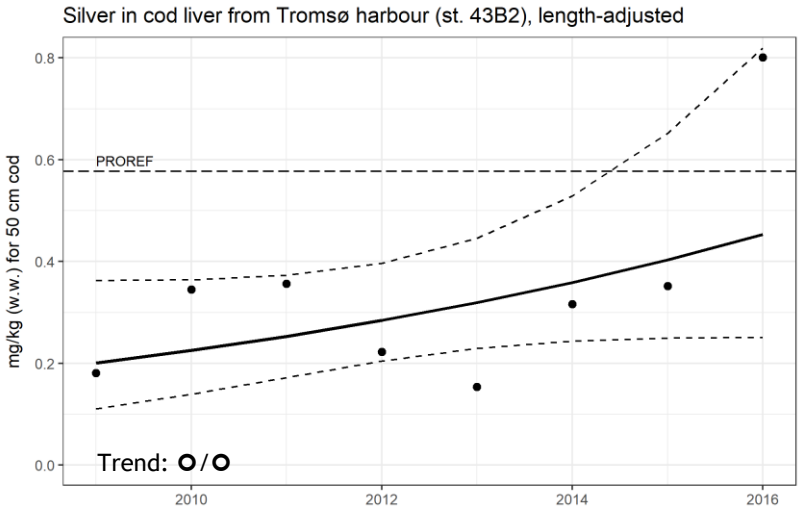


Figure 16. *Median concentrations (mg/kg w.w.) of silver (Ag) in cod liver from 2009 to 2016 in the Tromsø harbour (st. 43B2); no adjustment for length (***A***) and adjusted for length (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

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 17***). The discharges to water in 2016 were 0.44 kg Ag).

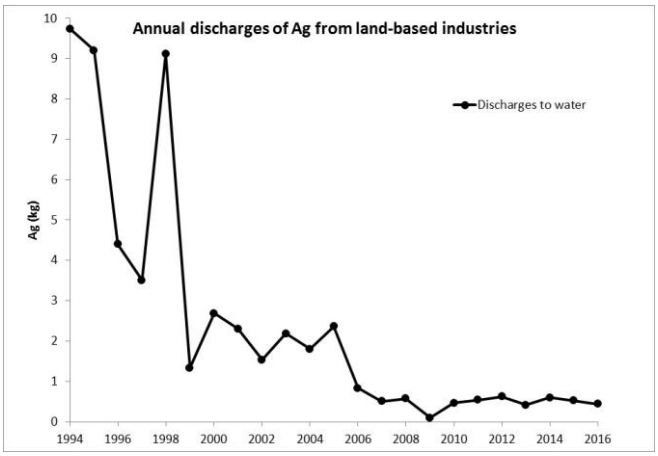


Figure 17. *Annual discharges of Ag to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

3.2.7 Arsenic (As)

Arsenic (As) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at Espevær (st. 22A) on the west coast exceeded PROREF by a factor of up to two.

Increase in PROREF factor since 2015

Blue mussel at Espevær (st. 22A) had As-concentration below the PROREF in 2015, but exceeded the limit by a factor of up to two in 2016.

Decrease in PROREF factor since 2015

Blue mussel at Utne (st. 64A) in the Outer Sørfjord and Vågsvåg (st. 26A2) in the Outer Nordfjord exceeded PROREF of As by a factor of up to two in 2015, while the As-concentration was below the PROREF in 2016.

Cod liver in the Inner Oslofjord exceeded the PROREF for As by a factor between two to five in 2015, while it was below the PROREF in 2016.

Downward trends

In blue mussel, both significant downward long- and short-term trends were observed in Gressholmen (st. 30A) in the Inner Oslofjord, at Bjørkøya (st. 71A) in the Langesundfjord, at Gåsøya-Ullerøya in Farsund (st.15A), at Svolvær airport area (st. 98A2) in Lofoten, and at Skallnes (st. 10A2) and Brashavn (st. 11X) in the Varangerfjord. There was a significant downward long-term trend in

blue mussel at Moholmen (st. I965) in the Ranfjord and short-term trend at Mølen (st. 35A) in the Mid Oslofjord.

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

Other studies

Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord revealed median concentration of 4.7 mg/kg As (w.w.) in 2016 while it was 27 mg/kg As (w.w.) in 2015. Cod liver from a comparable study in Inner Oslofjord in 2016 had higher mean concentration (21.749 mg/kg As w.w.) (Ruus *et al.* 2017 – M-812|2017, in press). As displayed statistically significant positive relationships between (log) concentrations and trophic position in the Inner Oslofjord in both 2015 and 2016 (Ruus *et al.* 2017 – M-812|2017, in press). The collection of cod in both studies took place during the autumn.

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 (2203 kg As/year) (***Figure 18***). Emission to air was 693 kg As/year in 2016.

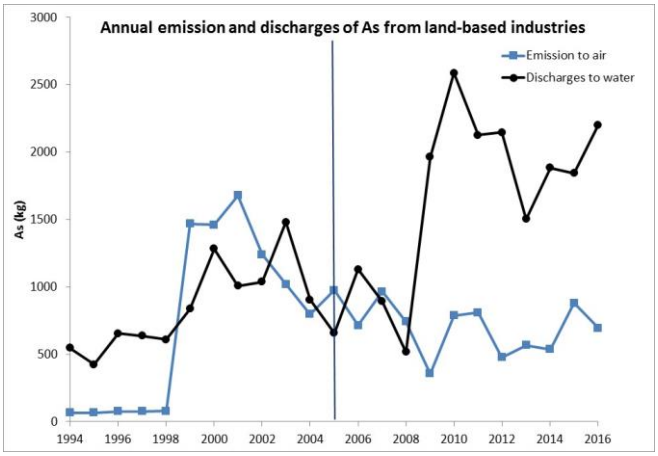


Figure 18. *Annual emissions of As to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). The vertical line at 2005 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, 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 35 tonnes in 2015 (Skarbøvik *et al.* 2016 – M-634|2016). Total riverine inputs of As were 13.8 tonnes to Skagerrak, 6.4 tonnes to the North Sea, 4.7 tonnes to the Norwegian Sea and 5.4 tonnes to the Barents Sea, indicating higher input in the southern part of Norway. Total As load increased 11 % to 30 tonnes in 2015 compared to the mean for the period 1990-2014 (27 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (0.2 tonnes) and industrial (4.8 tonnes) effluents amounting to 5 tonnes or about 14 % of the total (35 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.025 kg As in 2015. VEAS sewage treatment plant reported a discharge of 45 kg As in 2016 (VEAS 2017).

3.2.8 Nickel (Ni)

Nickel (Ni) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at Kirkøy at Hvaler (st. I204) and at Odderøya in the Kristiansand harbour (st. I133) exceeded the PROREF by a factor between two and five. Blue mussel at nine other stations exceeded this level by a factor of up to two. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304) and Solbergstrand (st. 31A) in the Inner Oslofjord, Risøya at Risør (st. 76A2), Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Inner Ranfjord, and Skallnes (st. 10A2) and Brashavn (st. 11X) in the Outer Varangerfjord.

Cod liver at Bømlo (st. 23B) exceeded the PROREF by a factor of more than 20, while cod liver at Bergen harbour area (st. 24B) exceeded the limit by a factor between 10 and 20. At the Inner Sørfjord (st. 53B), the exceedance was by a factor between five to 10. At Austnesfjord in Lofoten (st. 98B1), the exceedance was by a factor of up to two. The high concentrations of both Ni and Cr at these four stations may indicate contamination during sample preparation.

Increase in PROREF factor since 2015

Blue mussel at Kirkøy at Hvaler (st. I024) exceeded the PROREF by a factor of up to two in 2015, and between two and five in 2016. Mussel had Ni-concentrations below the PROREF in 2015 while it exceeded this limit bay a factor of up to two at five stations. This was at Akershuskaia (s. I301), Gåsøya (st. I304) and Solbergstrand (s. 31A) in the Inner Oslofjord, at Risøya in Risør (st. 76A2) and at Bjørnbærviken (st. I969) in the Ranfjord.

Ni-concentrations in cod liver from four stations exceeded PROREF in 2016, while the levels were below this limit in 2015. In 2016, these exceedances were a factor over 20 times at Bømlo (st. 23B) between 10 and 20 in Bergen harbour (st. 24B), between five to 10 times in the Inner Sørfjord (st. 53B), and up to two times at the Austnesfjord in Lofoten (st. 98B1).

Decrease in PROREF factor since 2015

Blue mussel at Singlekalven (st. I023) exceeded the PROREF by a factor between two and five in 2015, while the Ni-concentration was below this limit in 2016.

Upward trends

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

Downward trends

Both significant downward long- and short-term trends were found in blue mussel at Moholmen (st. I965) in the Inner Ranfjord and at Mjelle in the Bodø area (st. 97A2).

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

Other studies

Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord revealed a median concentration of 0.054 mg/kg Ni (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2016 showed almost the same mean concentration (0.085 mg/kg Ni w.w.)
(Ruus *et al*. 2017 – M-812|2017, in press). 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 2016 (6 004 kg Ni/year) (***Figure 19***).

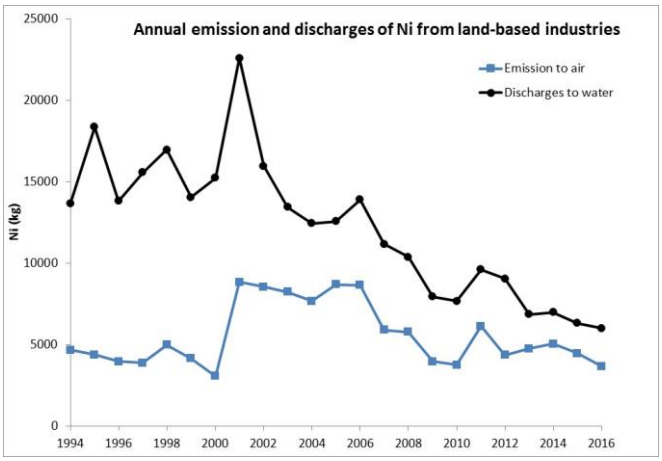


Figure 19. *Annual emissions of Ni to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 192 tonnes in 2015 (Skarbøvik *et al.* 2016 – M-634|2016). Total riverine inputs of Ni were 41 tonnes to Skagerrak, 19 tonnes to the North Sea, 25 tonnes to the Norwegian Sea and 106 tonnes to the Barents Sea. Total Ni load increased 37 % to 191 tonnes in 2015 compared to the mean for the period 1990-2014 (139 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 4 % of the total (200 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.070 tonnes Ni in 2015. VEAS sewage treatment plant reported a discharge of 236 kg Ni in 2016 (VEAS 2017).

3.2.9 Chromium (Cr)

Chromium (Cr) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at Moholmen (st. I965) in the Inner Ranfjord exceeded the PROREF by a factor between two and five. Blue mussel at five stations exceeded the PROREF by a factor of up to two. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, Kirkøy at Hvaler (st. I024) and Ørland area in the Outer Trondheimfjord (st. 91A2).

Cod liver at Bømlo (st. 23B) and Bergen harbour (st. 24B) exceeded the PROREF by a factor over 20, while cod liver from the Inner Sørfjord (st. 53B) exceeded the limit by a factor between 10 and 20. At the Austnesfjord in Lofoten (st. 98B1), the exceedance was by a factor between two and five. The high concentrations of both Ni and Cr at these four stations may indicate contamination during sample preparation.

Increase in PROREF factor since 2015
Blue mussel at Moholmen (st. I965) had Cr-concentrations below the PROREF in 2015, while it exceeded this limit by a factor between two and five in 2016. Mussels were below the PROREF in 2015, while it exceeded this limit by a factor of up to two in 2016 at the four stations Akershuskaia (st. I301) and Gåsøya (st. I304) in the Inner Oslofjord, Kirkøy at Hvaler (st. I024) and at Ørland area in the Outer Trondheimfjord (st. 91A2).

Cr-concentrations in cod liver from four stations exceeded PROREF in 2016, while the levels were below this limit in 2015. In 2016, these exceedances were a factor over 20 times at Bømlo (st. 23) and in Bergen harbour (st. 24B), between 10 to 20 times in the Inner Sørfjord (st. 53B), and between two to five times at the Austnesfjord in Lofoten (st. 98B1).

Decrease in PROREF factor since 2015
Mussels at Singlekalven (st. I023) and Odderøya (st. I133) exceeded PROREF for Cr by a factor between two to five in 2015, while the concentrations were below this limit in 2016.

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.

Downward trends
In blue mussel, both significant downward long- and short-term trends were found at Lastad in Søgne (st. I131A).

Both significant downward long- and short-term trends were found in cod liver in the Inner Oslofjord (st. 30B), at Kristiansand harbour (st. 13B), and at Kjøfjord in the Outer Varangerfjord (st. 10B).

Other studies
Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord revealed a median concentration of 0.035 mg/kg Cr (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2016 had almost the same mean concentration (0.038 mg/kg Cr w.w.)
(Ruus et *al*. 2017 – M-812|2017, in press). 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 20***.

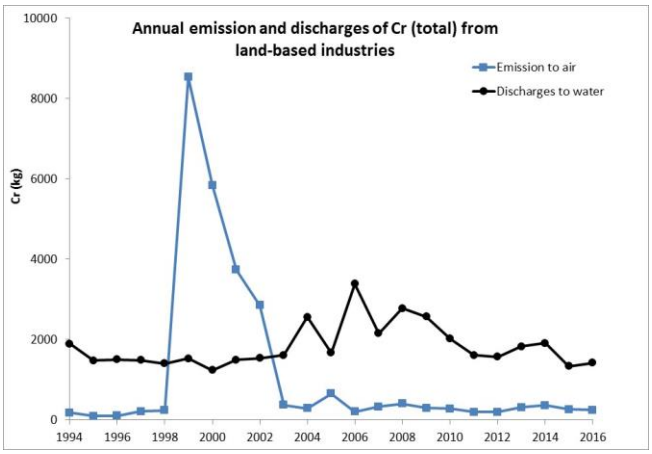


Figure 20. *Annual emissions of Cr to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted 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 52.5 tonnes in 2015 (Skarbøvik *et al.* 2016 – M-634|2016). The ranges of total riverine inputs of Cr were 15.2 tonnes to Skagerrak, 5.7 tonnes to the North Sea, 21.19 tonnes to the Norwegian Sea and 10.40 tonnes to the Barents Sea. Total Cr load dropped 44 % to 52 tonnes in 2015 compared to the mean for the period 1990-2014 (92 tonnes). In addition to riverine inputs, comes the contribution by direct discharges from sewage (0.6 tonnes) and industrial (1.3 tonnes) effluents amounting to 1.9 tonnes or about 4 % of the total (54 tonnes). The riverine input to the Inner Oslofjord from Alna river was 0.042 tonnes Cr in 2015. VEAS sewage treatment plant reported a discharge of 52 kg Cr in 2016 (VEAS 2017).

3.2.10 Cobalt (Co)

Cobalt (Co) was analysed in blue mussel at 32 stations and in cod liver at 16 stations.

Levels exceeding PROREF

Blue mussel at Odderøya (st. I133) exceeded the PROREF for Co by a factor between two to five. Mussel at 10 stations exceeded the PROREF by a factor of up to two. These stations were Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Ramtonholmen (st. I307), Færder (st. 36A) and Kirkøy (st. I024) in the Oslofjord. This was also the case at Ørland area (st. 91A2) in the Outer Trondheimfjord, at Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Inner Ranfjord, and at Skallnes (st. 10A2) in the Outer Varangerfjord.

Cod liver exceeded PROREF by a factor between five and ten at Bømlo (st. 23B), between two to five at Bergen harbour (st. 24B), and up to two in the Inner Sørfjord (st. 53B).

Increase in PROREF factor since 2015

Blue mussel at Odderøy (st. I133) exceeded PROREF by a factor between two and five in 2016, while the exceedance was less than a factor of two in 2015. Mussels at Skallnes (st. 10A2) had Co-concentrations below PROREF in 2015, but exceeded this limit by a factor of up to two in 2016.

Cod liver was below PROREF for Co in 2015, while the concentrations exceeded by a factor between five to 10 at Bømlo (st. 23B) and between two to five at Bergen harbour (st. 24B).

Decrease in PROREF factor since 2015

Blue mussel at Mølen (st. 35A) in the Mid Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord, and Krossanes (st. 57A) and Utne (st. 64A) in the Sørfjord had Co-concentrations below PROREF, but exceeded this limit by a factor of up to two in 2015.

Upward trends

Both significant upward long- and short-term trends were observed in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord, and at Bjørnbærviken (st. I969) in the Ranfjord. A significant short-term trend was found at Mølen (st. 35A).

Cod liver was below PROREF for Co in 2016, while the exceedance was by a factor of up to two at the Inner Oslofjord (st. 30B) and Tjøme (st. 36B) in 2015.

Downward trends

Both significant downward long- and short-term trends were observed in blue mussel at Lastad in Søgne (st. I131A), and Ranaskjer (st. 63A) and Vikingneset (st. 65A) in the Hardangerfjord.

General, large scale trends

Discharges of Co to water from land-based industries showed increasing values from 2013 (412 kg Co/year) to 2016 (510 kg Co/year), even though the highest concentration was in 2011 (754 kg Co/year) (***Figure 21***).

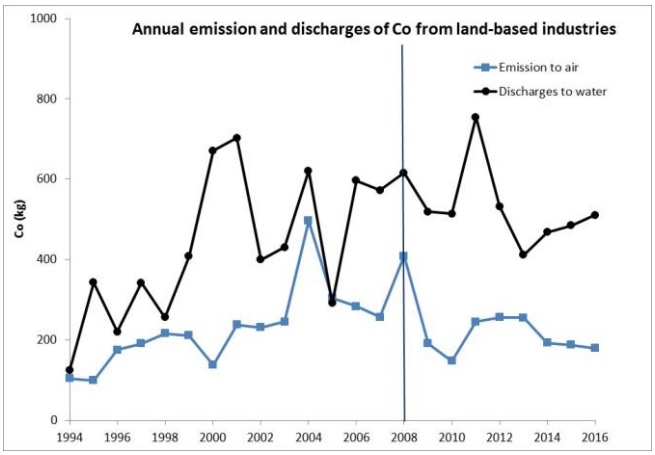


Figure 21. *Annual emissions of Co to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). The vertical grey line at 2008 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, 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.*

3.2.11 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. TBT was analysed in blue mussel at seven stations, dog whelk at eight stations and common periwinkle at one station. Imposex (VDSI) was investigated in dog whelk at all eight stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

When applying the EQS for TBT (150 µg/kg w.w.) in biota ("for fish") on blue mussel, dog whelk and periwinkle, all TBT-concentrations were below EQS in 2016 (***Table 10***), as in 2015.

Environmental Quality Standards (EQS) for Water region specific substances

When applying the EQS for triphenyltin (TPTIN) (152 µg/kg w.w.) in biota on blue mussel (<2.4 µg/kg w.w.), dog whelk (<0.3 µg/kg w.w.) and periwinkle (<0.3 µg/kg w.w.), all TPTIN-concentrations were below EQS in 2016 (***Table 10***).

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 between two and five.

Decrease in PROREF factor since 2015

Blue mussel at Gåsøya (st. I304) had TBT-concentration below PROREF in 2016, but exceeded this limit (by a factor of up to two) in 2015.

Downward trends

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

Dogwhelk

Levels of TBT

The TBT-levels in dog whelk at all eight stations were low (<0.3 µg/kg w.w.).

Increase in PROREF factor since 2015

The effect of TBT in dog whelk was higher at Melandsholmen in the Mid Karmsundet (st. 227G2) in 2016 (VDSI=1.912) than in 2015 (VDSI=0.828).

Downward trends

There were both significant downward long-term and short-term trends for TBT at Færder (st. 36G) in the Outer Oslofjord, Risøya at Risør (st. 76G), Lastad in Søgne (st. 131G), Gåsøya-Ullerøya in Farsund (st. 15G), Espevær (st. 22G) in the Outer Bømlafjord and at Svolvær airport area (st. 98G) in Lofoten. No trends could be calculated at Melandsholmen (st. 227G2) in the Mid Karmsundet and Brashavn (st. 11G) in the Outer Varangerfjord due to insufficient data.

Biological effects of TBT (imposex/VDSI) in dog whelk

The effect of TBT was near zero (VDSI=0.036) at Brashavn (st. 11G) in the Varangerfjord in 2016. No effects (VDSI=0) were found at Færder (st. 36G), Risøya (st. 76G), Lastad (st. 131G), Gåsøya-Ullerøya (st. 15G), Espevær (st. 22G) and Svolvær airport area (st. 98G) in 2016. These results were below the OSPARs Background Assessment Criteria (BAC=0.3, OSPAR 2009). The effects of TBT at

Melandsholmen had increased the last years from 2014 (VDSI=0.448), 2015 (VDSI=0.828) to 2016 (VDSI=1.91). In 2016, this result was above BAC but below the OSPARs Ecotoxicological Assessment Criteria (EAC=2, OSPAR 2013).

Downward trends

In dog whelk, 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), Lastad in Søgne (st. 131G) and Gåsøya-Ullerøya in Farsund (st. 15G).

No trends for VDSI could be calculated at Melandsholmen (st. 227G2) in the Mid Karmsundet due to insufficient data. No trends were observed for VDSI at Brashavn (st. 11G) in the Outer Varangerfjord. It can be noted that VDSI-values at this location have been low during the whole monitoring period since 2002.

Common periwinkle

Levels of TBT

The TBT-concentration in common periwinkle at Fugløyskjær (st. 71G) in the Outer Langesundfjord was <3.3 µg/kg (w.w.).

Trends of TBT

There were no significant trends for TBT at in common periwinkle at Fugløyskjær in the Outer Langesundfjord.

Other studies

Blue mussel from Langøya in the Holmestrandfjord in 2016 were below EQS for both TBT and triphenyltin at all six stations, included Mølen (st. 35A) (Gitmark *et al*. 2017).

General, large scale trends

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 dog whelk populations. Some of the previously effected snail populations have also re-established. 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 dog whelk was around level 4 in all dog whelk 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 22*** and ***Figure 23***). After 2008, the VDSI has been close to zero at many of the stations. A typical example of decreasing trends is shown for Færder in ***Figure 24***.

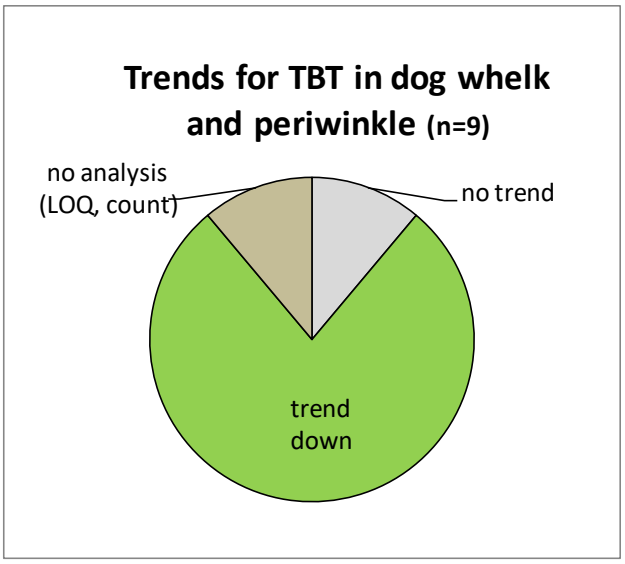


Figure 22. *Frequency of recent trends for the concentration of TBT in dog whelk (n=8) and periwinkle (n=1) (2007-2016). No upward trends were detected. Concerns about LOQ prevented some trend analyses.*

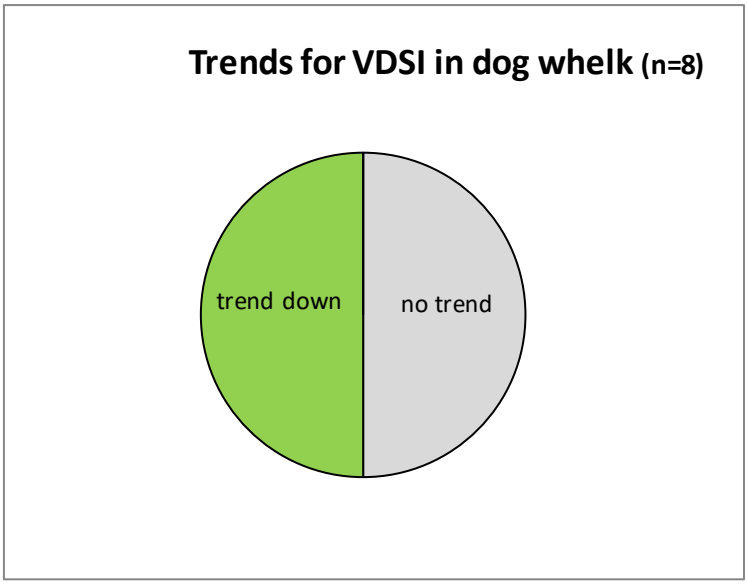


Figure 23. *Frequency of recent trends for VDSI in dog whelk (n=8) (2007-2016). No upward trends were detected.*

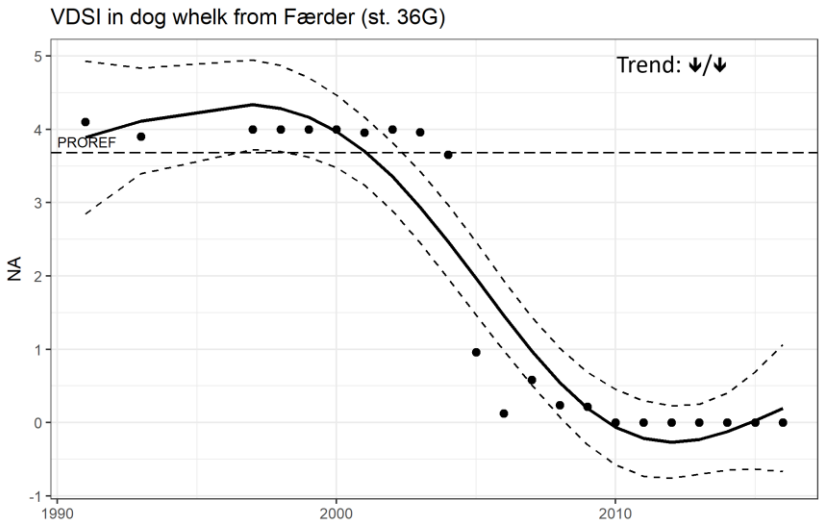


Figure 24. *Changes in VDSI for dog whelk from Færder (st. 36G) (1991-2016). The vertical black lines indicate the initial ban of TBT in 2003 and total ban in 2008. The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

Discharges of tributyltin and triphenyltin to water from land-based industries from 1997 to 2016 is shown in ***Figure 25***, 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 tributyltin and trienyltin/year) and 2009 (504 g tributyltin and triphenyltin/year), and these peaks were related to discharges to water from industry in Vestfold.

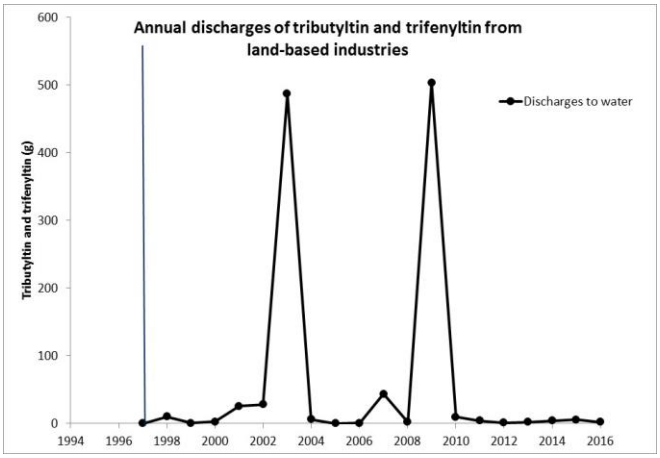


Figure 25. *Annual discharges of tributyltin and triphenyltin to water from land-based industries in the period 1997-2016 (data from www.norskeutslipp.no, 27 June 2017). The vertical grey line at 1997 marks when the MILKYS-measurements started. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of discharges might lead to changes in calculations of present and previous data.*

3.2.12 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. PCB-7 was analysed in blue mussel at 31 stations and in cod liver at 15 stations.

Environmental Quality Standards (EQS) for Water region specific substances

When applying the EQS for PCB-7 (0.6 µg/kg w.w.) in biota on blue mussel (see ***Table 6***), the concentrations at 9 stations are exceeding the limit. Many of these stations are located in the Oslofjord: Akershuskaia (st. I301), Gressholmen (st. 30A), Gåsøya (st. I304), Ramtonholmen (st. I307) and Håøya (st. I306). Concentrations of PCB-7 exceeding the EQS were also observed at Byrkjenes (st. 51A) in the Sørfjord and Nordnes in Bergen harbour (st. I241). Concentrations exceeding the EQS were also identified at Vågsvåg in the Outer Nordfjord (st. 26A2), and at Ørland area in the Outer Trondheimfjord (st. 91A2).

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

Levels exceeding PROREF

Blue mussel exceeded the provisional high reference concentration (PROREF) by a factor between five to 10 times at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Oslofjord, and between two and five times at Nordnes in Bergen harbour (st. I241). The exceedance was by a factor up to two at Gåsøya (st. I304), Ramtonholmen (st. I307) and Håøya (st. I306) in the Inner Oslofjord. This was also the result at Byrkjenes (st. 51A), Eitrheimsneset (st. 52A) and Kvalnes (st. 56A) in the Sørfjord, at Vågsvåg in the Outer Nordfjord (st. 26A2), and at Ørland area in the Outer Trondheimfjord (st. 91A2).

The PROREF in cod liver was exceeded by a factor between two and five in the Inner Oslofjord (st. 30B) and in Bergen harbour (st. 24B).

Increase in PROREF factor since 2015

Blue mussel at Vågsvåg in the Outer Nordfjord (st. 26A2) was under PROREF in 2015, while the exceedance was up to times in 2016.

Decrease in PROREF factor since 2015

Blue mussel at Nordnes (st. I241) in Bergen exceeded PROREF by a factor between five to 10 times in 2015, and between two to five times in 2016. Mussels at Gåsøya (st. I304) in the Inner Oslofjord and at Byrkjenes (st. 51A) in the Sørfjord exceeded PROREF by a factor between two to five times in 2015, and up to times in 2016. Mussels exceeded PROREF by a factor up to two times in 2015, while the concentration of PCB-7 was below the limit in 2016 at Solbergstrand (st. 31A), Mølen (st. 35A), Singlekalven (st. I023) and Kirkøy (st. I024) in the Oslofjord, and at Bjørkøya (st. 71A) in the Langesundfjord. This was also the result at Krossanes (st. 57A) and Utne (st. 64A) in the Sørfjord and Ranaskjer (st. 63A) in the Hardangerfjord.

Downward trends

For blue mussel, there were significant downward long-term trends at 20 of the 31 stations (***Table 11***). At five of these stations, there were also significant downward short-term trends at Gåsøya (st. I301), Ramtonholmen (st. I307), Bjørkøya (st. 71A), Mjelle in the Bodø area (st. 97A2) and Brashavn (st. 11X).

For cod liver, there were significant downward long-term trends at five of the 15 stations. These stations were Tjøme (st. 36B), Skågskjera in Farsund (st. 15B), Bømlo (st. 23B), Trondheim harbour (st. 80B) and Kjøfjord in the Varangerfjord (st. 10B). A significant downward short-term trend was observed in cod liver from Trondheim harbour (st. 80B).

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 and 2016.

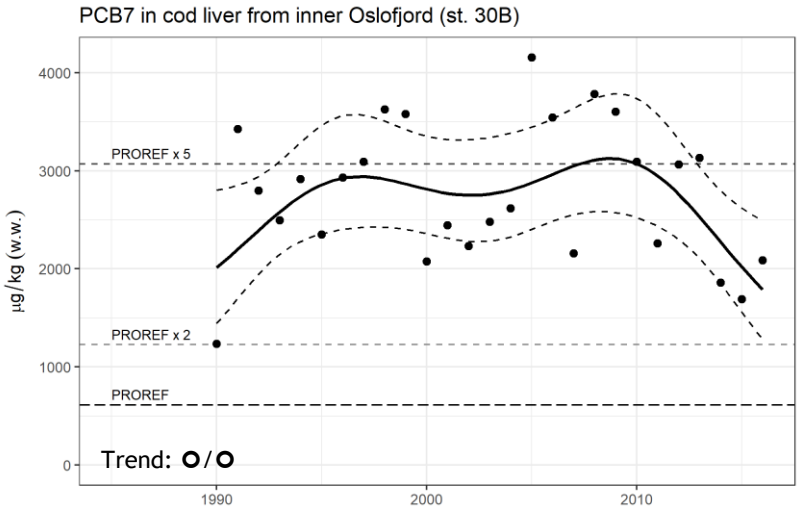
Cod liver caught at 100 m depth in the Inner Oslofjord (st. 30B) exceeded PROREF by a factor between two to five in both 2015 and 2016. Though no long-term or short-term trend was detected in 2016, when adjusting for length, a downward short-term trend was registered (***Figure 26a*** and ***b***, respectively).

Other studies

Cod liver samples from the 2016 MILKYS program in the Inner Oslofjord revealed a median concentration of 2088.7 µg ΣPCB-7/kg (w.w.). Cod liver from a comparable study in Inner Oslofjord in 2016 had higher mean concentration (2744.4 µg ΣPCB-7/kg w.w.) (Ruus *et al*. 2017 – M-812|2017, in press). 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.

A



B

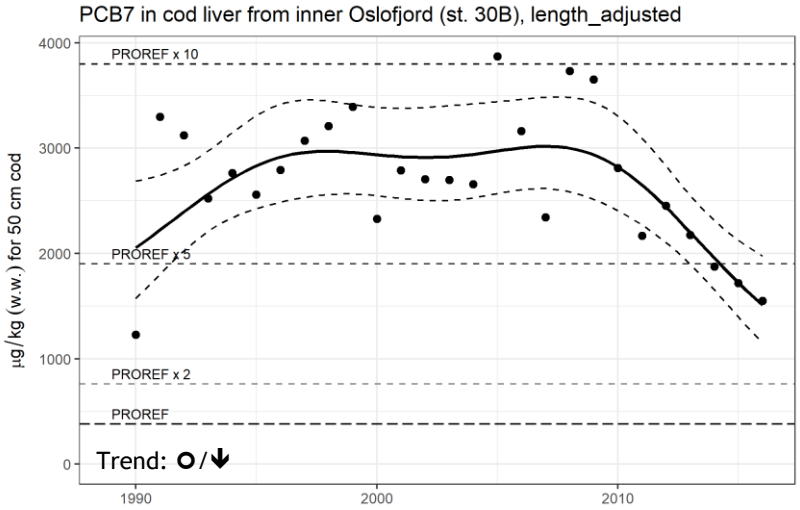


Figure 26. *Median concentrations (mg/kg w.w.) of PCB-7 in cod liver from 1990 to 2016 in the Inner Oslofjord (st. 30B); no adjustment for length (***A***) and adjusted for length (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

General, large scale trends

Production and new use of PCBs is also prohibited internationally through the ECE-POPs protocol and the Stockholm Convention.

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.

Emissions of PCBs to air and discharges to water from land-based industries are shown in ***Figure 27***. High emission to air was reported in 2008 (140 g PCB/year), while the emission was 40 g PCB/year in 2016. The discharges to water had decreased from 14.99 g PCB in 2013 to 4.58 g PCB 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 %.

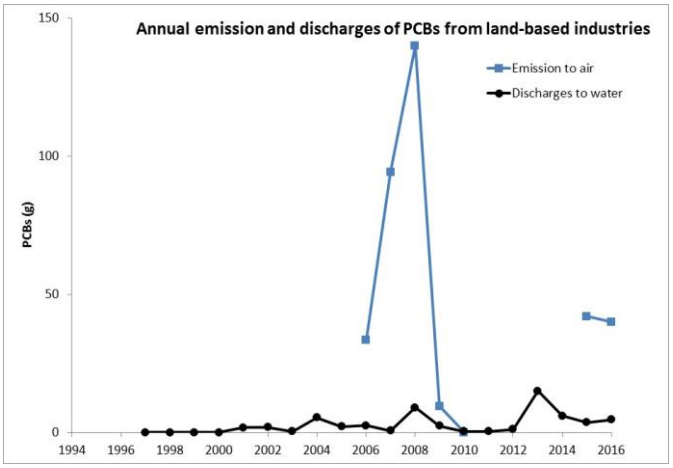


Figure 27. *Annual emissions of PCBs to air and discharges to water from land-based industries in the period 1997-2016 (data from www.norskeutslipp.no, 27 June 2017). No data for emissions to air are reported for 1994-2005 and 2011-2014. No data for discharges to water are reported for 1994-1996. Note 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.*

3.2.13 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, of which it is one of the more common breakdown products. The compounds are used for killing insects or plants. Dichlorodiphenyldichloroethylene (ppDDE) was analysed in cod liver at seven stations and in blue mussel at 19 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

EU has provided an EQS of 609 µg/kg w.w. in biota (see ***Table 6***). Applying this EQS for blue mussel and cod liver, all concentrations were below EQS.

Levels exceeding PROREF

Concentrations of ppDDE exceeded PROREF at 10 blue mussel stations (***Figure 28***). The highest concentrations were found in the Sørfjord and Hardangerfjord. Blue mussel exceeded PROREF by a factor over 20 at Kvalnes (st. 56A) in the Mid Sørfjord and at Krossanes (st. 57A) and Utne (st. 64A) in the Outer Sørfjord. Mussel exceeded PROREF by a factor between five and 10 at Byrkjenes (st. 51A), and Eitrheimsneset (st. 52A) in the Inner Sørfjord, and at Ranaskjer (st. 63A) in the Hardangerfjord. Mussel at Vikingneset (st. 65A) in the Hardangerfjord exceeded PROREF by a factor between two and five. At Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord and Espevær (st. 22A) on the west coast, the exceedance by a factor of up to two.

Concentrations of ppDDE exceeded PROREF at two cod stations (***Figure 28***). The highest concentration was found in cod liver from the Inner Sørfjord (st. 53B), where the PROREF was exceeded by a factor between two and five. In the Inner Oslofjord (st. 30B), the exceedance was by a factor of up to two.

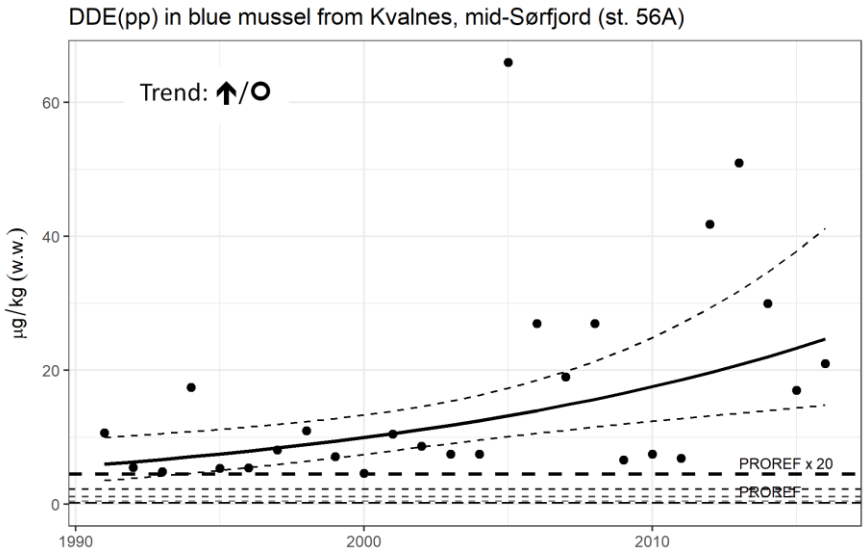


Figure 28. *Median concentrations (mg/kg w.w.) of ppDDE in blue mussel from 1992 to 2016 in the Mid Sørfjord at Kvalnes (st. 56A). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

Increase in PROREF factor since 2015

Blue mussel at Espevær (st. 22A) had concentration below PROREF in 2015, but exceeded this limit by a factor of up to two in 2016.

Cod liver in the Inner Oslofjord (st. 30B) had concentration below PROREF in 2015, and exceeded this limit by a factor of up to two in 2016.

Decrease in PROREF factor since 2015

Blue mussel at Vikingneset (st. 65A) exceeded PROREF by a factor between 10 and 20 in 2015, but the exceedance was by a factor between two to five in 2016. Mussel at Akershuskaia (st. I301) and Gressholmen (st. 30A) exceeded the limit by a factor between two and five in 2015, and up to two in 2016. At Solbergstrand (st. 31A), the exceedance was by a factor between two and five in 2015, and below PROREF in 2016. At Gåsøya (st. I304) and Færder (st. 36A) in the Oslofjord, and Bjørkøya

(st. 71A) and Sylterøya (st. I714) in the Langesundfjord, the exceedances were by a factor up to two in 2015, and below the limit in 2016.

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

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 five stations. These stations were the Inner Oslofjord (st. 30B), Skågskjera in Farsund (st. 15B), Bømlo (st. 23B), Austnesfjord (st. 98B1) and Kjøfjord in the Outer Varangerfjord (st. 10B).

Other studies, Sørfjord
In the present study in the Outer Sørfjord, blue mussel from Krossanes (st. 57A) had concentration of 4.9 μg/kg ppDDE (w.w.) and mussels from Utne (st. 64A), on the opposite side of the fjord, had concentration of 6.2 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). Skei *et al*. (2005) concluded that the variations in concentrations of ΣDDT and the ratio between p,p'-DDT/p,p'DDE (insecticide vs. metabolite) in blue mussel from Byrkjenes and Krossanes corresponds with periods with much precipitation and is most likely a result of wash-out from sources on shore. 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 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 in all countries in Europe, USA, and Canada. 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.

3.2.14 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. PAHs[15] was analysed in blue mussel at 10 stations.

Levels exceeding PROREF

Blue mussel at Moholmen in the Inner Ranfjord (st. I965) exceeded provisional high reference concentration (PROREF) for PAH-16 by a factor of five to ten in 2016. Mussels at Akershuskaia (st. I301) in the Inner Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord and Bjørnbærviken (st. I969) in the Inner Ranfjord exceeded PROREF by a factor between two and five. Mussels at Gressholmen (st. 30A) in the Inner Oslofjord and Sylterøya (st. I714) in the Langesundfjord exceeded PROREF by a factor up to two.

Increase in PROREF factor since 2015

Mussel at Bjørkøya (st. 71A) in the Langesundfjord exceeded PROREF by a factor up to two times in 2015, while the exceedance was between two to five in 2016.

Decrease in PROREF factor since 2015

Mussels at Akershuskaia (st. I301) in the Inner Oslofjord and Bjørnbærviken (st. I969) in the Inner Ranfjord exceeded PROREF by a factor between 10 to 20 in 2015, while the exceedance was between two and five in 2016. Mussels at Gressholmen (st. 30A) in the Inner Oslofjord and Sylterøya (st. I714) in the Langesundfjord exceeded PROREF by a factor between two and five in 2015, while the exceedance was up to two in 2016. Mussels at Lastad (st. I131A) exceeded PROREF by a factor between two and five in 2015, while it was no exceedance in 2016.

Downward trends

Both significant downward long- and short-term trends were found at Gressholmen (st. 30A) in the Inner Oslofjord, and in the Inner Ranfjord at Moholmen (st. I965) and Bjørnbærviken (st. I969). A significant downward long-term trend was observed at Akershuskaia (st. I301) in the Inner Oslofjord. A significant downward short-term trend was found at Svolvær airport area (st. 98A2) in Lofoten.

General, large scale trends

Emissions of PAHs to air and discharges to water from land-based industries can be seen in ***Figure 29***. In 2016, the emission to air was 62 960 kg PAHs. Most emission of PAHs to air came from Vest-

[15] 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**).

Agder (47 792 kg in 2016). No data was reported for emission to water from 1994 to 2001. The discharges to water were 4 595 kg PAHs in 2016. In 2016, 4 154 kg PAHs was discharged to water from Møre and Romsdal and 1 588 kg PAHs from Vest-Agder, according to www.norskeutslipp.

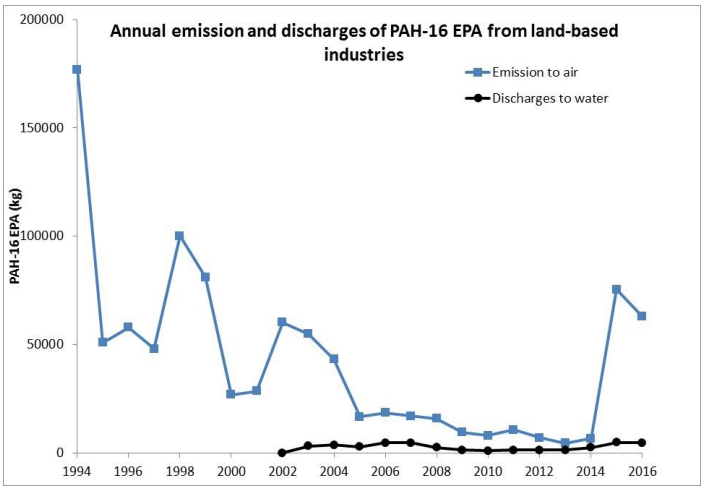


Figure 29. *Annual emissions of PAHs (PAH-16 EPA) to air and discharges to water from land-based industries in the period 2002-2016 (data from www.norskeutslipp.no, 27 June 2017). No data for emissions to air are reported for 1994-2006. No data for discharges to water are reported for 1994-2001. Note 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.*

3.2.15 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs, see **Appendix B**) was analysed in blue mussel at 10 stations.

Levels exceeding PROREF

Blue mussel at eight stations exceeded PROREF for KPAHs. The exceedance was by a factor over 20 at Bjørkøya (st. 71A) in the Langesundfjord and Moholmen (st. I965) in the Inner Ranfjord. Mussel at Bjørnbærviken (st. I969) in the Inner Ranfjord exceeded PROREF by a factor between 10 and 20. The exceedances of PROREF were by a factor between five and 10 at Akershuskaia (st. I301) in the Inner Oslofjord and at Sylterøya (st. I714) in the Langesundfjord. Mussels exceeded PROREF by a factor between two and five at Gressholmen (st. 30A) in the Inner Oslofjord. Mussels at Gåsøya (st. I304) in the Inner Oslofjord and at Lastad in Søgne (st. I131A) exceeded PROREF by a factor up to two times.

Increase in PROREF factor since 2015

Blue mussel at Bjørkøya (st. 71A) exceeded PROREF by a factor between five and 10 in 2015, while the exceedance was over 20 in 2016. Mussels at Gåsøya (st. I304) in the Inner Oslofjord did not exceed PROREF in 2015, while the concentrations exceeded this limit by a factor up to two in 2016.

Decrease in PROREF factor since 2015

Blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord and at Sylterøya (st. I714) in the Langesundfjord exceeded PROREF by a factor between 10 and 20 in 2015, but between five and 10

in 2016. Mussels at Lastad (st. I131A) exceeded PROREF by a factor between five and 10 in 2015, while the exceedance was up to two in 2016.

Downward trends
There were both significant downward long- and short-term trends in blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord and at Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Inner Ranfjord. A significant short-term trend was observed in mussel at Akershuskaia (st. I301).

3.2.16 Anthracene

Anthracene is a PAH-compound. Anthracene was analysed in blue mussel at 10 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants
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 2016 (see ***Table 10***), as in 2015.

Levels exceeding PROREF
Blue mussel at Moholmen (st. I965) in the Ranfjord exceeded in 2016 PROREF by a factor of up to two in 2016.

Increase in PROREF factor since 2015
Blue mussel at Moholmen (st. I965) in the Inner Ranfjord had concentrations of anthracene below PROREF in 2015, while the exceedance was up to two times in 2016.

Decrease in PROREF factor since 2015
Blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord exceeded PROREF by a factor between two to five times in 2015, while the concentration of anthracene was below this limit in 2016. Mussels at Bjørnbærviken (st. I969) in the Inner Ranfjord exceeded PROREF up to two times in 2015, while the concentrations of anthracene were below this limit in 2016.

Downward trends
A significant downward long-term trend was found at Gressholmen (st. 30A) in the Inner Oslofjord, and a significant downward short-term trend was observed at Moholmen (st. I965) in the Inner Ranfjord.

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 2016 were below EQS for anthracene at all six stations, included Mølen (st. 35A) (Gitmark *et al*. 2017).

In the Kristiansandfjord in 2016, blue mussel concentrations of anthracene were below EQS at five blue mussel stations (Lumber, Fiskå, Timlingen, Svensholmen and Flekkerøygapet) (Næs *et al*. 2017).

In the Ranfjord in 2016, blue mussel had concentrations below EQS for anthracene at Toraneskaia, Bjørnbærviken and Moholmen (Øxnevad *et al*. 2017).

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

Benzo[a]pyrene (B[a]P) is a PAH-compound. B[a]P was analysed in blue mussel at 10 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

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 in 2016 (see ***Table 10***), as in 2015.

Levels exceeding PROREF

Blue mussel at Moholmen (st. I965) in the Ranfjord exceeded PROREF by a factor of up to two.

Increase in PROREF factor since 2015

Blue mussel at Bjørkøya (st. I965) in the Langesundfjord exceeded PROREF by a factor up to two in 2016, while the concentration was below this limit in 2015.

Downward trends

Both significant long- and short-term trends were found in blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord, and at Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Inner Ranfjord.

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 six stations, included Mølen (st. 35A) (Gitmark *et al*. 2017).

Blue mussel concentrations of B[a]P exceeded EQS at one station (Lumber), and were below EQS at four stations (Fiskå, Timlingen, Svensholmen and Flekkerøygapet) in the Kristiansandfjord in 2016 (Næs *et al*. 2017).

In the Ranfjord, blue mussel had concentrations below EQS for B[a]P at Toraneskaia, Bjørnbærviken and Moholmen (Øxnevad *et al*. 2017).

3.2.18 Fluoranthene

Fluoranthene is a PAH-compound. Fluoranthene was analysed in blue mussel at 10 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

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 10***).

Levels exceeding PROREF

Blue mussel at Moholmen (st. I965) in the Ranfjord exceeded PROREF by a factor between two and five. Mussel at Akershuskaia (st. I301) exceeded PROREF up to two times.

Decrease in PROREF factor since 2015

Blue mussel at Akershuskaia (st. I301) in the Inner Oslofjord and Bjørnbærviken (st. I969) in the Inner Ranfjord exceeded PROREF by a factor between two and five in 2015, while the exceedance was by a factor of up to two at Akershuskaia and below the limit at Bjørnbærviken in 2016.

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), and short-term trends at Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Inner Ranfjord.

Other studies
Blue mussel from Langøya in the Holmestrandfjord in 2016 were below EQS for fluoranthene at all six stations, included Mølen (st. 35A) (Gitmark *et al*. 2017).

Blue mussel concentrations of fluoranthene exceeded EQS at one station (Lumber), and were below EQS at four stations (Fiskå, Timlingen, Svensholmen and Flekkerøygapet) in the Kristiansandfjord in 2016 (Næs *et al*. 2017).

Another recent survey showed that blue mussel exceeded EQS for fluoranthene at Toraneskaia, but not at Bjørnbærviken or Moholmen in the Ranfjord in 2016 (Øxnevad *et al*. 2017).

3.2.19 Naphthalene
Naphthalene is a PAH-compound. Naphthalene was analysed in blue mussel at 10 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants
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 in 2016 (see ***Table 10***).

Downward trends
Significant downward long-term trends were seen at Akershuskaia (st. I301), Gressholmen (st. 30A) and Gåsøya (st. I304) in the Inner Oslofjord, at Lastad (st. I131A) in Søgne and at Moholmen (st. I965) in the Inner Ranfjord.

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 2016 were below EQS for naphthalene at all six stations, included Mølen (st. 35A) (Gitmark *et al*. 2017).

In the Kristiansandfjord in 2016, blue mussel concentrations of naphthalene were below EQS at five blue mussel stations (Lumber, Fiskå, Timlingen, Svensholmen and Flekkerøygapet) (Næs *et al* 2017).

In the Ranfjord in 2016, blue mussel had concentrations below EQS for naphthalene at Toraneskaia, Bjørnbærviken and Moholmen (Øxnevad *et al*. 2017).

3.2.20 Benzo(a)anthracene
Benzo(a)anthracene is a PAH-compound. Benzo(a)anthracene was analysed in blue mussel at 10 stations.

Environmental Quality Standards (EQS) for Water region specific substances
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 in 2016 (see ***Table 10***), as in 2015.

Levels exceeding PROREF
Blue mussel at Moholmen (st. I965) in the Ranfjord exceeded PROREF by a factor between two and five. Mussel at Bjørkøya (st. 71A) in the Langesundfjord and Bjørnbærviken (st. I969) in the Inner Ranfjord exceeded PROREF by a factor of up to two.

Increase in PROREF factor since 2015
Blue mussel at Bjørkøya (st. 71A) in the Langesundfjord exceeded PROREF by a factor of up to two in 2016, while the concentration was below this limit in 2015.

Decrease in PROREF factor since 2015
Mussel at Akershuskaia (st. I301) exceeded PROREF by a factor between two and five in 2015, and were below this limit in 2016. Mussel at Sylterøya (st. I714) in the Langesundfjord exceeded PROREF up to two times in 2015, while the concentration was below this limit in 2016.

Downward trends
There were both significant downward long- and short-term trends at Akershuskaia (st. I301) and Gressholmen (st. 30A) in the Inner Oslofjord, and at Moholmen (st. I965) and Bjørnbærviken (st. I969) in the Inner Ranfjord. 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 2016 were below EQS for benzo(a)anthracene at all six stations, included Mølen (st. 35A) (Gitmark *et al.* 2017).

In the Kristiansandfjord in 2016, blue mussel concentrations of benzo(a)anthracene were below EQS at five blue mussel stations (Lumber, Fiskå, Timlingen, Svensholmen and Flekkerøygapet) (Næs *et al.* 2017).

3.2.21 Polybrominated diphenyl ethers (PBDEs)

The EQS for brominated diphenylethers (0.0085 µg/kg w.w.) in biota for "fish" is the sum of the concentrations of congener numbers BDE28, 47, 99, 100, 153 and 154 (sum BDEs). Applying this EQS for blue mussel, sum BDEs were above EQS at Singlekalven in Hvaler (st. I023), Nordnes in Bergen (st. I241), Vågsvåg in Outer Nordfjord (st. 26A2), Ørland area in Outer Trondheimfjord (st. 91A2), and at Mjelle in Bodø area (st. 97A2) (see ***Table 10***).

Applying this EQS for cod liver, sum BDEs were above EQS (see ***Table 10***).

The median concentration of BDE47 alone in both blue mussel and cod liver exceeded this EQS value at all stations (see **Table 10**). These results indicate that the EQS might not be a useful criterion to judge the condition of the environment with respect to this contaminant in biota. It can be noted

that BDE6S (sum that included BDE47) was zero for some stations, an artefact due to the treatment of values below the limit of quantification (see section 2.6.1).

Levels exceeding PROREF

Blue mussel at Nordnes (st. I241) in Bergen harbour exceeded the provisional high reference concentration (PROREF) of sum BDEs (28, 47, 99, 100, 153 and 154) by a factor up to two. Mussels from this location also exceeded PROREF by a factor up to two for BDE47 and 99. Mussels exceeded PROREF by a factor up to two for BDE47 at Ørland area in the Outer Trondheimsfjord (st. 91A2) and for BDE99 at Vågsvåg in the Outer Nordfjord (st. 26A2).

Cod liver from the Inner Oslofjord (st. 30B) and 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 exceeded PROREF by a factor of between two and five for BDE47 and 100 at Bergen harbour (st. 24B) and for BDE100 in the Inner Oslofjord (st. 30B). Cod liver exceeded PROREF by a factor of up to two for BDE47, 99 and 154 in the Inner Oslofjord (st. 30B), and for BDE154 in Bergen harbour (st. 24B). Cod liver exceeded PROREF by a factor of up to two for BDE100 in Tromsø harbour (st. 43B2) and for BDE154 in the Inner Sørfjord (st. 53B) (***Table 11***, ***Table 12*** and ***Figure 30***).

BDE47

The most dominant congener in 2016 was BDE47, as was also the case in the previous year. BDE47 was detected at all blue mussel and cod stations sampled in 2016, as in 2015. The highest median concentrations of BDE47 were found in mussels from Nordnes (st. I241) in Bergen harbour (0.15 µg BDE47/kg w.w.) and in cod liver from Nordnes (40.00 µg/kg w.w.).

Increase in PROREF factor since 2015

Blue mussel was below PROREF for BDE99 at Vågsvåg in Outer Nordfjord (st. 26A2) and for BDE47 at Ørland area in the Outer Trondheimsfjord (st. 91A2) in 2015, but exceeded PROREF by a factor up to two times in 2016.

Cod liver exceeded PROREF by a factor up to two in 2015 in the Inner Oslofjord (st. 30B) for BDE100 and sum BDEs (28, 47, 99, 100, 153 and 154) and in Bergen harbour (st. 24B) for BDE100, while the exceedances were between two and five in 2016. Cod liver was below PROREF in 2015 in Bergen harbour (st. 24B) for BDE47 and sum BDEs (28, 47, 99, 100, 153 and 154), while the exceedances were between two and five in 2016. Cod liver was below PROREF in 2015 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.

Decrease in PROREF factor since 2015

Blue mussel at Nordnes (st. I241) in Bergen harbour exceeded PROREF for BDE99 by a factor between two and five in 2015, while the exceedance was by a factor of up to two in 2016. At the same station, BDE100 exceeded this limit by a factor of up to two in 2015, while the concentration was below PROREF in 2016.

Cod liver at Austnesfjord (st. 98B1) in Lofoten exceeded PROREF for BDE99 by a factor between two and five in 2015, while the concentration was below this limit in 2016. Cod liver at Tromsø harbour (st. 43B2) exceeded PROREF for both BDE100 and -154 by a factor of up to two in 2015, while the concentrations were below PROREF 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.

Downward trends
Significant downward long-term trends were found for BDE47 in blue mussel from Gressholmen (st. 30A) in the Inner Oslofjord, Bjørkøya (st. 71A) in the Langesundfjord and Svolvær airport area (st. 98A2) in Lofoten. A significant downward long-term trend was also found for BDE99 at Bjørkøya (st. 71A), and significant downward short-term trends were found for BDE47 and 99 at the same station.

Both significant downward long- and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B) for BDE28, 47, 100 and sum BDEs (28, 47, 99, 100, 153 and 154). This was also the result at Kristiansand harbour (st. 13B) for BDE28 and at Bømlo (st. 23B) for BDE47. Similar trends were observed for the Inner Sørfjord (st. 53B) and Trondheim harbour (st. 80B) for BDE28. Tromsø harbour (st. 43B2) showed significant downward long-term and short-term trends for BDE28, 47, 99, 153 and for sum BDEs (28, 47, 99, 100, 153 and 154). Significant downward long-term trends were observed at Inner Oslofjord (st. 30B) for BDE99, 153 and 154, Tjøme (st. 36B) for BDE47 and 99 and Bømlo (st. 23B) for BDE 28, 100, 153 and for sum BDEs (28, 47, 99, 100, 153 and 154). Significant downward short-term trends were found for BDE47, 153 and sum BDEs (28, 47, 99, 100, 153 and 154) in the Inner Sørfjord (st. 53B).

Statistical considerations for cod liver
The standard deviation varied considerably among stations, also for other PBDEs. The highest deviation was found in the Inner Oslofjord (st. 30B) for BDE47 (***Table 12***) in 2016. 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 significantly higher levels than in remote areas like 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 31***). 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 2016, PBDEs were analysed in cod from 10 stations (***Table 12***). Of the PBDEs, only congeners BDE28, -47, -99, -100 and -154 were above the quantification limit in at least half of the samples from each station in cod liver.

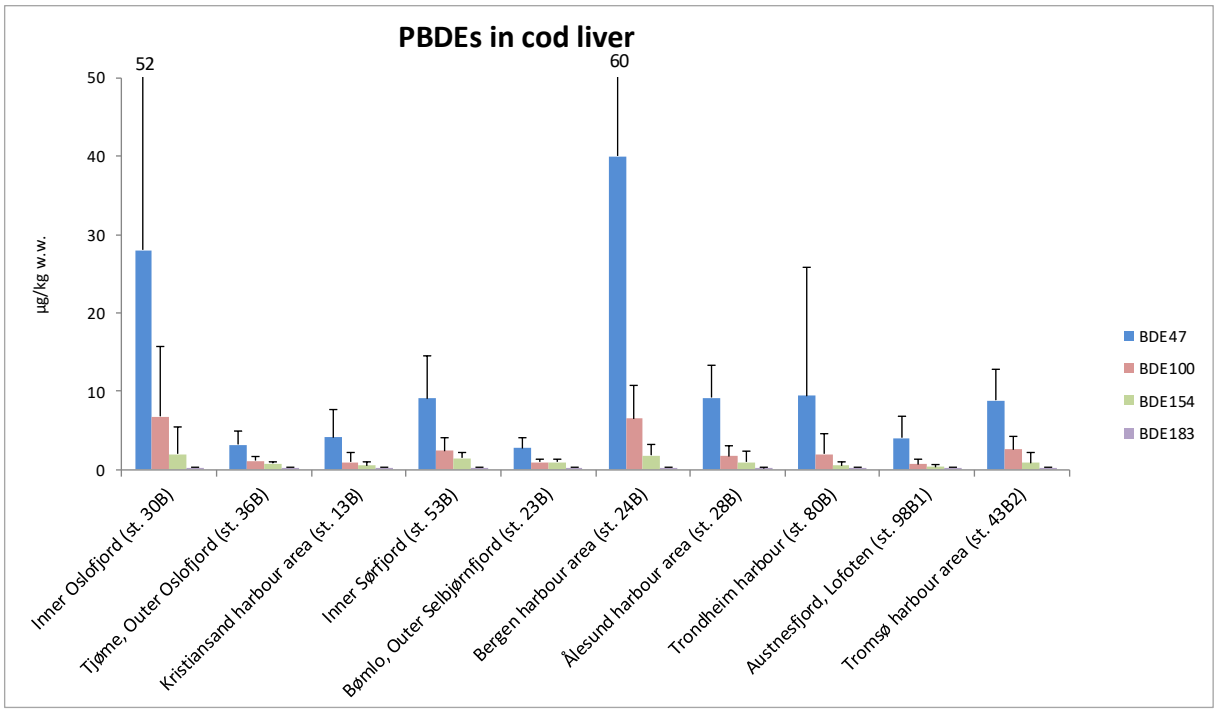


***Figure 30**. Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2016. Only the results are shown where concentrations were above the quantification limit for half or more of the samples. The error bar indicates one standard deviation above the median.*

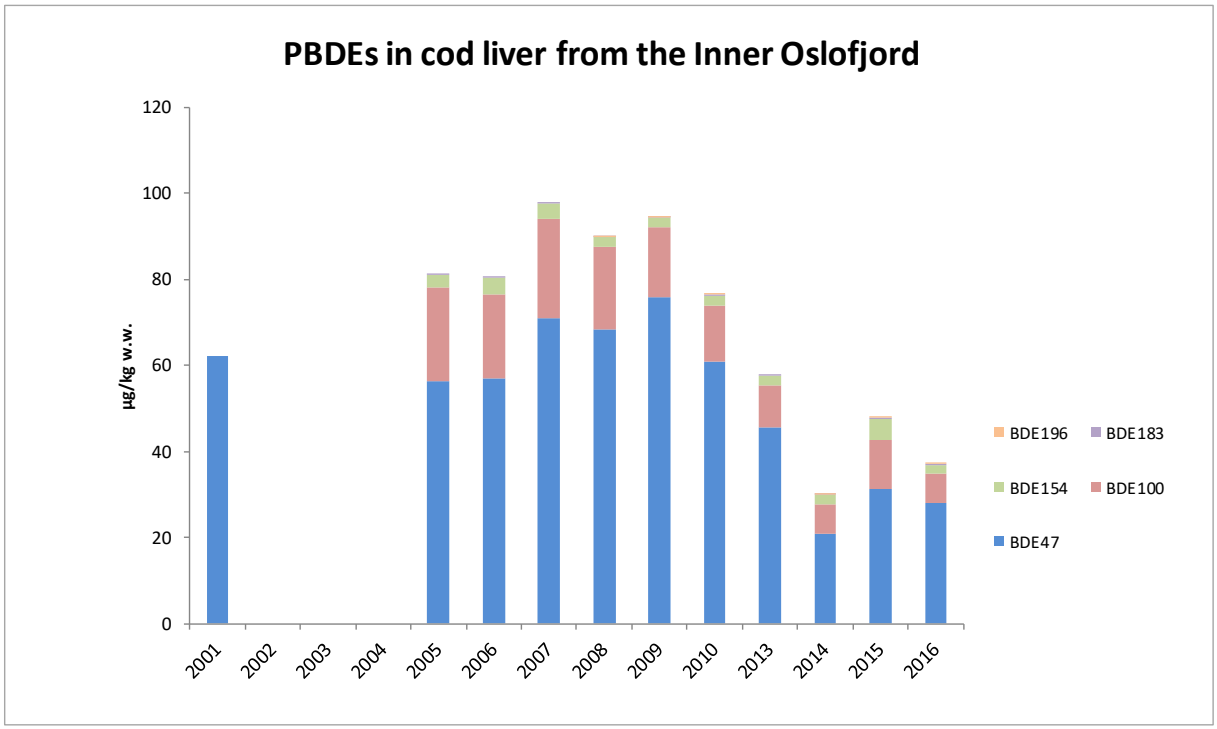


***Figure 31**. Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2016 in the Inner Oslofjord (st. 30B).*

***Table 12**. Median concentrations (µg/kg w.w.) and standard deviations for PBDE congeners in blue mussel and cod liver in 2016. 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. BDE6S is the sum of BDE -28, -47, -99, -100, -153 and -154 as used in the EQS, whereas BDESS is the sum of all PBDEs analysed (see **Table 6**, see also Chapter 2.7 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	BDE28			BDE47			BDE99			BDE100			BDE126			BDE153		
Species and sampling locality	2016	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(3-37)	0.100	0.000		0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Færder, Outer Oslofjord (st. 36A)	3(3-20)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Singlekalven, Hvaler (st. I023)	3(3-92)	0.050	0.000		0.120	0.015	3 (0.1 - 0.13)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	0.050	0.000		0.050	0.000	1 (0.05 - 0.05)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Sylterøya, Langesundfjord (st. I714)	3(3-50)	0.050	0.000		0.050	0.006	1 (0.06 - 0.06)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Nordnes, Bergen harbour (st. I241)	3(3-20)	0.050	0.000		0.150	0.000	3 (0.15 - 0.15)	0.080	0.017	2 (0.08 - 0.08)	0.050	0.000		0.050	0.000		0.050	0.000	
Vågsvåg, Outer Nordfjord (st. 26A2)	3(3-111)	0.050	0.000		0.120	0.015	3 (0.1 - 0.13)	0.060	0.006	3 (0.06 - 0.07)	0.050	0.000		0.050	0.000		0.050	0.000	
Ørland area, Outer Trondheimsfjord (st. 91A2)	3(3-78)	0.050	0.000		0.140	0.049	3 (0.13 - 0.22)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Mjelle, Bodø area (st. 97A2)	3(3-100)	0.050	0.000		0.090	0.015	3 (0.07 - 0.1)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Svolvær airport area (st. 98A2)	3(3-120)	0.050	0.000		0.050	0.000	1 (0.05 - 0.05)	0.050	0.000		0.050	0.000		0.050	0.000		0.050	0.000	
Cod, liver																			
Inner Oslofjord (st. 30B)	15(2-2)	0.590	0.547	15 (0.14 - 2.3)	28.000	24.131	15 (8.3 - 87)	1.300	0.700	14 (0.13 - 2.7)	6.800	8.911	15 (3.8 - 35)	0.100	0.000		0.100	0.103	2 (0.12 - 0.5)
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	0.110	0.039	10 (0.1 - 0.22)	3.200	1.659	15 (1.6 - 7.8)	0.100	0.108	6 (0.1 - 0.52)	1.100	0.505	15 (0.79 - 2.7)	0.100	0.000		0.100	0.000	
Kristiansand harbour area (st. 13B)	15	0.140	0.080	12 (0.11 - 0.36)	4.100	3.563	15 (2.1 - 14)	0.100	0.063	7 (0.11 - 0.29)	0.950	1.168	15 (0.46 - 4.7)	0.100	0.000		0.100	0.000	
Inner Sørfjord (st. 53B)	15(12-2)	0.210	0.154	15 (0.11 - 0.72)	9.100	5.362	15 (6.7 - 27)	0.380	0.173	15 (0.12 - 0.77)	2.400	1.634	15 (1.7 - 7.8)	0.100	0.000		0.100	0.003	1 (0.11 - 0.11)
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.100	0.040	8 (0.1 - 0.22)	2.800	1.302	15 (0.65 - 6.3)	0.310	0.247	13 (0.1 - 0.86)	0.950	0.361	15 (0.22 - 1.8)	0.100	0.000		0.100	0.048	7 (0.1 - 0.24)
Bergen harbour area (st. 24B)	15(3-3)	0.990	0.636	15 (0.13 - 2.1)	40.000	20.310	15 (4.7 - 76)	0.350	0.285	15 (0.16 - 1)	6.500	4.332	15 (1 - 16)	0.100	0.000		0.100	0.014	3 (0.11 - 0.15)
Ålesund harbour area (st. 28B)	7(1-2)	0.250	0.178	6 (0.13 - 0.56)	9.200	4.156	7 (2.9 - 14)	0.110	0.124	4 (0.11 - 0.41)	1.700	1.368	7 (0.71 - 4.5)	0.100	0.000		0.100	0.000	1 (0.1 - 0.1)
Trondheim harbour (st. 80B)	14(3-2)	0.235	0.356	13 (0.12 - 1.1)	9.450	16.384	14 (2.4 - 59)	0.315	0.174	11 (0.15 - 0.62)	1.950	2.592	14 (0.33 - 8.2)	0.100	0.000		0.100	0.000	
Austnesfjord, Lofoten (st. 98B1)	15	0.160	0.139	15 (0.11 - 0.59)	4.000	2.769	15 (1.6 - 12)	0.100	0.000		0.730	0.550	15 (0.25 - 2.1)	0.100	0.000		0.100	0.000	
Tromsø harbour area (st. 43B2)	12(3-2)	0.185	0.085	12 (0.13 - 0.38)	8.850	3.888	12 (5.6 - 17)	0.365	0.403	12 (0.11 - 1.5)	2.600	1.580	12 (1.3 - 6.6)	0.100	0.000		0.100	0.029	1 (0.2 - 0.2)

Table 12. (cont.)

Component	Count	BDE154			BDE183			BDE196			BDE209			BDE6S			BDESS		
Species and sampling locality	2016	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(3-37)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.000	0.000	3 (0 - 0)	0.000	0.000	3 (0 - 0)
Færder, Outer Oslofjord (st. 36A)	3(3-20)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.000	0.000	3 (0 - 0)	0.000	0.000	3 (0 - 0)
Singlekalven, Hvaler (st. I023)	3(3-92)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.120	0.015	3 (0.1 - 0.13)	0.120	0.015	3 (0.1 - 0.13)
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.000	0.029	3 (0 - 0.05)	0.000	0.029	3 (0 - 0.05)
Sylterøya, Langesundfjord (st. I714)	3(3-50)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.000	0.035	3 (0 - 0.06)	0.000	0.035	3 (0 - 0.06)
Nordnes, Bergen harbour (st. I241)	3(3-20)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.230	0.046	3 (0.15 - 0.23)	0.230	0.046	3 (0.15 - 0.23)
Vågsvåg, Outer Nordfjord (st. 26A2)	3(3-111)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.190	0.017	3 (0.16 - 0.19)	0.190	0.017	3 (0.16 - 0.19)
Ørland area, Outer Trondheimsfjord (st. 91A2)	3(3-78)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.140	0.049	3 (0.13 - 0.22)	0.140	0.049	3 (0.13 - 0.22)
Mjelle, Bodø area (st. 97A2)	3(3-100)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.090	0.015	3 (0.07 - 0.1)	0.090	0.015	3 (0.07 - 0.1)
Svolvær airport area (st. 98A2)	3(3-120)	0.050	0.000		0.300	0.000		0.300	0.000		0.500	0.000		0.000	0.029	3 (0 - 0.05)	0.000	0.029	3 (0 - 0.05)
Cod, liver																			
Inner Oslofjord (st. 30B)	15(2-2)	2.000	3.410	15 (1.3 - 14)	0.300	0.000		0.300	0.000		0.500	0.000		42.020	34.744	15 (13.92 - 110.62)	42.020	34.744	15 (13.92 - 110.62)
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	0.770	0.293	15 (0.57 - 1.7)	0.300	0.000		0.300	0.000		0.500	0.000		5.060	2.509	15 (3 - 12.72)	5.060	2.509	15 (3 - 12.72)
Kristiansand harbour area (st. 13B)	15	0.500	0.544	15 (0.31 - 2.4)	0.300	0.000		0.300	0.000		0.500	0.408		5.940	5.208	15 (3.03 - 20.21)	5.940	5.208	15 (3.03 - 20.21)
Inner Sørfjord (st. 53B)	15(12-2)	1.500	0.695	15 (0.88 - 3.7)	0.300	0.000		0.300	0.000		0.500	2.453		13.810	7.645	15 (10.01 - 39.61)	13.810	7.645	15 (10.01 - 39.61)
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.930	0.341	15 (0.37 - 1.6)	0.300	0.000		0.300	0.000		0.500	0.000		5.420	2.011	15 (1.61 - 10.48)	5.420	2.011	15 (1.61 - 10.48)
Bergen harbour area (st. 24B)	15(3-3)	1.800	1.444	15 (0.46 - 5.8)	0.300	0.000		0.300	0.000		0.500	2.453		49.740	25.447	15 (6.54 - 95.01)	49.740	25.447	15 (6.54 - 95.01)
Ålesund harbour area (st. 28B)	7(1-2)	1.000	1.393	7 (0.35 - 4.5)	0.300	0.011	1 (0.33 - 0.33)	0.300	0.129	1 (0.64 - 0.64)	0.500	5.480		12.480	6.839	7 (4.26 - 24.07)	12.480	6.963	7 (4.26 - 24.71)
Trondheim harbour (st. 80B)	14(3-2)	0.560	0.483	14 (0.23 - 1.6)	0.300	0.000		0.300	0.000		0.500	0.000		12.140	19.720	14 (3.38 - 70.05)	12.140	19.720	14 (3.38 - 70.05)
Austnesfjord, Lofoten (st. 98B1)	15	0.380	0.262	15 (0.13 - 1.2)	0.300	0.000		0.300	0.000		0.500	0.000		5.190	3.677	15 (2.1 - 15.89)	5.190	3.677	15 (2.1 - 15.89)
Tromsø harbour area (st. 43B2)	12(3-2)	0.915	1.227	12 (0.56 - 4.9)	0.300	0.000		0.300	0.000		0.500	0.000		13.130	6.974	12 (8.05 - 30.56)	13.130	6.974	12 (8.05 - 30.56)

Levels in blue mussel

Only congeners BDE47 showed concentrations above the quantification limit for half or more of the samples at all stations (***Table 11***, ***Table 12***, ***Figure 32***).

The most dominant congener in 2016 was BDE47, as was also the case in the previous year. BDE47, - was detected at all stations in 2015, as in 2014. The highest median concentration was found in mussels from Nordnes (st. I241) in Bergen harbour (0.1500 µg BDE47/kg w.w.).

Statistical considerations of blue mussel

Blue mussel from Nordnes in the Bergen harbour area (st. I241) and Ørland area (st. 91A2) showed significantly higher concentrations of BDE47 than mussels from all the other stations (Tukey-Kramer HSD test, see also ***Figure 32***).

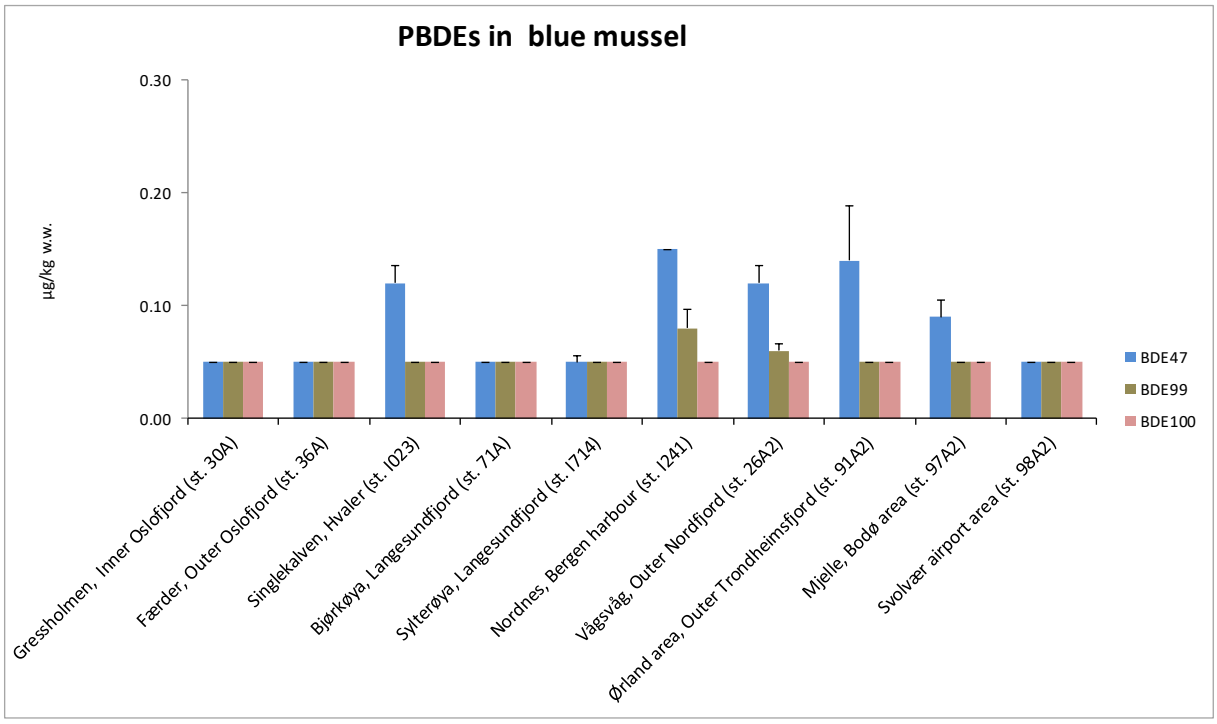


Figure 32*. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2016. Only the results where concentrations were above the quantification limit for half or more of the samples are shown. The error bar indicates one standard deviation above the median.*

Inner Oslofjord

Parts of the Inner Oslofjord are densely populated with much urban activities and accompanying PBDEs in certain products. 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 28 µg BDE47/kg (w.w.), while the mean concentration in a comparable study in 2016 (Ruus *et al*. 2017 – M-812|2017, in press) was 45.4 µg BDE47/kg (w.w.). The median concentration of BDE100 was 6.8 µg /kg (w.w.) in the present study, while the mean concentration was 13.3 µg/kg (w.w.) in the study performed by Ruus *et al*. (2017 – M-812|2017, in press). The median concentration of BDE154 was 2 µg/kg (w.w.) in the present study, while the mean concentration

was 2.1 µg/kg (w.w.) in the comparable study (Ruus *et al.* 2017 – M-812|2017, in press). The collection of cod in both studies took place during the autumn.

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 PDEs (28, 47, 99, 100, 153 and 154) (42.12 µg/kg w.w.) found at MILKYS cod stations in the Inner Oslofjord (st. 30B) (cf. ***Figure 30***). Average concentrations found at two cod stations in the North Sea was 14.6 and 15.4 µg/kg w.w. (Green *et al.* 2011a – TA-2810/2011) and 5.89, 12.9 and 19 µg/kg w.w. at three cod stations in the Norwegian Sea (Green *et al.* 2012b – TA-2935/2012). It can be suspected that this high background concentration might be too high. The median concentration observed for the Inner Oslofjord for sum BDEs (42.12 µg/kg w.w.) was in the interval for sum PBDEs of 37-112 µg/kg w.w. found in other contaminated areas (Fjeld *et al.* 2005 – TA-2096/2005, Berge *et al.* 2006 – TA-2146/2006). Bakke *et al.* (2007 – TA-2284/2007) found mean concentrations of sum BDEs in remote areas to be within the range 3.4-29.0 µg/kg w.w.

The congeners BDE47 and -100 were observed to be most dominant in 2016, 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 (Løvik *et al.* 2016).

General, large scale trends

No significant upward long-term trends were found. All three significant upward short-term trends were found in cod liver from Tjøme (st. 36B), Bømlo (st. 23B) and Austnesfjord in Lofoten (st. 98B1).

There was a total of 23 significant downward long-term trends (sum BDE not included), four were found in blue mussel and 19 in cod liver. Of 15 significant downward short-term trends, two were found in blue mussel and 13 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 PFCs) 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.

3.2.22 Perfluorinated alkylated substances (PFAS)

Perfluorinated alkylated substances (PFAS) are organofluorine compounds used as oil-, stain- and water-repellent surfactants and a number of other products. PFAS were analysed in cod liver at nine stations (***Table 11*** and ***Figure 33***). PFAS have been analysed annually in cod liver since 2005. Samples collected in the Inner Oslofjord (st. 30B) and Bømlo (st. 23B) in 1993 have also been analysed for PFAS.

Environmental Quality Standards (EQS) for EU-priority pollutants

The EQS for PFOS in biota (fish) is 9.1 µg/kg w.w. which applies to whole fish (2013/39/EU). Therefore, 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 2.7 µg/kg w.w. in the Inner Oslofjord).

Environmental Quality Standards (EQS) for Water region specific substances

The EQS for PFOA is 91.3 µg/kg w.w. in biota (2013/39/EU). Applying this EQS for cod liver, all concentrations were below EQS (see ***Table 10***).

Levels exceeding PROREF

No PFAS-concentrations exceeded the provisional high reference concentrations (PROREF) in 2016.

Decrease in PROREF factor since 2015

Cod liver from the Inner Oslofjord (st. 30B) exceeded PROREFs for PFOSA up to two times in 2015, while the concentrations were below this limit in 2016.

Upward trends

No upward trends for any PFAS-concentrations were found.

Downward trends

For PFOS, both significant downward long- and short-term trends were found in cod liver from the Inner Oslofjord (st. 30B), Tjøme (st. 36B), Kristiansand harbour (st. 13B), Inner Sørfjord (st. 53B) and Tromsø harbour (st. 43B2). For PFOSA, both significant downward long- and short-term trends were found in cod liver from Kristiansand harbour (st. 13B) and Bømlo (st. 23B). A significant downward short-term trend was found for PFNA in the Inner Sørfjord (st. 53B).

PFOS

The median concentration of perfluorooctonoic sulfonate (PFOS) in cod liver was highest in the Inner Oslofjord (st. 30B, 2.7 µg/kg w.w.) and lowest in Tromsø harbour (st. 43B2, 0.455 µg/kg w.w.) (***Table 13***). The concentration found in the Inner Oslofjord had decreased from 6.5 µg/kg (w.w.) in 2015 to 2.7 µg/kg (w.w.) in 2016. At Tjøme (st. 36B) the concentrations had decreased from 2.4 µg/kg (w.w.) in 2015 to 2.1 µg/kg (w.w.) in 2016.

Significant downward trends for PFOS were dominating in 2016, 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) and Tromsø harbour (st. 43B2).

Cod from the Inner Oslofjord had significant higher levels of PFOS in liver than all other stations (Tukey-Kramer HSD test, see also ***Figure 33***).

PFOSA

Perfluorooctane sulfonamide (PFOSA) had a maximum median concentration of 5 µg/kg (w.w.) in the Inner Oslofjord (st. 30B), and a minimum level at Kristiansand harbour (st. 13B) (0.670 µg/kg w.w.). The concentration of PFOSA was higher than PFOS in the Inner Oslofjord and at Tjøme in 2016 (***Figure 33***, ***Figure 34***), as in 2015.

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

The median concentrations of the remaining PFAS were mostly below the quantification limits (**Table 13**).

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.

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

Cod liver samples from the 2016 MILKYS program from the Inner Oslofjord had median concentrations of 2.7 µg PFOS/kg (w.w.) and 5 µg PFOSA/kg (w.w.) in 2016. Cod liver from a comparable study in the Inner Oslofjord in 2016 had higher mean concentrations of both PFOS (5.1 µg/kg w.w.) and PFOSA (6.3 µg/kg w.w.) (Ruus *et al*. 2017 – M-812|2017, in press). The collection of cod in both studies took place during the autumn.

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 2016 were below EQS for PFOA at all six stations, included Mølen (st. 35A) (Gitmark *et al*. 2017).

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 only 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 2015 (Fjeld *et al*. 2016 – M-548|2016). 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 2–12 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 183 and 346 µg/kg w.w., respectively. Concentrations of PFOS in liver varied considerably but were on the average about 25 times higher than in fillet. The differences between fillet and liver concentrations seemed to increase with decreasing carbon chain length.

PFOA has been strictly regulated nationally in consumer products from June 2014[16]. PFOA-data at all stations was inadequate for trend analysis due to concerns about the limit of quantifications.

General, large scale trends

Seven of the nine stations showed significant downward short-term trends in PFOS for the period 2007-2016. Significant downward trends for PFOS were dominating in 2013, 2014, 2015 and 2016, unlike the previous year (2012) when no trends were observed. The observed downward trends could reflect the overall reduction in production and use of PFAS for the past 30 years (Nost *et al*. 2014, Axmon *et al*. 2014). It is however unclear why downward trends were not seen in 2012. A decrease in concentrations of PFAS 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).

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

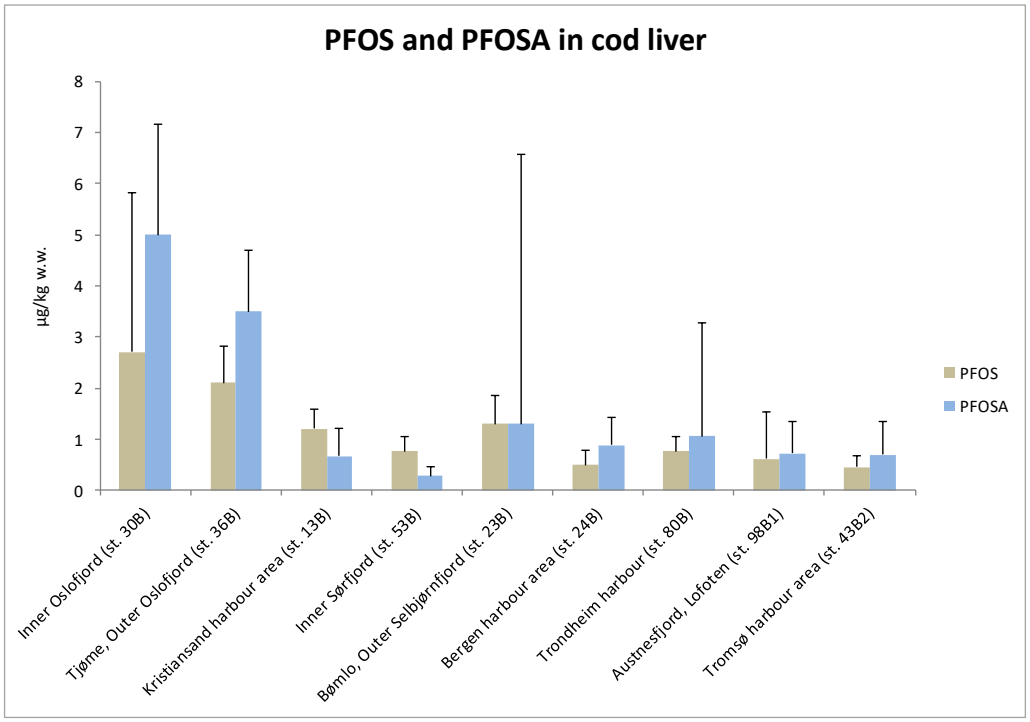


***Figure 33**. Median concentrations (µg/kg w.w.) of two PFAS compounds in cod liver in 2016. The error bar indicates one standard deviation above the median. (See also **Table 13**).*

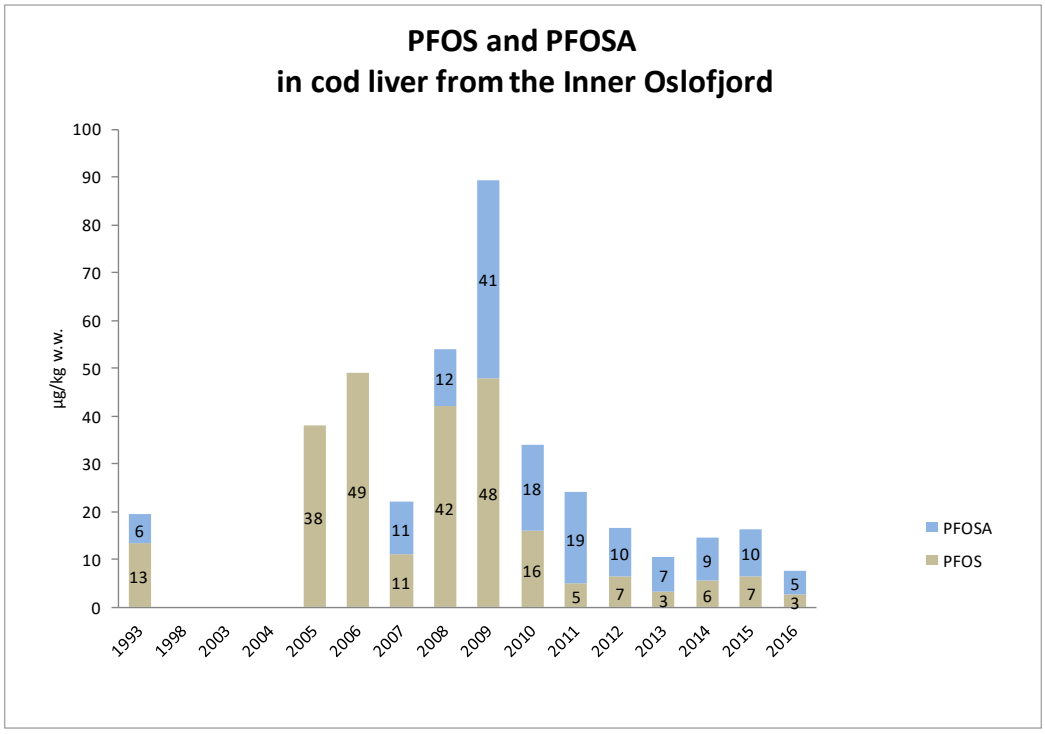


***Figure 34**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2016 in the Inner Oslofjord (st. 30B).*

***Table 13**. Median concentrations (µg/kg w.w.) and standard deviations of the PFAS-compounds analysed in cod liver in 2016. 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 2.7 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	PFBS			PFNA			PFOA			PFOS			PFOSA			PFUDA		
Species and sampling locality	2016	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)	15(2-2)	0.2	0		0.5	0.049	1[0.69]	0.5	0		2.7	3.123	15[0.86 - 14]	5	2.163	15[1.8 - 11]	0.42	0.502	9[0.42 - 2.3]
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	0.2	0		0.5	0.065	1[0.75]	0.5	0		2.1	0.724	15[1.4 - 3.9]	3.5	1.182	15[1.3 - 5.8]	0.4	0.062	6[0.41 - 0.62]
Kristiansand harbour area (st. 13B)	15	0.2	0		0.5	0.013	1[0.55]	0.5	0		1.2	0.38	15[0.66 - 2]	0.67	0.539	15[0.2 - 2.2]	0.5	0.138	7[0.51 - 0.95]
Inner Sørfjord (st. 53B)	15(12-2)	0.2	0		0.5	0.155	1[1.1]	0.5	0		0.76	0.299	14[0.52 - 1.2]	0.28	0.192	15[0.18 - 0.81]	0.88	0.367	13[0.61 - 1.5]
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.2	0		0.5	0		0.5	0		1.3	0.552	15[0.58 - 2.9]	1.3	5.259	15[0.25 - 21]	0.4	0.114	3[0.4 - 0.84]
Bergen harbour area (st. 24B)	15(3-3)	0.2	0		0.5	0		0.5	0.081	5[0.51 - 0.81]	0.5	0.279	15[0.38 - 1.4]	0.89	0.535	15[0.35 - 2.1]	0.4	0.051	3[0.46 - 0.58]
Trondheim harbour (st. 80B)	14(3-2)	0.2	0.045	1[0.37]	0.5	0		0.5	0		0.765	0.29	14[0.25 - 1.2]	1.065	2.22	13[0.16 - 7.4]	0.4	0.056	2[0.4 - 0.61]
Austnesfjord, Lofoten (st. 98B1)	15	0.2	0		0.5	0.023	1[0.59]	0.5	0		0.62	0.914	15[0.31 - 3.2]	0.73	0.616	15[0.16 - 2.2]	0.4	0.06	5[0.47 - 0.6]
Tromsø harbour area (st. 43B2)	12(3-2)	0.2	0		0.5	0		0.5	0		0.455	0.229	12[0.12 - 0.86]	0.695	0.654	11[0.11 - 2.5]	0.4	0	

3.2.23 Hexabromocyclododecanes (HBCD)

Hexabromocyclododecanes (HBCD) is a persistent pollutant which bioaccumulates 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 cod liver at 12 stations and in blue mussel at nine stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

When applying the EQS for HBCD (167 µg/kg w.w.), all concentrations were below EQS in 2016 for both blue mussel and cod liver.

Levels exceeding PROREF

The concentrations of HBCD in blue mussel from Nordnes (st. I241) in Bergen exceeded the provisional high reference concentration (PROREF) by a factor up to two.

The concentrations of HBCD in cod liver from the Inner Oslofjord (st. 30B) exceeded PROREF by a factor between two and five.

Downward trends

Significant downward long-term and short-term trends were found for HBCD in blue mussel from Svolvær airport area (st. 98A2).

There were significant downward long-term and short-term trends for HBCD in cod liver from Stathelle area in the Langesundfjord (st. 71B).

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 35***, ***Table 14***). Highest concentrations of HBCD were also found in cod from the Inner Oslofjord (st. 30B), Bergen harbour (st. 24B) and Trondheim harbour (st. 80B). The median concentration of HBCD in cod liver from the Inner Oslofjord (st. 30B) was 16.2 µg/kg w.w.

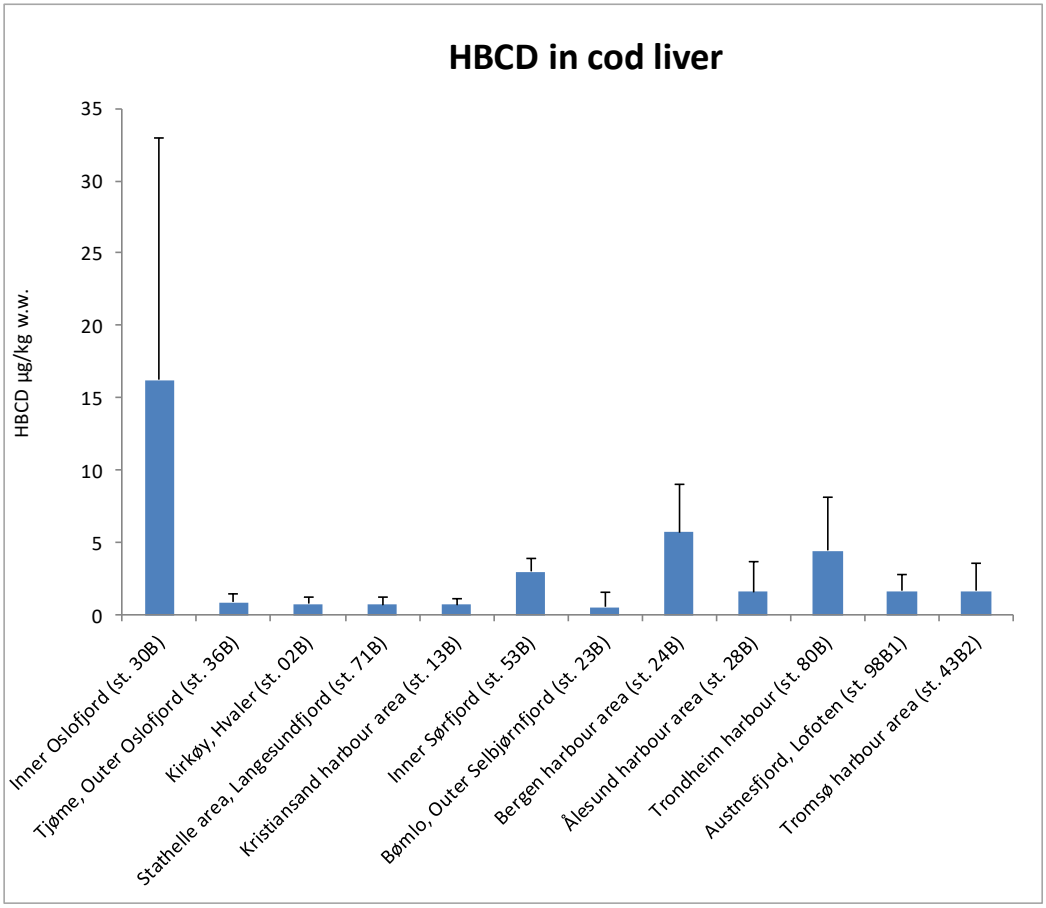


***Figure 35**. Median concentration (µg/kg w.w.) of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver in 2016. The error bar indicates one standard deviation above the median.*

***Table 14**. Median concentration (µg/kg w.w.) with standard deviation of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver and blue mussel in 2016.* 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 2.7 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	α–HBCD			γ–HBCD			β–HBCD			HBCD		
Species and sampling locality	2016	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(3-37)	0.099	0.009	3 (0.085 - 0.103)	0.006	0.001	3 (0.005 - 0.008)	0.003	0.000	3 (0.003 - 0.004)	0.107	0.008	3 (0.097 - 0.112)
Færder, Outer Oslofjord (st. 36A)	3(3-20)	0.013	0.002	3 (0.01 - 0.013)	0.002	0.001	3 (0.001 - 0.003)	0.001	0.000		0.015	0.003	3 (0.011 - 0.016)
Singlekalven, Hvaler (st. I023)	3(3-92)	0.065	0.012	3 (0.06 - 0.082)	0.007	0.001	3 (0.006 - 0.007)	0.005	0.001	3 (0.003 - 0.006)	0.078	0.010	3 (0.072 - 0.091)
Bjørkøya, Langesundfjord (st. 71A)	1(1-20)	0.046	0.000	1 (0.046 - 0.046)	0.019	0.000	1 (0.019 - 0.019)	0.003	0.000	1 (0.003 - 0.003)	0.067	0.000	1 (0.067 - 0.067)
Sylterøya, Langesundfjord (st. I714)	3(3-50)	0.024	0.003	3 (0.021 - 0.026)	0.005	0.000	3 (0.005 - 0.005)	0.001	0.000	3 (0.001 - 0.002)	0.030	0.002	3 (0.027 - 0.032)
Nordnes, Bergen harbour (st. I241)	1(1-20)	0.188	0.000	1 (0.188 - 0.188)	0.022	0.000	1 (0.022 - 0.022)	0.006	0.000	1 (0.006 - 0.006)	0.216	0.000	1 (0.216 - 0.216)
Ørland area, Outer Trondheimsfjord (st. 91A2)	2(2-78)	0.086	0.083	2 (0.027 - 0.145)	0.011	0.011	2 (0.003 - 0.019)	0.010	0.012	2 (0.001 - 0.018)	0.107	0.106	2 (0.032 - 0.182)
Mjelle, Bodø area (st. 97A2)	3(3-100)	0.0444	0.008	3 (0.033 - 0.048)	0.0081	0.002	3 (0.006 - 0.01)	0.0029	0.000	3 (0.002 - 0.003)	0.0555	0.010	3 (0.042 - 0.06)
Svolvær airport area (st. 98A2)	2(2-90)	0.01305	0.002	2 (0.012 - 0.014)	0.0039	0.003	2 (0.002 - 0.006)	0.0013	0.000	1 (0.001 - 0.001)	0.01765	0.006	2 (0.013 - 0.022)
Cod, liver													
Inner Oslofjord (st. 30B)	15(2-2)	16	16.397	15 (2.14 - 71.6)	0.356	0.320	2 (0.002 - 0.006)	0.0665	0.065	12 (0.035 - 0.272)	16.2232	16.760	15 (2.191 - 73.192)
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	0.823	0.560	15 (0.413 - 2.61)	0.029	0.016	15 (0.051 - 1.32)	0.028	0.001		0.850	0.575	15 (0.413 - 2.651)
Kirkøy, Hvaler (st. 02B)	5(4-2)	0.460	0.306	5 (0.271 - 1.05)	0.389	0.186		0.062	0.064	5 (0.041 - 0.199)	0.763	0.516	5 (0.516 - 1.833)
Stathelle area, Langesundfjord (st. 71B)	15(6-2)	0.543	0.338	15 (0.171 - 1.41)	0.092	0.303	5 (0.118 - 0.584)	0.029	0.004		0.698	0.535	15 (0.233 - 2.255)
Kristiansand harbour area (st. 13B)	15	0.644	0.430	15 (0.275 - 1.77)	0.031	0.009	15 (0.048 - 1.16)	0.030	0.001		0.667	0.439	15 (0.275 - 1.813)
Inner Sørfjord (st. 53B)	15(12-2)	2.750	0.896	15 (0.878 - 3.59)	0.125	0.088	9 (0.03 - 0.057)	0.029	0.038		2.986	0.913	15 (0.915 - 3.777)
Bømlo, Outer Selbjørnfjord (st. 23B)	15	0.449	0.326	15 (0.201 - 1.34)	0.053	0.614	15 (0.037 - 0.323)	0.030	0.153		0.534	1.055	15 (0.207 - 4.379)
Bergen harbour area (st. 24B)	15(3-3)	5.670	3.349	15 (0.365 - 11.5)	0.043	0.038	11 (0.035 - 2.42)	0.029	0.002		5.690	3.372	15 (0.365 - 11.632)
Ålesund harbour area (st. 28B)	7(1-2)	1.440	2.100	7 (0.262 - 6.34)	0.084	0.036	11 (0.038 - 0.133)	0.030	0.006		1.597	2.112	7 (0.33 - 6.457)
Trondheim harbour (st. 80B)	14(3-2)	4.240	3.646	14 (0.276 - 11.7)	0.148	0.115	6 (0.05 - 0.131)	0.029	0.015		4.409	3.731	14 (0.331 - 11.935)
Austnesfjord, Lofoten (st. 98B1)	15	1.570	1.136	15 (0.37 - 4.32)	0.038	0.040	14 (0.05 - 0.378)	0.030	0.078		1.667	1.167	15 (0.37 - 4.368)
Tromsø harbour area (st. 43B2)	12(3-2)	1.515	1.572	12 (0.532 - 5.14)	0.108	0.603	10 (0.032 - 0.181)	0.033	0.302	6 (0.037 - 1.09)	1.651	1.893	12 (0.575 - 5.487)

Cod liver showed about-100 times higher concentrations than in blue mussel on a wet weight basis (compare ***Figure 36*** and ***Figure 37***). The difference was smaller on a lipid basis. There are some indications of biomagnification for specific diastereomers of HBCD (Haukås 2009).

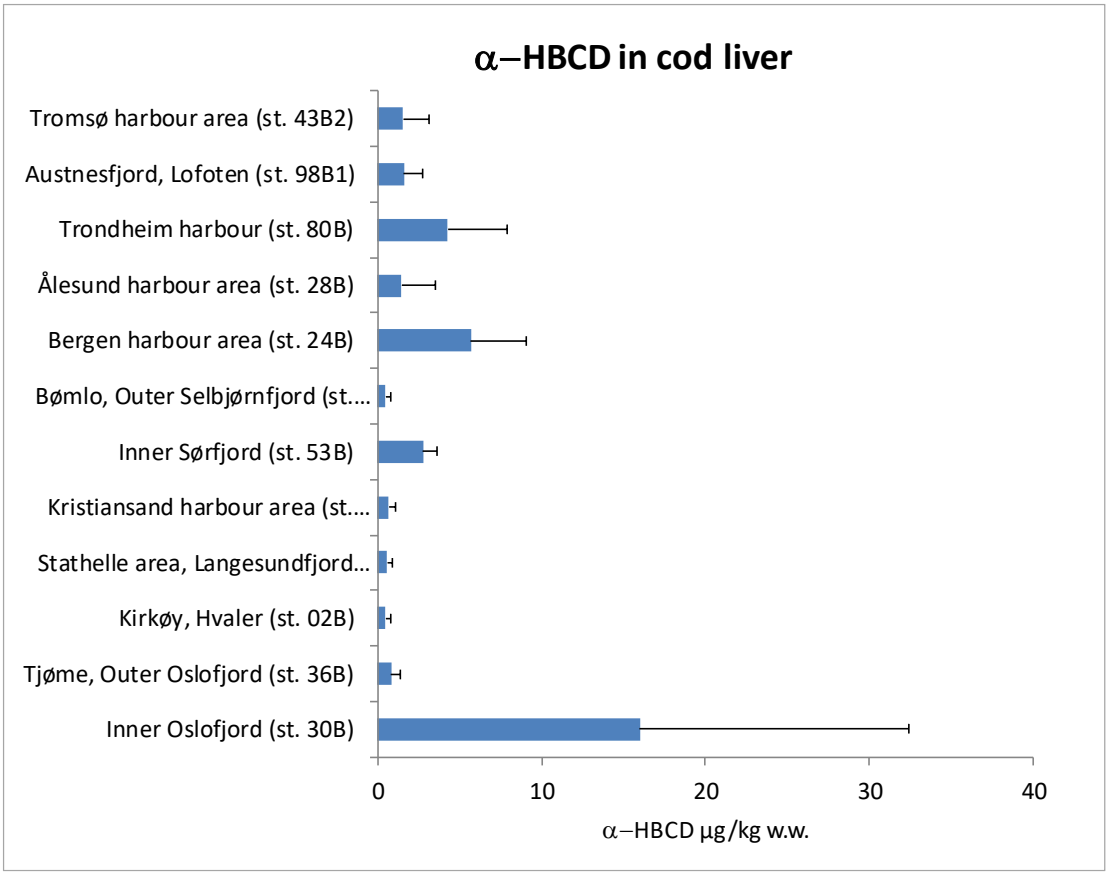


Figure 36*. Mean concentration (µg/kg w.w.) of α–HBCD in cod liver in 2016. The error bar indicates one standard deviation above the mean.*

Blue mussel from Bergen harbour (Nordnes, st. I241) had concentrations of α–HBCD that were significantly higher than for all the other stations (Tukey-Kramer HSD test, see also ***Figure 37***).

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 38***). In 2006, the discharge to water was 0.51 kg and during the following years the discharges have gradually decreased to 0.09 kg in 2015.

Riverine loads for HBCD isomers for 2014 has been estimated to be in the range 0.026-4.2 g/year for river Alna (Inner Oslofjord), 35-280 g/year for river Drammenselva (Mid Oslofjord) and 210-1079 g/year for river Glomma (Outer Oslofjord) (Skarbøvik *et al*. 2015 – M-439|2015).

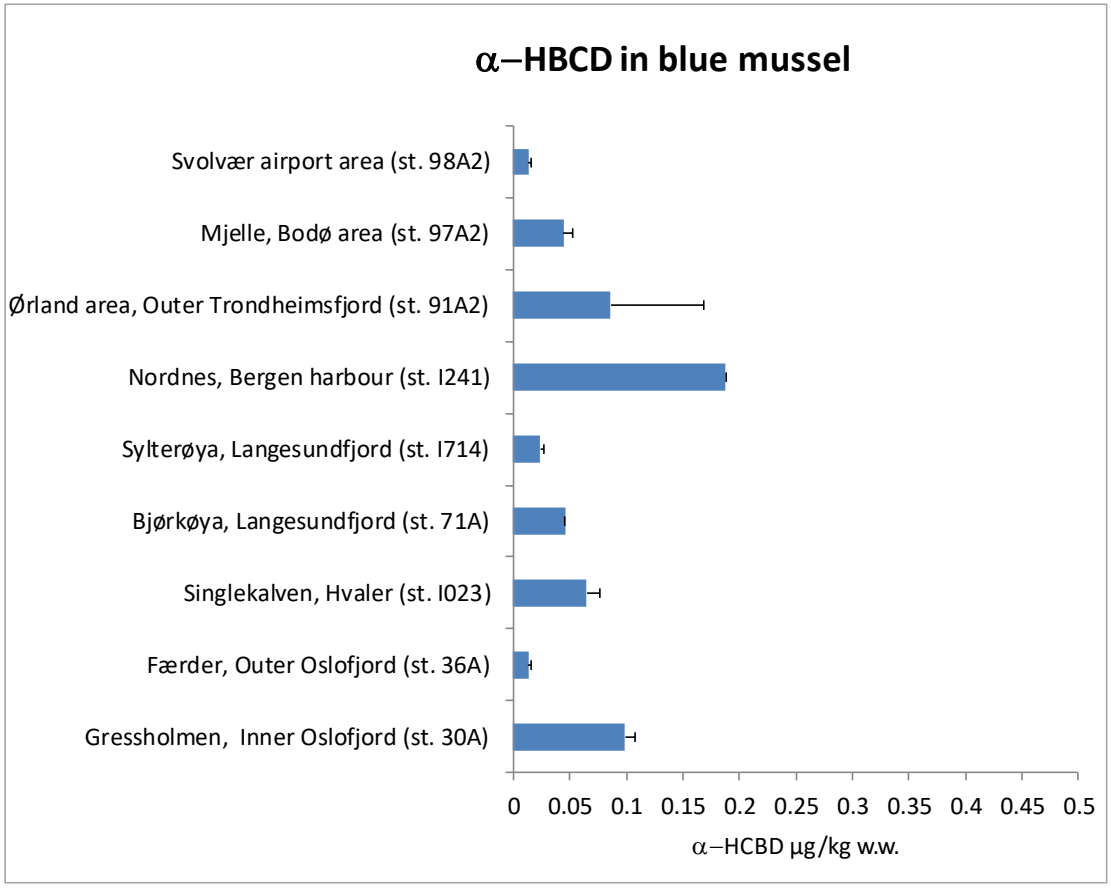


***Figure 37**. Mean concentration (µg/kg w.w.) of α–HBCD in blue mussel in 2016. The error bar indicates one standard deviation above the mean.*

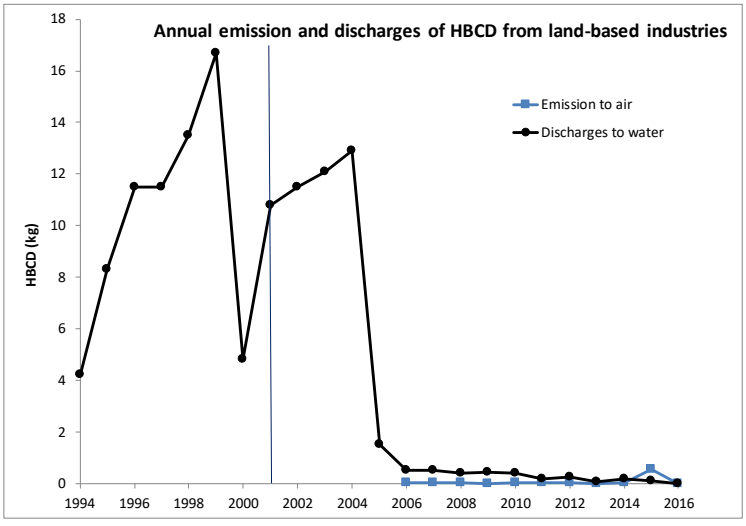


***Figure 38**. Annual emissions of HBCD to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). HBCD has been monitored in this project since 2001 (indicated with a vertical line). No data for emissions to air are reported for 2002-2005. Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

3.2.24 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 cod liver at 10 stations and in blue mussel at 10 stations.

Chlorinated paraffins are subdivided according to their carbon chain length into short chain chlorinated paraffins (SCCPs, C_{10-13}) and medium chain chlorinated paraffins (MCCPs, C_{14-17}). The EQS for SCCP and MCCP in biota 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 pollutants

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 Water region specific substances

When applying the EQS for MCCP (170 µg/kg w.w.) in biota, median concentrations MCCP in cod liver exceeded EQS for eight of the stations. Only cod from Bømlo, Outer Selbjørnfjord (st. 23B) and Kristiansand harbour area (st. 13B) had concentrations of MCCP in liver below the EQS. Cod from Bergen harbour (st. 24B) had highest concentration of MCCPs with median concentration of 1850 µg/kg w.w., and maximum concentration of 2689 µg/kg w.w. High individual variation was observed (***Figure 42***, ***Table 15***). Cod from the Inner Oslofjord (st. 30B) showed also high concentrations of MCCPs in liver, with median concentration of 848 µg/kg.

Levels exceeding PROREF

The concentration of SCCP in cod liver ranged from 31 to 493 µg/kg w.w., with highest concentrations in cod from Bergen harbour area (st. 24B, ***Figure 40***, ***Table 15***). The median concentration of SCCPs in cod liver from Bergen harbour area exceeded the provisional high reference concentration PROREF by a factor between two and five.

The concentrations of MCCPs found in cod from the Inner Oslofjord and Bergen harbour area 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. 98B2). There were significant short-term and long-term upward trends for MCCP in cod liver from Kirkøy, Hvaler (st. 02B). A significant long-term upward trend was found for MCCP in liver of cod from Bømlo, Outer Selbjørnfjord (st. 23B). Though no trend was detected for MCCP in liver from the Inner Oslofjord (st. 30B), a significant upward trend was registered when fish length was taken into account (***Figure 39a*** and ***b***, respectively).

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

General, large scale trends

The concentration of SCCP in blue mussel ranged from 1.42 to 20.8 µg/kg w.w. in this study and the highest concentration was found in the samples from Bjørkøya, Langesundfjord (st. 71A, ***Figure 41***).

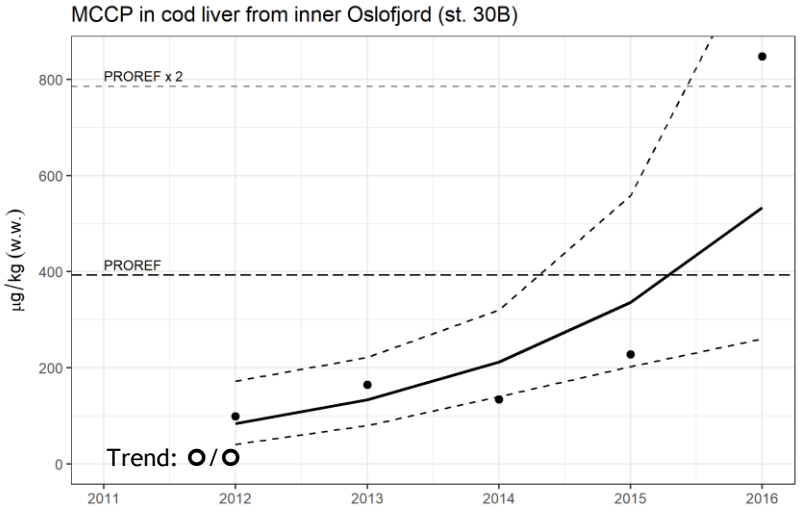
The concentrations of MCCPs in blue mussel were lower than in cod, and ranged from 14.6 to 114 µg/kg w.w. Blue mussel from Nordnes, Bergen harbour (st. I241), Sylterøya, Langesundfjord (st. I714) and Vågsvåg, Outer Nordfjord (st. 26A2) revealed the highest concentrations of MCCPs (***Figure 43***).

Other studies

Cod from the Inner Oslofjord had concentrations of SCCP in liver in the range of 111 to 555 µg/kg w.w. Ruus *et al.* (2016b) found similar levels of SCCP in cod from the Inner Oslofjord (3.5 to 107 µg/kg w.w.). Concentrations observed in samples from urban areas are frequently higher than from other more sparsely populated areas.

Riverine loads for SCCPs for 2014 has been estimated to 0.82 kg/year for river Alna (Inner Oslofjord), 6.9 kg/year for river Drammenselva (Mid Oslofjord) and 15.8-19.4 kg/year for river Glomma (Outer Oslofjord) (Skarbøvik 2015). Riverine loads for MCCPs for 2014 has been estimated to 0.31 kg/year for river Alna, 4.2 kg/year for river Drammenselva and 11.8 kg/year for river Glomma.

A



B

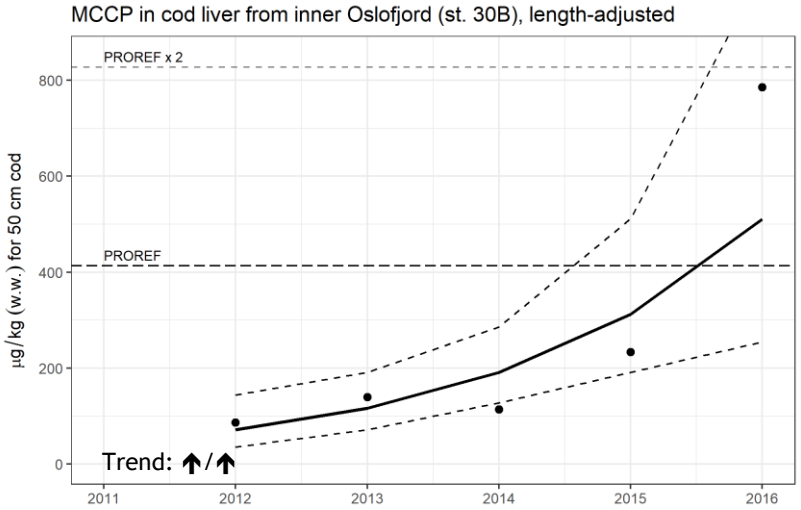


***Figure 39**. Median concentrations (mg/kg w.w.) of MCCP in cod liver from 2012 to 2016 in the Inner Oslofjord (st. 30B); no adjustment for length (**A**) and adjusted for length (**B**). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C**). *NB: Time-series is 5 years, hence, long-term and short-term trend analyses are identical. Also 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 0.0512 and where there is an adjusted for length (**B**) the p-values is 0.0423, and hence significant.*

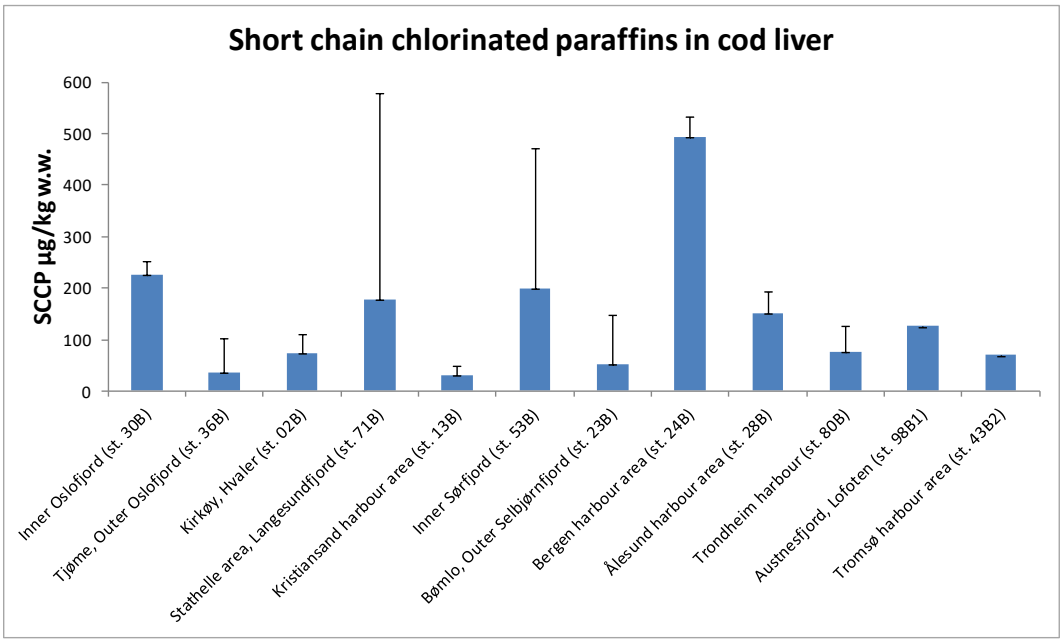


***Figure 40**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in cod liver in 2016. The error bar indicates one standard deviation above the median.*

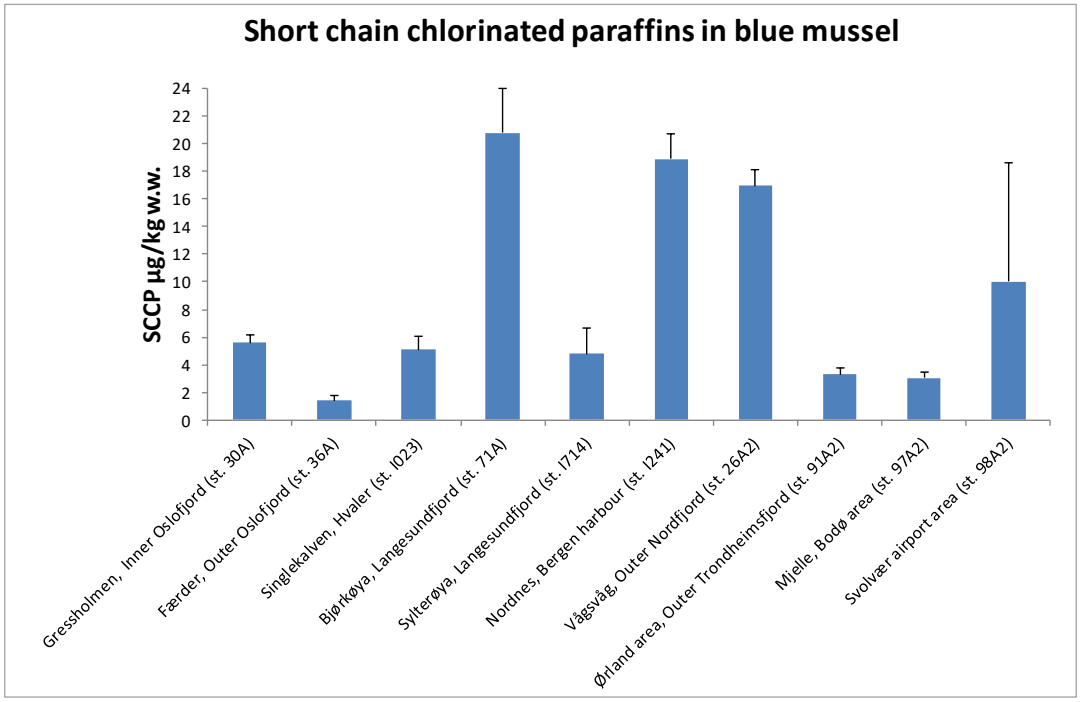


***Figure 41**. Median concentration (µg/kg w.w.) of short chain chlorinated paraffins (SCCP) in blue mussel in 2016. The error bar indicates one standard deviation above the median.*

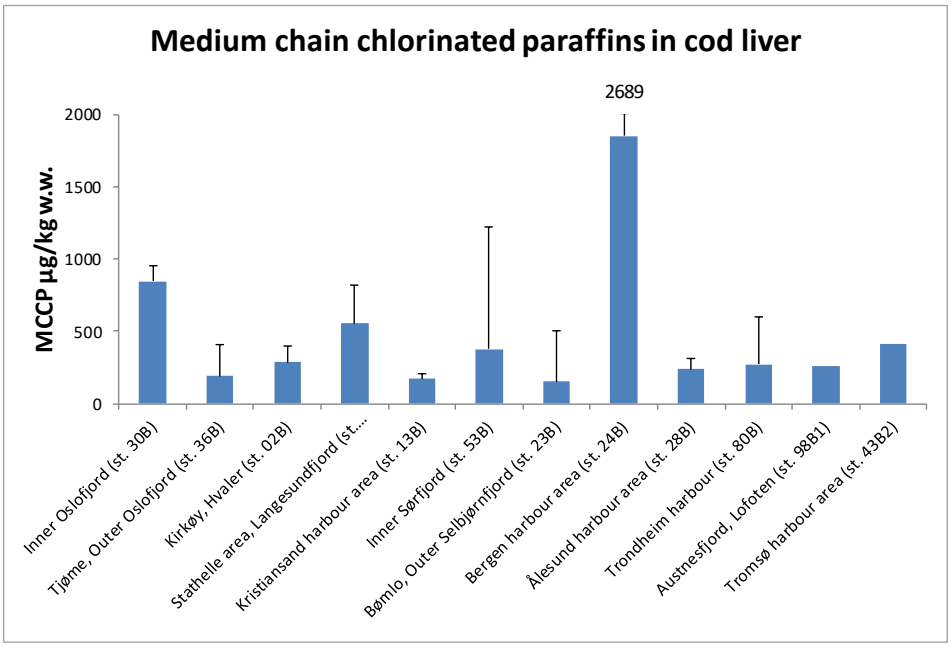


***Figure 42**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in cod liver in 2016. The error bar indicates one standard deviation above the median.*

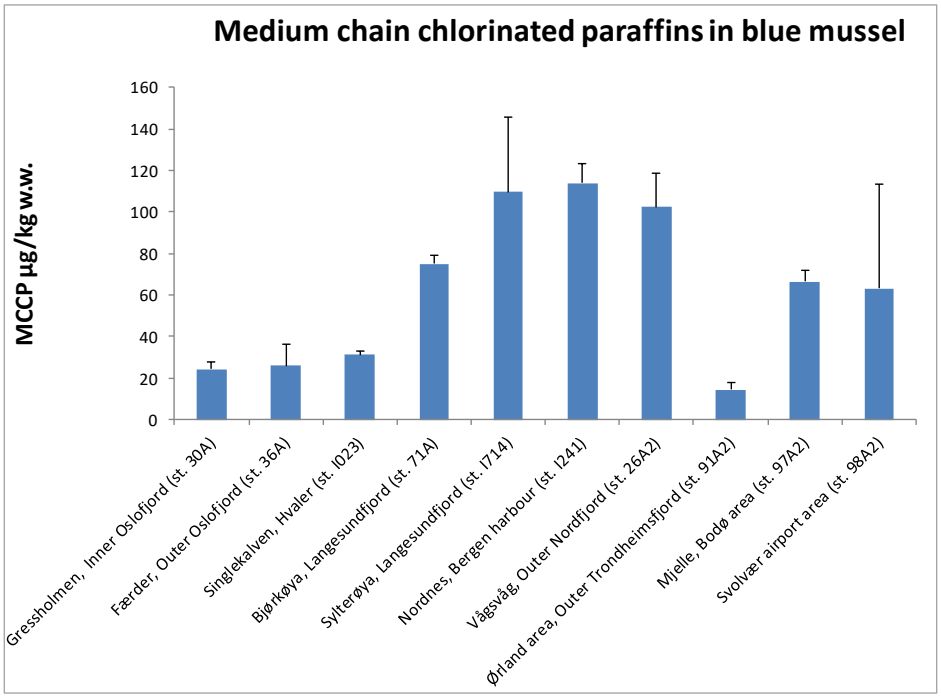


***Figure 43**. Median concentration (µg/kg w.w.) of medium chain chlorinated paraffins (MCCPs) in blue mussel in 2016. The error bar indicates one standard deviation above the median.*

***Table 15**. Median concentrations (µg/kg w.w.) with standard deviation of short chain chlorinated paraffins (SCCPs) and medium chain chlorinated paraffins (MCCPs) in blue mussel and cod in 2016. 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 2.7 for more details.)*

Component	Count	SCCP			MCCP		
Species and sampling locality	2016	Med.	S.d.	D.d.i	Med.	S.d.	D.d.i
Blue mussel							
Gressholmen, Inner Oslofjord (st. 30A)	3(3-37)	5.57	0.57	3[4.84 - 5.97]	24.20	4	3[19.6 - 26.8]
Færder, Outer Oslofjord (st. 36A)	3(3-20)	1.42	0.34	3[1.11 - 1.79]	25.90	10.666	3[20.4 - 41]
Singlekalven, Hvaler (st. I023)	3(3-92)	5.08	0.96	3[3.59 - 5.39]	31.40	1.808	3[29.3 - 32.9]
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	20.80	3.18	3[15.5 - 21.2]	75.20	4.119	3[69.5 - 77.5]
Sylterøya, Langesundfjord (st. I714)	2(2-50)	4.81	1.81	2[3.53 - 6.09]	109.65	35.85	2[84.3 - 135]
Nordnes, Bergen harbour (st. I241)	3(3-20)	18.90	1.79	3[18.7 - 21.9]	114.00	9.609	3[102 - 121]
Vågsvåg, Outer Nordfjord (st. 26A2)	2(2-65)	16.95	1.20	2[16.1 - 17.8]	102.50	16.263	2[91 - 114]
Ørland area, Outer Trondheimsfjord (st. 91A2	3(3-78)	3.30	0.46	3[2.99 - 3.9]	14.60	3.625	3[13.9 - 20.5]
Mjelle, Bodø area (st. 97A2)	3(3-100)	3.07	0.41	3[2.97 - 3.72]	66.40	5.369	3[59.2 - 69.7]
Svolvær airport area (st. 98A2)	2(2-120)	10.00	8.63	2[3.9 - 16.1]	63.30	50.487	2[27.6 - 99]
Cod, liver							
Inner Oslofjord (st. 30B)	15(2-2)	225.00	117.77	15[111 - 555]	848.00	675.997	15[245 - 2590]
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	35.70	15.90	15[24.4 - 73.5]	193.00	70.448	15[101 - 350]
Kirkøy, Hvaler (st. 02B)	4(3-2)	74.15	25.33	4[46.7 - 107]	288.00	104.555	4[190 - 396]
Stathelle area, Langesundfjord (st. 71B)	15(6-2)	178.00	66.04	15[68.7 - 313]	556.00	212.559	15[278 - 1170]
Kristiansand harbour area (st. 13B)	15	31.00	35.96	15[20.7 - 140]	170.00	114.125	15[116 - 480]
Inner Sørfjord (st. 53B)	15(12-2)	199.00	399.31	15[37.9 - 1600]	379.00	266.129	15[190 - 1090]
Bømlo, Outer Selbjørnfjord (st. 23B)	15	51.80	16.48	15[19 - 64.1]	154.00	34.396	15[76.8 - 174]
Bergen harbour area (st. 24B)	15(3-3)	493.00	272.10	15[205 - 1260]	1850.00	838.592	15[784 - 4460]
Ålesund harbour area (st. 28B)	7(1-2)	151.00	95.23	7[32.5 - 313]	240.00	352.039	7[134 - 1140]
Trondheim harbour (st. 80B)	14(3-2)	75.95	39.48	14[21.4 - 153]	272.00	152.828	14[90.1 - 586]
Austnesfjord, Lofoten (st. 98B1)	15	126.00	42.14	15[60.9 - 190]	259.00	74.516	15[151 - 393]
Tromsø harbour area (st. 43B2)	11(3-2)	70.70	50.15	11[36.1 - 185]	411.00	331.764	11[321 - 1330]

3.2.25 Organophosphorus flame retardants (PFRs)

Organophosphorus flame retardants (PFRs) were analysed in cod liver at 10 stations and in blue mussel at 10 stations.

Many of the PFRs are persistent and bioaccumulate. Some of the PFRs are classified as hazardous to the environment. These include: tri(2-chloroethyl)phosphate (TCEP), 2-ethylhexyl-di-phenylphosphate (EHDPP), tri(1,3-dichloro-2-propyl)phosphate (TDCP), tricresylphosphate (TCrP) and triphenylphosphate (TPhP). TDCP and TCEP are suspected to cause cancer, and neurological and reproductive harm. Some of the PFRs are suspected to be carcinogenic (TBP, TCEP and TDCP). TCEP is on the priority list of Norwegian Environment Agency[1]. These substances are used *inter alia* as a softener in vinyl plastics, as a flame retardant and as an additive in hydraulic fluids (van der Veen & de Boer 2012).

The concentrations of PFRs were generally low and all median concentrations were below the quantification limits (***Table 16***). It should be noted that PFRs are generally difficult to separate from the lipid portion of a sample before chemical analysis. The difficulty to separate PFRs can lead to analytical interference and often result in a higher quantification limit. This problem can vary from sample to sample. Hence more variable and higher quantification limits are typical for PFR analyses when compared to analyse of other contaminant groups such as PCBs, PBDEs (***Table 12***) or PFAS (***Table 13***).

[1] *http://www.miljostatus.no/Tema/Kjemikalier/Kjemikalielister/Prioritetslisten/*

***Table 16**. Median concentrations (µg/kg w.w.) with standard deviation of organophosphorus flame retardants (PFRs) in blue mussel and cod liver in 2016. 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 2.7 for more details and **Appendix B** for description of chemical codes.)*

Component	Count	TBEP			TBP			TCEP			TCPP			TDCP			TEHP			EHDPP		
Species and sampling locality	2016	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																						
Gressholmen, Inner Oslofjord (st. 30A)	3(3-37)	5.9	3.9		5.9	3.9		3.0	1.9		5.9	3.9		3.0	2.9		11.8	7.8		5.9	3.9	
Singlekalven, Hvaler (st. I023)	3(3-92)	0.8	0.2		0.8	0.2		0.4	0.1		1.6	0.3	2[1.55 - 1.56]	0.4	0.1		1.6	0.4		0.8	0.2	
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	1.3	0.0		1.3	0.0		0.7	0.0		1.4	0.1		0.7	0.0		2.6	0.1		1.3	0.0	
Nordnes, Bergen harbour (st. I241)	3(3-20)	2.1	0.1		2.1	0.1		1.1	0.1		2.4	1.2	1[4.17]	1.1	0.2		4.2	0.2		2.1	0.1	
Vågsvåg, Outer Nordfjord (st. 26A2)	2(2-65)	1.5	0.2		1.5	0.2		0.8	0.1		2.1	0.6	1[2.56]	0.8	0.1		3.0	0.4		1.5	0.2	
Ørland area, Outer Trondheimsfjord (st. 91A2)	2(2-78)	1.1	0.0		1.1	0.0		0.5	0.0		1.3	0.3		0.5	0.0		2.2	0.0		1.1	0.0	
Mjelle, Bodø area (st. 97A2)	2(2-50)	0.9	0.0		0.9	0.0		0.4	0.0		0.9	0.0		0.4	0.0		1.7	0.1		0.9	0.0	
Svolvær airport area (st. 98A2)	3(3-120)	1.9	0.1		1.9	0.1		0.9	0.0		1.9	0.2		0.9	0.0		3.7	0.2		1.9	0.1	
Cod, liver																						
Inner Oslofjord (st. 30B)	15(2-2)	15.1	1.5		15.1	1.5		7.5	0.8		15.1	1.5		7.5	0.8		30.1	3.0		15.1	1.5	
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	12.9	1.0		12.9	1.0		6.4	0.5		12.9	1.0		6.4	0.5		25.7	2.1		12.9	1.0	
Kirkøy, Hvaler (st. 02B)	4(3-2)	11.3	0.5		11.7	1.4		5.6	0.2		11.3	0.5		5.6	0.2		22.6	1.0		11.3	0.5	
Stathelle area, Langesundfjord (st. 71B)	15(6-2)	13.5	1.5		13.6	1.4		6.8	0.7		13.5	1.5		6.8	0.7		27.0	2.9		13.5	1.5	
Kristiansand harbour area (st. 13B)	15	12.9	1.2		13.1	1.3		6.4	0.6		12.9	1.2		6.4	0.6		25.7	2.5		12.9	1.2	
Inner Sørfjord (st. 53B)	15(12-2)	14.4	1.4		14.4	1.4		7.2	0.7		14.4	1.4		7.2	0.7		28.7	2.7		14.4	1.4	
Bømlo, Outer Selbjørnfjord (st. 23B)	15	14.1	2.1		14.1	2.1		7.1	1.0		14.1	2.1		7.1	1.0		28.3	4.1		14.1	2.1	
Bergen harbour area (st. 24B)	15(3-3)	13.6	0.7		13.6	0.7		6.8	0.3		13.6	0.7		6.8	0.3		27.2	1.3		13.6	0.7	
Ålesund harbour area (st. 28B)	6(1-2)	14.5	2.9		15.7	2.6		7.3	1.4		14.5	2.9		7.3	1.4		29.1	5.8		14.5	2.9	
Trondheim harbour (st. 80B)	14(3-2)	13.8	3.7		13.9	4.1		6.9	1.8		13.8	3.7		6.9	1.8		27.6	7.3		13.8	3.7	
Austnesfjord, Lofoten (st. 98B1)	15	15.2	0.9		15.4	1.0		7.6	0.4		15.2	0.9		7.6	0.4		30.5	1.8		15.2	0.9	
Tromsø harbour area (st. 43B2)	12(3-2)	15.1	2.2		15.1	2.2		7.5	1.1		15.1	2.2		7.5	1.1		30.2	4.4		15.1	2.2	

3.2.26 Bisphenol A (BPA)

Bisphenol A (BPA) was analysed in cod liver from 11 locations and in blue mussel from 10 stations.

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].

The concentrations of BPA in cod liver and blue mussel were very low and all concentrations were below the quantification limits (***Table 17***). Hence, no conclusion can be drawn regarding possible differences between stations.

Table 17*. Median concentrations (µg/kg w.w.) with standard deviation of bisphenol A (BPA) in blue mussel and cod liver in 2016. 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 2.7 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(3-37)	1.0	0.0	
Færder, Outer Oslofjord (st. 36A)	3(3-20)	1.0	0.0	
Singlekalven, Hvaler (st. I023)	3(3-92)	1.0	0.0	
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	1.0	0.0	
Sylterøya, Langesundfjord (st. I714)	3(3-50)	1.0	0.0	
Nordnes, Bergen harbour (st. I241)	3(3-20)	1.0	0.0	
Vågsvåg, Outer Nordfjord (st. 26A2)	3(3-111)	1.0	0.0	
Ørland area, Outer Trondheimsfjord (st. 91A2)	3(3-78)	1.0	0.0	
Mjelle, Bodø area (st. 97A2)	3(3-100)	1.0	0.0	
Svolvær airport area (st. 98A2)	3(3-120)	1.0	0.0	
Cod, liver				
Inner Oslofjord (st. 30B)	15(2-2)	1.0	0.0	
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	1.0	0.0	
Kirkøy, Hvaler (st. 02B)	5(4-2)	1.0	0.0	
Stathelle area, Langesundfjord (st. 71B)	15(6-2)	1.0	0.0	
Kristiansand harbour area (st. 13B)	15	1.0	0.0	
Inner Sørfjord (st. 53B)	15(12-2)	1.0	0.0	
Bømlo, Outer Selbjørnfjord (st. 23B)	15	1.0	0.0	
Bergen harbour area (st. 24B)	15(3-3)	1.0	0.0	
Ålesund harbour area (st. 28B)	6(1-2)	1.0	0.0	
Trondheim harbour (st. 80B)	14(3-2)	1.0	0.0	
Tromsø harbour area (st. 43B2)	12(3-2)	1.0	0.0	

[1] *http://www.miljostatus.no/Tema/Kjemikalier/Kjemikalielister/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 at 11 stations and in blue mussel at 10 stations.

Concentrations of TBBPA found in cod liver were generally low. Cod from Hvaler had median concentration of 0.5 µg/kg w.w., for the other stations the median concentrations were below the limit of quantification. TBBPA in blue mussels were below the limit of quantification for 5 of 10 stations (***Table 18***). The median concentrations were low, ranging from 0.021 to 0.072 µg/kg w.w.

Table 18. *Median concentrations (µg/kg w.w.) with standard deviation of TBBPA in blue mussel and cod liver in 2015. 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 2.7 for more details.)*

Component	Count	TBBPA		
Species and sampling locality	2016	Med.	S.d.	D.d.i.
Blue mussel				
Gressholmen, Inner Oslofjord (st. 30A)	3(3-37)	0.0	0.0	
Færder, Outer Oslofjord (st. 36A)	2(2-20)	0.0	0.0	
Singlekalven, Hvaler (st. I023)	3(3-92)	0.1	0.0	3[0.051 - 0.0819]
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	0.1	0.1	2[0.0715 - 0.142]
Sylterøya, Langesundfjord (st. I714)	3(3-50)	0.0	0.0	2[0.0225 - 0.0882]
Nordnes, Bergen harbour (st. I241)	3(3-20)	0.1	0.1	1[0.0672]
Vågsvåg, Outer Nordfjord (st. 26A2)	2(2-65)	0.0	0.0	1[0.0252]
Ørland area, Outer Trondheimsfjord (st. 91A2)	3(3-78)	0.0	1.8	
Mjelle, Bodø area (st. 97A2)	2(2-50)	0.0	0.0	1[0.0337]
Svolvær airport area (st. 98A2)	3(3-120)	0.2	0.1	2[0.0328 - 0.0849]
Cod, liver				
Inner Oslofjord (st. 30B)	15(2-2)	0.9	0.1	1[0.774]
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	0.6	1.1	
Kirkøy, Hvaler (st. 02B)	5(4-2)	0.5	1.8	2[0.937 - 4.59]
Stathelle area, Langesundfjord (st. 71B)	15(6-2)	0.5	0.0	
Kristiansand harbour area (st. 13B)	15	0.5	1.6	1[6.56]
Inner Sørfjord (st. 53B)	15(12-2)	1.0	0.2	
Bømlo, Outer Selbjørnfjord (st. 23B)	15	3.6	1.4	
Bergen harbour area (st. 24B)	15(3-3)	0.5	0.0	
Ålesund harbour area (st. 28B)	6(1-2)	0.5	0.0	
Trondheim harbour (st. 80B)	14(3-2)	0.5	0.1	

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 11 locations, and in blue mussel from 12 stations.

Environmental Quality Standards (EQS) for EU-priority pollutants

When applying the EQS for nonylphenol (3000 µg/kg w.w.) and octylphenol (0.004 µg/kg w.w.) in biota, all cocentrations were below the EQS in 2016 (***Table 19***). 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 both cod liver and blue mussel were low. All concentrations were below the quantification limits (***Table 19***).

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 1434 kg in 2015 (***Figure 44***).

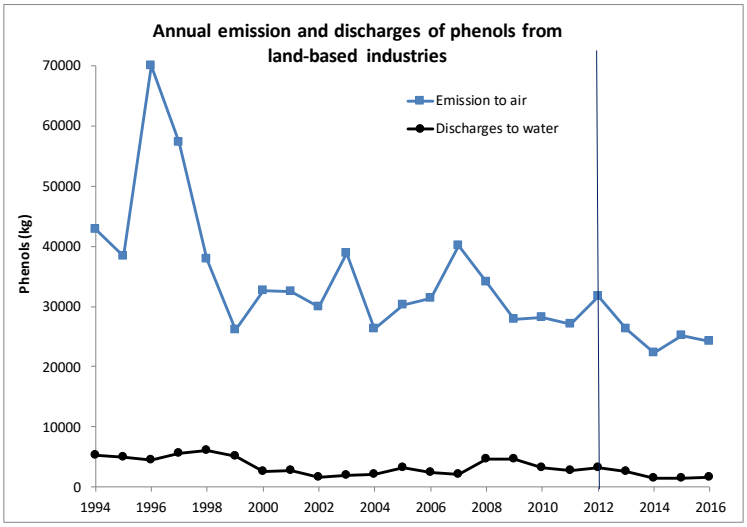


Figure 44. *Annual emissions of phenols to air and discharges to water from land-based industries in the period 1994-2016 (data from www.norskeutslipp.no, 27 June 2017). Phenols have been monitored in this project since 2012 (indicated with a vertical line). Note that emissions and discharges from municipal treatment plants, land runoff, transportation and offshore industry are not accounted for in the figure. New calculation methods for data of emissions and discharges might lead to changes in calculations of present and previous data.*

***Table 19**. Median concentrations (µg/kg w.w.) with standard deviation of alkylphenols in blue mussel and cod liver in 2016. 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 2.7 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	2016	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(3-37)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Singlekalven, Hvaler (st. I023)	3(3-92)	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Bjørkøya, Langesundfjord (st. 71A)	2(2-87)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Nordnes, Bergen harbour (st. I241)	3(3-20)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Vågsvåg, Outer Nordfjord (st. 26A2)	2(2-65)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Ørland area, Outer Trondheimsfjord (st. 91A	2(2-78)	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Mjelle, Bodø area (st. 97A2)	3(3-100)	10.0	0.00		10.0	0.00		150.0	0.00		10.0	0.00	
Svolvær airport area (st. 98A2)	3(3-120)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Cod, liver													
Inner Oslofjord (st. 30B)	15(2-2)	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Tjøme, Outer Oslofjord (st. 36B)	15(14-2)	10.0	0.00		10.0	0.00		100.0	0.00		10.0	0.00	
Kirkøy, Hvaler (st. 02B)	5(4-2)	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Stathelle area, Langesundfjord (st. 71B)	15(6-2)	25.0	0.00		25.0	0.00		200.0	0.00		25.0	0.00	
Kristiansand harbour area (st. 13B)	15	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Inner Sørfjord (st. 53B)	15(12-2)	25.0	1.29		10.0	2.58		100.0	0.00		10.0	0.00	
Bømlo, Outer Selbjørnfjord (st. 23B)	15	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Bergen harbour area (st. 24B)	15(3-3)	25.0	5.86		25.0	5.10		150.0	0.00		25.0	5.03	
Ålesund harbour area (st. 28B)	6(1-2)	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	
Trondheim harbour (st. 80B)	14(3-2)	20.0	0.00		20.0	0.00		100.0	46.44		20.0	0.00	
Tromsø harbour area (st. 43B2)	12(3-2)	20.0	0.00		20.0	0.00		100.0	0.00		20.0	0.00	

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 2016 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) was about half of that in 2015, i.e. approximately the same as in 2013-2014, and ~30 % lower than the 2012-concentration. Median OH-pyrene bile concentration in 2016 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 2016 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.

A significant upward long-term trend could be observed in the Sørfjord (st. 53B) over the last 10 years (**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.

In 2015, ALA-D activities in the blood of cod from the Inner Oslofjord (st. 30B), the Sørfjord (st. 53B) and the Bømlo area (st. 23B) had apparently decreased slightly, or were at the approximate same level as the two previous years. Trend analyses suggest a significant downward

temporal trend over the last 10 years at the reference station (Bømlo area; 23B; **Appendix F**). No significant temporal trend in lead concentrations, could be observed over the last 10 years (**Appendix F**).

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 2016 was apparently at the same level as in the Bømlo-Sotra area (st. 23B, reference station), while the median activity in the Inner Sørfjord (st. 53B) was lower. 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 2013-2016) 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 0.033 mg/kg and 0.051 mg/kg, respectively, in 2016. In the Bømlo-Sotra area (st. 23B) the concentration was below the limit of detection (<0.03 mg/kg). The higher concentrations of lead in cod liver are generally observed in the Inner Oslofjord and Inner Sørfjord compared to Bømlo, though with a relatively large individual variation.

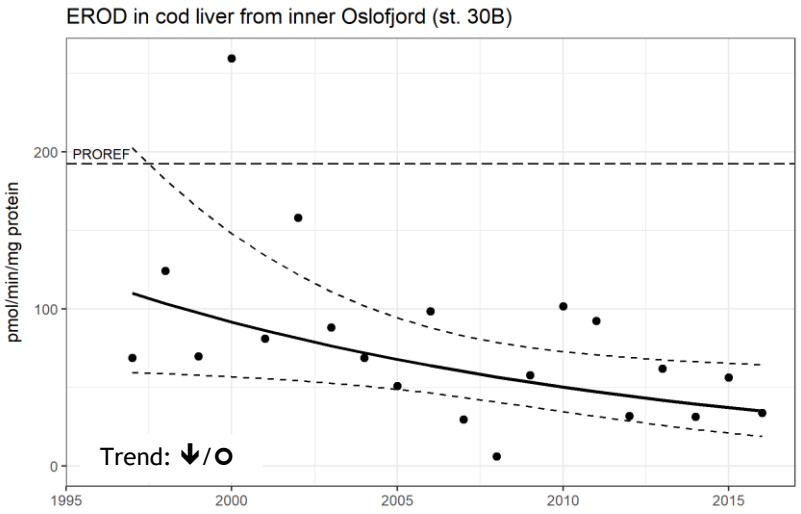
3.3.3 EROD-activity and amount of CYP1A in liver

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 2016, median EROD-activity in liver of cod from the Inner Oslofjord (st. 30B) was similar to that observed in 2014 (i.e. approximately half of that in 2013 and 2015). 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). This was not the case in 2016, as in 2014, when EROD activities in cod from the Inner Oslofjord (st. 30B) and Bømlo (st. 23B) were similar. The median EROD activity in cod from the Sørfjord (st. 53B) was also similar to that at the reference station (Bømlo, st. 23B) in 2016. Statistically significant downward trends in EROD activity were observed on a long-term basis (whole data series) in the Inner Oslofjord (st. 30B) and Bømlo (st. 23B) (***Figure 45a*** and ***b***, respectively). 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. Statistical analyses indicate 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.

Most years (since 2003), the median amount of CYP1A in the liver of cod from the Oslofjord (st. 30B) appeared higher than in liver of cod from the Sørfjord (st. 53B) and the Bømlo area (st. 23B). This was also the case in 2016, suggesting a higher exposure to planar organic compounds in the Oslofjord area.

A



B

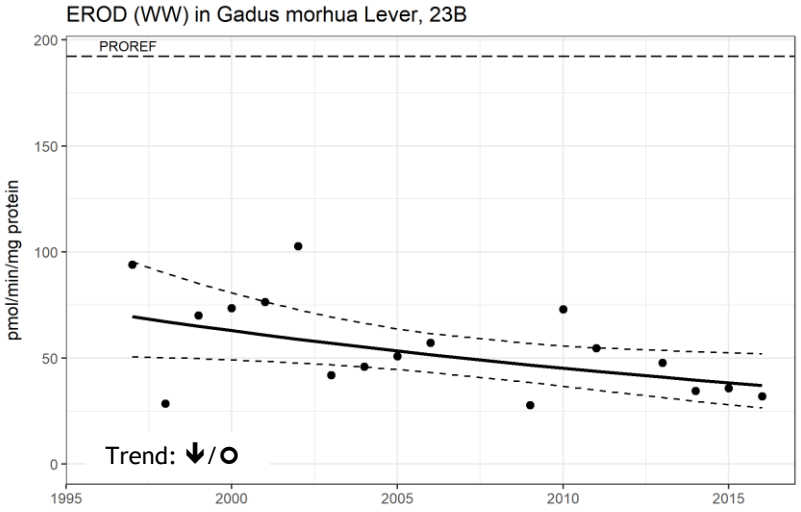


Figure 45. *Median concentrations (mg/kg w.w.) of EROD in cod liver from 1990 to 2016 in the Inner Oslofjord (st. 30B) (***A***) and from 1997 to 2016 in Bømlo (***B***). The provisional high reference concentration (PROREF) and the factor exceeding PROREF are indicated with horizontal dashed lines (see* **Figure 4** *and* **Appendix C***).*

3.4 Analysis of stable isotopes

3.4.1 General description of method

Stable isotopes of carbon and nitrogen are useful indicators of food origin and trophic levels. $\delta^{13}C$ gives an indication of carbon source in the diet or a food web. For instance, it is in principle possible to detect differences in the importance of autochthonous (native marine) and allochthonous (watershed/origin on land) carbon sources in the food web, since the $\delta^{13}C$ signature of the land-based energy sources is lower (greater negative number). 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 locations, or that the same species may inhabit different trophic levels on different locations (***Table* 20**). As previously noted, it is anticipated that statistical temporal analyses may be applied to perform more "refined" assessments, when the "MILKYS" stable isotope database is further expanded. So far (2012-2015; Green et al. 2016 – M-618|2016) 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 future MILKYS campaigns, it may be worthwhile 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.

In the following, the $\delta^{15}N$ data (Atlantic cod) is 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 δ^{15}N in cod. The data material for Hg and PCB153 is larger (more individuals analysed per station), than for the other contaminants. Noteworthy observations from these regressions are referred to, below.

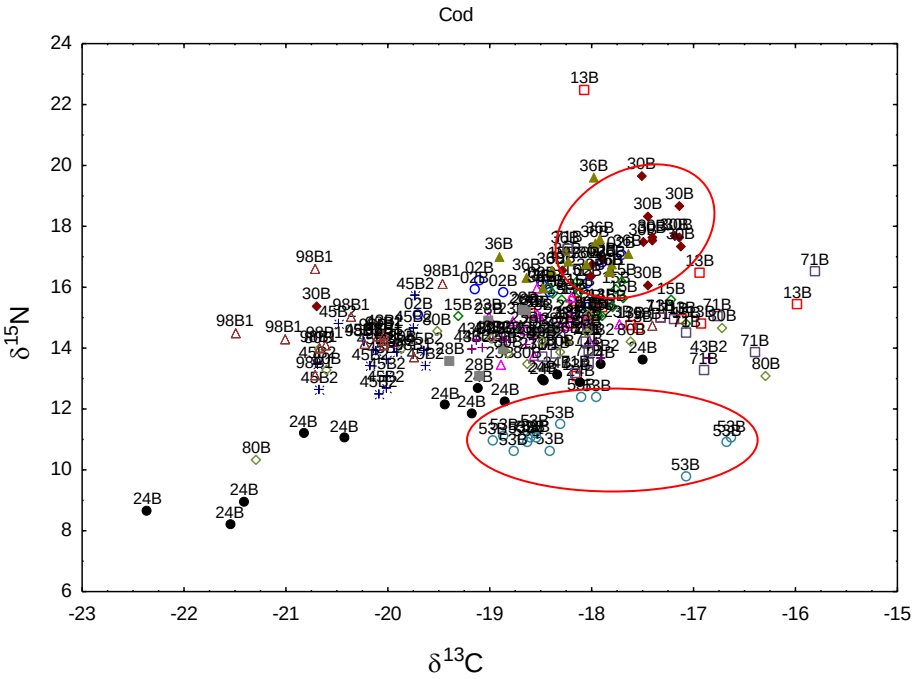
3.4.2 Results and discussion

As mentioned, the results of the stable isotope analysis generally show the same pattern as observed 2012-2015 (Green et al. 2016 – M-618|2016), i.e. a continual geographical pattern, suggesting a spatial trend persistent in time. As such, the results suggest that the different cod populations surveyed can be placed on approximately the same trophic level. As mentioned, an increase in δ^{15}N of 3 to 5 ‰ represent one full trophic level, while the differences observed were generally lower, except between stations situated at each end of the scale (***Figure 47***). The geographical differences in cod isotopic signatures are also largely reflected in the blue mussel isotopic signatures (***Figure 47***), indicating geographical differences in the baseline isotopic signatures (see discussion below). It is therefore reasonable to assume that any differences in the concentrations of pollutants between areas are 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 δ^{15}N) (less than one full trophic level) (Ruus *et al*. 2013 – M-15|2013), indicating that differences in δ^{15}N, corresponding to less than one full trophic level also are of interest in terms of explaining differences in bioaccumulation.

Although there were generally no major differences in δ^{15}N between cod from different locations, individual cod from the Sørfjord (st. 53B) and Bergen harbour (station 24B; both in Hordaland County) stand out with particularly low δ^{15}N signature (***Figure 47***). 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 δ^{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 46***) indicating a high baseline (and not a higher trophic position of the Oslofjord cod). Furthermore, this was also shown in 2012, 2013 and 2014. In fact, the stations show very similar patterns from 2012, through 2013 and 2014, to 2015 in terms of isotopic signatures, suggesting that this is a spatial trend more than a temporal trend. The stations show very similar patterns in terms of isotopic signatures through the years 2012-2016, indicating a geographical trend, persistent in time. Bergen harbour (station 24B) was introduced in 2015.

Table 20. *Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ in blue mussel and cod, 2016. Statistics shown are count (n), mean and standard deviation.*

	Blue mussel						Atlantic Cod					
	$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$			$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$		
Station ID	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.
presumed less impacted, summary >>	**3**	**-20.44**	**0.94**	**3**	**5.49**	**0.22**	**14**	**-18.99**	**0.53**	**14**	**15.10**	**0.73**
Mølen, Mid Oslofjord (st. 35A)	3	-19.85	0.17	3	6.03	0.16						
Færder, Outer Oslofjord (st. 36A)	3	-20.89	0.18	3	7.63	0.15						
Singlekalven, Hvaler (st. I023)	3	-19.23	0.06	3	6.78	0.20						
Bjørkøya, Langesundfjord (st. 71A)	3	-20.22	0.62	3	4.55	0.38						
Gåsøya-Ullerøya, Farsund (st. 15A)	3	-15.09	10.31	3	8.44	0.47						
Krossanes, Outer Sørfjord (st. 57A)	3	-20.23	0.09	3	2.68	0.22						
Ranaskjer, Ålvik, Hardangerfjord (st. 63A)	3	-19.65	0.40	3	3.04	0.18						
Terøya, Outer Hardangerfjord (st. 69A)	3	-20.89	0.14	3	3.50	0.06						
Espevær, Outer Bømlafjord (st. 22A)	3	-21.25	0.25	3	5.92	0.25						
Vågsvåg, Outer Nordfjord (st. 26A2)	3	-21.35	0.04	3	5.13	0.17						
Ørland area, Outer Trondheimsfjord (st. 91A2)	3	-21.14	0.50	3	5.47	0.16						
Mjelle, Bodø area (st. 97A2)	3	-21.13	0.02	3	6.44	0.14						
Svolvær airport area (st. 98A2)	3	-22.75	0.18	3	5.75	0.16						
Brashavn, Outer Varangerfjord (st. 11X)	3	-22.50	0.24	3	5.56	0.33						
Tjøme, Outer Oslofjord (st. 36B)							15	-18.15	0.35	15	16.85	1.09
Kirkøy, Hvaler (st. 02B)							10	-18.54	0.65	10	16.05	0.60
Skågskjera, Farsund (st. 15B)							15	-18.00	0.54	15	15.66	0.54
Bømlo, Outer Selbjørnfjord (st. 23B)							15	-18.43	0.35	15	14.82	0.64
Sandnessjøen area (st. 96B)							15	-19.53	0.44	15	13.84	0.76
Austnesfjord, Lofoten (st. 98B1)							15	-20.18	0.92	15	14.53	0.88
Kjøfjord, Outer Varangerfjord (st. 10B)							15	-20.12	0.49	15	13.95	0.63
presumed more impacted, summary >>	**3**	**-19.87**	**0.10**	**3**	**5.73**	**0.24**	**14**	**-18.55**	**0.84**	**14**	**14.04**	**1.08**
Gressholmen, Inner Oslofjord (st. 30A)	3	-19.32	0.10	3	7.73	0.68						
Gåsøya, Inner Oslofjord (st. I304)	3	-19.55	0.10	3	7.52	0.13						
Håøya, Inner Oslofjord (st. I306)	3	-18.89	0.07	3	7.47	0.04						
Ramtonholmen , Inner Oslofjord (st. I307)	3	-19.01	0.08	3	7.63	0.33						
Kirkøy, Hvaler (st. I024)	1	-20.13		1	7.54							
Sylterøya, Langesundfjord (st. I714)	3	-20.90	0.16	3	5.90	0.19						
Odderøya, Kristiansand harbour (st. I133)	3	-20.64	0.10	3	6.60	0.10						
Byrkjenes, Inner Sørfjord (st. 51A)	3	-20.55	0.07	3	2.41	0.27						
Eitrheimsneset, Inner Sørfjord (st. 52A)	3	-20.07	0.05	3	2.48	0.14						
Kvalnes, Mid Sørfjord (st. 56A)	3	-19.65	0.16	3	2.05	0.28						
Inner Oslofjord (st. 30B)							15	3.15	0.04	15	-17.75	0.89
Stathelle area, Langesundfjord (st. 71B)							15	3.12	0.06	15	-17.52	0.81
Kristiansand harbour area (st. 13B)							15	-17.64	0.68	15	15.50	2.06
Inner Sørfjord (st. 53B)							15	-18.18	0.77	15	11.11	0.65
Bergen harbour area (st. 24B)							15	-19.47	1.49	15	11.74	1.78
Ålesund harbour area (st. 28B)							8	-18.83	0.33	8	14.40	0.79
Trondheim harbour (st. 80B)							15	-18.79	1.42	15	13.83	1.10
Tromsø harbour area (st. 43B2)							15	-18.71	0.79	15	14.16	0.24
Hammerfest harbour area (st. 45B2)							15	-20.08	0.34	15	13.74	0.88
Average between the two groups	**3**	**-20.16**	**0.52**	**3**	**5.61**	**0.23**	**14**	**-18.77**	**0.68**	**14**	**14.57**	**0.91**



b

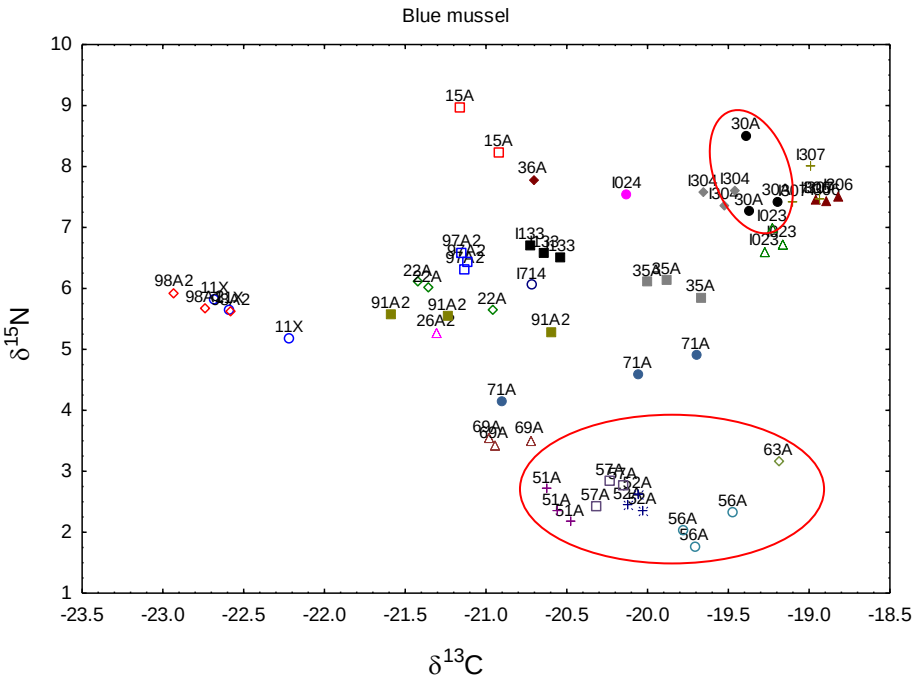


Figure 46. *$\delta^{13}C$ plotted against $\delta^{15}N$ in for cod (a) and blue mussel (b). Station codes are superimposed. Red ellipses indicate cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.*

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]; $P<0.00001$, with very poor goodness-of-fit; $R^2=0.1039$; ***Figure 47***). However, this is likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations. But a linear regression excluding stations 53B and 30B also produced significant result ($R^2=0.2750$; $P<0.0003$). However, from ***Figure 47***, 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 23B, 24B, 36B and 98B1.

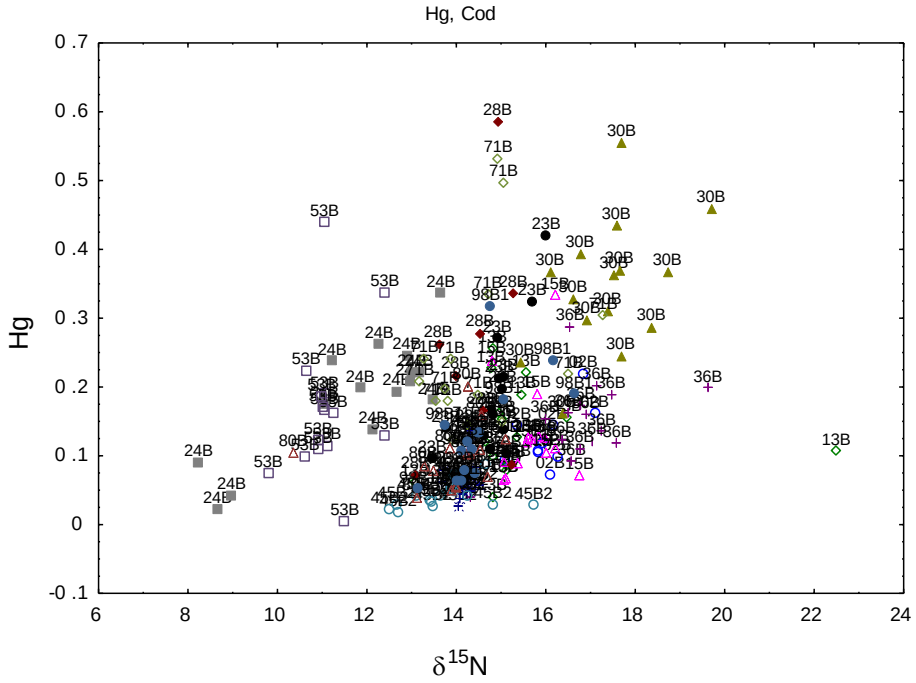


Figure 47. *$\delta^{15}N$ plotted against the concentration of Hg in cod. Station codes are superimposed.*

As Hg, PCB153 is a compound with known biomagnifying properties (Ruus *et al*. 2016b – M-601|2016). The correlation between $\delta^{15}N$ and the concentration of PCB153 in cod hardly suggested higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[PCB153]; $P<0.0042$, with very poor goodness-of-fit; $R^2=0.0652$; ***Figure 48***. However, this could also partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations. In Bergen harbour (24B), PCB-exposure was high in combination with low $\delta^{15}N$, and the same could be said for some individuals from the Sørfjord (53B). In the Inner Oslofjord (30B), PCB-exposure was high in combination with high $\delta^{15}N$. A linear regression excluding stations 24B, 30B and 53B produced a significant positive relationship between log[PCB-153] and $\delta^{15}N$ ($R^2=0.1303$; $P<0.0003$). Linear regressions isolated for each station produced significant positive linear relationships between $\delta^{15}N$ and Log[CB153] for stations 23B, 30B and 80B.

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]; $R^2=0.2808$; $P=<0.00001$; ***Figure 49***), However, this could partly be a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high PFOS-exposure as well as high $\delta^{15}N$ in cod from the Oslofjord). But a linear regression excluding station 30B also produced significant result, however with a very poor goodness-of-fit ($R^2=0.0950$; $P=<0.006$). Linear regressions isolated for each station yielded no significant relationship between $\delta^{15}N$ and Log[PFOS].

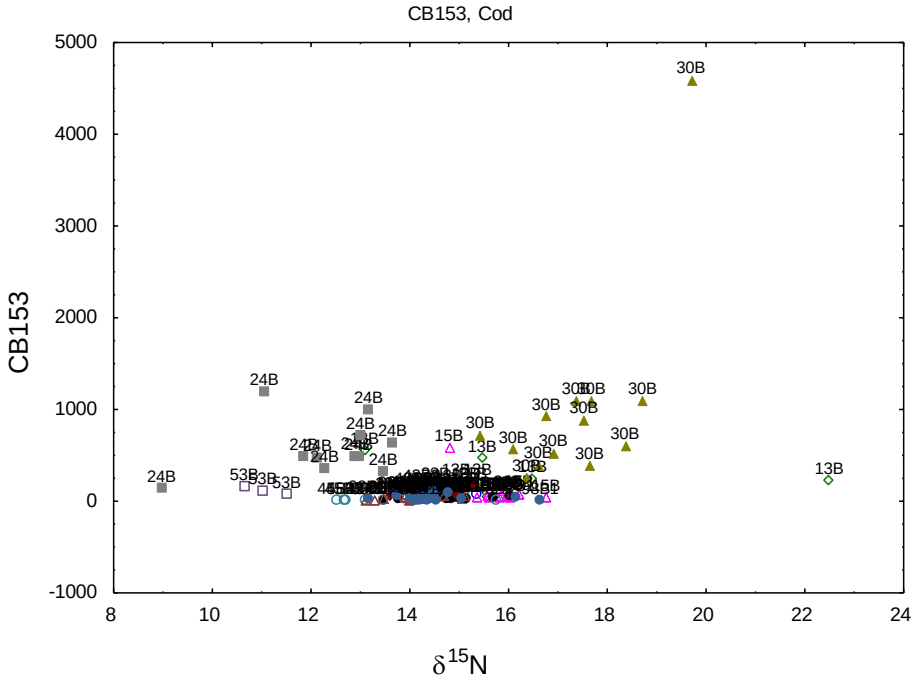


***Figure 48**. $\delta^{15}N$ plotted against the concentration of PCB153 in cod. Station codes are superimposed.*

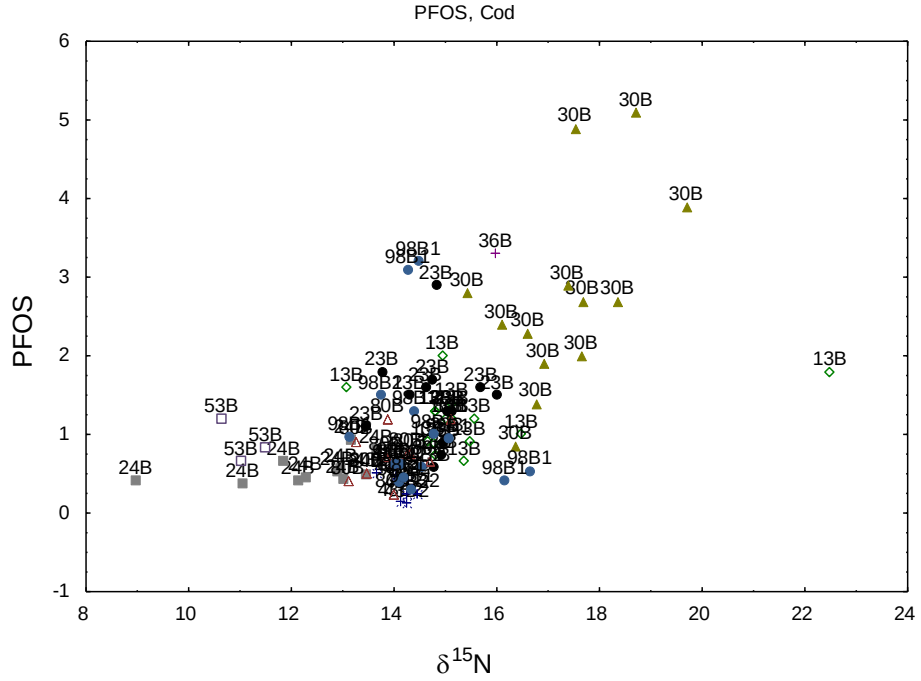


Figure 49. $\delta^{15}N$ plotted against the concentration of PFOS in cod. Station codes are superimposed.

3.5 Time trends for contaminants in cod when taking length into account

In the two annual reports (Green *et al.* 2015 – M-433|2015, 2016 – M-618|2016), we have analysed how length affects contamination and the perceived time trends. The effect of such variation is to a large degree dampened by the sampling strategy, which says that if possible, one should ideally use three cod for each of five length-classes (see ***Table 1***). However, the actual cod used in sampling for several reasons may differ from this ideal situation.

The present analysis takes into account lessons learned during the two previous years' analyses. In addition, we analyse time trends using GAM (Generalized Additive Models), based on OSPAR's currently standard method and the same method used in the rest of this report. We chose to analyse the effect length on contaminant concentration separately for each time series, i.e. for a given contaminant at a given location. We assumed a linear relationship between log-transformed concentration and length, in addition to an additive effect of the year:

$$Log(Concentration_i) = a*Length_i + b*Year_i + \varepsilon_i \qquad eq.\ 1$$

where $Concentration_i$ is the concentration of a given substance in sample i, $Length_i$ is the length of the fish (in millimetres) from which sample i was taken (the mean length if the sample is a pooled sample of liver from several fish), and $Year_i$ is year as a categorical variable, allowing for general differences in contamination among years.

The result (***Figure 50***) shows large differences among contaminants. As expected, Hg shows consistently a positive effect of length on contamination, statistically significant on nearly all stations. For Hg, there is on average a 36% increase in mercury concentrations when cod becomes 10 cm longer. Also DDE(pp), PCB7 (CB_S7 in the figure), BDE47 and BDE100 shows the same pattern, with a concentration increase per 10 cm ranging from 23% in PCB7 to 39% in BDE100. For some contaminants, such as Ag and Cu, the length effect appears to be markedly different among stations. Finally, some time series show negative length effects, especially Ni, whose concentration on average decreases 16% for each 10 cm increase in length. The length-concentration relationship is often not so obvious in plots for each single year, even in cases where the relationship is highly statistically significant when all years are analysed together; see ***Figure 51*** for an example.

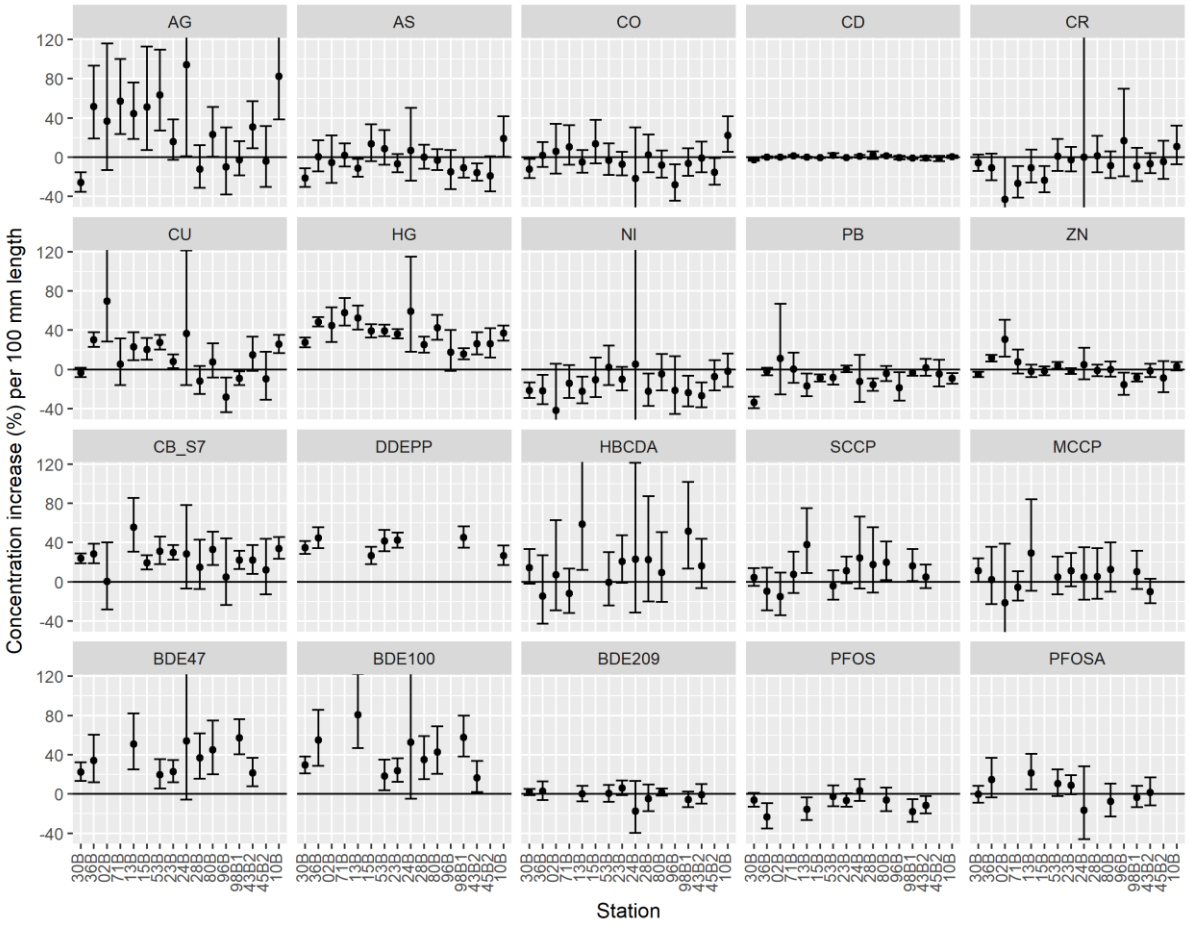


***Figure 50**. The estimated increase in concentration when firsh length is increased by 100 mm (based on the slope of the relationship between log(concentration) and cod length). All contamination values are from cod liver, except for Hg which was measured in cod muscle. All contamination values are from cod liver, except for Hg which was measured in cod muscle.*

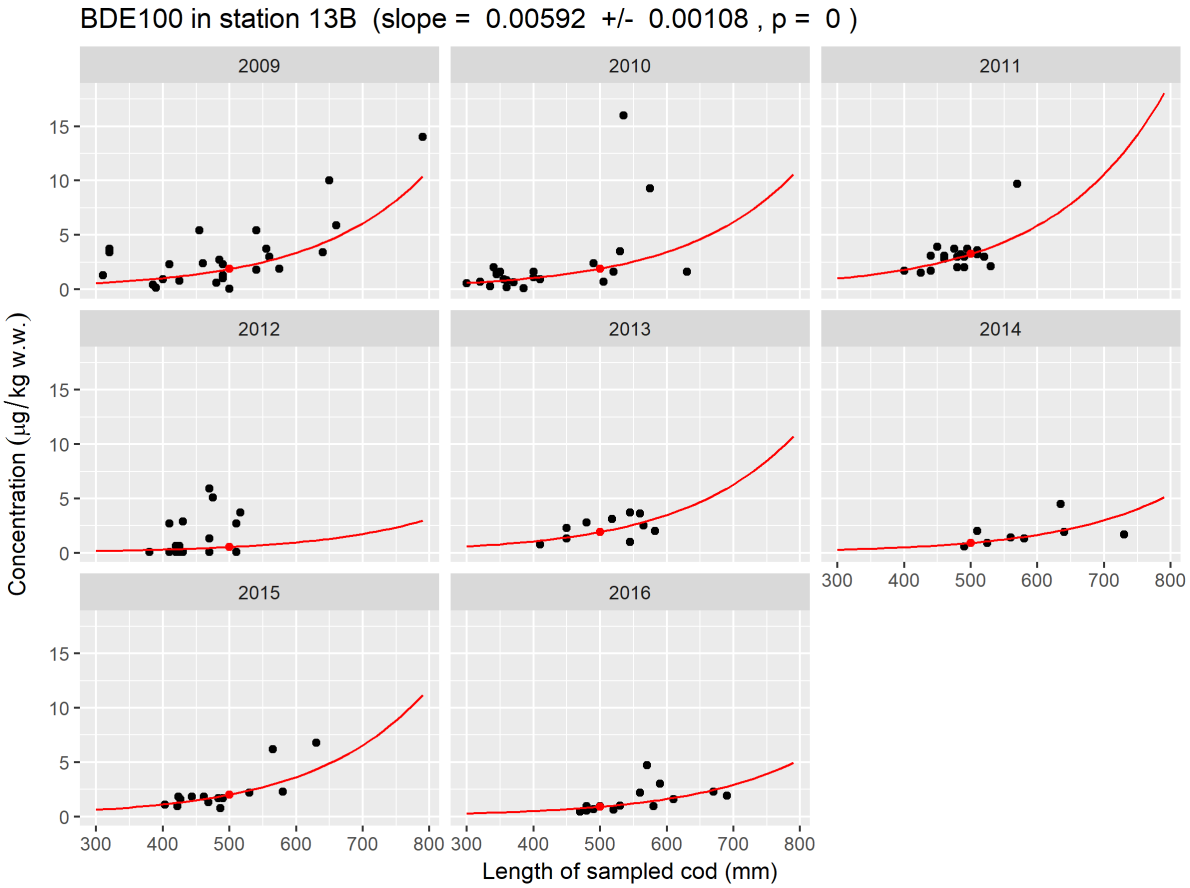


***Figure 51**. One example of length affecting concentrations; BDE100 on station 13B (Kristiansand harbour). The regression line (red) was fitted as a linear relationship using log-transformed data; after back-transformation, it appears curved. In this case, a = 0.0059, corresponding to a 81% increase in BDE100 concentration for 10 cm longer cod. The relationship is statistically significant with p < 0.0001.*

Time trends of cod length (***Figure 52***) show that in spite of attempting to standardize the length of sampled cod, time trends appear in some stations. Several stations show an increasing trend since 2010. Station 36B (Tjøme) appears to have the most consistent time series, while cod in 10B (Varangerfjord) decreased in length during the 1990s and has remained generally smaller than cod from other stations since 2000.

***Figure 52**. Median cod length (dot), as well as the 10th and 99th percentile (bars), for each year for cod stations with at least 5 years of data and data for 2016. The vertical range of each bar shows the 10% and 90% percentiles of cod length (i.e., they cover the "middle 80%"). The blue line shows a loess trend for illustration.*

The estimated effect of length on concentrations was used to adjust the concentration of each sample to the expected concentration of a 50 cm cod. This was achieved by moving each sample point parallel to the regression line; thus, the unexplained variation among samples (the "noise") was retained. We then recalculated median values and proceeded with time series analysis in the same manner. In most cases, length-adjustment does not change our assessment of time trends (***Table 21***). Most of the long-term trends that change are observed in a few stations. For instance, in station 43B2 (Tromsø harbour), Ag and Hg apparently has increasing long-term trends, but these trends are no longer signinficant after length-adjustment (***Table 22***). PBDEs and PCB in several locations show decreasing time trends when length is taken into account. On the other hand, Ni shows an increasing trend only when the concetrations are length-adjusted. Obviously, series that are relatively short and have a marked changed in the length of sampled cod are mosty likely to be affected by this effect (***Figure 52***). It should be noted that if the p-value of a time trend is j+ust above or just below the signinficance level of P = 0.05, length-adjustment may cause the time series to go from "not significant" to "significant" even when length-adjustment has a very small effect. It should also be noted that even if mean length does not change over time, length-adjustment can turn a non-signinficant time trend into a significant one by removing part of the unexplained variance and thereby decrease the uncdertainty of the time trend.

While these results shows that it is possible to "standardise" contaminant concentrations by statistical adjustment to a standard length, this adjustment introduces an extra level of uncertainty. For instance, in some stations/years the adjustment to 50 cm cod is an extrapolation outside the range of sampled cod. If possible, standardized sampling where the distribution of cod size is kept constant over the years is preferable. However, this is in practice often challenging due

to decrease in cod abundance, changes in cod age structure (e.g. due to low cod recruitment), and demands for sufficient tissue for chemical analyses.

***Table 21**. The number of station with significant time trends using unadjusted (symbol before the vertical bar) and length-adjusted concentrations (symbol after the vertical bar, using concentrations adjusted to 500 mm fish length). For instance, the column "O|↑" indicates the number of time series which had no significant time trend for unadjusted concentrations, but a significantly increasing time trend for adjusted concentrations. "Differs" and "Differs %" are the number and percentage, respectively, of time series where the trend differs for unadjusted and adjusted concentrations. Series that are too short or have too many medians under LOQ are not included. Names of stations are given in the next table.*

Station	O|O	O|↑	O|↓	↑|O	↓|O	↑|↑	↓|↓	Difference	Difference (%)
Long-term trends (only series >10 years included)									
10B	2	0	0	0	2	0	13	2	11.8
15B	7	0	0	0	0	0	11	0	0
23B	11	0	1	0	3	0	18	4	12.1
30B	14	0	0	0	3	1	15	3	9.1
36B	3	0	3	0	0	0	16	3	13.6
53B	25	1	0	0	1	0	6	2	6.1
98B1	10	0	6	0	0	0	7	6	26.1
10 year trends									
02B	21	0	0	0	1	1	0	1	4.3
10B	22	0	2	0	0	0	0	2	8.3
13B	28	0	1	0	2	0	5	3	8.3
15B	16	2	0	0	0	4	5	2	7.4
23B	36	0	2	0	2	3	2	4	8.9
30B	31	1	6	0	1	0	8	8	17
36B	30	0	2	1	0	2	4	3	7.7
43B2	27	0	0	2	1	1	6	3	8.1
53B	36	0	2	0	1	2	6	3	6.4
71B	12	0	0	0	0	1	3	0	0
80B	21	0	5	0	0	0	10	5	13.9
98B1	33	1	0	2	1	0	0	4	10.8

Table 22. *Stations and parameters where unadjusted and length-adjusted concentrations had different time trends.*

Type	Station	Station name	Parameters
O|↑ (no significant trend in unadjusted, upward trend in adjusted concentrations)			
10 year	15B	Skågskjera, Farsund	PA1O, PYR1O
10 year	30B	Inner Oslofjord	MCCP
10 year	98B1	Austnesfjord, Lofoten	Ni
Long	53B	Inner Sørfjord	CYP1A
O|↓ (no significant trend in unadjusted, downward trend in adjusted concentrations)			
10 year	10B	Kjøfjord, Outer Varangerfjord	CB118, Pb
10 year	13B	Kristiansand harbour area	CB118
10 year	23B	Bømlo, Outer Selbjørnfjord	BDE6S, BDESS
10 year	30B	Inner Oslofjord	PCB7,CB118,CB138,CB153,CB180,DDEPP
10 year	36B	Tjøme, Outer Oslofjord	CB180,Cu
10 year	53B	Inner Sørfjord	Hg,PFNA
10 year	80B	Trondheim harbour	Ag,BDE100,BDE47,BDE6S,Cd
Long	23B	Bømlo, Outer Selbjørnfjord	HCB
Long	36B	Tjøme, Outer Oslofjord	BDE6S,CB138,DDEPP
Long	98B1	Austnesfjord, Lofoten	BDE47,BDE6S,PCB7,CB138,CB153,TDEPP
↑|O (upward trend in unadjusted, no significant trend in adjusted concentrations)			
10 year	36B	Tjøme, Outer Oslofjord	Pb
10 year	43B2	Tromsø harbour area	Ag, Hg
10 year	98B1	Austnesfjord, Lofoten	BDE154, Delta15N
↓|O (downward trend in unadjusted, no significant trend in adjusted concentrations)			
10 year	02B	Kirkøy, Hvaler	CB52
10 year	13B	Kristiansand harbour area	Cr, PFOSA
10 year	23B	Bømlo, Outer Selbjørnfjord	CB101, PFOSA
10 year	30B	Inner Oslofjord	Sn
10 year	43B2	Tromsø harbour area	PFOS
10 year	53B	Inner Sørfjord	PFOS
10 year	98B1	Austnesfjord, Lofoten	PFAS
Long	10B	Kjøfjord, Outer Varangerfjord	HCB,Hg
Long	23B	Bømlo, Outer Selbjørnfjord	CB52 ,EROD, PFOSA
Long	30B	Inner Oslofjord	CB52, EROD, Pb
Long	53B	Inner Sørfjord	Pb

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 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 2016 investigations were:

- Of the 801 median values from 2016 for the 30 selected contaminants, 252 values could be assessed against the EQS of which 171 (68 %) were below the EQS.
- Of the 801 median values from 2016 for the 30 selected contaminants, all values could be assessed against the provisional high reference concentration (PROREF) of which 608 (75.9 %) 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.
- Significant long-term increase in mercury was found in cod from the Inner Oslofjord. Both significant upward long-term and short-term trends were found in the Tromsø harbour area for mercury, while significant upward short-term trends were found at Færder and Farsund. While mercury concentration is strongly linked to fish length, these trends were all significant also after adjusting for cod length.
- Highest concentrations of PBDEs, predominantly BDE47, were found in the Bergen harbour and Inner Oslofjord for cod liver, and in Bergen harbour (Nordnes) and Ørland area for blue mussel.
- 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 and the Outer Oslofjord had significantly higher levels of PFOS than the eight other stations investigated.
- The dominant hexabromocyclododecane in cod liver was α–HBCD. The concentration of α–HBCD in cod liver was highest in the Inner Oslofjord and in blue mussel it was highest in Bergen harbour, probably related to urban activities.
- Short chain chlorinated paraffins (SCCP) and medium chain chlorinated paraffins (MCCP) were highest in cod liver in Bergen harbour. MCCP was also highest in blue mussel from Bergen harbour, whereas SCCP was highest in blue mussel from the Langesundfjord.
- The median concentrations of organophosphorus flame retardants (PFRs) were low or for the most part below the quantification limit, the exception being for TCPP in blue mussel from three stations.
- 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.
- 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 indicated exposure to organic contaminants.

- The Inner Oslofjord, and to a lesser degree the harbour areas of Bergen, Kristiansand, Trondheim, 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, and no recent-trend was observed, neither for both 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 2016 in terms of isotopic signatures, suggesting that this is a spatial trend more than a temporal trend.
- Contaminant concentrations statistically adjusted to a standard cod-length can help explain some observed trends, however it also introduces an extra level of uncertainty especially where sampling has been inconsistent.

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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 2016 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 PFCs.

Summary of quality control results
Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly (***Table 23***). 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 paraffines and octyl/nonylphenols, spiked fish meal was used. For organophosphorous flame retardants, spiked internal reference material was used.

***Table 23**. Summary of the quality control of results for the 2016 biota samples analysed in 2016-2017. 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), organophosporous flame retardants (pg/sample) and PFCs (% recovery). Tissue types were: mussel soft body (SB), fish liver (LI) and fish fillet (MU).*

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
Ag	**Silver**	SB/LI	DOLT-5	2.05±0.08	31	14	1,8262	0,0721
As	**Arsenic**	SB/LI	DORM-4	6,80±0,64	43	15	6,38	0,2823
Cd	**Cadmium**	SB/LI	DORM-4	0,306±0,015	43	15	0,301	0,0132
Cr	**Chromium**	SB/LI	DORM-4	1,87±0,16	43	15	1,799	0,1901
Co	**Cobalt**	SB/LI	DOLT-5	0.267±0.026	29	10	0,2378	0,0114
Cu	**Copper**	SB/LI	DORM-4	15,9±0,9	43	15	14,2	0,7806
Hg	**Mercury**	SB/MU	DORM-4	0,41±0,055	50	15	0,39	0,0292
Ni	**Nickel**	SB/LI	DORM-4	1,36±0,22	43	15	1,27	0,1072
Pb	**Lead**	SB/LI	DORM-4	0,416±0,053	43	15	0,4	0,0235
Zn	**Zinc**	SB/LI	DORM-4	52,2±3,2	43	15	49,29	2,1970
Sn	**Tin**	SB/LI	DOLT-5	0.069±0.036	28	15	0,098	0,0220
BDE-28	**2,2,4' Tribromodiphenylether**	LI	QBC032BT (Quasimeme)	0,39	10	14	0,345	0,069
BDE-47	**2,2',4,4',-Tetrabromodiphenylether**	LI	QBC032BT (Quasimeme)	*23,2* [1]	10	14	21,182	4,517
BDE-100	**2,2',4,4',6-Pentabromodiphenylether**	LI	QBC032BT (Quasimeme)	6,91	10	14	6,370	1,214
BDE-99	**2,2',4,4',5-Pentabromodiphenylether**	LI	QBC032BT (Quasimeme)	*0,01* [1]	10	14	0,008	0,002
BDE-126		LI	QBC032BT (Quasimeme)					
BDE-154	**2,2',4,4',5,6'-Hexabromodiphenylether**	LI	QBC032BT (Quasimeme)	1,68	10	14	2,088	0,488
BDE-153	**2,2',4,4'5,5'-Hexabromodiphenylether**	LI	QBC032BT (Quasimeme)	*0,86* [1]	10	14	0,657	0,144
BDE-183	**2,2',3,4,4,5',6-Heptabromodiphenylether**	LI	QBC032BT (Quasimeme)					
BDE-196		LI	QBC032BT (Quasimeme)					
BDE-209	**Decabromodiphenylether**	LI	QBC032BT (Quasimeme)					
BDE-28	**2,2,4' Tribromodiphenylether**	LI	HSD-1	1,9	19	6	1,910	0,119
BDE-47	**2,2',4,4',-Tetrabromodiphenylether**	LI	HSD-1	18,8	19	6	16,370	2,042
BDE-100	**2,2',4,4',6-Pentabromodiphenylether**	LI	HSD-1	5,06	19	6	4,690	0,377
BDE-99	**2,2',4,4',5-Pentabromodiphenylether**	LI	HSD-1	1,56	19	6	1,540	0,186
BDE-126		LI	HSD-1	1,02	19	6	1,190	0,135
BDE-154	**2,2',4,4',5,6'-Hexabromodiphenylether**	LI	HSD-1	3,19	19	6	3,080	0,180
BDE-153	**2,2',4,4'5,5'-Hexabromodiphenylether**	LI	HSD-1	1,2	19	6	1,220	0,149
BDE-183	**2,2',3,4,4,5',6-Heptabromodiphenylether**	LI	HSD-1	1,72	19	6	1,660	0,139
BDE-196		LI	HSD-1	0,98	19	6	0,960	0,187
BDE-209	**Decabromodiphenylether**	LI	HSD-1	1,05	19	6	1,050	0,222
BDE-28	**2,2,4' Tribromodiphenylether**	SB	SRM2974	0,905	8	2	0,890	0,258
BDE-47	**2,2',4,4',-Tetrabromodiphenylether**	SB	SRM2974	14,3	8	2	10,540	0,662
BDE-100	**2,2',4,4',6-Pentabromodiphenylether**	SB	SRM2974	2,83	8	2	2,000	0,115
BDE-99	**2,2',4,4',5-Pentabromodiphenylether**	SB	SRM2974	1,36	8	2	5,120	0,283

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
BDE-126		SB	SRM2974					
BDE-154	2,2',4,4',5,6'-Hexabromodiphenylether	SB	SRM2974	0,297	8	2	0,300	0,023
BDE-153	2,2',4,4'5,5'-Hexabromodiphenylether	SB	SRM2974	0,201	8	2	0,150	0,013
BDE-183	2,2',3,4,4,5',6-Heptabromodiphenylether	SB	SRM2974					
BDE-196		SB	SRM2974					
BDE-209	Decabromodiphenylether	SB	SRM2974					
PCB 28	PCB congener CB-28	SB	QOR110BT (Quasimeme)	0,37	22	14	0,340	0,021
PCB 31	PCB congener CB-31	SB	QOR110BT (Quasimeme)	0,33	22	14	0,270	0,027
PCB 52	PCB congener CB-52	SB	QOR110BT (Quasimeme)	1,11	22	14	1,100	0,032
PCB 101	PCB congener CB-101	SB	QOR110BT (Quasimeme)	3,12	22	14	3,260	0,116
PCB 105	PCB congener CB-105	SB	QOR110BT (Quasimeme)	0,47	22	14	0,450	0,023
PCB 118	PCB congener CB-118	SB	QOR110BT (Quasimeme)	2,2	22	14	2,070	0,091
PCB 138	PCB congener CB-52	SB	QOR110BT (Quasimeme)	4,46	22	14	5,370	0,244
PCB 153	PCB congener CB-153	SB	QOR110BT (Quasimeme)	7,93	22	14	6,880	0,223
PCB 156	PCB congener CB-156	SB	QOR110BT (Quasimeme)	0,2	22	14	0,150	0,027
PCB 180	PCB congener CB-180	SB	QOR110BT (Quasimeme)	0,48	22	14	0,460	0,021
PCB 209	PCB congener CB-209	SB	QOR110BT (Quasimeme)		22	14		
PCB 28	PCB congener CB-28	LI	HSD-1	3,2	28	17	3,190	0,269
PCB 31	PCB congener CB-31	LI	HSD-1	1,4	28	17	1,370	0,151
PCB 52	PCB congener CB-52	LI	HSD-1	7,3	28	17	7,320	0,546
PCB 101	PCB congener CB-101	LI	HSD-1	22	28	17	21,730	1,751
PCB 105	PCB congener CB-105	LI	HSD-1	8,4	28	17	8,450	0,794
PCB 118	PCB congener CB-118	LI	HSD-1	24	28	17	24,390	2,300
PCB 138	PCB congener CB-52	LI	HSD-1	55	28	17	54,700	4,806
PCB 153	PCB congener CB-153	LI	HSD-1	63	28	17	63,370	6,319
PCB 156	PCB congener CB-156	LI	HSD-1	4	28	17	4,030	0,422
PCB 180	PCB congener CB-180	LI	HSD-1	17	28	17	17,350	1,930
PCB 209	PCB congener CB-209	LI	HSD-1	1,3	28	17	1,330	0,634
DDEPP	4.4'-DDE	SB	QOR110BT (Quasimeme)	1,4	22	14	1,150	0,114
TDEPP	4.4'-DDD	SB	QOR110BT (Quasimeme)	0,59	22	14	0,430	0,044
DDTPP	4.4'-DDT	SB	QOR110BT (Quasimeme)	*0,14* [1]	22	14	0,002	0,003
DDEPP	4.4'-DDE	LI	HSD-1	159	28	17	158,850	14,569
TDEPP	4.4'-DDD	LI	HSD-1	41	28	17	40,810	9,134
DDTPP	4.4'-DDT	LI	HSD-1	3,4	28	17	3,374	0,765
α-HBCDD	α-Hexabromocyclododecane	SB/LI	Folkehelse RM (Salmon 2011)	1,97 ± 0,53	5	5	2,28	0,46
ß-HBCDD	ß- Hexabromocyclododecane	SB/LI	Folkehelse RM (Salmon 2011)	0,04 ± 0,02	5	5	0,06	0,02
γ-HBCDD	γ- Hexabromocyclododecane	SB/LI	Internal RM	0,32 ± 0,06	22	13	0,35	0,05
PAHNPD	Naftalen	SB	QPH065BT (Quasimeme)	5,05	17	13	2,613	0,391
PAHNPD	1-Metylnaftalen	SB	QPH065BT (Quasimeme)	*1,31*	17	13	1,263	0,252
PAHNPD	C1-Naftalen	SB	QPH065BT (Quasimeme)		17	13	1,844	0,338
PAHNPD	2-Metylnaftalen	SB	QPH065BT (Quasimeme)	*0,86*	17	13	0,804	0,098
PAHNPD	C2-Naftalen	SB	QPH065BT (Quasimeme)		17	13	3,881	1,137
PAHNPD	Acenaftylen	SB	QPH065BT (Quasimeme)	0,45	17	13	0,089	0,021
PAHNPD	Acenaften	SB	QPH065BT (Quasimeme)	0,77	17	13	0,568	0,119
PAHNPD	C3-Naftalen	SB	QPH065BT (Quasimeme)		17	13	5,171	0,961
PAHNPD	Fluoren	SB	QPH065BT (Quasimeme)	1,59	17	13	0,970	0,065
PAHNPD	Dibenzotiofen	SB	QPH065BT (Quasimeme)	0,58	17	13	0,433	0,020
PAHNPD	Fenantren	SB	QPH065BT (Quasimeme)	8,18	17	13	6,498	0,266
PAHNPD	Antracen	SB	QPH065BT (Quasimeme)	0,75	17	13	0,599	0,118
PAHNPD	C1-Dibenzotiofen	SB	QPH065BT (Quasimeme)		17	13	1,328	0,121
PAHNPD	C1-Fenantren/Antracen	SB	QPH065BT (Quasimeme)	12,7	17	13	12,013	1,168

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
PAHNPD	2-Metylfenantren	SB	QPH065BT (Quasimeme)	3,65	17	13	2,962	0,655
PAHNPD	C2-Dibenzotiofen	SB	QPH065BT (Quasimeme)		17	13	2,549	0,229
PAHNPD	C2-Fenantren/Antracen	SB	QPH065BT (Quasimeme)	22,8	17	13	19,146	2,239
PAHNPD	3,6-Dimetylfenantren	SB	QPH065BT (Quasimeme)	*2,84*	17	13	3,510	4,381
PAHNPD	Fluoranten	SB	QPH065BT (Quasimeme)	13,8	17	13	9,173	1,163
PAHNPD	C3-Dibenzotiofen	SB	QPH065BT (Quasimeme)		17	13	5,558	1,474
PAHNPD	Pyren	SB	QPH065BT (Quasimeme)	11,1	17	13	7,244	1,129
PAHNPD	Benzo[a]fluoren	SB	QPH065BT (Quasimeme)	*0,95*	17	13	0,880	0,320
PAHNPD	C3-Fenantren/Antracen	SB	QPH065BT (Quasimeme)	37 [1]	17	13	12,312	1,614
PAHNPD	1-Metylpyren	SB	QPH065BT (Quasimeme)	*0,95*	17	13	1,037	0,129
PAHNPD	Benzo[a]antracen	SB	QPH065BT (Quasimeme)	5,26	17	13	4,069	0,441
PAHNPD	Krysen/Trifenylen	SB	QPH065BT (Quasimeme)	7,19	17	13	5,860	0,733
PAHNPD	Benzo[b/j]fluoranten	SB	QPH065BT (Quasimeme)	4,99	17	13	3,876	0,623
PAHNPD	Benzo[k]fluoranten	SB	QPH065BT (Quasimeme)	2,00	17	13	3,208	0,466
PAHNPD	Benzo[e]pyren	SB	QPH065BT (Quasimeme)	5,70	17	13	5,659	0,858
PAHNPD	Benzo[a]pyren	SB	QPH065BT (Quasimeme)	1,50	17	13	1,185	0,140
PAHNPD	Perylen	SB	QPH065BT (Quasimeme)	2,31	17	13	1,931	0,250
PAHNPD	Indeno[1,2,3-cd]pyren	SB	QPH065BT (Quasimeme)	1,52	17	13	1,155	0,188
PAHNPD	Dibenzo[a,h]antracen	SB	QPH065BT (Quasimeme)	0,43	17	13	0,323	0,063
PAHNPD	Benzo[ghi]perylen	SB	QPH065BT (Quasimeme)	2,39	17	13	1,778	0,293
TBBPA	Tetrabromobisphenol-A	SB/LI	Internal RM	1,50 ± 0,28	8	10	1,37	0,08
SCCP	C10-C13 Chlorinated paraffines	SB/LI	Internal RM (spiked)		6	10	2500	880
MCCP	C13-C17 Chlorinated paraffines	SB/LI	Internal RM (spiked)		6	10	8500	4800
APO	4-n-nonylphenol	LI/SB	Internal RM (spiked)	-	13	10	42,8	2,3
APO	4-n-octylphenol	LI/SB	Internal RM (spiked)	-	13	10	40,0	1,5
APO	4-Nonylphenol	LI/SB	-	-	-	-	-	-
APO	4-tert-octylphenol	LI/SB	Internal RM (spiked)	-	13	10	44,9	2,5
TIBP	Triisobutylphosphate	LI/SB	Internal RM (spiked)	5,57	7	8	5,37	0,61
TBP	Tributylphosphate	LI/SB	Internal RM (spiked)	5,22	7	8	4,76	0,38
TCEP	Tris(2-chloroethyl)phosphate	LI/SB	Internal RM (spiked)	5,22	7	8	5,44	0,16
TCPP	Tris(2-chloro-isopropyl)phosphate	LI/SB	Internal RM (spiked)	5,57	7	8	5,21	0,44
TDCP	Tris(1,3-chloro-isopropyl)phosphate	LI/SB	Internal RM (spiked)	5,22	7	8	5,43	0,23
TBEP	Tris(2-butoxyethyl)phosphate	LI/SB	Internal RM (spiked)	5,22	3	8	4,72	0,30
TPhP	Triphenylphosphate	LI/SB	Internal RM (spiked)	5,22	7	8	5,42	0,20
EHDPP	2-Ethylhexyl-diphenylphosphate	LI/SB	Internal RM (spiked)	5,22	7	8	5,27	0,39
TEHP	Tris(2-ethylhexyl) phosphate	LI/SB	Internal RM (spiked)	5,22	7	8	5,22	0,96
ToCrP	o-Tricresylphosphate	LI/SB	Internal RM (spiked)	5,22	7	8	5,47	0,24
TIBP	Triisobutylphosphate	LI/SB	Internal RM (spiked)	5,57	7	8	5,37	0,61
PFBS	Perfluorobutane sulphonate	LI		100 %[2)]	9	m	94	7,9
PFHxA	Perfluorohexane acid	LI		100 %[2)]	9	m	95	7,5
PFHpA	Perfluoroheptane acid	LI		100 %[2)]	9	m	98	4,5
PFOA	Perfluorooctane acid	LI		100 %[2)]	9	m	103	5,3
PFNA	Perfluorononane acid	LI		100 %[2)]	9	m	98	3,7
PFOS	Perfluorooctane sulphonate	LI		100 %[2)]	9	m	102	11,6
PFOSA	Perfluorooctane sulphone amide	LI		100 %[2)]	9	m	99	3,6
PFHxS	Perfluorohexane sulphonate	LI		100 %[2)]	9	m	91	4,8

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
PFDA	**Perfluorodecanoic acid**	LI		100 %[2)]	9	m	101	4,8
PFUDA	**Perfluoroundecanoic acid**	LI		100 %[2)]	9	m	103	11,2
PFDS	**Perfluorodecanesulphonate**	LI		100 %[2)]	9	m	80	10,1

* 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

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, spesifikk 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	*hexaklorobutadien*	OC-CL
PFAS	**perfluorinated alkylated substances**	***Perfluoralkylerte stoffer***	
PFBS	perfluorobutane sulfonate	*perfluorbutan sulfonat*	PFAS
PFDCA	perfluorodecanoic acid	*perfluordekansyre*	PFAS
PFDCS	ammonium henicosafluorodecanesulphonate	*ammonium henikosafluordekansulfonat*	PFAS
PFHxA	perfluorohexanoic acid	*perfluorhexansyre*	PFAS
PFHpA	perfluoroheptanoic acid	*perfluorheptansyre*	PFAS
PFOA	perfluorooctanoic acid	*perfluoroktansyre*	PFAS
PFNA	perfluorononanoic acid	*perfluornonansyre*	PFAS
PFOS	Perfluorooctanesulfonic acid	*Perfluorooktansulfonatsyre*	PFAS
PFOSA	perfluorooctanesulfonamide	*perfluorooktansulfonamid*	PFAS
PFUDA	perfluoroundecanoic acid	*perfluorundekansyre*	PFAS
SCCP	short chain chlorinated paraffins, C_{10-13}	*kortkjedete klorerte parafiner, C_{10-13}*	

Abbreviation[1]	English	*Norwegian*	Param. group
MCCP	medium chain chlorinated, C_{14-17} paraffins	*mediumkjedete klorerte parafiner, C_{14-17}*	
Alkylphenols	**phenols/chlorophenols**	***fenoler/klorfenoler***	
4-n-NP	4-n-nonylphenol	*4-n-nonylfenol*	
4-n-OP	4-n-octylphenol	*4-n-oktylfenol*	
4-t-NP	4-tert-nonylphenol	*4-tert-nonylfenol*	
4-t-OP	4-tert-octylphenol	*4-tert-oktylfenol*	
PFRs	**Phosphorus Flame Retardants**	***Fosforflammehemmere***	
TIBP	tri-*iso*-butylphosphate	*tri-iso-butylfosfat*	
TBP	tributylphosphate	*tributylfosfat*	
TCEP	tri(2-chloroethyl)phosphate	*tri(2-kloretyl)fosfat*	
TCPP	tri(1-chloro-2-propyl)phosphate	*tri(1-klor-2-propyl)fosfat*	
TDCP	tri(1,3-dichloro-2-propyl)phosphate	*tri(1,3-diklor-2-propyl)fosfat*	
TBEP	tri(2-butoxyethyl)phosphate	*tri(2-butokysetyl)fosfat*	
TPhP	triphenylphosphate	*trifenylfosfat*	
EHDPP	2-ethylhexyl-di-phenylphosphate	*2-etylheksyl-difenylfosfat*	
V6	tetrekis(2-chlorethyl)dichloroisopentyldiphosphate	*tetrakis-(2-kloroetyl)diklorisopentyldifosfat*	
DBPhP	dibutylphenylphosphate	*dibutylfenylfosfat*	
BdPhP	butyldiphenylphosphate	*butyldifenylfosfat*	
TEHP	tris(2-etylhexyl)phosphate	*tris(2-etylheksyl)fosfat*	
ToCrP	tris-o-cresylphosphate	*tris-o-kresylfosfat*	
TCrP	tricresyl phosphate	*trikresylfosfat*	
	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*	

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

Abbreviation[1]	English	*Norwegian*	Param. group
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 24**. Provisional high reference concentrations* (PROREF) for contaminants in blue mussel (*Mytilus edulis*), perwinkle (*Littorina littorea*), dog whelk (*Nucella lapillus)* and Atlantic cod (*Gadus* morhua) for whole soft body, liver and muscle based on MILYKYS data (see section 2.5). All values are on a wetweight 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's EQS) 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*	1	*1.075*
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**				

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
CB81	Mytilus edulis	Soft body	76A	1	18	U	**0**				
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*		

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	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*
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*	1	*0.002*
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	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**				

Parameter Code	Species	Tissue	Reference stations	Station count	Value count	Unit	PROREF	Class I	*Class I / Q95*	EQS	*EQS / Q95*
HBCDB	Gadus morhua	Liver	43B2, 80B	2	135	U	**0.4**				
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 1981-2016
(cf. Appendix E)

Appendix D (cont.) Map of stations

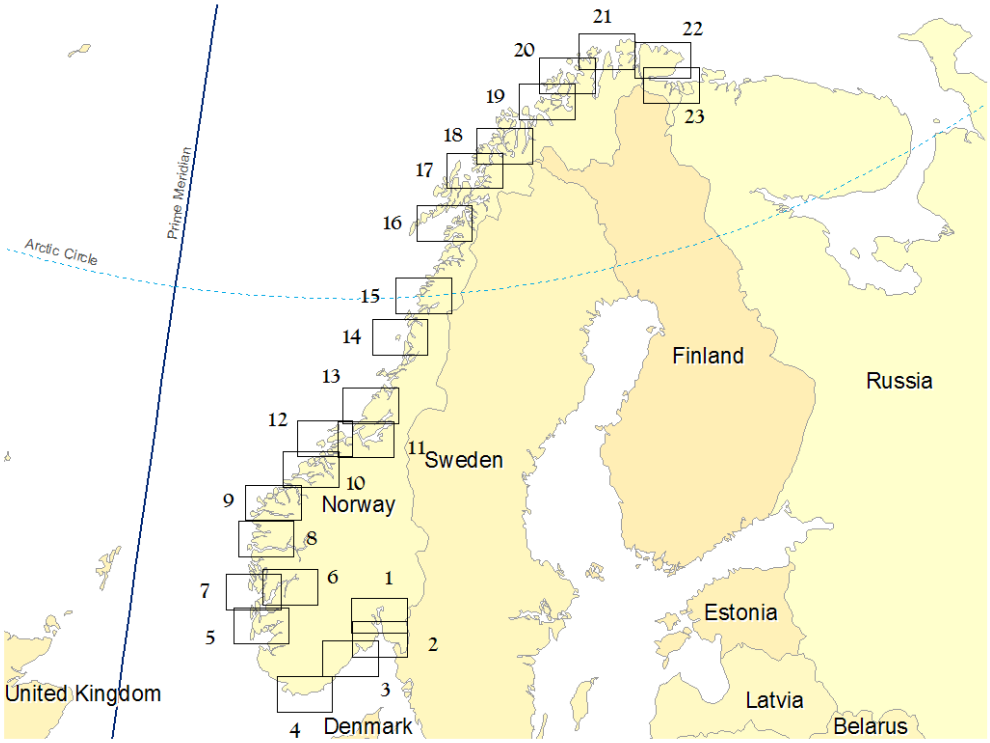
NOTES

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.

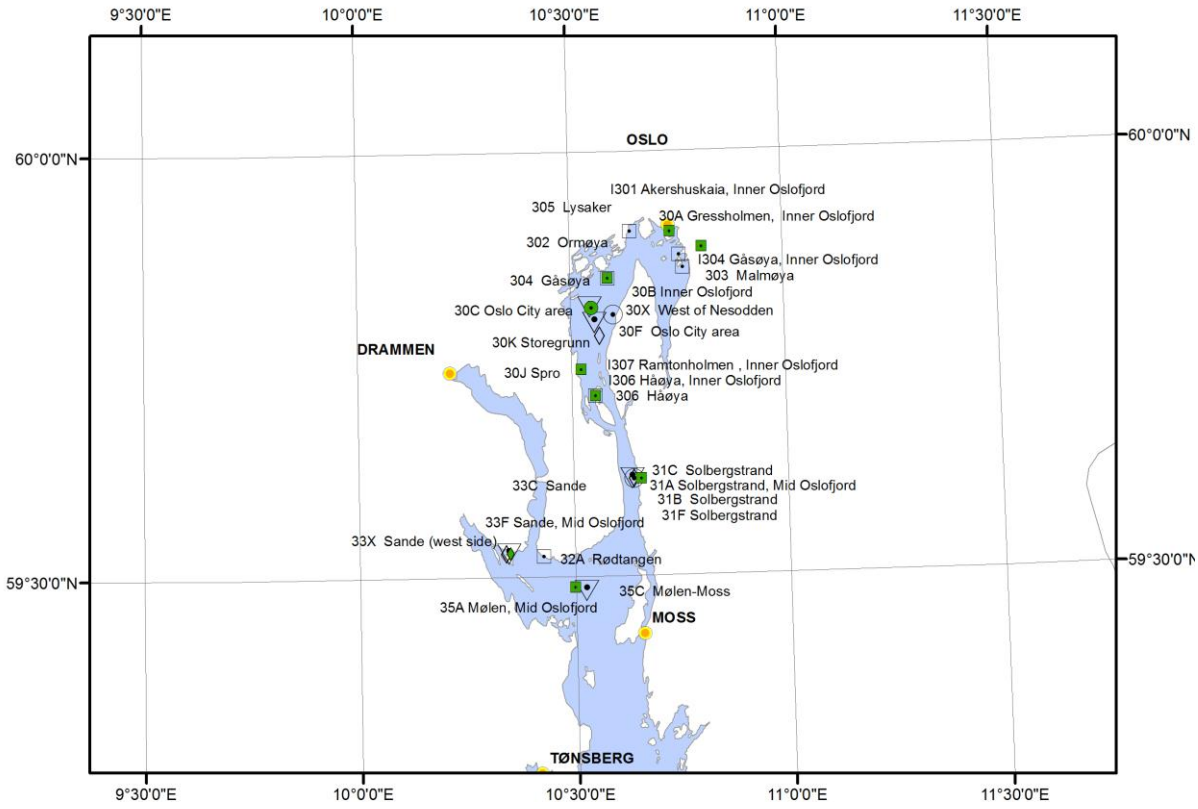
The following symbols and codes apply:

All years	2016	Explanation	Station code
		Sediment	<number>S
		Blue mussel	<number>A
		Blue mussel	I<number/letter> [1]
		Blue mussel	R<number/letter> [1]
		Dog whelk	<number>F
		Prawn	<number>C
		Atlantic cod	<number>A
		Flatfish	<number>D/E
		Other round fish	
		Town or city	

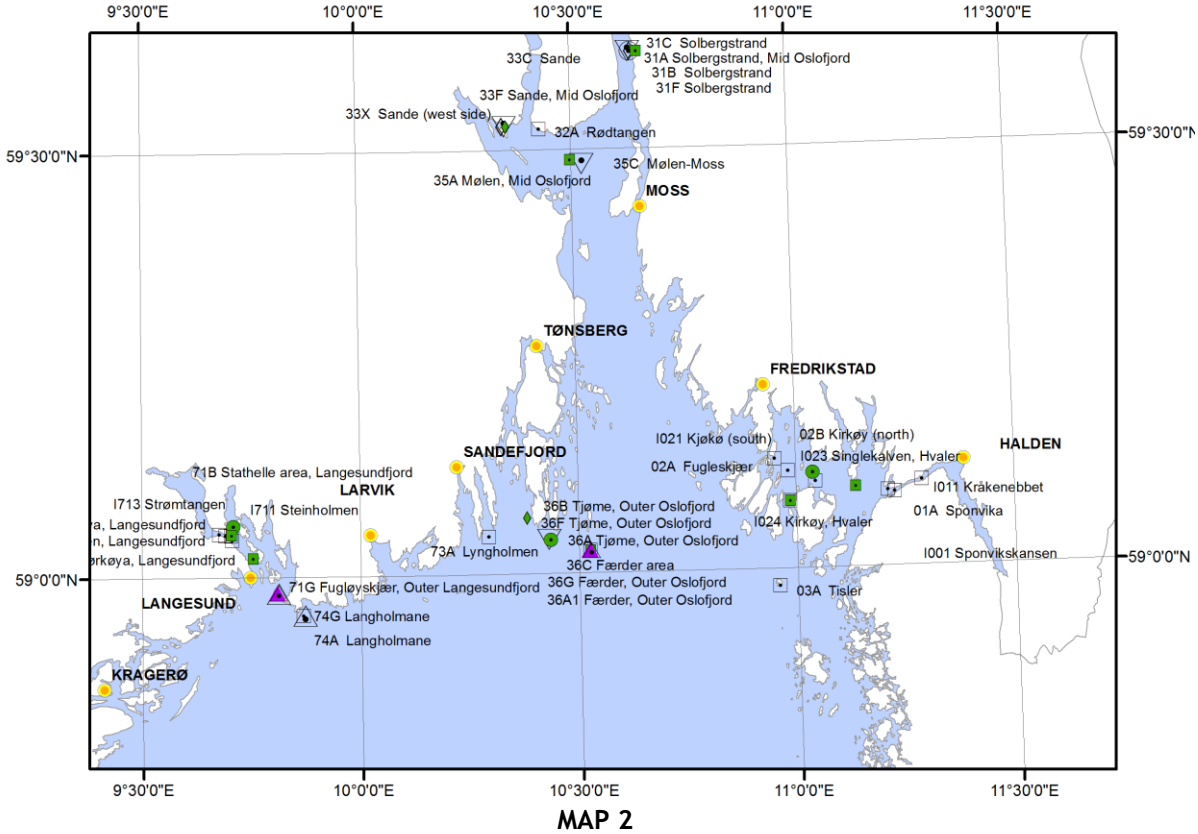
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (cf. Green *et al.* 2011b – TA-2862/2011).



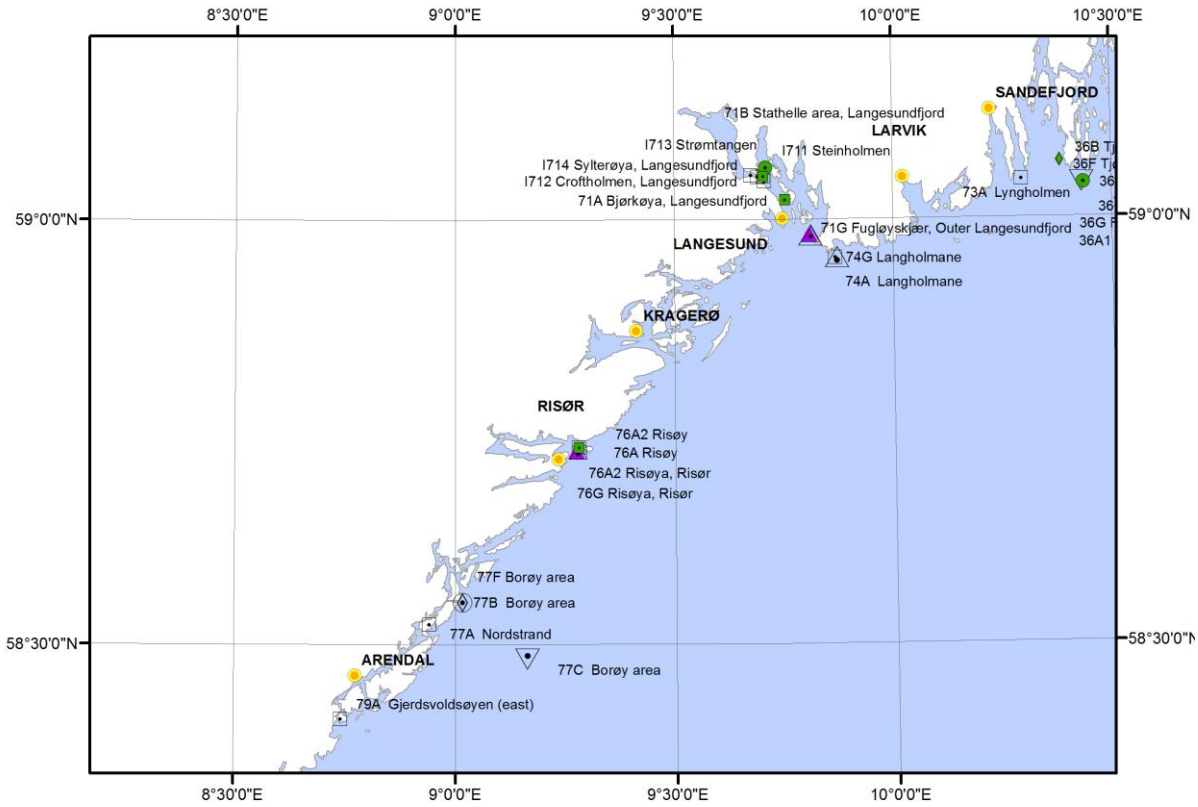
Maps presenting MILKYS stations in Norway. Numbers refer to map references that follow. Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


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
I301 Akershuskaia, Inner Oslofjord
305 Lysaker
30A Gressholmen, Inner Oslofjord
302 Ormøya
I304 Gåsøya, Inner Oslofjord
303 Malmøya
304 Gåsøya
30B Inner Oslofjord
30C Oslo City area
30X West of Nesodden
30F Oslo City area
30K Storegrunn
DRAMMEN
30J Spro
I307 Ramtonholmen , Inner Oslofjord
I306 Håøya, Inner Oslofjord
306 Håøya
31C Solbergstrand
33C Sande
31A Solbergstrand, Mid Oslofjord
31B Solbergstrand
31F Solbergstrand
33F Sande, Mid Oslofjord
33X Sande (west side)
32A Rødtangen
35C Mølen-Moss
35A Mølen, Mid Oslofjord
MOSS
TØNSBERG

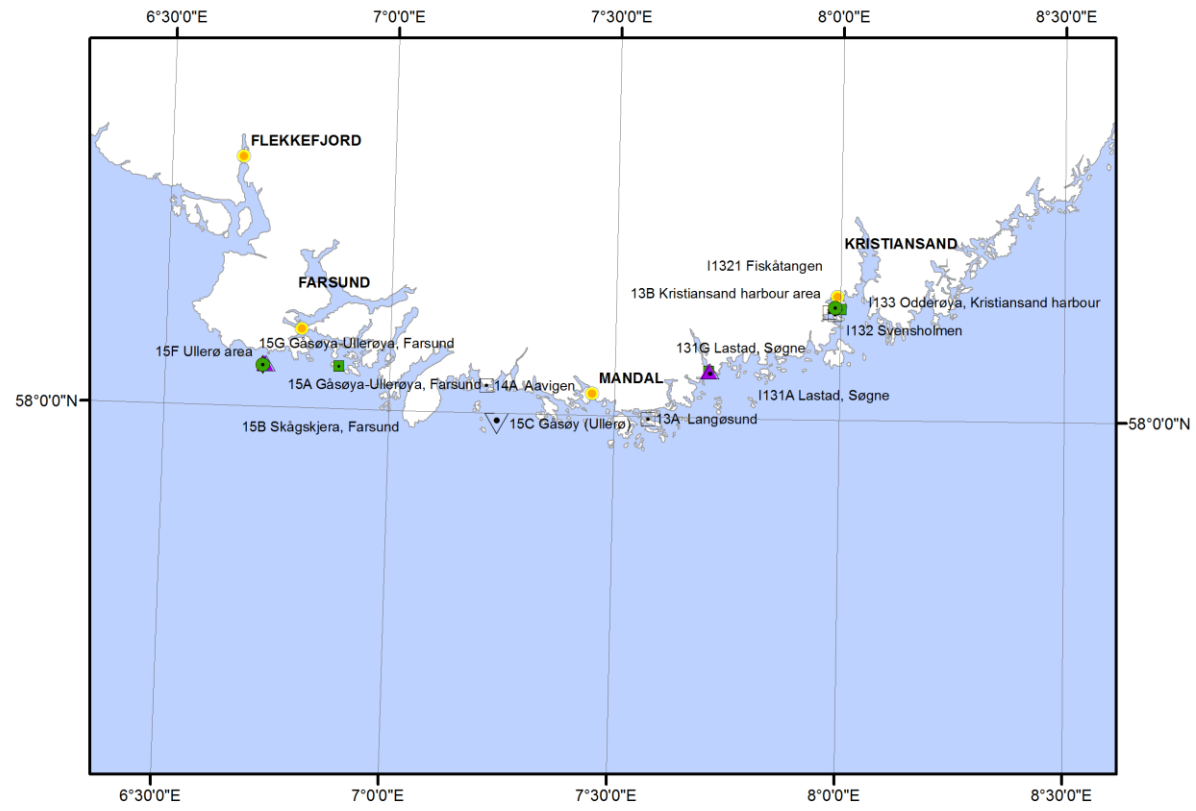
MAP 1


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

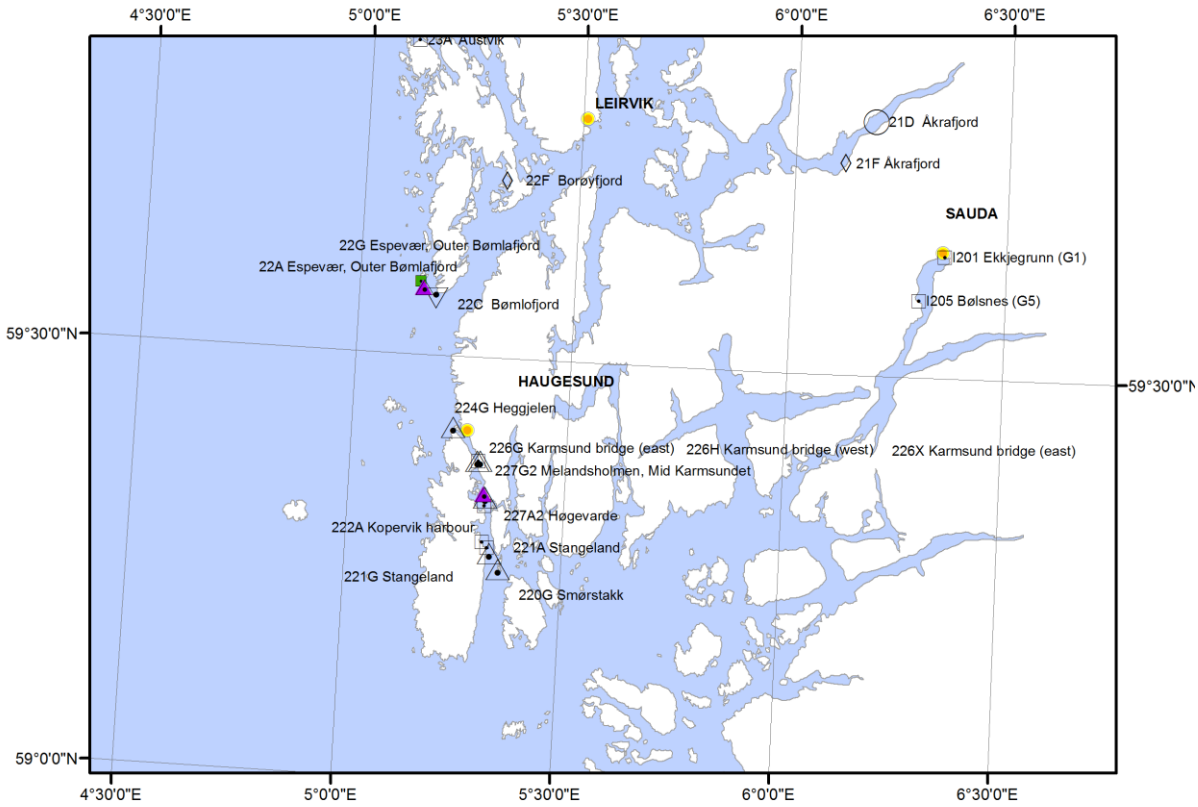
MAP 2


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
71B Stathelle area, Langesundfjord
I713 Strømtangen
I711 Steinholmen
I714 Sylterøya, Langesundfjord
I712 Croftholmen, Langesundfjord
71A Bjørkøya, Langesundfjord
73A Lyngholmen
71G Fugløyskjær, Outer Langesundfjord
LANGESUND
74G Langholmane
74A Langholmane
KRAGERØ
RISØR
76A2 Risøy
76A Risøy
76A2 Risøya, Risør
76G Risøya, Risør
77F Borøy area
77B Borøy area
77A Nordstrand
ARENDAL
77C Borøy area
79A Gjerdsvoldsøyen (east)

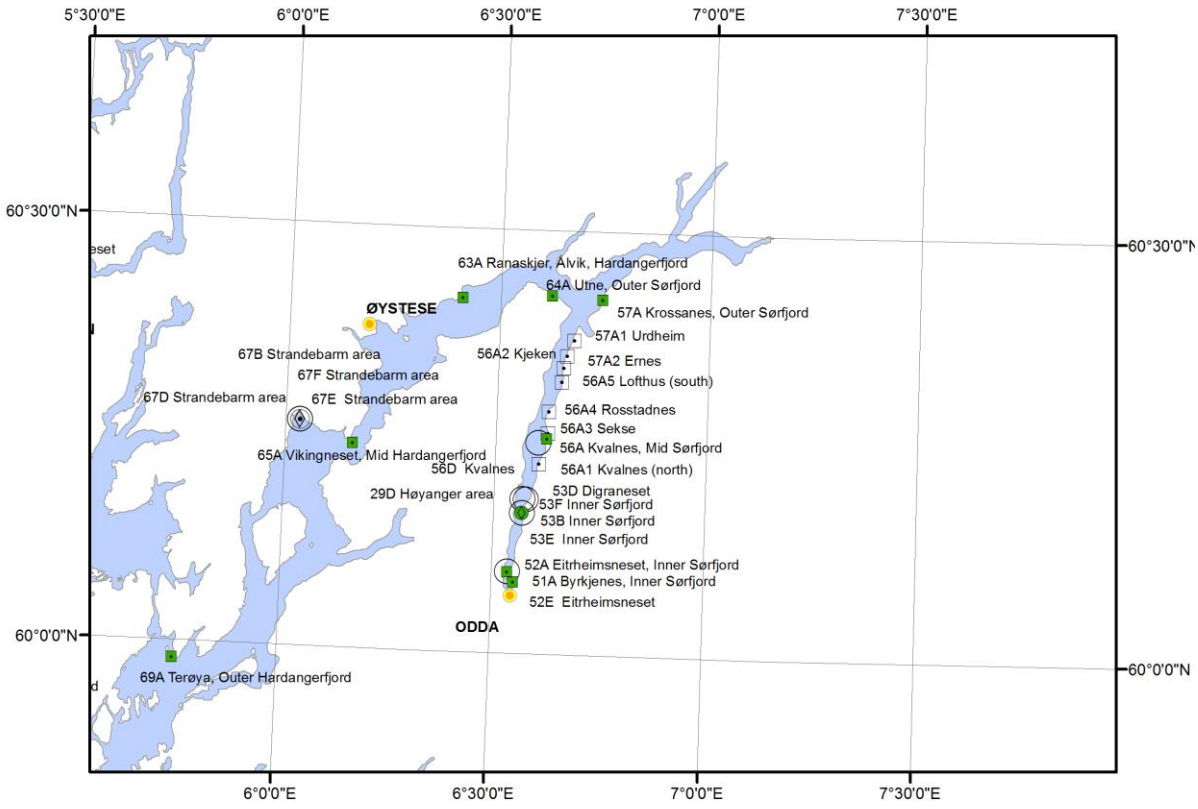
MAP 3


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

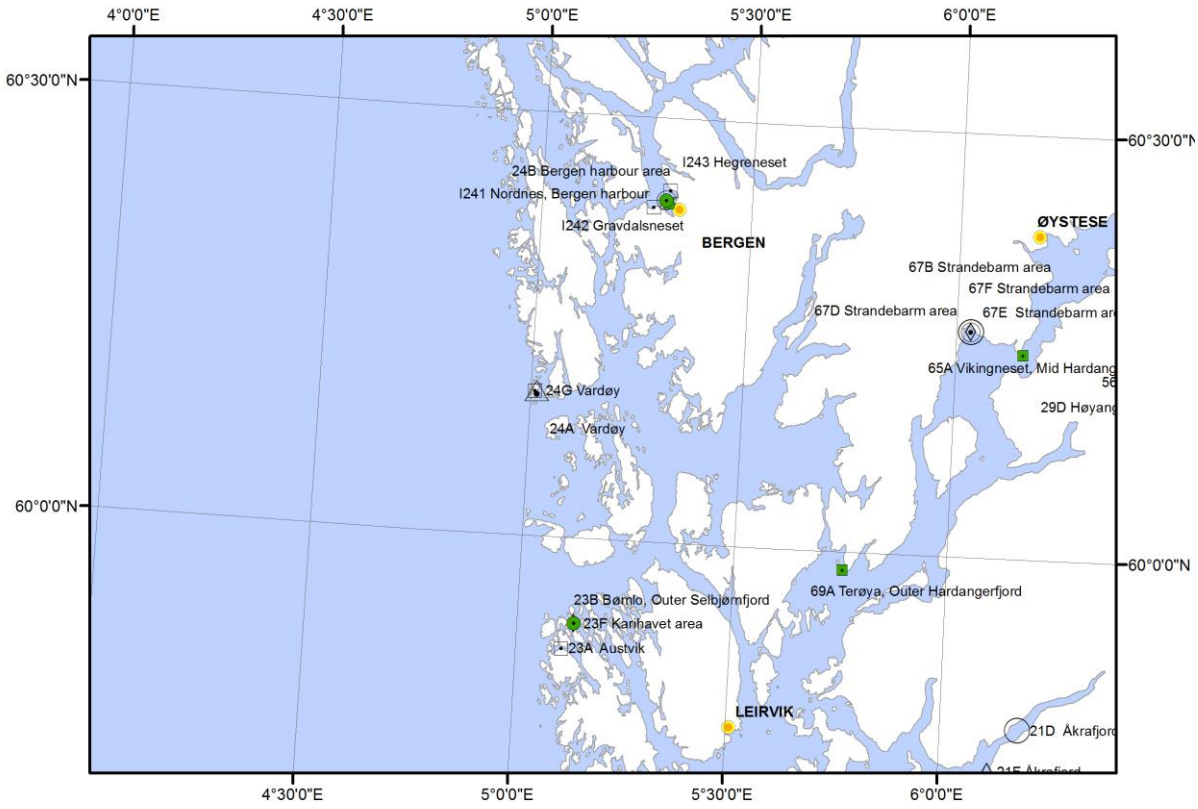
MAP 4


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
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
226G Karmsund bridge (east)
226H Karmsund bridge (west)
226X Karmsund bridge (east)
227G2 Melandsholmen, Mid Karmsundet
227A2 Høgevarde
222A Kopervik harbour
221A Stangeland
221G Stangeland
220G Smørstakk

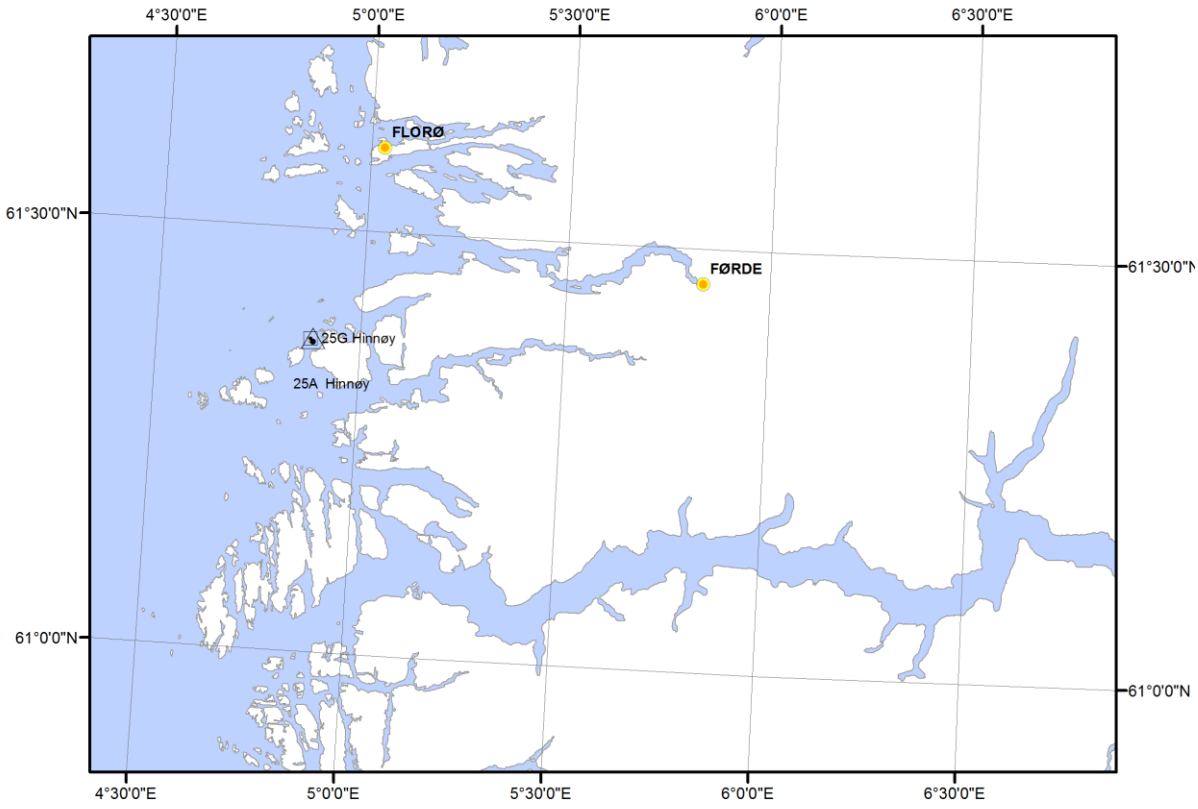
MAP 5


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, Alvik, 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
56A Kvalnes, Mid Sørfjord
56D Kvalnes
56A1 Kvalnes (north)
29D Høyanger area
53D Digraneset
53F Inner Sørfjord
53B Inner Sørfjord
53E Inner Sørfjord
52A Eitrheimsneset, Inner Sørfjord
51A Byrkjenes, Inner Sørfjord
52E Eitrheimsneset
ODDA
69A Terøya, Outer Hardangerfjord

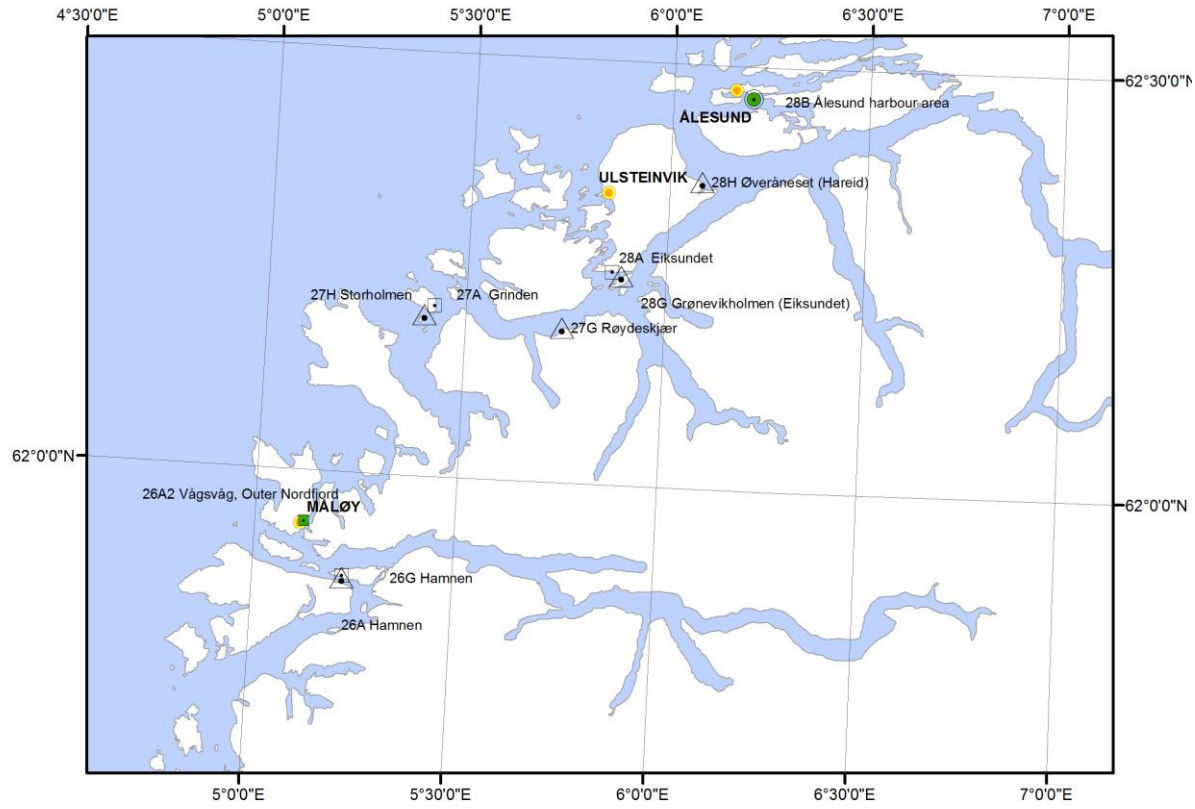
MAP 6


4°0'0"E
4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
60°30'0"N
60°0'0"N
24B Bergen harbour area
I243 Hegreneset
I241 Nordnes, Bergen harbour
I242 Gravdalsneset
BERGEN
ØYSTESE
67B Strandebarm area
67F Strandebarm area
67D Strandebarm area
67E Strandebarm ar
65A Vikingneset, Mid Hardang
29D Høyang
24G Vardøy
24A Vardøy
69A Terøya, Outer Hardangerfjord
23B Bømlo, Outer Selbjørnfjord
23F Karihavet area
23A Austvik
LEIRVIK
21D Åkrafjord

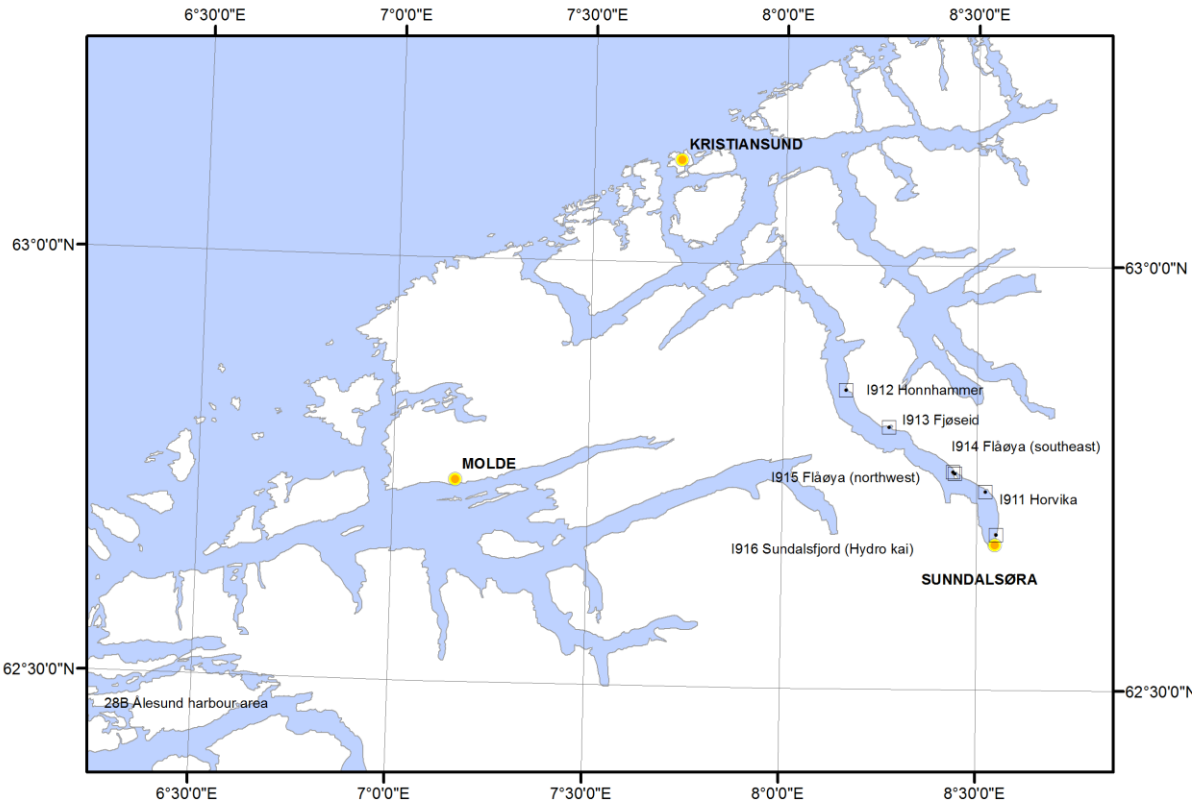
MAP 7


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
61°30'0"N
61°0'0"N
FLORØ
FØRDE
25G Hinnøy
25A Hinnøy

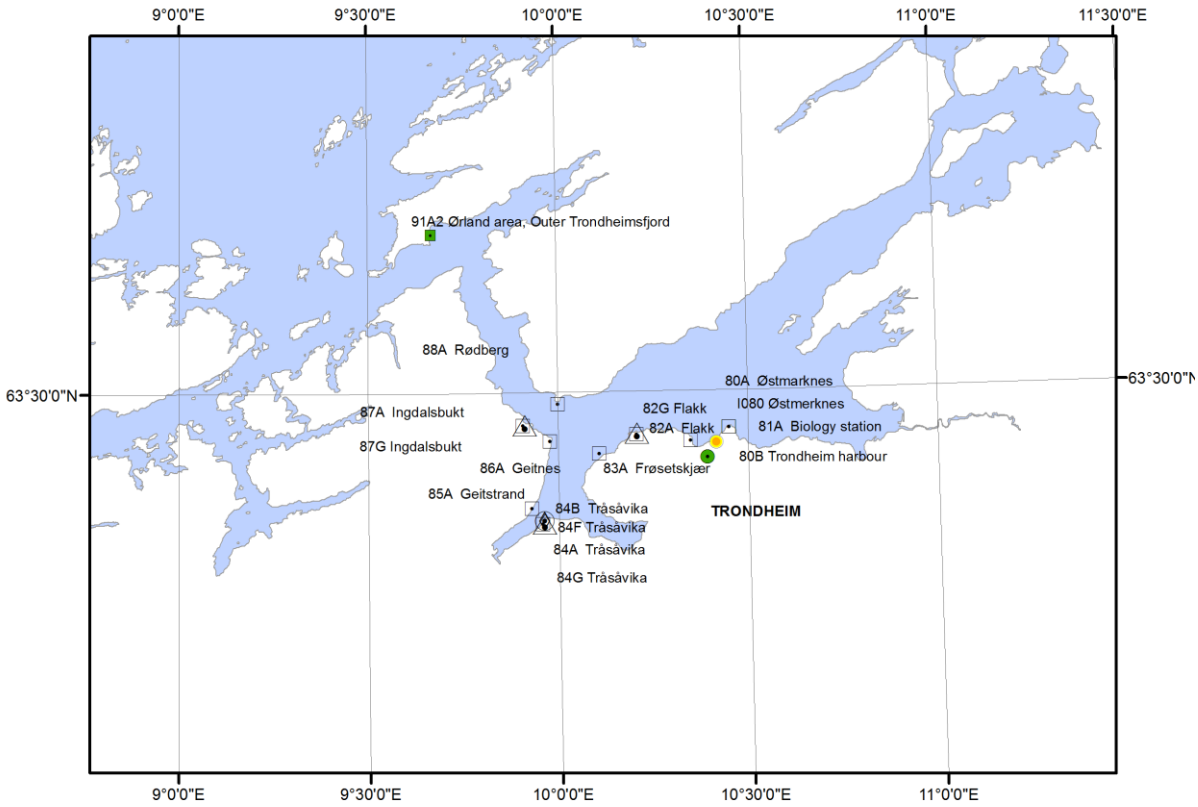
MAP 8


4°30'0"E
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
ÅLESUND
28B Ålesund harbour area
ULSTEINVIK
28H Øveråneset (Hareid)
28A Eiksundet
27H Storholmen
27A Grinden
28G Grønevikholmen (Eiksundet)
27G Røydeskjær
26A2 Vågsvåg, Outer Nordfjord
MÅLØY
26G Hamnen
26A Hamnen

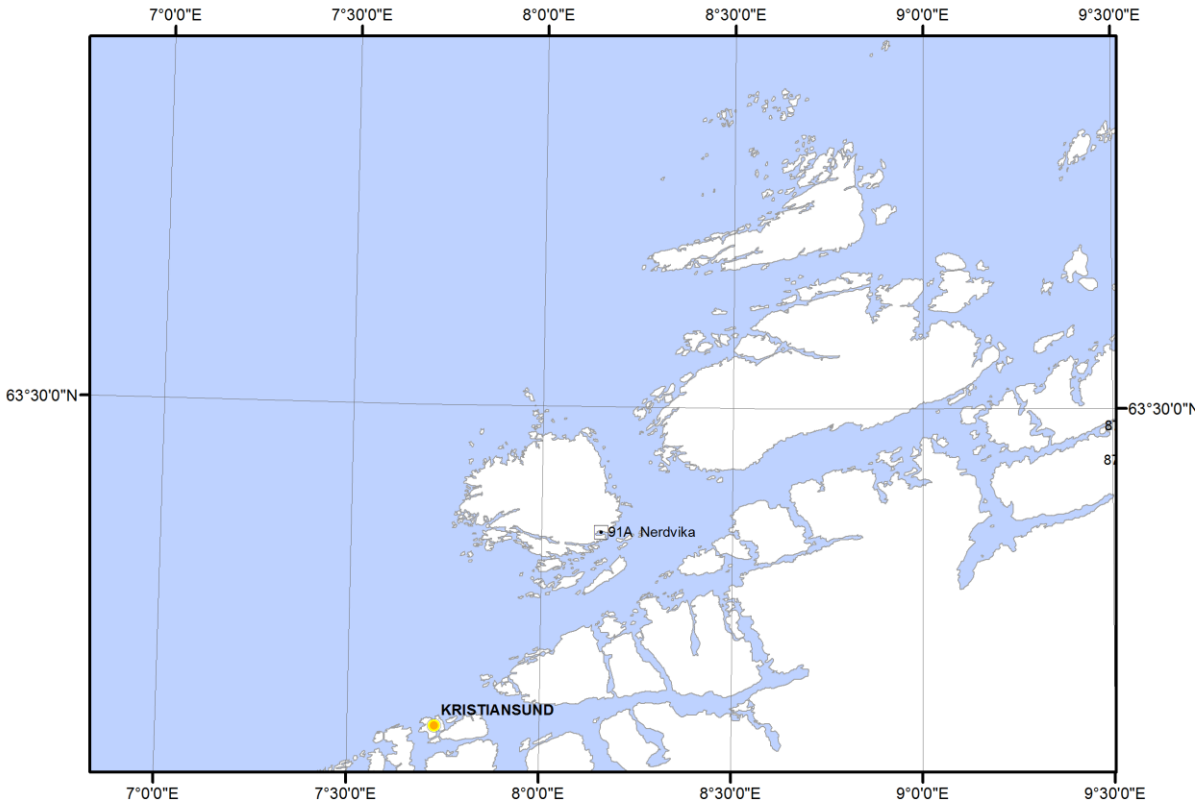
MAP 9


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
I912 Honnhammer
I913 Fjøseid
I914 Flåøya (southeast)
MOLDE
I915 Flåøya (northwest)
I911 Horvika
I916 Sundalsfjord (Hydro kai)
SUNNDALSØRA
28B Ålesund harbour area

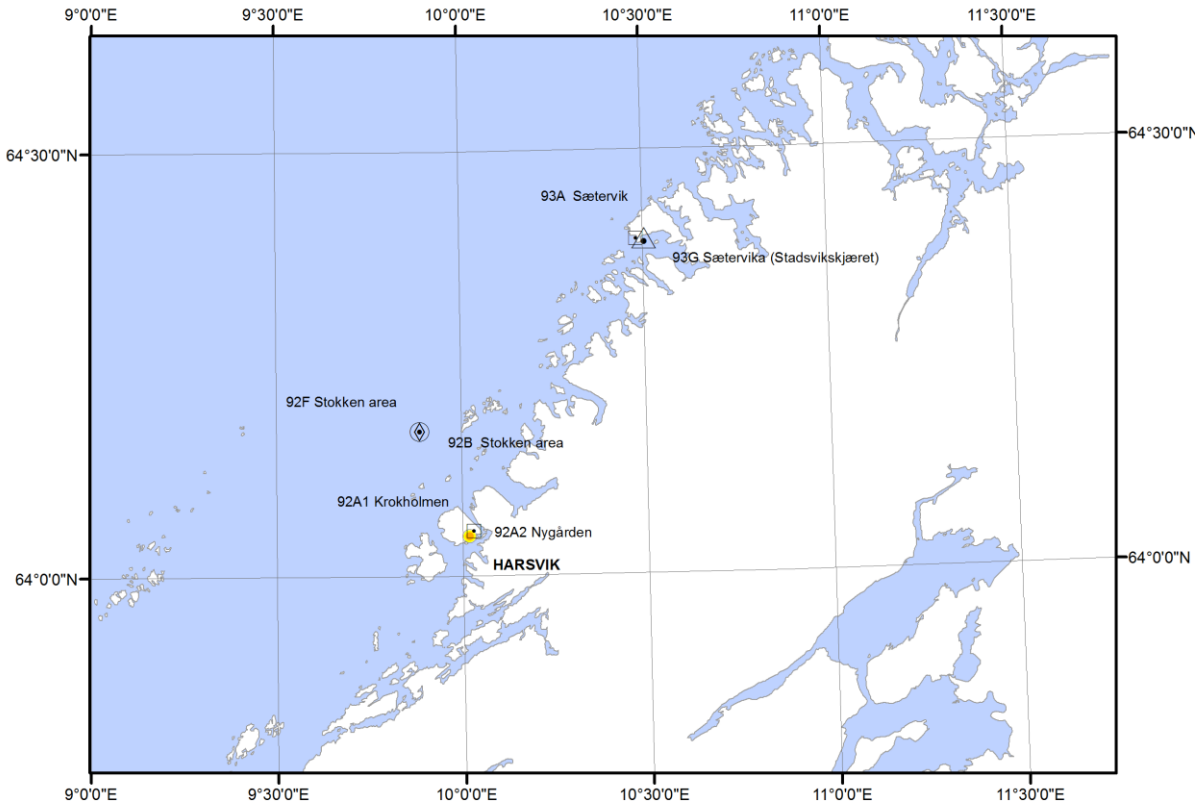
MAP 10


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

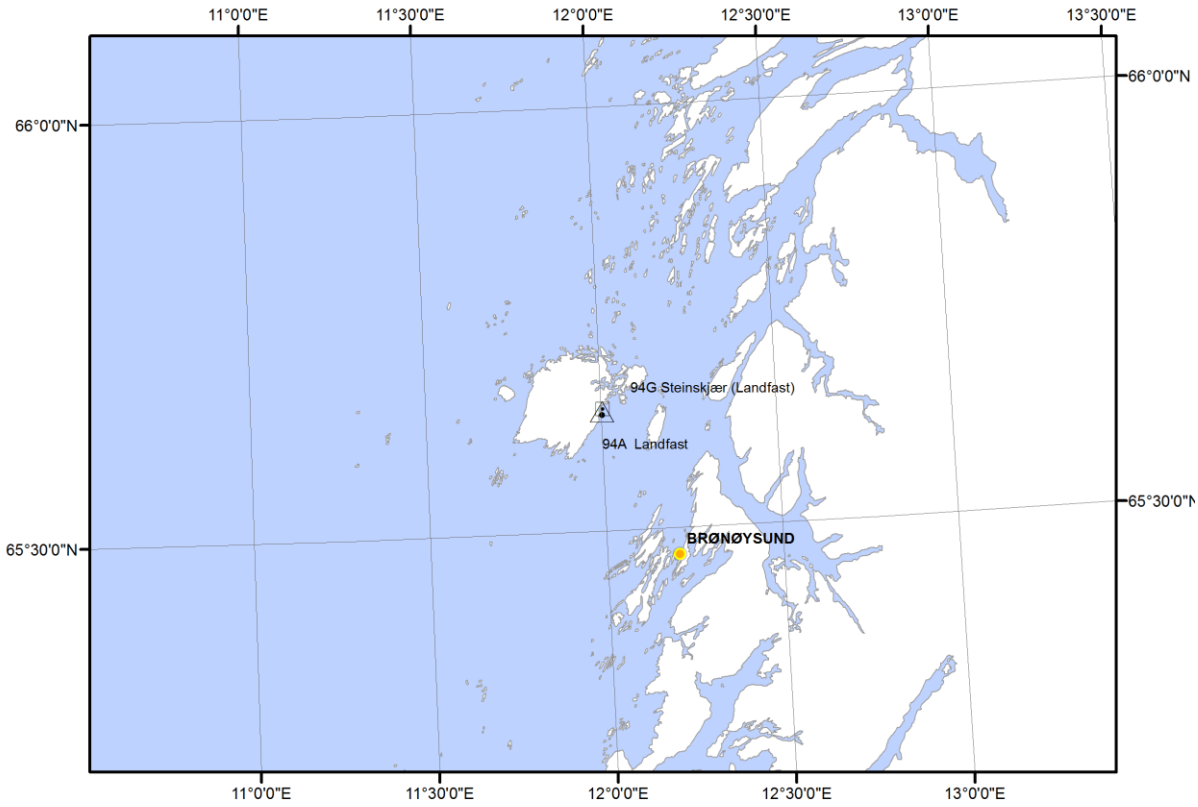
MAP 11


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

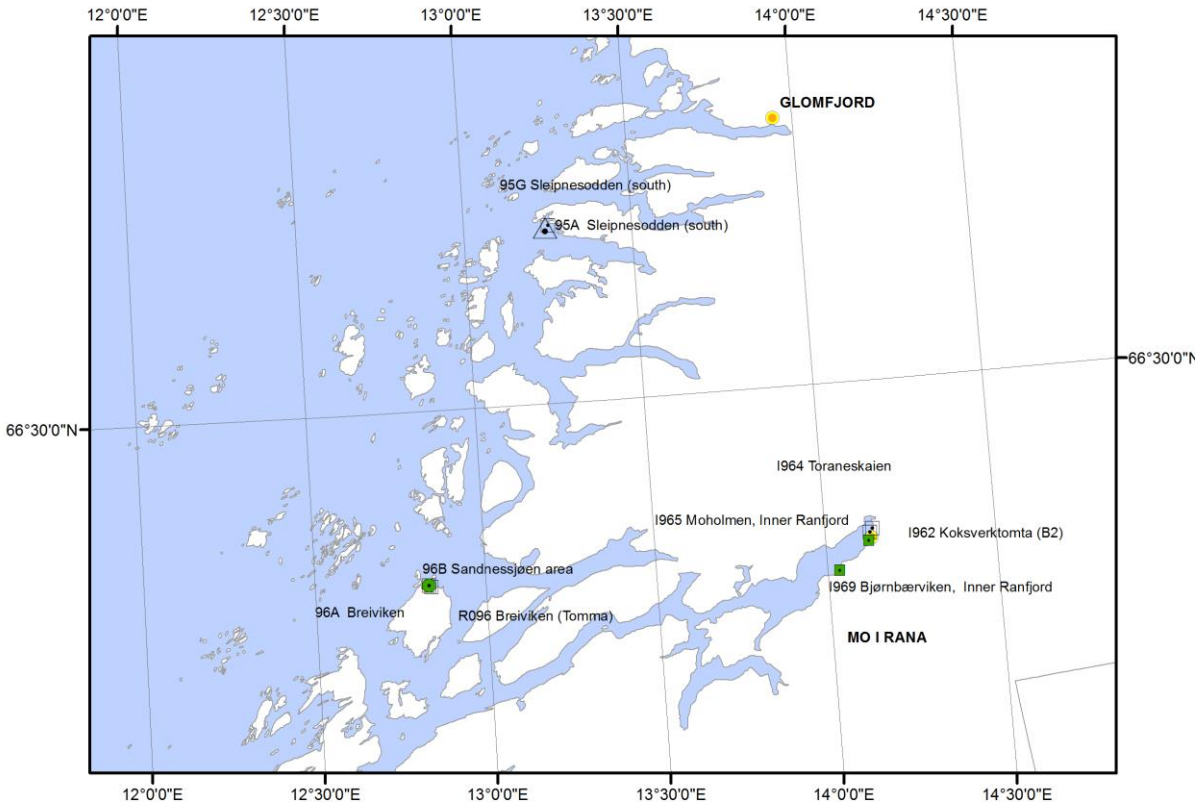
MAP 12


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

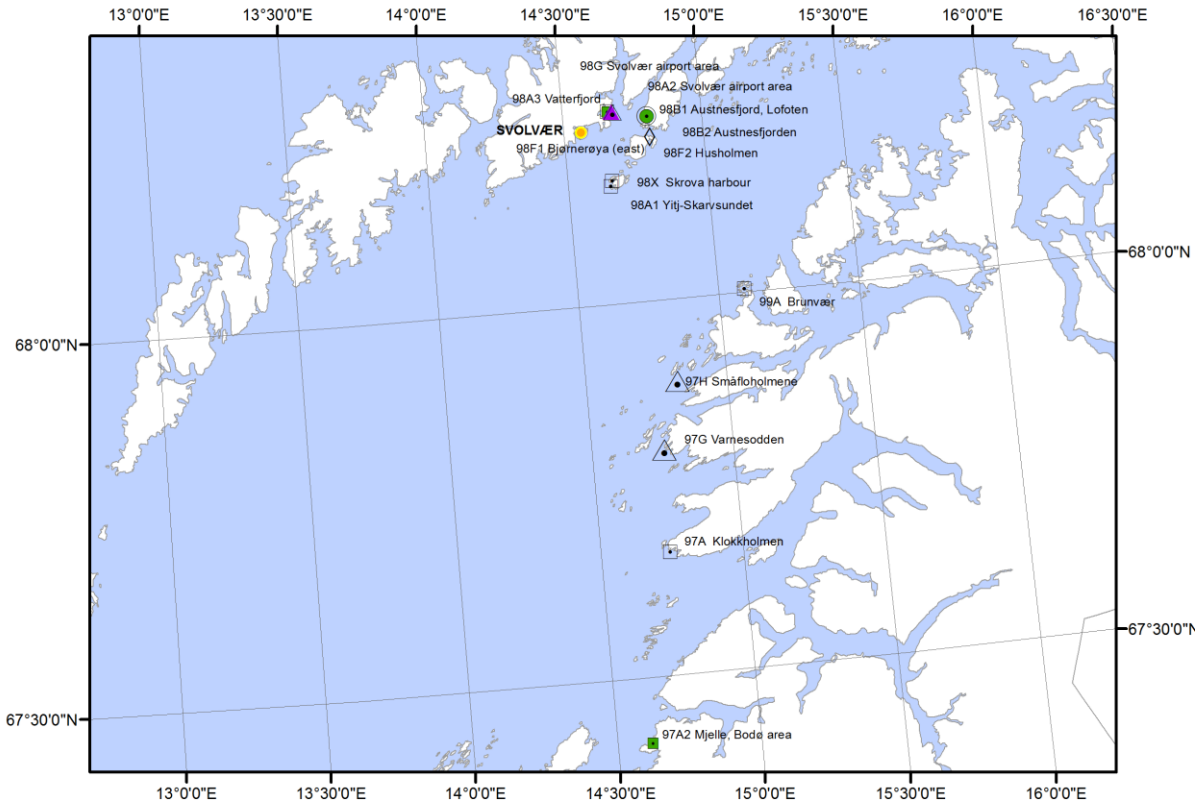
MAP 13


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
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

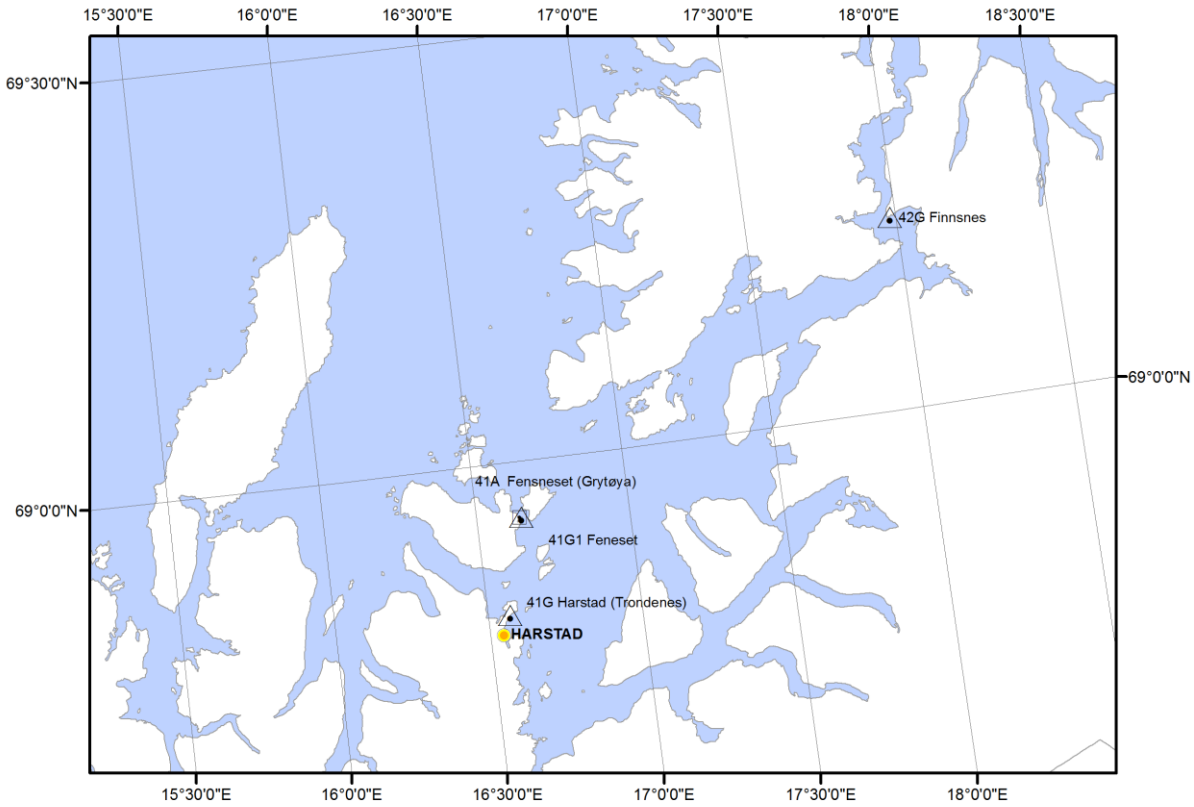
MAP 14


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

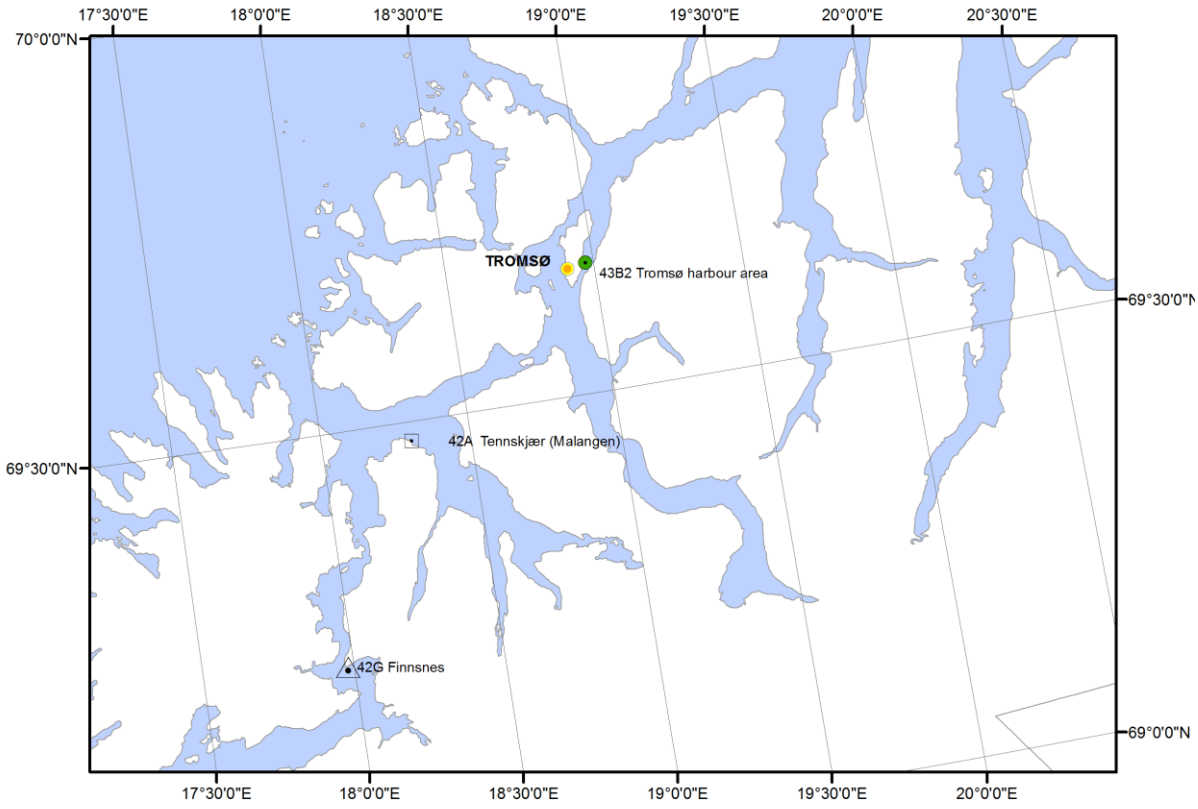
MAP 15


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

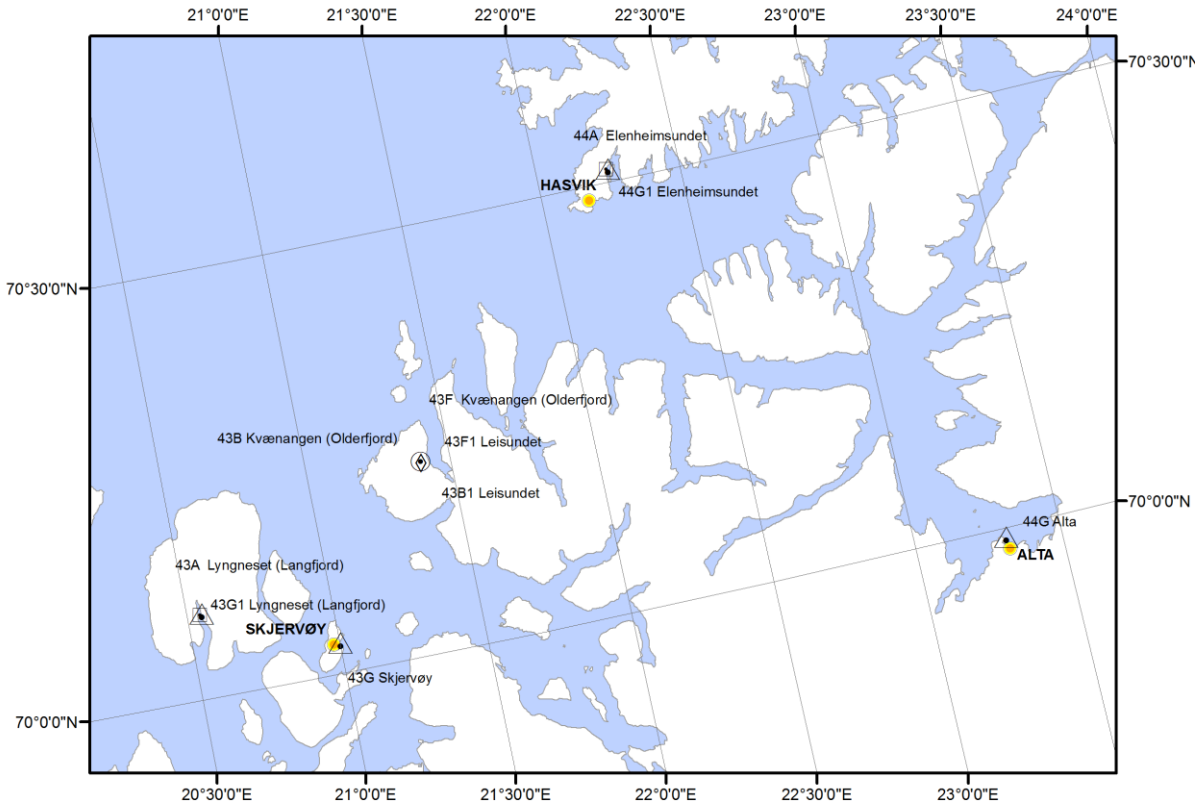
MAP 16


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

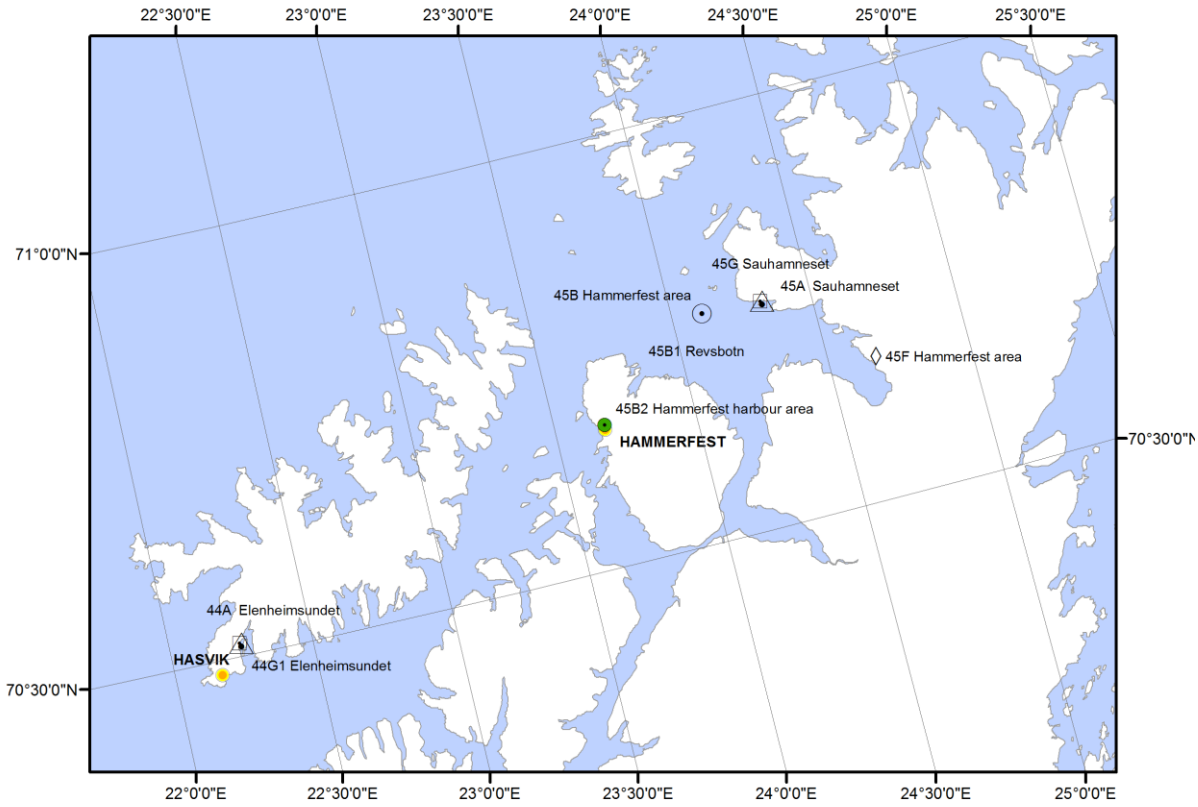
MAP 17


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

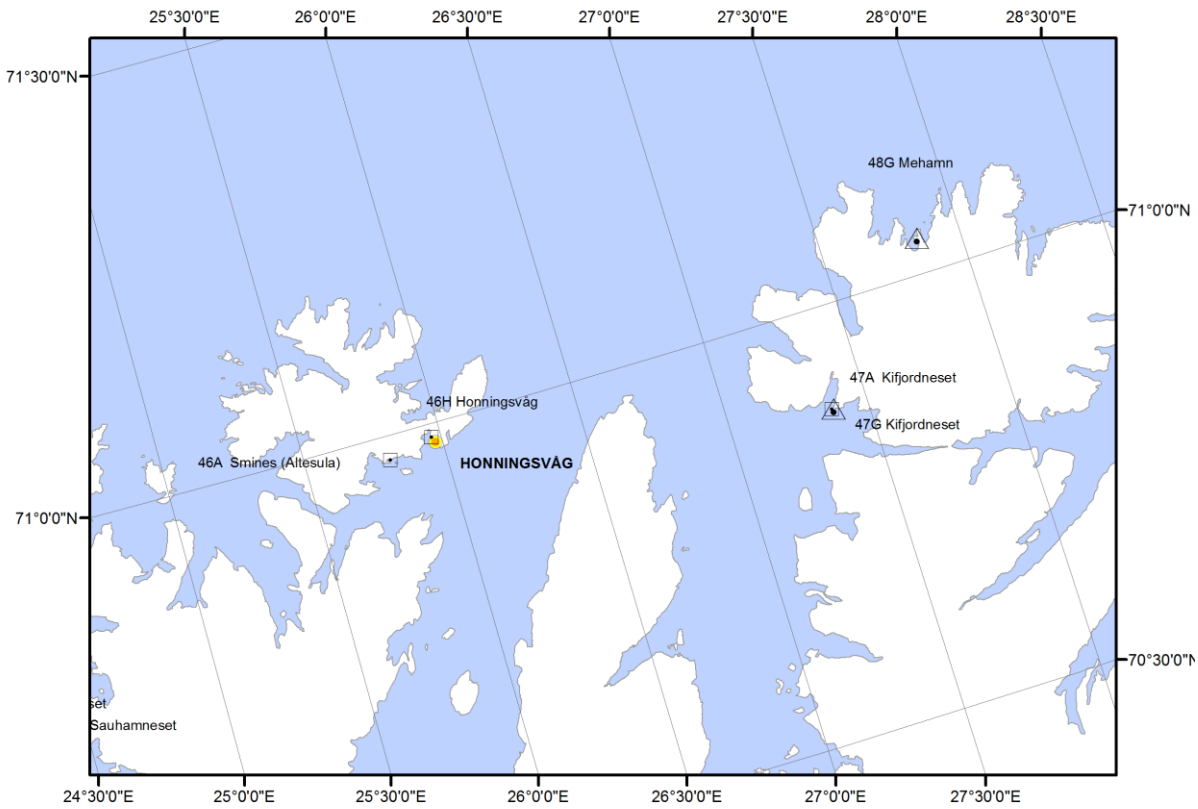
MAP 18


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

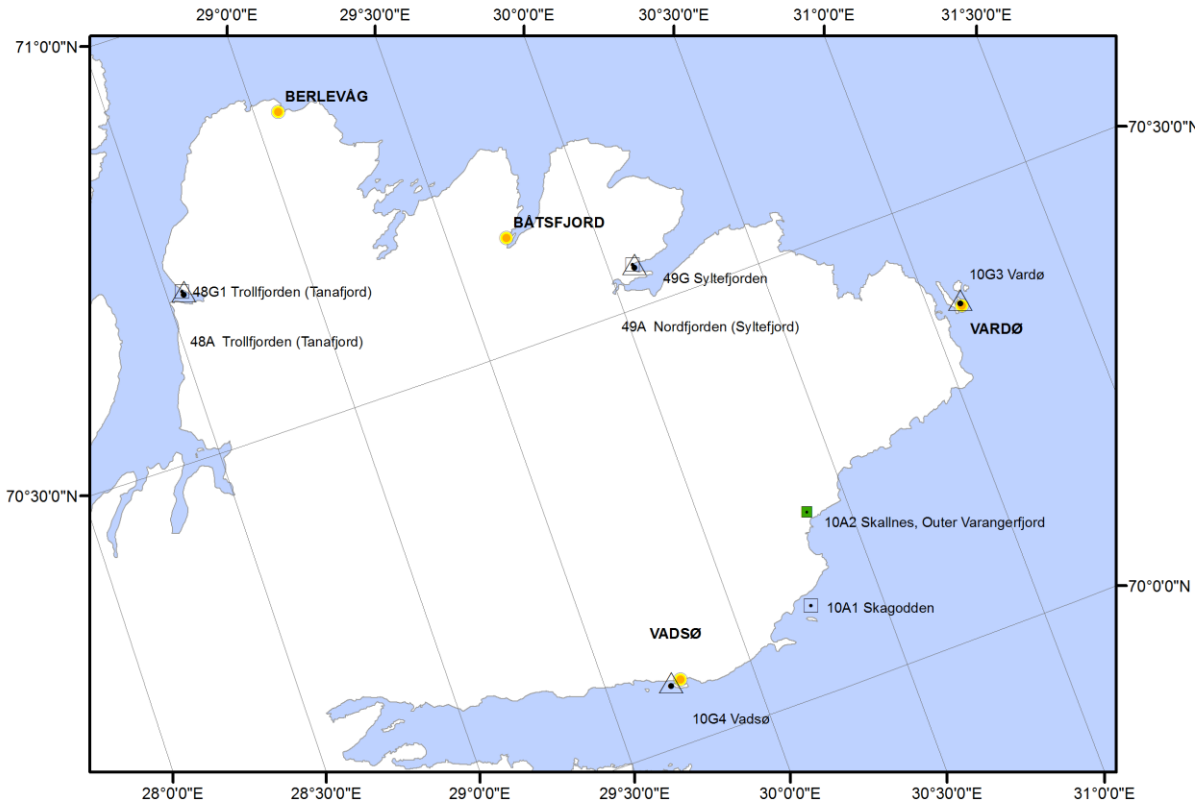
MAP 19


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
45B2 Hammerfest harbour area
HAMMERFEST
44A Elenheimsundet
HASVIK
44G1 Elenheimsundet

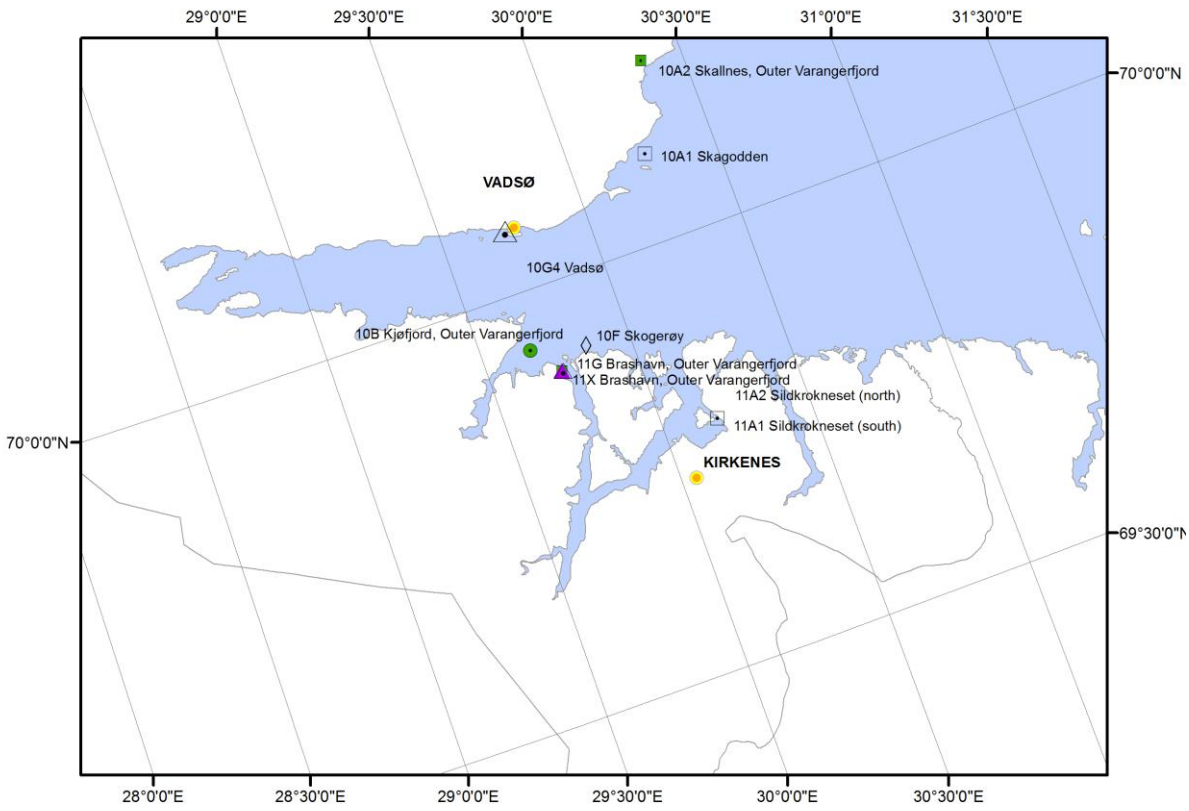
MAP 20


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
46A Smines (Altesula)
HONNINGSVÅG
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
28°0'0"E
28°30'0"E
29°0'0"E
29°30'0"E
30°0'0"E
30°30'0"E
10A2 Skallnes, Outer Varangerfjord
10A1 Skagodden
VADSØ
10G4 Vadsø
10B Kjøfjord, Outer Varangerfjord
10F Skogerøy
11G Brashavn, Outer Varangerfjord
11X Brashavn, Outer Varangerfjord
11A2 Sildkrokneset (north)
11A1 Sildkrokneset (south)
KIRKENES

MAP 23

Appendix E
Overview of materials and analyses 2015-2016

Nominal station positions are shown on maps in Appendix D

Year:
2015t - samples taken in 2015
2016p – samples planned in 2016
2016t – samples taken in 2016

Species:
Atlantic cod (*Gadus morhua***)**
Blue Mussel (*Mytilus edulis***)**
Dog whelk (*Nucella lapillus***)**
Periwinkle (*Littorina littorea)*

Tissue:
SB-Soft body tissue
LI-Liver tissue, in fish
MU-Muscle tissue, in fish
BL-Blood, in fish
BI-Bile, fish

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) 2015-2016:

code	Description	Me-SB	NI/LI-SB	Gm-BI	Gm-BL	Gm-LI	Gm-MU
I-MET	metals [1)]	x				X	
I-MET	Hg	x					x
ISOTO	$\delta^{15}N$ and $\delta^{13}C$	x					x
O-BR	PBDEs [2)]	x				x	x
OC-CB	PCBs [3)]	x				x	
OC-CL	HCB	x				x	x
OC-CP	SCCP, MCCP	x				x	
OC-DD	DDT, DDE, DDD	x				x	
OC-HC	α-, γ-HCH	x				x	
O-FL	PFAS [4)]					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
PFRs	PFRs [9)]	x	x			x	x
PHC	PHCs [10)]	x	x			x	x
BE	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)] PFRs – Phosphorus Flame Retardants and includes a selection of: TIBP, TBP, TCEP, TCPP, TDCP, TBEP, TPhP, EHDPP, V6, DBPhP, BdPhP, TEHP, ToCrP, TCrP.

[10)] PHC – phenols including BPA, TBBPA.

[11)] Biological effects methods.

[12)] Cod only.

***Appendix E**. Sampling and analyses for 2015-2016 –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
2015t	Gadus morhua	Bile	Inner Oslofjord (st. 30B)	59.8127	10.5518	12														12
2016p	Gadus morhua	Bile	Inner Oslofjord (st. 30B)	59.8127	10.5518	15														15
2016t	Gadus morhua	Bile	Inner Oslofjord (st. 30B)	59.8127	10.5518	15														15
2015t	Gadus morhua	Bile	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15														15
2016p	Gadus morhua	Bile	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15														15
2016t	Gadus morhua	Bile	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15														15
2015t	Gadus morhua	Bile	Inner Sørfjord (st. 53B)	60.0973	6.5397	14														14
2016p	Gadus morhua	Bile	Inner Sørfjord (st. 53B)	60.0973	6.5397	15														15
2016t	Gadus morhua	Bile	Inner Sørfjord (st. 53B)	60.0973	6.5397	15														15
2015t	Gadus morhua	Bile	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15														15
2016p	Gadus morhua	Bile	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15														15
2016t	Gadus morhua	Bile	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15														15
2015t	Gadus morhua	Blood	Inner Oslofjord (st. 30B)	59.8127	10.5518	12														12
2016p	Gadus morhua	Blood	Inner Oslofjord (st. 30B)	59.8127	10.5518	15														15
2016t	Gadus morhua	Blood	Inner Oslofjord (st. 30B)	59.8127	10.5518	15														15
2015t	Gadus morhua	Blood	Inner Sørfjord (st. 53B)	60.0973	6.5397	14														14
2016p	Gadus morhua	Blood	Inner Sørfjord (st. 53B)	60.0973	6.5397	15														15
2016t	Gadus morhua	Blood	Inner Sørfjord (st. 53B)	60.0973	6.5397	15														15
2015t	Gadus morhua	Blood	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15														15
2016p	Gadus morhua	Blood	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15														15
2016t	Gadus morhua	Blood	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15														15
2015t	Gadus morhua	Liver	Inner Oslofjord (st. 30B)	59.8127	10.5518	12		12	12	12	11	12		12		12	12	12		15
2016p	Gadus morhua	Liver	Inner Oslofjord (st. 30B)	59.8127	10.5518	15		15	15	15	15	15		15		15	15	15		15
2016t	Gadus morhua	Liver	Inner Oslofjord (st. 30B)	59.8127	10.5518	15		15	15	15	15	15		15		15	15	15		15
2015t	Gadus morhua	Liver	Tjøme, Outer Oslofjord (st. 36B)	59.0405	10.4358	15		15	15	15	15	15		15		15	15	15		

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM
2016p	Gadus morhua	Liver	Tjøme, Outer Oslofjord (st. 36B)	59.0405	10.4358	15		15	15	15	15	15		15		15	15	15		
2016t	Gadus morhua	Liver	Tjøme, Outer Oslofjord (st. 36B)	59.0405	10.4358	15		15	15	15	15	15		15		15	15	15		
2015t	Gadus morhua	Liver	Kirkøy, Hvaler (st. 02B)	59.0648	10.9735	5		5	5		5					5	5	5		
2016p	Gadus morhua	Liver	Kirkøy, Hvaler (st. 02B)	59.0648	10.9735	15		15	15		15					15	15	15		
2016t	Gadus morhua	Liver	Kirkøy, Hvaler (st. 02B)	59.0648	10.9735	5		5	5		4					5	4	5		
2015t	Gadus morhua	Liver	Stathelle area, Langesundfjord (st. 71B)	59.0465	9.7028	15		15			15					15	15	15		
2016p	Gadus morhua	Liver	Stathelle area, Langesundfjord (st. 71B)	59.0465	9.7028	15		15			15					15	15	15		
2016t	Gadus morhua	Liver	Stathelle area, Langesundfjord (st. 71B)	59.0465	9.7028	15		15			15					15	15	15		
2015t	Gadus morhua	Liver	Kristiansand harbour area (st. 13B)	58.1328	7.9885	14		14	14		14			14		14	14	14		
2016p	Gadus morhua	Liver	Kristiansand harbour area (st. 13B)	58.1328	7.9885	15		15	15		15			15		15	15	15		
2016t	Gadus morhua	Liver	Kristiansand harbour area (st. 13B)	58.1328	7.9885	15		15	15		15			15		15	15	15		
2015t	Gadus morhua	Liver	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15			15	15		15								15
2016p	Gadus morhua	Liver	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15			15	15		15								15
2016t	Gadus morhua	Liver	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15			15	15		15								15
2015t	Gadus morhua	Liver	Inner Sørfjord (st. 53B)	60.0973	6.5397	14		14	14	14	14	14		14		14	14	14		15
2016p	Gadus morhua	Liver	Inner Sørfjord (st. 53B)	60.0973	6.5397	15		15	15	15	15	15		15		15	15	15		15
2016t	Gadus morhua	Liver	Inner Sørfjord (st. 53B)	60.0973	6.5397	15		15	15	15	15	15		15		15	15	15		16
2015t	Gadus morhua	Liver	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15		15	15	15	15	15		15		15	15	15		15
2016p	Gadus morhua	Liver	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15		15	15	15	15	15	15	15		15	15	15		15
2016t	Gadus morhua	Liver	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15		15	15	15	15	15	15	15		15	15	15		15
2015t	Gadus morhua	Liver	Bergen harbour area (st. 24B)	60.3966	5.2707	15		15	15		15			15			7			
2016p	Gadus morhua	Liver	Bergen harbour area (st. 24B)	60.3966	5.2707	15		15	15		15			15		15	15	15		
2016t	Gadus morhua	Liver	Bergen harbour area (st. 24B)	60.3966	5.2707	15		15	15		15			15		15	15	15		
2015t	Gadus morhua	Liver	Ålesund harbour area (st. 28B)	62.4678	6.0686	6		12	6		6					6	6	6		
2016p	Gadus morhua	Liver	Ålesund harbour area (st. 28B)	62.4678	6.0686	15		15	15		15					15	15	15		
2016t	Gadus morhua	Liver	Ålesund harbour area (st. 28B)	62.4678	6.0686	7		14	6		7					6	6	6		

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
2015t	Gadus morhua	Liver	Trondheim harbour (st. 80B)	63.4456	10.3717	15		15	15		15			15		15	15	15		
2016p	Gadus morhua	Liver	Trondheim harbour (st. 80B)	63.4456	10.3717	15		15	15		15			15		15	15	15		
2016t	Gadus morhua	Liver	Trondheim harbour (st. 80B)	63.4456	10.3717	14		14	14		14			14		14	14	14		
2015t	Gadus morhua	Liver	Sandnessjøen area (st. 96B)	66.0444	12.5036	15			15											
2016p	Gadus morhua	Liver	Sandnessjøen area (st. 96B)	66.0444	12.5036	15			15											
2016t	Gadus morhua	Liver	Sandnessjøen area (st. 96B)	66.0444	12.5036	15			15											
2015t	Gadus morhua	Liver	Austnesfjord, Lofoten (st. 98B1)	68.1858	14.7081	14		15	15	15	15	15		15			15			
2016p	Gadus morhua	Liver	Austnesfjord, Lofoten (st. 98B1)	68.1858	14.7081	15		15	15	15	15	15		15			15			
2016t	Gadus morhua	Liver	Austnesfjord, Lofoten (st. 98B1)	68.1858	14.7081	15		15	15	15	15	15		15			15			
2015t	Gadus morhua	Liver	Tromsø harbour area (st. 43B2)	69.6530	18.9740	13		13	13		13			13		13	13	13		
2016p	Gadus morhua	Liver	Tromsø harbour area (st. 43B2)	69.6530	18.9740	15		15	15		15			15		15	15	15		
2016t	Gadus morhua	Liver	Tromsø harbour area (st. 43B2)	69.6530	18.9740	12		12	12		11			12		12	12	12		
2015t	Gadus morhua	Liver	Hammerfest harbour area (st. 45B2)	70.6500	23.6333	11			11											
2016p	Gadus morhua	Liver	Hammerfest harbour area (st. 45B2)	70.6500	23.6333	15			15											
2016t	Gadus morhua	Liver	Hammerfest harbour area (st. 45B2)	70.6500	23.6333	13			13											
2015t	Gadus morhua	Liver	Kjøfjord, Outer Varangerfjord (st. 10B)	69.8162	29.7602	11			11	11		11								
2016p	Gadus morhua	Liver	Kjøfjord, Outer Varangerfjord (st. 10B)	69.8162	29.7602	15			15	15		15								
2016t	Gadus morhua	Liver	Kjøfjord, Outer Varangerfjord (st. 10B)	69.8162	29.7602	13			13	13		13								
2015t	Gadus morhua	Fillet	Inner Oslofjord (st. 30B)	59.8127	10.5518	15													15	
2016p	Gadus morhua	Fillet	Inner Oslofjord (st. 30B)	59.8127	10.5518	15													15	
2016t	Gadus morhua	Fillet	Inner Oslofjord (st. 30B)	59.8127	10.5518	15													15	
2015t	Gadus morhua	Fillet	Tjøme, Outer Oslofjord (st. 36B)	59.0405	10.4358	15													15	
2016p	Gadus morhua	Fillet	Tjøme, Outer Oslofjord (st. 36B)	59.0405	10.4358	15													15	
2016t	Gadus morhua	Fillet	Tjøme, Outer Oslofjord (st. 36B)	59.0405	10.4358	15													15	
2015t	Gadus morhua	Fillet	Kirkøy, Hvaler (st. 02B)	59.0648	10.9735	14													14	
2016p	Gadus morhua	Fillet	Kirkøy, Hvaler (st. 02B)	59.0648	10.9735	15													15	

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM
2016t	Gadus morhua	Fillet	Kirkøy, Hvaler (st. 02B)	59.0648	10.9735	10													10	
2015t	Gadus morhua	Fillet	Stathelle area, Langesundfjord (st. 71B)	59.0465	9.7028	15													15	
2016p	Gadus morhua	Fillet	Stathelle area, Langesundfjord (st. 71B)	59.0465	9.7028	15													15	
2016t	Gadus morhua	Fillet	Stathelle area, Langesundfjord (st. 71B)	59.0465	9.7028	15													15	
2015t	Gadus morhua	Fillet	Kristiansand harbour area (st. 13B)	58.1328	7.9885	15													15	
2016p	Gadus morhua	Fillet	Kristiansand harbour area (st. 13B)	58.1328	7.9885	15													15	
2016t	Gadus morhua	Fillet	Kristiansand harbour area (st. 13B)	58.1328	7.9885	15													15	
2015t	Gadus morhua	Fillet	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15													15	
2016p	Gadus morhua	Fillet	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15													15	
2016t	Gadus morhua	Fillet	Skågskjera, Farsund (st. 15B)	58.0514	6.7469	15													15	
2015t	Gadus morhua	Fillet	Inner Sørfjord (st. 53B)	60.0973	6.5397	15													15	
2016p	Gadus morhua	Fillet	Inner Sørfjord (st. 53B)	60.0973	6.5397	15													15	
2016t	Gadus morhua	Fillet	Inner Sørfjord (st. 53B)	60.0973	6.5397	15													15	
2015t	Gadus morhua	Fillet	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15													15	
2016p	Gadus morhua	Fillet	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15													15	
2016t	Gadus morhua	Fillet	Bømlo, Outer Selbjørnfjord (st. 23B)	59.8956	5.1086	15													15	
2015t	Gadus morhua	Fillet	Bergen harbour area (st. 24B)	60.3966	5.2707	15													15	
2016p	Gadus morhua	Fillet	Bergen harbour area (st. 24B)	60.3966	5.2707	15													15	
2016t	Gadus morhua	Fillet	Bergen harbour area (st. 24B)	60.3966	5.2707	15													15	
2015t	Gadus morhua	Fillet	Ålesund harbour area (st. 28B)	62.4678	6.0686	8													8	
2016p	Gadus morhua	Fillet	Ålesund harbour area (st. 28B)	62.4678	6.0686	15													15	
2016t	Gadus morhua	Fillet	Ålesund harbour area (st. 28B)	62.4678	6.0686	8													8	
2015t	Gadus morhua	Fillet	Trondheim harbour (st. 80B)	63.4456	10.3717	15													15	
2016p	Gadus morhua	Fillet	Trondheim harbour (st. 80B)	63.4456	10.3717	15													15	
2016t	Gadus morhua	Fillet	Trondheim harbour (st. 80B)	63.4456	10.3717	15													15	
2015t	Gadus morhua	Fillet	Sandnessjøen area (st. 96B)	66.0444	12.5036	15													15	

YEAR	LATIN_NAME	TISSUE_NAME	Station name	Latitude	Longitude	I-MET	O-MET	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-HC	O-FL	O-PAH	O-PHE	PFR	PHC	ISOTO	BEM
2016p	Gadus morhua	Fillet	Sandnessjøen area (st. 96B)	66.0444	12.5036	15													15	
2016t	Gadus morhua	Fillet	Sandnessjøen area (st. 96B)	66.0444	12.5036	15													15	
2015t	Gadus morhua	Fillet	Austnesfjord, Lofoten (st. 98B1)	68.1858	14.7081	15													15	
2016p	Gadus morhua	Fillet	Austnesfjord, Lofoten (st. 98B1)	68.1858	14.7081	15													15	
2016t	Gadus morhua	Fillet	Austnesfjord, Lofoten (st. 98B1)	68.1858	14.7081	15													15	
2015t	Gadus morhua	Fillet	Tromsø harbour area (st. 43B2)	69.6530	18.9740	15													15	
2016p	Gadus morhua	Fillet	Tromsø harbour area (st. 43B2)	69.6530	18.9740	15													15	
2016t	Gadus morhua	Fillet	Tromsø harbour area (st. 43B2)	69.6530	18.9740	15													15	
2015t	Gadus morhua	Fillet	Hammerfest harbour area (st. 45B2)	70.6500	23.6333	15													15	
2016p	Gadus morhua	Fillet	Hammerfest harbour area (st. 45B2)	70.6500	23.6333	15													15	
2016t	Gadus morhua	Fillet	Hammerfest harbour area (st. 45B2)	70.6500	23.6333	15													15	
2015t	Gadus morhua	Fillet	Kjøfjord, Outer Varangerfjord (st. 10B)	69.8162	29.7602	15													15	
2016p	Gadus morhua	Fillet	Kjøfjord, Outer Varangerfjord (st. 10B)	69.8162	29.7602	15													15	
2016t	Gadus morhua	Fillet	Kjøfjord, Outer Varangerfjord (st. 10B)	69.8162	29.7602	15													15	
2015t	Mytilus edulis	Whole soft body	Akershuskaia, Inner Oslofjord (st. I301)	59.9053	10.7363	3	3		3	3		3			3					
2016p	Mytilus edulis	Whole soft body	Akershuskaia, Inner Oslofjord (st. I301)	59.9053	10.7363	3	3		3	3		3			3					
2016t	Mytilus edulis	Whole soft body	Akershuskaia, Inner Oslofjord (st. I301)	59.9053	10.7363	3	3		3	3		3			3					
2015t	Mytilus edulis	Whole soft body	Gressholmen, Inner Oslofjord (st. 30A)	59.8836	10.7110	3	3		3	3	3	3			3	3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Gressholmen, Inner Oslofjord (st. 30A)	59.8836	10.7110	3	3	3	3	3	3	3			3	3	3	3	3	
2016t	Mytilus edulis	Whole soft body	Gressholmen, Inner Oslofjord (st. 30A)	59.8836	10.7110	3	3	3	3	3	3	3			3	3	3	3	3	
2015t	Mytilus edulis	Whole soft body	Gåsøya, Inner Oslofjord (st. I304)	59.8513	10.5890	3	3		3	3		3			3				3	
2016p	Mytilus edulis	Whole soft body	Gåsøya, Inner Oslofjord (st. I304)	59.8513	10.5890	3	3		3	3		3			3				3	
2016t	Mytilus edulis	Whole soft body	Gåsøya, Inner Oslofjord (st. I304)	59.8513	10.5890	3	3		3	3		3			3				3	
2015t	Mytilus edulis	Whole soft body	Håøya, Inner Oslofjord (st. I306)	59.7133	10.5552	3			3	3		3							3	

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2016p	Mytilus edulis	Whole soft body	Håøya, Inner Oslofjord (st. I306)	59.7133	10.5552	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Håøya, Inner Oslofjord (st. I306)	59.7133	10.5552	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Ramtonholmen , Inner Oslofjord (st. I307)	59.7445	10.5228	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Ramtonholmen , Inner Oslofjord (st. I307)	59.7445	10.5228	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Ramtonholmen , Inner Oslofjord (st. I307)	59.7445	10.5228	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Solbergstrand, Mid Oslofjord (st. 31A)	59.6155	10.6515	3	3		3	3		3								
2016p	Mytilus edulis	Whole soft body	Solbergstrand, Mid Oslofjord (st. 31A)	59.6155	10.6515	3	3		3	3		3								
2016t	Mytilus edulis	Whole soft body	Solbergstrand, Mid Oslofjord (st. 31A)	59.6155	10.6515	3	3		3	3		3								
2015t	Mytilus edulis	Whole soft body	Mølen, Mid Oslofjord (st. 35A)	59.4836	10.4950	3	1		3					1	1				3	
2016p	Mytilus edulis	Whole soft body	Mølen, Mid Oslofjord (st. 35A)	59.4836	10.4950	3			3										3	
2016t	Mytilus edulis	Whole soft body	Mølen, Mid Oslofjord (st. 35A)	59.4836	10.4950	3			3										3	
2015t	Mytilus edulis	Whole soft body	Tjøme, Outer Oslofjord (st. 36A1)	59.0736	10.4252	3	3	3	3	3	3	3				3	3	3	3	
2015t	Mytilus edulis	Whole soft body	Færder, Outer Oslofjord (st. 36A)	59.0274	10.5250	2	2	1	2	2	1	2				2	2	2	2	
2016p	Mytilus edulis	Whole soft body	Færder, Outer Oslofjord (st. 36A)	59.0274	10.5250	3	3	3	3	3	3	3						3	3	
2016t	Mytilus edulis	Whole soft body	Færder, Outer Oslofjord (st. 36A)	59.0274	10.5250	3	3	3	3	3	3	3						3	3	
2015t	Mytilus edulis	Whole soft body	Singlekalven, Hvaler (st. I023)	59.0951	11.1368	3		3	3		3				3	3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Singlekalven, Hvaler (st. I023)	59.0951	11.1368	3		3	3		3				3	3	3	3	3	
2016t	Mytilus edulis	Whole soft body	Singlekalven, Hvaler (st. I023)	59.0951	11.1368	3		3	3		3				3	3	3	3	3	
2015t	Mytilus edulis	Whole soft body	Kirkøy, Hvaler (st. I024)	59.0791	10.9873	3			3										3	
2016p	Mytilus edulis	Whole soft body	Kirkøy, Hvaler (st. I024)	59.0791	10.9873	3			3										3	
2016t	Mytilus edulis	Whole soft body	Kirkøy, Hvaler (st. I024)	59.0791	10.9873	2			1										1	
2015t	Mytilus edulis	Whole soft body	Bjørkøya, Langesundfjord (st. 71A)	59.0233	9.7537	3		3	1	3	3	3			3	3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Bjørkøya, Langesundfjord (st. 71A)	59.0233	9.7537	3		3	3	3	3	3			3	3	3	3	3	
2016t	Mytilus edulis	Whole soft body	Bjørkøya, Langesundfjord (st. 71A)	59.0233	9.7537	3		2	3	3	3	3			3	2	3	3	3	
2015t	Mytilus edulis	Whole soft body	Croftholmen, Langesundfjord (st. I712)	59.0453	9.7068	3		3	3	3	3	3			3	3	3	3	3	
2015t	Mytilus edulis	Whole soft body	Sylterøya, Langesundfjord (st. I714)	59.0514	9.7038	3		3	3	3	3	3			3	3	3	3	3	

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2016p	Mytilus edulis	Whole soft body	Sylterøya, Langesundfjord (st. I714)	59.0514	9.7038	3		3	3	3	3	3			3			3	3	
2016t	Mytilus edulis	Whole soft body	Sylterøya, Langesundfjord (st. I714)	59.0514	9.7038	3		3	3	3	2	3			3			3	3	
2015t	Mytilus edulis	Whole soft body	Risøya, Risør (st. 76A2)	58.7327	9.2810	3			3	3		3								
2016p	Mytilus edulis	Whole soft body	Risøya, Risør (st. 76A2)	58.7327	9.2810	3			3	3		3								
2016t	Mytilus edulis	Whole soft body	Risøya, Risør (st. 76A2)	58.7327	9.2810	3			3	3		3								
2015t	Mytilus edulis	Whole soft body	Lastad, Søgne (st. I131A)	58.0556	7.7083	3									3					
2016p	Mytilus edulis	Whole soft body	Lastad, Søgne (st. I131A)	58.0556	7.7083	3									3					
2016t	Mytilus edulis	Whole soft body	Lastad, Søgne (st. I131A)	58.0556	7.7083	3									3					
2015t	Mytilus edulis	Whole soft body	Odderøya, Kristiansand harbour (st. I133)	58.1317	8.0017	3	3		3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Odderøya, Kristiansand harbour (st. I133)	58.1317	8.0017	3	3		3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Odderøya, Kristiansand harbour (st. I133)	58.1317	8.0017	3	3		3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Gåsøya-Ullerøya, Farsund (st. 15A)	58.0461	6.9159	3			3										3	
2016p	Mytilus edulis	Whole soft body	Gåsøya-Ullerøya, Farsund (st. 15A)	58.0461	6.9159	3			3										3	
2016t	Mytilus edulis	Whole soft body	Gåsøya-Ullerøya, Farsund (st. 15A)	58.0461	6.9159	3			3										3	
2015t	Mytilus edulis	Whole soft body	Byrkjenes, Inner Sørfjord (st. 51A)	60.0843	6.5510	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Byrkjenes, Inner Sørfjord (st. 51A)	60.0843	6.5510	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Byrkjenes, Inner Sørfjord (st. 51A)	60.0843	6.5510	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Eitrheimsneset, Inner Sørfjord (st. 52A)	60.0968	6.5329	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Eitrheimsneset, Inner Sørfjord (st. 52A)	60.0968	6.5329	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Eitrheimsneset, Inner Sørfjord (st. 52A)	60.0968	6.5329	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Kvalnes, Mid Sørfjord (st. 56A)	60.2205	6.6020	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Kvalnes, Mid Sørfjord (st. 56A)	60.2205	6.6020	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Kvalnes, Mid Sørfjord (st. 56A)	60.2205	6.6020	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Krossanes, Outer Sørfjord (st. 57A)	60.3871	6.6895	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Krossanes, Outer Sørfjord (st. 57A)	60.3871	6.6895	3			3	3		3							3	

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2016t	Mytilus edulis	Whole soft body	Krossanes, Outer Sørfjord (st. 57A)	60.3871	6.6895	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Ranaskjer, Ålvik, Hardangerfjord (st. 63A)	60.4210	6.4050	8			3	3		3			1				3	
2016p	Mytilus edulis	Whole soft body	Ranaskjer, Ålvik, Hardangerfjord (st. 63A)	60.4210	6.4050	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Ranaskjer, Ålvik, Hardangerfjord (st. 63A)	60.4210	6.4050	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Utne, Outer Sørfjord (st. 64A)	60.4239	6.6223	3			3			3								
2016p	Mytilus edulis	Whole soft body	Utne, Outer Sørfjord (st. 64A)	60.4239	6.6223	3			3			3								
2016t	Mytilus edulis	Whole soft body	Utne, Outer Sørfjord (st. 64A)	60.4239	6.6223	3			3			3								
2015t	Mytilus edulis	Whole soft body	Vikingneset, Mid Hardangerfjord (st. 65A)	60.2423	6.1527	3			3	3		3								
2016p	Mytilus edulis	Whole soft body	Vikingneset, Mid Hardangerfjord (st. 65A)	60.2423	6.1527	3			3	3		3								
2016t	Mytilus edulis	Whole soft body	Vikingneset, Mid Hardangerfjord (st. 65A)	60.2423	6.1527	3			3	3		3								
2015t	Mytilus edulis	Whole soft body	Terøya, Outer Hardangerfjord (st. 69A)	59.9840	5.7545	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Terøya, Outer Hardangerfjord (st. 69A)	59.9840	5.7545	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Terøya, Outer Hardangerfjord (st. 69A)	59.9840	5.7545	3			3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Espevær, Outer Bømlafjord (st. 22A)	59.5871	5.1520	3	3		3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Espevær, Outer Bømlafjord (st. 22A)	59.5871	5.1520	3	3		3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Espevær, Outer Bømlafjord (st. 22A)	59.5871	5.1520	3	3		3	3		3							3	
2015t	Mytilus edulis	Whole soft body	Nordnes, Bergen harbour (st. I241)	60.4008	5.3040	3		3	3		3					3	3	3		
2016p	Mytilus edulis	Whole soft body	Nordnes, Bergen harbour (st. I241)	60.4008	5.3040	3		3	3		3					3	3	3		
2016t	Mytilus edulis	Whole soft body	Nordnes, Bergen harbour (st. I241)	60.4008	5.3040	3		2	3		3					3	3	3		
2015t	Mytilus edulis	Whole soft body	Vågsvåg, Outer Nordfjord (st. 26A2)	61.9362	5.0488	3		3	3		3					3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Vågsvåg, Outer Nordfjord (st. 26A2)	61.9362	5.0488	3		3	3		3					3	3	3	3	
2016t	Mytilus edulis	Whole soft body	Vågsvåg, Outer Nordfjord (st. 26A2)	61.9362	5.0488	3		3	3		2					2	2	3	3	
2015t	Mytilus edulis	Whole soft body	Ørland area, Outer Tronheimfjord (st. 91A2)	63.6514	9.5639	3		3	3		3					3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Ørland area, Outer Tronheimfjord (st. 91A2)	63.6514	9.5639	3		3	3		3					3	3	3	3	

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2016t	Mytilus edulis	Whole soft body	Ørland area, Outer Tronheimfjord (st. 91A2)	63.6514	9.5639	3		3	3		3					2	2	3	3	
2015t	Mytilus edulis	Whole soft body	Moholmen, Inner Ranfjord (st. I965)	66.3116	14.1254	3									3					
2016p	Mytilus edulis	Whole soft body	Moholmen, Inner Ranfjord (st. I965)	66.3116	14.1254	3									3					
2016t	Mytilus edulis	Whole soft body	Moholmen, Inner Ranfjord (st. I965)	66.3116	14.1254	3									3					
2015t	Mytilus edulis	Whole soft body	Bjørnbærviken, Inner Ranfjord (st. I969)	66.2802	14.0349	3									3					
2016p	Mytilus edulis	Whole soft body	Bjørnbærviken, Inner Ranfjord (st. I969)	66.2802	14.0349	9									3					
2016t	Mytilus edulis	Whole soft body	Bjørnbærviken, Inner Ranfjord (st. I969)	66.2802	14.0349	9									6					
2015t	Mytilus edulis	Whole soft body	Mjelle, Bodø area (st. 97A2)	67.4127	14.6219	3		3	3		3					3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Mjelle, Bodø area (st. 97A2)	67.4127	14.6219	3		3	3		3					3	3	3	3	
2016t	Mytilus edulis	Whole soft body	Mjelle, Bodø area (st. 97A2)	67.4127	14.6219	3		3	3		3					3	2	3	3	
2015t	Mytilus edulis	Whole soft body	Svolvær airport area (st. 98A2)	68.2492	14.6627	3		3	3		3				3	3	3	3	3	
2016p	Mytilus edulis	Whole soft body	Svolvær airport area (st. 98A2)	68.2492	14.6627	3		3	3		3				3	3	3	3	3	
2016t	Mytilus edulis	Whole soft body	Svolvær airport area (st. 98A2)	68.2492	14.6627	3		3	3		2				3	3	3	3	3	
2015t	Mytilus edulis	Whole soft body	Skallnes, Outer Varangerfjord (st. 10A2)	70.1373	30.3417	3			3	3		3								
2016p	Mytilus edulis	Whole soft body	Skallnes, Outer Varangerfjord (st. 10A2)	70.1373	30.3417	3			3	3		3								
2016t	Mytilus edulis	Whole soft body	Skallnes, Outer Varangerfjord (st. 10A2)	70.1373	30.3417	3			3	3		3								
2015t	Mytilus edulis	Whole soft body	Brashavn, Outer Varangerfjord (st. 11X)	69.8993	29.7410	3			3	3		3							3	
2016p	Mytilus edulis	Whole soft body	Brashavn, Outer Varangerfjord (st. 11X)	69.8993	29.7410	3			3	3		3							3	
2016t	Mytilus edulis	Whole soft body	Brashavn, Outer Varangerfjord (st. 11X)	69.8993	29.7410	3			3	3		3							3	
2015t	Littorina littorea	Whole soft body	Fugløyskjær, Outer Langesundfjord (st. 71G)	58.9850	9.8046		1													
2016p	Littorina littorea	Whole soft body	Fugløyskjær, Outer Langesundfjord (st. 71G)	58.9850	9.8046		1													1
2016t	Littorina littorea	Whole soft body	Fugløyskjær, Outer Langesundfjord (st. 71G)	58.9850	9.8046		1													1
2015t	Nucella lapillus	Whole soft body	Færder, Outer Oslofjord (st. 36G)	59.0278	10.5256		1													1

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2016p	Nucella lapillus	Whole soft body	Færder, Outer Oslofjord (st. 36G)	59.0278	10.5256		1													1
2016t	Nucella lapillus	Whole soft body	Færder, Outer Oslofjord (st. 36G)	59.0278	10.5256		1													1
2015t	Nucella lapillus	Whole soft body	Risøya, Risør (st. 76G)	58.7280	9.2755		1													1
2016p	Nucella lapillus	Whole soft body	Risøya, Risør (st. 76G)	58.7280	9.2755		1													1
2016t	Nucella lapillus	Whole soft body	Risøya, Risør (st. 76G)	58.7280	9.2755		1													1
2015t	Nucella lapillus	Whole soft body	Lastad, Søgne (st. 131G)	58.0284	7.6990		1													1
2016p	Nucella lapillus	Whole soft body	Lastad, Søgne (st. 131G)	58.0284	7.6990		1													1
2016t	Nucella lapillus	Whole soft body	Lastad, Søgne (st. 131G)	58.0284	7.6990		1													1
2015t	Nucella lapillus	Whole soft body	Gåsøya-Ullerøya, Farsund (st. 15G)	58.0493	6.9012		1													1
2016p	Nucella lapillus	Whole soft body	Gåsøya-Ullerøya, Farsund (st. 15G)	58.0493	6.9012		1													1
2016t	Nucella lapillus	Whole soft body	Gåsøya-Ullerøya, Farsund (st. 15G)	58.0493	6.9012		1													1
2016p	Nucella lapillus	Whole soft body	Melandsholmen, Mid Karmsundet (st. 227G2)	59.3396	5.3122		1													1
2016t	Nucella lapillus	Whole soft body	Melandsholmen, Mid Karmsundet (st. 227G2)	59.3396	5.3122		1													1
2015t	Nucella lapillus	Whole soft body	Espevær, Outer Bømlafjord (st. 22G)	59.5837	5.1445		1													1
2016p	Nucella lapillus	Whole soft body	Espevær, Outer Bømlafjord (st. 22G)	59.5837	5.1445		1													1
2016t	Nucella lapillus	Whole soft body	Espevær, Outer Bømlafjord (st. 22G)	59.5837	5.1445		1													1
2015t	Nucella lapillus	Whole soft body	Svolvær airport area (st. 98G)	68.2470	14.6664		1													1
2016p	Nucella lapillus	Whole soft body	Svolvær airport area (st. 98G)	68.2470	14.6664		1													1
2016t	Nucella lapillus	Whole soft body	Svolvær airport area (st. 98G)	68.2470	14.6664		1													1
2015t	Nucella lapillus	Whole soft body	Brashavn, Outer Varangerfjord (st. 11G)	69.8995	29.7419		1													1
2016p	Nucella lapillus	Whole soft body	Brashavn, Outer Varangerfjord (st. 11G)	69.8995	29.7419		1													1
2016t	Nucella lapillus	Whole soft body	Brashavn, Outer Varangerfjord (st. 11G)	69.8995	29.7419		1													1

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2016

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 2015 or 2016 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**-Dog whelk (*Nucella lapillus*)
- **GADU MOR**-Atlantic cod (*Gadus morhua*)

Tissue:
- **SB**-Soft body tissue
- **LI**-Liver tissue
- **MU**-Muscle tissue
- **BL**-Blood
- **BI**-Bile

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 1981-2016. 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's 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 2.6).

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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.