MILJØ-
DIREKTORATET

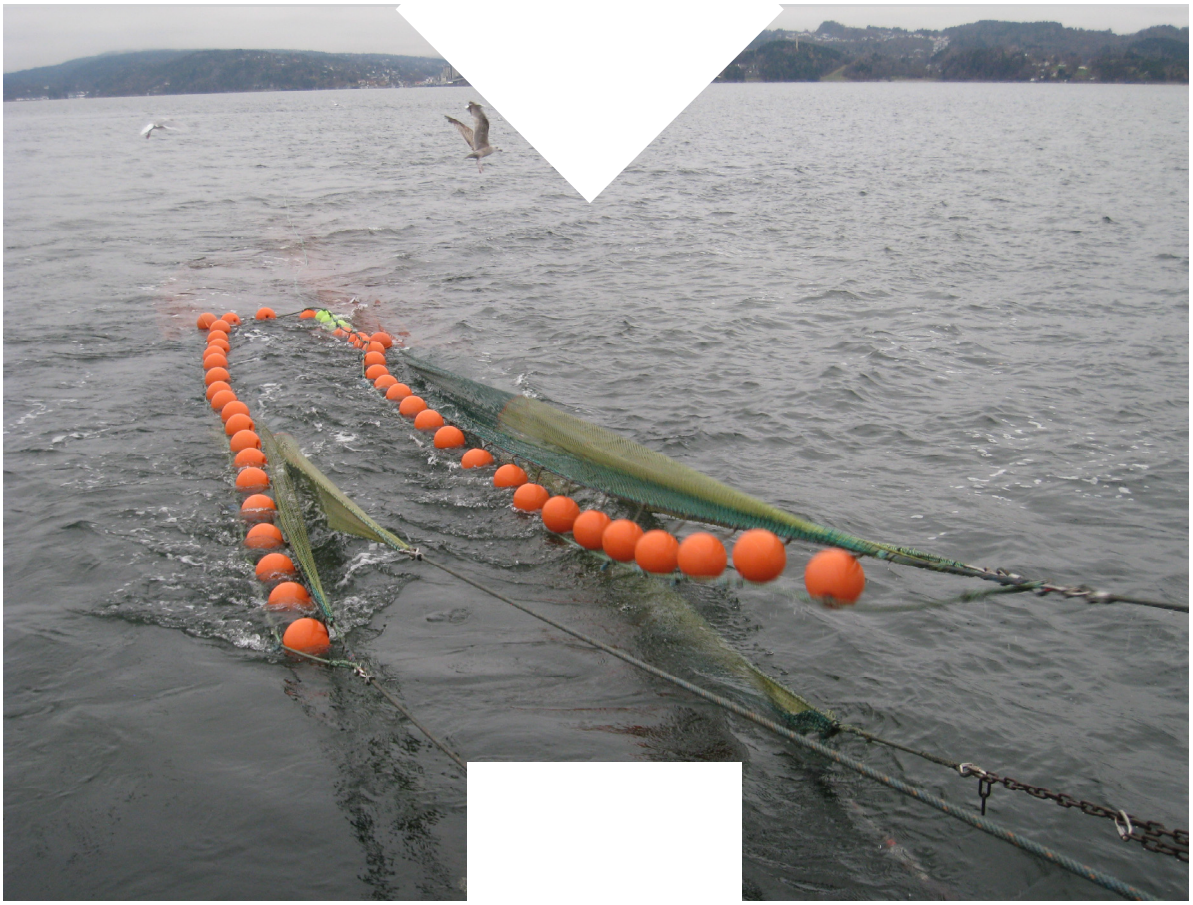
Statlig program for forurensningsovervåking

RAPPORT

M-69/2013
SPFO 1154 69/2013

Contaminants in coastal waters of Norway 2012

Miljøgifter i kystområdene 2012



Contractor:

NIVA
Norwegian Institute for Water Research

Foreword

This report presents the investigations of contaminants in Norwegian coastal waters 2012 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 levels, trends and effects of hazardous substances. Theresults 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 2012 investigations was carried out by the Norwegian Institute for Water Research (NIVA) by contract from the Norwegian Environment Agency (*Miljødirektoratet* where the former Climate and Pollution Agency is now a part of). The project leader at the Norwegian Environment Agency is Bård Nordbø.

Acknowledgments: Thanks are due to many colleagues at NIVA, for fieldwork, sample preparations and data entry: Lise Tveiten, Merete Schøyen, Åse K. Gudmundson Rogne, Sigurd Øxnevad, Jarle Håvardstun, Bjørnar Beylich, Janne Gitmark, Marijana Brkljacic, Gunhild Borgersen, Kate Hawley, Torbjørn Johnsen, Morten Bergan, Mette Cecilie Lie, and Ingar Becsan. For organic analyses: Kine Bæk, Alfhild Kringstad, Katherine Langford and their colleagues and Hanne-Monika Reinbeck, Bjørn Tore Kildahl, Hege Grindheim and Line Roaas and their colleagues at Eurofins (in Moss and Gfa in Germany). For metal analyses: Marit Villø and her colleagues. For stable isotope measurements: Ingar Johansen and his colleagues at Institute for enery technology (IFE). For biological effects measurements: Adam Lillicrap, Eivind Farmen and their colleagues. For analytical quality assurance: Trine Olsen and Kristin Allan and their colleagues. For data programme management and operation: Tore Høgåsen and Roar Brænden. To the other authors: Merete Schøyen, Sigurd Øxnevad Anders Ruus (biological effects methods) and Ian Allan (passive samplers). For quality assurance: John Arthur Berge and Morten Schaanning. Thanks go also to the numerous fishermen and their boat crews for which we have had the pleasure of working with.

Oslo, 21st November 2013.

Norman W. Green
Project Manager
Norwegian Institute for Water Research

Norwegian Institute for Water Research
– an institute in the Environmental Research Alliance of Norway

REPORT

Main Office
Gaustadalléen 21
NO-0349 Oslo, Norway
Phone (47) 22 18 51 00
Telefax (47) 22 18 52 00
Internet: www.niva.no

Regional Office, Sørlandet
Jon Lilletunss vei 3
NO-4879 Grimstad, Norway
Phone (47) 22 18 51 00
Telefax (47) 37 04 45 13

Regional Office, Østlandet
Sandvikaveien 41
NO-2312 Ottestad, Norway
Phone (47) 22 18 51 00
Telefax (47) 62 57 66 53

Regional Office, Vestlandet
Thormøhlensgt. 53 D
NO-5006 Bergen, Norway
Phone (47) 22 18 51 00
Telefax (47) 55 31 22 44

Regional Office Central
Pirsenteret, Havnegt. 9
NO-7462 Trondheim
Phone (47) 22 18 51 00
Telefax (47) 73 54 63 87

Title		Serial No.	Date
Contaminants in coastal waters of Norway 2012. *Miljøgifter i kystområdene 2012*		6582-2013	21.11.2013
		Report No. O-13330	Pages 130
Author(s) Norman W. Green Merete Schøyen Sigurd Øxnevad Anders Ruus Ian Allan	Tore Høgåsen Bjørnar Beylich Jarle Håvardstun Åse K. Gudmundson Rogne Lise Tveiten	Topic group Marine ecology	Distribution Open
		Geographical area Oslofjord to Varangerfjord	Printed NIVA

Client(s)	Client ref.
Norwegian Environment Agency / *Miljødirektoratet* *Statlig program for forurensningsovervåking rapport nr.* 1154/2013 M rapportnr. 69/2013	Bård Nordbø

Abstract

This programme examines long term changes for legacy and some emerging contaminants in biota along the coast of Norway from the Oslofjord and Hvaler region in the southeast to the Varangerfjord in the northeast, in both polluted areas and areas remote from point sources. The 2012-investigation included the monitoring of blue mussel (23 stations), dog whelk (8 stations), common periwinkle (1 station) cod (14 stations) and seawater (passive samplers, 3 stations). Thirty contaminants were chosen for this report as reasonable representation of the chemicals investigated. This selection has 272 time series of which there were statistically significant trends in 50 cases: 34 (12.5 %) were downwards and 16 (5.9 %) upwards. The dominance of downward trends indicates that contamination is decreasing. Of the 272 cases, 156 could be classified by the environmental classification system used by the Norwegian Environment Agency, 81.4 % were classified as insignificantly polluted, 13.5 % as moderately polluted, 4.5 % as markedly polluted, 0 % as severely polluted and 0.6 % as extremely polluted. Analyses of HBCD, SCCP, MCCP, PFRs, BPA, and TBBPA and the use of passive samplers were included in this programme for the first time. Some cases warrant special concern. These were for example upward trend for mercury in cod fillet from the inner Oslofjord, high concentrations of hexabromocyclododecane (a-HBCD) in cod liver from the same area, and high concentrations of medium chain chlorinated paraffins (MCCP) in cod liver from Sørfjord.

4 keywords, Norwegian	4 keywords, English
1. Miljøgifter	1. Contaminants
2. Biologiske effekter	2. Biological effects
3. Marin	3. Marine
4. Norge	4. Norway

Project Manager *Norman W. Green*	*Research Manager* *Morten Schaanning*	*Research Director* *Kristoffer Næs*

ISBN 978-82-577-6317-6

English summary

This programme examines long term changes for legacy contaminants in biota along the coast of Norway in both polluted and in areas remote from point sources. In addition, the programme includes supplementary analyses of some emerging contaminants. As such, the programme provides a basis for assessing the state of the environment for the coastal waters with respect to contaminants. Most trends are downwards. However there are also cases that warrant special concern, for example upward trend for mercury in cod fillet from the inner Oslofjord, high concentrations of hexabromocyclododecane (α–HBCD) in cod liver from the same area, and high concentrations of medium chain chlorinated paraffins (MCCP) in cod liver from Sørfjord.

Part of the Norwegian effort to monitor contaminants along its coast contributes to OSPAR's Coordinated Environmental Monitoring Programme (CEMP). The 2012 investigation monitored blue mussel (23 stations), dog whelk (8 stations), common periwinkle (1 station) and cod (14 stations) along the coast of Norway from the Oslofjord and Hvaler region in the southeast to the Varangerfjord in the northeast. The stations are located both in areas with known or presumed point sources of contaminants, in areas of diffuse load of contamination like city areas, and in more remote areas exposed to presumed low and diffuse pollution. The programme includes the monitoring of metals, organochlorines, pesticides, dioxins, brominated flame retardants, perfluorinated compounds, as well as biological effects methods. Analyses of hexabromcyclododecanes (HBCD), short and medium chained chlorinated paraffins (SCCP, MCCP), organophorphorus flame retardants (PFRs), bisphenol-A (BPA), and tetrabrombisphenol A (TBBPA) were included in this programme for the first time.

The results from 2012 supplied data for a total of 1576 data sets (contaminant-station-species) on 101 different contaminants. Thirty contaminants were chosen for this report as reasonable representation of this investigation. This selection has 272 time series of which there were statistically significant trends in 50 cases: 34 (12.5 %) were downwards and 16 (5.9%) upwards. The downward trends were primarily associated with Tributyltin (TBT) and *Vas Deferens* Sequence Index (VDSI) (the effect of TBT) (44 %) and metals (35 %). The dominance of downward trends indicates that contamination is decreasing. The 16 upward trends were mainly associated with metals (88 %), primarily mercury (50 %).

Of the 272 cases, 156 could be classified by the environment classification system of the Norwegian Environment Agency, 81.4 % were classified as insignificantly polluted, 13.5 % as moderately polluted, 4.5 % as markedly polluted, 0 % as severely polluted and 0.6 % as extremely polluted. Even though most concentrations observed can be considered moderately polluted or better the 5.1% of the cases that are worse cannot be disregarded. For example the extremely polluted case for blue mussel in the Sørfjord due to DDE.

Sampling rates for silicone rubber passive samplers deployed at Hvaler, Oslofjord and Ålesund were low. Data from these passive samplers were mostly below limits of detection (particularly for the Hvaler and Ålesund sites). Only BDE-47, α-HBCD and para-t-octylphenol could be measured in waters of the Oslofjord. The α-isomer of HBCD was also measured above limits of detection at Ålesund but at a concentration lower than in the Oslofjord. Concentrations appear in line with literature data.

Concentrations of contaminants in fish

Cod fillet from the Inner Oslofjord and Ålesund harbour was markedly polluted by mercury. The inner Oslofjord had a significant upward trend for mercury for the period 1984-2012. There are currently no data to support hypotheses about local mechanisms such as runoff or altered trophic links, that could account for this increase.

The cod from the inner Oslofjord and Hammerfest harbour were markedly polluted with ΣPCB-7. Contamination of cod was otherwise generally low (insignificantly or moderately polluted). The high concentrations of PCB observed in cod liver in the Inner Oslofjord are probably related to urban activities in combination with reduced water exchange with the Outer fjord.

Polybrominated diphenyl ethers (PBDEs) and have been investigated in cod liver since 2005. In 2012, the concentration of sum PBDE was highest in the Inner Oslofjord and second highest in the Trondheim harbour. PBDE was lowest in cod from Lofoten. BDE47 was the dominant PBDE in all samples. As for PCB, the high concentrations of PBDE are probably related to urban activities and water exchange conditions.

Perfluroalkyl compounds (PFAS) have been investigated in cod liver since 2005. PFOS, an abundant PFAS, was highest in cod from Færder and lowest in Tromsø harbour. PFOSA, also an abundant PFAS, was highest in the Inner Oslofjord and lowest in harbours of Trondheim, Skrova and Tromsø. PFAS are found in a wide range of products including fire-fighting foam, surfactants and surface protector for industrial and consumer applications and has a worldwide distribution in different environmental compartments. The differences between the stations cannot be yet explained.

Concentrations of contaminants in blue mussel
Blue mussel from one station in the Sørfjord was extremely polluted with DDE. Mussels from one station in the Hardangerfjord were markedly polluted with the same contaminant. Contamination of this substance is related to earlier use of DDT as pesticide in orchards along the fjord (ca.1945-1970).

One station in the inner Oslofjord and one station from the inner Ranfjord were markedly contaminated with one or more groups of PAHs most likely related to harbour and industrial activities, respectively. No trends were detected for these cases. Contamination of blue mussel was otherwise generally low (insignificantly or moderately polluted).

New contaminants
The α–HBCD was the most abundant diastereomer. Cod from the Oslo city area had the highest median concentration of HBCD in the liver. Parts of the Inner Oslofjord are densely populated driving urban activities which could apply HBCD in certain products. The high concentrations of HBCD observed in cod are probably related to these activities, as well as to reduced water exchange with the Outer fjord.

Of the chlorinated paraffins significantly higher medium chain chlorinated paraffins (MCCP) were found in cod liver from the Inner Sørfjord compared to the other stations. The source of the MCCPs in the Sørfjord is unknown, but there are several metal related industries as well as a hydroelectric power plant located in this fairly restricted area. Further investigations are warranted.

Only two organicphosphorus flame retardants (PFRs) were detected, EHDPP in one sample of cod and TCPP in 10 samples of blue mussel. This indicates that the concentrations of PFRs are generally low, however no conclusions could be drawn regarding the differences among the stations.

The variability bisphenol A among individual cod was high and no conclusion can be drawn regarding possible differences between stations. The reason for this high variability is unknown but suggests the need for further investigations of BPA along the Norwegian coast.

Biological effects
The median concentration of CYP1A protein levels and EROD activity in the Inner Oslofjord was lower in 2012 than in 2011 and below the ICES/OSPAR assessment criterion (background assessment criteria, BAC).

In 2012 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord were about 25 % lower than the 2011-concentration but still above the ICES/OSPAR assessment criterion (background assessment criteria, BAC).

The ALA-D activity in the Inner Oslofjord in 2012 was about one third of the activity reported in 2011 Reduced activities of ALA-D reflect higher exposure to lead. However, the median concentration of lead in cod liver decreased from 2011 to 2012.

The effects from TBT on dog whelk were relatively low (VDSI<1.19) at all eight stations investigated in 2012. All stations showed significant downward trends except for Brashavn 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 $\delta^{15}N$ data (cod) is 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 (BPA, TCEP, MCCP and TBBPA), $\delta^{15}N$ has been plotted against concentration to examine potential increase in concentration of the specific

contaminants with increasing $\delta^{15}N$. For these selected contaminants, plotting $\delta^{15}N$ against the concentration of BPA in cod gave no indication of higher concentrations in individuals with higher $\delta^{15}N$, but merely indicated stations with the highest exposure, as well as a difference in isotopic baseline signature among stations (also shown by the isotopic signature in blue mussel at the same locations). At specific stations, Hg and PCB-153 (contaminants with well-known biomagnifying properties) concentrations increased with higher $\delta^{15}N$ (i.e. higher concentrations in individuals with slightly higher trophic position).

Sammendrag

Denne undersøkelsen omhandler langtidsendringer av miljøgifter i biota langs norskekysten, både fra forurensede områder og fra områder som ligger langt fra kjente forurensningskilder. I tillegg er det gjort analyser av nyere miljøgifter. Undersøkelsen gir grunnlag for vurdering av miljøstatus langs kysten med hensyn på miljøgifter. Resultatene viser at det er hovedsakelig nedadgående trender for de undersøkte miljøgiftene. Det er imidlertid noen resultater som gir grunn til bekymring, f.eks oppadgående trend for kvikksølv i torskefilét fra Indre Oslofjord, høye konsentrasjoner av heksabromsyklododekan (α–HBCD) i torskelever fra Indre Oslofjord og høye konsentrasjoner av mellomkjedete klorparafiner (MCCP) i torskelever fra Sørfjorden.

Undersøkelsen bidrar til OSPARs koordinerte miljøovervåkingsprogram (CEMP). I 2012 omfattet overvåkingen miljøgifter i blåskjell (23 stasjoner), purpursnegl (8 stasjoner), strandsnegl (1 stasjon) torsk (14 stasjoner) og sjøvann (passive prøvetakere, 3 stasjoner) langs kysten fra Oslofjord-Hvaler området i sørøst til Varangerfjorden i nordøst. Det er analysert prøver fra områder med kjente og antatt kjente punktkilder, områder med diffus tilførsel av miljøgifter (som byområder) og i områder med antatt lav eller diffus eksponering for miljøgifter. Undersøkelsen omfatter overvåking av metaller, klororganiske stoffer, pestisider, dioksiner, bromerte flammehemmere, perfluorerte alkylstoffer og biologiske effekter. For første gang er det inkludert analyser av heksabromsyklododekan (HBCD), kort- og mellomkjedete klorparafiner (SCCP og MCCP), fosfororganiske flammehemmere (PFR), bisfenol A (BPA) og tetrabrombisfenol A (TBBPA).

Resultatene for 2012 omfatter 1576 datasett for 101 forskjellige miljøgifter. Et utvalg på 30 representative miljøgifter er omtalt i denne undersøkelsen. Dette utvalget består av 272 tidsserier hvorav 50 hadde statistisk signifikante trender: 34 (12,5 %) var nedadgående og 16 (5,9 %) var oppadgående. De nedadgående trendene omfattet primært TBT og biologisk effekt av TBT (44 %) og metaller (35 %). Dominansen av nedadgående trender indikerer at nivåene av miljøgifter er synkende. Av de 16 oppadgående trendene var de fleste for metaller (88 %), primært kvikksølv (50 %). Av de 272 tidsseriene kunne 156 av dem klassifiseres i henhold til Miljødirektoratets klassifiseringssystem. 81,4 % var ubetydelig-lite forurenset, 13,5 % var moderat forurenset, 4,5 % var markert forurenset, 0 % var sterkt forurenset og 0,6 % var meget sterkt forurenset. Selv om det fleste observerte nivåene kan betraktes som moderat forurenset eller bedre, så kan vi likevel ikke se bort ifra de 5,1 % som er mer forurenset. Et eksempel på dette er blåskjell i Sørfjorden som er meget sterkt forurenset av DDE.

Opptaksrater i passive silikonprøvetakere satt ut i Hvaler, Indre Oslofjord og Ålesund havneområde var lave. Resultatene var for det meste under deteksjonsgrensen (særlig for prøver fra Hvaler og Ålesund). Bare BDE-47, α-HBCD, og para-t-octylphenol ble detektert i Indre Oslofjord. I Ålesund ble α-HBCD påvist også, men med lavere konsentrasjon enn i Indre Oslofjord. De påviste konsentrasjonene samsvarer med resultater fra litteraturen.

Konsentrasjoner av miljøgifter i fisk

Torsk fra Indre Oslofjord og Ålesund havn var markert forurenset av kvikksølv i filéten. For torsk fra Indre Oslofjord var det en signifikant oppadgående trend for kvikksølv i filét for perioden 1984-2012. Det finnes ikke data til å støtte hypoteser om lokale prosesser som avrenning eller endring at trofisk nivå som kan forklare denne økningen.

Torsk fra Indre Oslofjord og Hammerfest havn var markert forurenset av ΣPCB-7. Torsk var ellers generelt lite forurenset (ubetydelig eller moderat forurenset). De høye konsentrasjonene av PCB funnet i lever av torsk fra Indre Oslofjord skyldes trolig menneskelig aktiviteter samt redusert vannutskifting i Indre Oslofjord.

Polybromerte difenyletere (PBDE) har blitt undersøkt i torskelever siden 2005. I 2012 var konsentrasjonen av sumPBDE høyest i torsk fra Indre Oslofjord og nest høyest i torsk fra Trondheim havn. Torsk fra Lofoten hadde lavest konentrasjon av PBDE. BDE47 var den domminerende av PBDEen i alle prøvene. Som for PCB, er urban aktivitet og vannutskiftingsforhold trolig årsaker til de høye nivåene.

Perfluorerte alkystoffer (PFAS) har blitt undersøkt i torskelever siden 2005. Perfluoroktylsulfonat (PFOS) ble funnet å være høyest i torsk fra Færder og lavest i torsk fra Tromsø havn. Perfluoroktansulfonamid (PFOSA) ble funnet i høyest konsentrasjon i torsk fra Indre Oslofjord og lavest i torsk fra Trondheim havn, Skrova og Tromsø havn. Nivåforskjellene mellom de ulike områdene kan foreløpig ikke forklares.

Konsentrasjoner av miljøgifter I blåskjell
Blåskjell fra en stasjon i Sørfjorden var meget sterkt forurenset av DDE. I Hardangerfjorden var blåskjell fra en stasjon markert forurenset av den samme miljøgiften. Forurensning av denne miljøgiften skyldes tidligere bruk av DDT som sprøytemiddel i frukthager langs fjorden (ca. 1945-1970).

En stasjon i Indre Oslofjord og en stasjon i Indre Ranfjord var markert forurenset av en eller flere PAH-forbindelser. Dette skyldes trolig havne- og industriaktivitet. Det ble ikke påvist trender for disse tilfellene. Blåskjellstasjonene som er omfattet i denne undersøkelsen var ellers generelt lite forurenset (ubetydelig til moderat forurenset).

Nye miljøgifter
Torsk fra Indre Oslofjord hadde høyest konsentrasjon av HBCD (heksabromsyklododekan), og det var mest av varianten α–HBCD. Det høye nivået i torskelever fra Indre Oslofjord er trolig knyttet til urbane aktiviteter i dette tett befolkede området samt lav vannutskifting.

Det var signifikant høyere nivå av mellomkjedete klorerte parafiner (MCCP) i torskelever fra Indre Sørfjorden sammenlignet med de andre stasjonene. Kilden til denne parafinforbindelsen i Sørfjorden er ikke kjent, men det finnes flere metallindustrivirksomheter og vannkraftverk i dette området som kan være potensielle kilder. Dette bør undersøkes nærmere.

Bare to typer fosfororganiske flammehemmere (PFR) ble påvist; EHDPP i en torskeprøve og TCPP i 10 prøver av blåskjell. Dette indikerer at det generelt er lave nivåer av fosfororganiske flammehemmere.

Det var stor individuell forskjell i konsentrasjon av bisfenol A i torsk, og årsaken til dette er uklar. Det bør derfor gjøres ytterligere undersøkelser av bisfenol A langs norskekysten.

Biologiske effekter
Nivåene av CYP1A protein og EROD-aktivitet i Indre Oslofjord var lavere i 2012 enn i 2011, og lavere enn ICES/OSPAR's vurderingskriterium for bakgrunnsnivå. I Indre Oslofjord var det i 2012 25 % lavere konsentrasjonen av OH-pyren metabolitter i torskegalle enn i 2011. Likevel var dette nivået over ICES/OSPAR's vurderingskriterium for bakgrunnsnivå. Aktiviteten av ALA-D i Indre Oslofjord var omtrent en tredjedel av nivået som ble rapportert i 2011. Redusert aktivitet av ALA-D tyder på høyere eksponering for bly. Fra 2011 til 2012 har imidlertid konsentrasjonen av bly i torskelever avtatt. Effektene av TBT på purpursnegl var lave (VDSI < 1,19) på alle de undersøkte stasjonene. Det var signifikant nedadgående trender for VDSI på alle stasjonene bortsett fra for Brashavn (som har hatt lavt nivå gjennom hele perioden). Resultatene indikerer at forbudet mot bruk av TBT har vært effektivt.

Stabile isotoper
Data for stabile isotoper (δ^{15}N) er vurdert i sammenheng med konsentrasjoner av utvalgte miljøgifter. Fisk spiser større byttedyr etterhvert som de vokser, og dette medfører ofte overgang til høyrer trofisk nivå. Det er interessant å vurdere om det er korrelasjon mellom konsentrasjoner av miljøgifter og δ^{15}N, siden dette gir en grundigere vurdering av miljøgiftenes potensiale for å biomagnifisere. Konsentrasjoner av utvalgte miljøgifter (BPA, TCEP, MCCP og TBBPA) har blitt plottet mot δ^{15}N for å undersøke eventuelle sammenhenger. Det ble ikke funnet sammenheng mellom konsentrasjon av BPA i torsk og nivå av δ^{15}N. Det ble funnet økende konsentrasjon av kvikksølv og PCB-153 med økende nivå av δ^{15}N, dvs. høyere konsentrasjoner i individer på noe høyere trofisk nivå.

Contents

1. Introduction

This report concerns investigations of contaminants in coastal waters of Norway under the programme "Miljøgifter i kystområdene".

1.1 Background

The programme "Contaminants in the coastal waters of Norway" (*Miljøgifter I kystområdene* - MILKYS) is administered by the Norwegian Environment Agency (*Miljødirektorat*). 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. For this report, all the results 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 to have a potential for causing detrimental biological effects

Concentrations of hazardous substances in sediment/pore water, mussels and fish constitute time-integrating state indicators for coastal water quality. With respect to organisms, these substances have a tendency to accumulate in their tissues (bioaccumulation), 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 when analysing water or sediment. Another advantage of using concentrations in biota as indicators, as opposed to using water or sediment, is that they 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 as far as practical. These OSPAR methods suggest monitoring of sediment at about 10-year intervals and blue mussels, snails, cod, and flatfish species monitored on a yearly basis. MILKYS monitors blue mussel, two snail species and Atlantic cod.

An overview of MILKYS stations in Norway is shown in maps in Appendix D. The program has included the monitoring of sediment, seawater and biota since 1981 with particular emphasis on four areas:

- Oslofjord-area (including the Hvaler area, Singlefjord and Grenland fjords area)
- Sørfjord/Hardangerfjord
- Orkdalsfjord area

During 1990-1995 and 2008-2011 Norway has also included

- Arendal and Lista areas

The previous investigations have shown that the Inner Oslofjord area has enhanced levels of polychlorinated biphenyls (PCBs) in cod liver, mercury, lead and zinc in sediments and moderately elevated values of mercury in cod fillet. 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. It can be noted that environmental status is classified according to environmental quality criteria (based on the classification system of the Norwegian Environment Agency, or presumed background levels) and must not be confused with limit values for human consumption and associated advice issued by the Norwegian Food Safety Authorities. Investigations in Orkdalsfjord were discontinued during the period 1996 to 2003 and from 2006. Blue mussel from the Orkdalsfjord were monitored for the period 1984-1996, and then again in 2004-2005 when bulk samples from three stations were investigated. The results from these investigations have been reported earlier (Green *et al*. 2007, Green & Ruus 2008).

In addition to the monitoring of Oslofjord area and Sørfjord/Hardangerfjord MILKYS also includes the annual monitoring 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.

Concentrations of metals, organochlorines (including pesticides), polycyclic aromatic hydrocarbons (PAH), polybrominated diphenyl ethers (PBDE) or perfluorinated compounds (PFAS) in blue mussel or fish were determined at the Norwegian Institute for Water Research (NIVA) and Eurofins laboratories in Moss and Germany. Measurements of stable isotopes were performed at the Institute for Energy Technology.

Analytical methods have been described previously (Green *et al*. 2008a). Parameter abbreviations are given in Appendix B.

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 ecosystems are affected by toxic compounds, i.e. contaminants, 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. Just one reason is the vast number of chemicals (known and unknown) that organisms are exposed to, in combination, in the environment. In addition to enable 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 gastropods as well as biomarkers in fish. The methods for fish were selected for specificity, for 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, gastropod, 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 bringing the total to 15. The blue mussel stations were reduced from 38 to 26. Choice of chemical analyses for each station has changed considerably from 2011 to 2012 (Appendix E). Pesticide and dioxin analyses were discontinued with the except for DDTs at some stations in the Sørfjord/Hardangerfjord. However, many new analyses were added, including analyses of: short chain and medium chain chlorinated paraffins, phenols (bisphenol A, tetrabrombisphenol A), phosphorus flame retardants and stabile isotopes. The Norwegian Pollution and Reference Indices (cf. Green et al. 2012) are not included in the revised programme but passive sampling has been added.

The change in the programme has meant that many times series were at risk of being discontinued. This was the case for the 2012 investigation. However independent funding from the Norwegian Department of the Environment ensured that some of these time series could maintained, at least for the 2013-investigations, though extra analyses (mostly pesticides) of MILKYS-samples or collection and analyses of blue mussel and flatfish station that were discontinued. This additional funding for 2013 also ensured that investigation of biological effect in cod from the Inner Sørfjord and from Karihavet on the West Coast could be continued.

Where possible, MILKYS is integrated with other national monitoring programmes to achieve a better practical and scientific solution to assessing the levels, trends and effects of micropollutants. In particular, this concerns sampling for the Norwegian sample bank, a programme funded by the Norwegian Department of the Environment to sustain time trend monitoring and local (county) investigations. There is also coordination with Comprehensive Study on Riverine Inputs and Direct Discharges (RID) and The Norwegian Costal Monitoring Programme (*Kystovervåkingsprogrammet*, KYO). Both programmes are operated by NIVA on behalf of Norwegian Environment Agency (*Miljødirektoratet*).

1.2 Purpose

An aim of the Norwegian Environmental Agency, which now incorporates the earlier Climate and pollution Agency (Klif), 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, together with other agencies and research institutions, seek to develope a knowledgeable basis for the public and management.

The programme Contaminants in Coastal Waters of Norway (MILKYS) will be used to assess endeavours, through appropriate actions and measures, the move towards cessation of discharges, emissions and losses of hazardous substances by the year 2020. This will be accomplished though:

1. Monitoring the levels of a selection of hazardous substances in biota and passive samplers;
2. Evaluate the bioaccumulation of priority hazardous substances in biota of coastal waters;
3. Assess the effectiveness of remedial action;
4. Consider the need for additional remedial action;
5. Assess the risk to biota in coastal waters
6. For fill obligations to regional sea convention (OSPAR)

The programme will also contribute to the demands of the Water Framework Directive (WFD) (2000/60/EC) and its daughter directive the Environmental Quality Standards Directive (EQSD – 2008/106/EC, also taking into consideration the directive 2013/39/EU) as well as the Marine Strategy Framework Directive (MSFD) (2008/56/EC).

MILKYS is part of the Norwegian contribution to CEMP is designed to address issues relevant to OSPAR (cf. OSPAR 2007, SIME 2004a) including OSPAR priority substances (SIME 2004b). Moreover, in this regard it will be relevant to implementation of international initiatives such as The Water Framework Directive. One of the goals of both of these EU directives 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 were collected and analysed, where practical, according to OSPAR guidelines (more explicitly for 2012 sampling: OSPAR 2003b and OSPAR 2009)[1]. The data was screened and submitted to ICES by agreed procedures (ICES 1996)). MILKYS currently only includes monitoring of biota which is done annually following the OSPAR guidelines where possible. Blue mussel, gastropod (dog whelk and periwinkle) and Atlantic cod are the target species 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 the snails are also abundant, robust and widely monitored in a comparable way. The species are, however, restricted to the shallow waters of the shore line. Cod is a widely distributed and commercially important fish species. Cod is a predator and, as such, will reflect contamination levels in their prey.

The sampling for 2012 went nearly as planned but at some stations there were insufficient quantity of the target species despite the catch effort. The 2012-sampling involved blue mussel at 23 stations where 26 were planned, dog whelk at eight stations where nine stations were planned, periwinkle at one station and cod at 14 stations where 15 stations were planned (***Figure 1***, ***Figure 2***, ***Figure 3***). Since 2009, the monitoring included the three cod-stations in the harbour areas of: Kristiansand (st. 13BH), Trondheim (st. 80BH) and Tromsø (st. 43BH) and since 2012 cod in the harbour area of Ålesund (st.28B) and Hammerfest (st.45B) have been added. The Norwegian MILKYS has been expanded since 1989 to include monitoring also in more diffusely polluted areas. Sufficient samples have not always been practical to obtain. When this applies to blue mussel, a new site in the vicinity is often chosen. As for fish, the quota of 25 individuals (±10 %) prior to 2012 and 15 individuals in 2012 was not always met.

Samples for the investigation of contaminants in 2012 were collected along the Norwegian coast, from the Swedish boarder in the south to the Russian border in the north (**Figure 1** Appendix D).

[1] See also www.ospar.org/eng/ > measures > list of other agreements

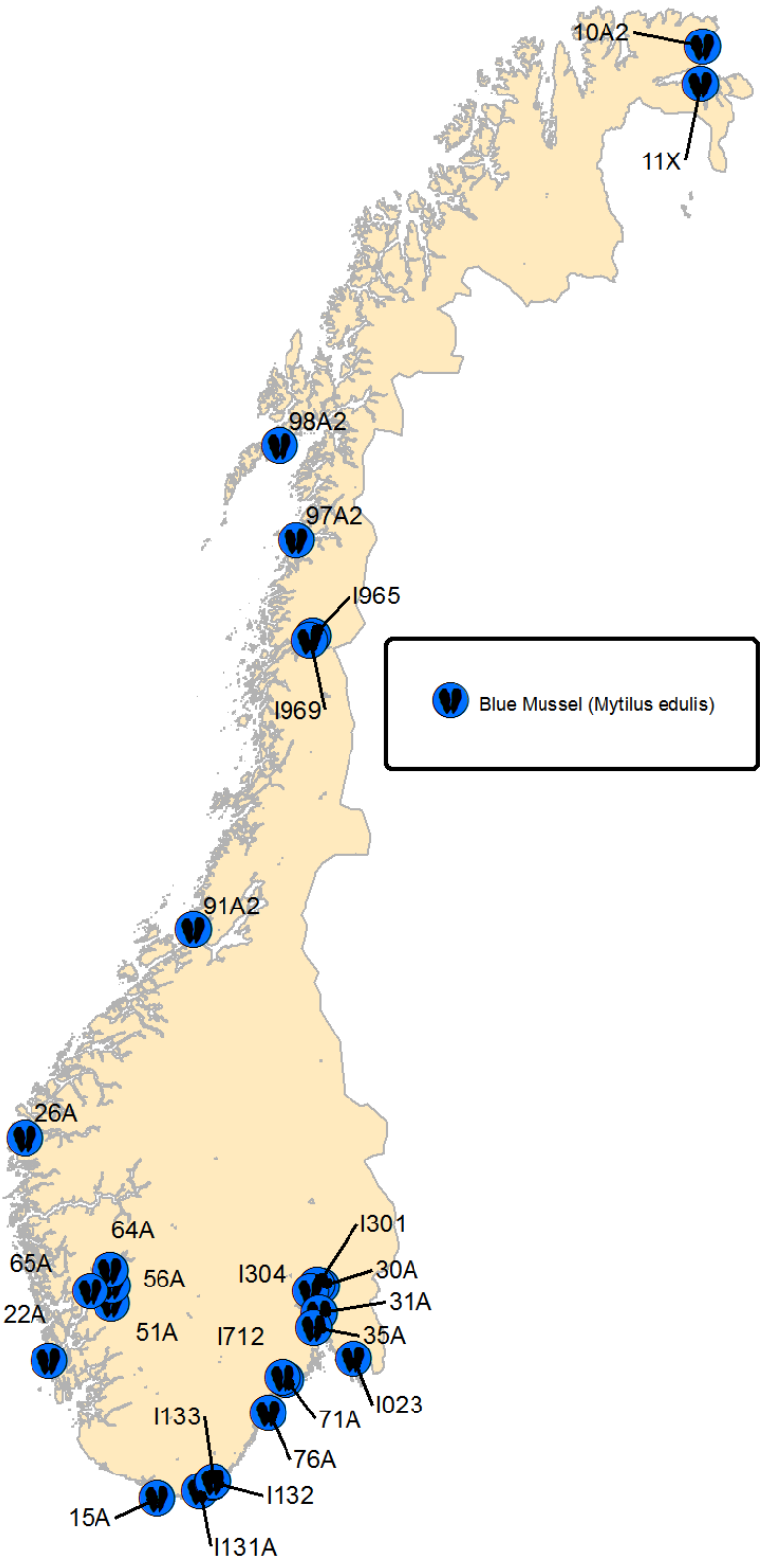


***Figure 1**. Stations where blue mussel was sampled in 2012. See also station information in detailed maps in Appendix D.*

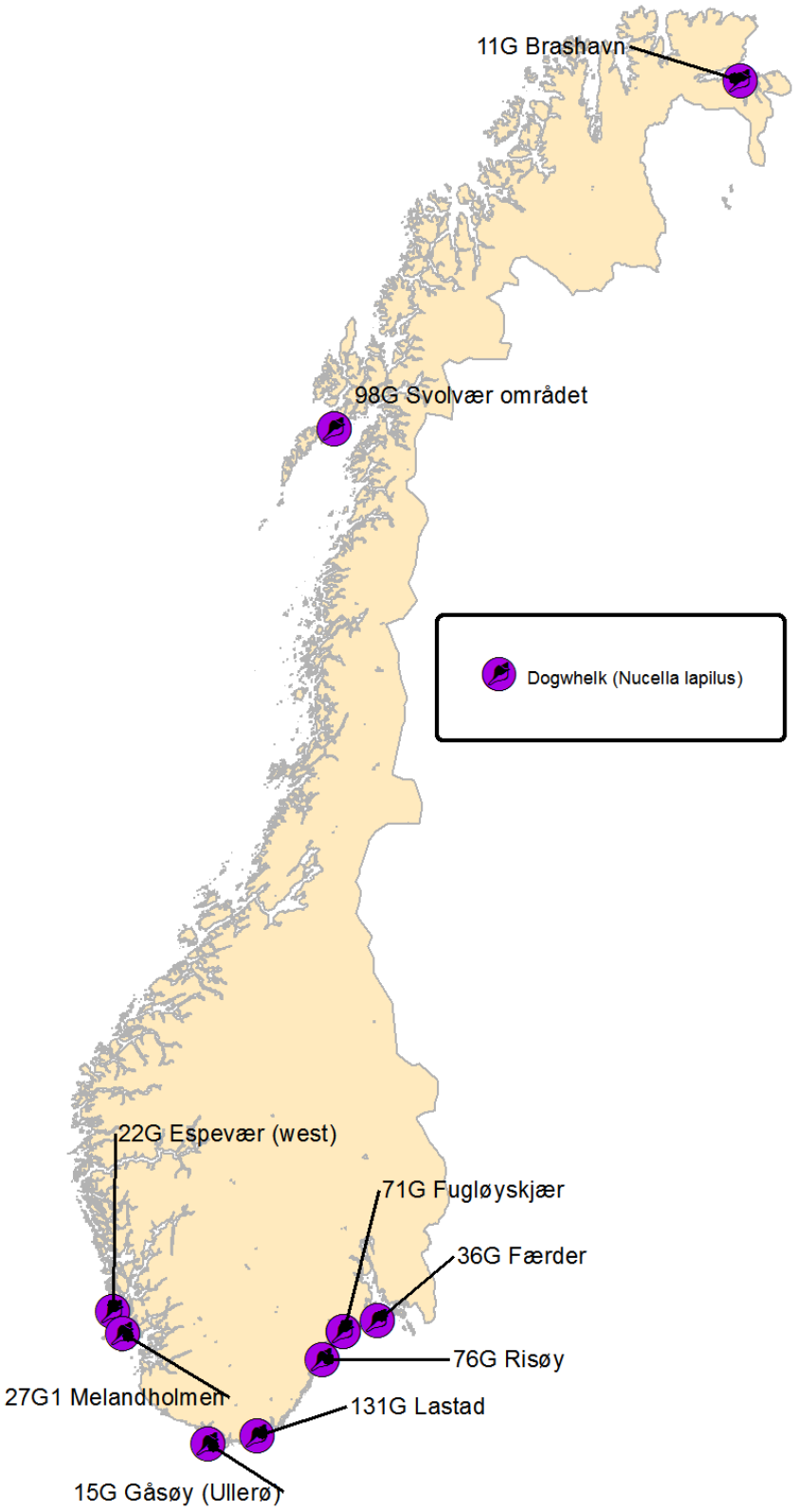


***Figure 2**. Stations where dog whelk was sampled in 2012. See also station information in detailed maps in Appendix D.*

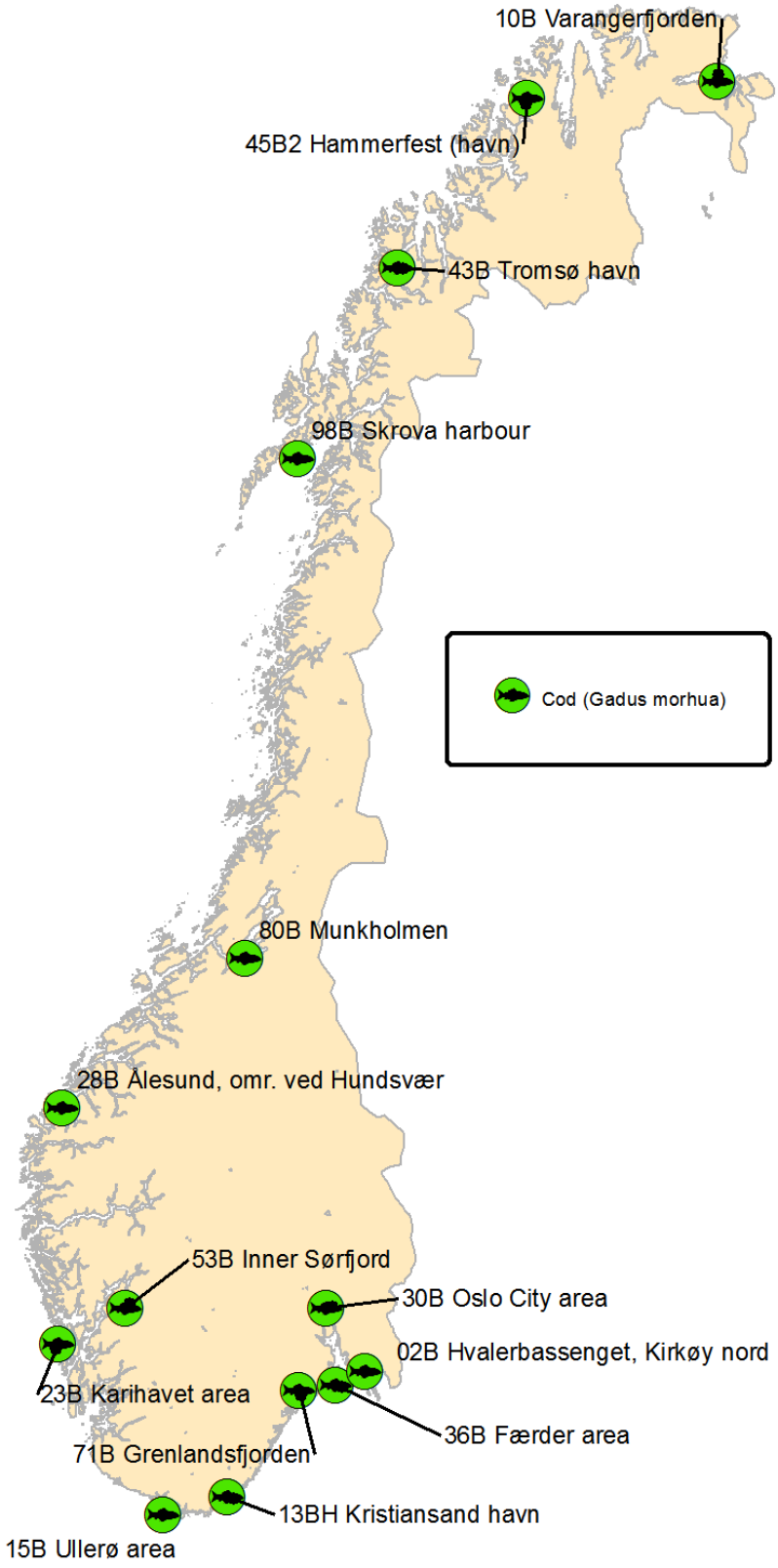


***Figure 3**. Stations where cod was sampled in 2012. Note that biological effects methods were applied to cod samples from the Oslo City area. See also station information in detailed maps in Appendix D.*

2.1.2 Atlantic cod

For fish, 15 individuals of Atlantic Cod (*Gadus morhua)* were to be sampled for each station. Prior to 2012, 25 individuals was the target number. This revision was agreed at Hazardous Substances and Eutrophication Committee (HASEC, 2012). The Norwegian Environment Agency had requested analysis to show how the precision of trend assessments will be affected by changes in the monitoring program for hazardous substances in biota. Two issues were addressed that concerned cod:

- **The first issue** (monitoring with 2 or 3 years intervals instead of yearly) has been studied by running the Norwegian CEMP trend assessment procedure on subsets of data corresponding to monitoring each 2nd or 3rd year, running over all possible starting points. It cannot be recommended generally to decrease the monitoring frequency in cases where possible trends are of concern, but it may be considered for stations where established time series show concentrations well below levels of any concern, and without any upward trend over a number of years.
- **The second issue** (changing the number of cod liver) has been studied by analysing long cod liver time series with approximately 25 fish per year. It can be concluded that reducing the number of replicates per sampling location from 25 to 20 fish per year has only a marginal effect on the trend detection ability, increasing the minimum detectable trend under given conditions by only 2-7 %, while a reduction to 15 fish would increase the detectable trend by 3 to 22 % (less than 10 % for most stations and parameters). These increases show a reduced ability to detect trends when reducing the number of replicates, but the effect is generally small or moderate.

It was largely on the basis of this report that the number of cod samples was reduced from 25 to 15.

If possible, the 15 individuals of cod are sampled in five length classes (***Table 1***), three individuals in each class. Tissue samples from each fish are both prepared in the field and stored frozen (-20°C) until analysis or the fish is frozen directly and later prepared 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

2.1.3 Blue mussel

A third issue coupled to the revision discussed above also applied to blue mussel (HASEC, 2012):

- **The third issue** (reducing number of yearly samples for mussel monitoring) has been studied by analysing subsets of mussel data in the Norwegian CEMP program from the Grenland region southwest of Oslo, and from Sørfjord in Hardanger, in both cases supplemented by data from local or regional monitoring programs. Reducing to a single mussel sample per year for a station may lead to a considerable reduction in trend detection ability. A more cautious reduction, to fewer, but still more than one sample, could probably be implemented without a large effect on the ability to detect trends.

Sufficient sample of blue mussel (*Mytilus edulis*) were found at 23 of the 25 stations planned. The 23 stations are located along the coast of Norway (***Figure 1***, see also maps in Appendix D). The stations were chosen to show highly polluted stations and reference stations distributed along the Norwegian coast. It has been shown that the collected species are not all *Mytilus edulis* (Brooks & Farmen 2013) but possible differences in contaminant uptake were not taken into account for this investigation.

There is some evidence that the effect of shell length and difference in bulk sample size are of little or no significance (WGSAEM 1993; Bjerkeng & Green 1994). However, for historical reasons, three size groups of blue mussel (*Mytilus edulis*) have been sampled from most of the stations: 2-3, 3-4 and 4-5 cm. In order to obtain at least 50 g wet weight, which is necessary for analyses and potential reanalyses of all variables, fifty to hundred individuals were sampled for each class. In 1992 a stricter approach (ICES 1992) was applied for new stations north of the Bømlo area at which 3 pooled samples of 20 individuals each were collected in the size range of 3-5 cm. Pending revision of the guidelines, all blue mussel samples from the new stations are collected according to this ICES method. Shell length was measured by slide callipers. The blue mussels were scraped clean on the outside by using knives or scalpels before taking out the tissue for the analysis.

For certain stations and prior to the 2012-investigations the intestinal canal was emptied (depuration) in mussels (cf. Green *et al*. 2012). There is some evidence that for a specific population/place the depuration has no significant influence on the body burden of the contaminants measured (cf. Green 1989; Green et al. 1996). This practice was discontinued in 2012. Mussels were shucked and frozen (-20°C).

The blue mussel samples were collected from September 5 to November 9, 2012. Generally, blue mussels are 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 mussel collected in the Ranfjord, Lofoten and Varangerfjord, which were collected by local contacts.

2.1.4 Dog whelk and periwinkle

Concentrations and effects of organotin were investigated at eight stations for dog whelk (*Nucella lapillus*) and one stations for periwinkle (*Littorina littorea*) (***Figure 2***, see also maps in Appendix D). TBT-induced development of male sex-characters in females, 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) and concentrations of organotin in dog whelk or periwinkle 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 October 10 to November 9 2012.

2.2 Chemical analysis

2.2.1 Choice of chemical analyses and target species/tissues

An overview of chemical analyses 2012 is shown in Table 2. Note that the table also included an overview of supplementary analyses that will be reported in 2014.

Table 2 *Analyses and target organisms 2012. The value indicates the number of stations investigated.*

Parameter	Blue mussel	Dog whelk	Common periwinkle	Cod fillet	Cod liver	Cod bile	Cod blood	Passive samplers
Metals Cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), silver (Ag), arsenic (As), chrome (Cr), nickel (Ni), cobolt (Co) and tin (Sn)	21				14			
Mercury (Hg) Total-Hg	21			14				
PAH-16	10							
PCB-7 PCB-28, 52, 101, 118, 138, 153, and 180	18				13			
∑DDT p-p`-DDT, p-p`-DDE, p-p`-DDD	4				1			
Polybrominated diphenyl ethers (PBDE) BDE-47, 99, 100, 126, 153, 154, 183, 196 and 209	8				9			3
3Hexabromcyclododecane (HBCD) α, ß, γ-HBCD	8				11			3
Tetrabrombisphenol A (TBBPA)	8				10			
Bisphenol A (BPA)	5				10			
Perfluorinated alkylated substances (PFAS) PFNA, PFOA, PFHpA, PFHxA, PFOS, PFBS, PFOSA					7-8			
Chlorinated paraffins SCCP (C10-C13) and MCCP (C14-C17)	8				11			
Alkylphenol Oktylphenol, nonylphenol								3
Organotin monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), trifenyltin (TPT)		8	1					
Phosphorus flame retardants (PFR) tri-iso-butylphosphate (TIBP) tributylphosphate (TBP) tri(2-chlorethyl)phosphate (TCEP) tri(1-chlor-2-propyl)phosphate (TCPP) tri(1,3-dichlor-2-propyl)phosphate (TDCP) tri(2-butoxyethyl)phosphate (TBEP) triphenylphosphate (TPhP) 2-ethylhexyl-di-phenylphosphate (EHDPP) tetrekis-(2-chloroethyl)dichlorisopentyldiphosphate (V6) dibutylphenylphosphate (DBPhP) butyldiphenylphosphate (BdPhP) tris(2-ethylhexyl)phosphate (TEHP) tris-o-cresylphosphate (ToCrP) tricresylphosphate (TCrP)	8				10			

Parameter	Blue mussel	Dog whelk	Common periwinkle	Cod fillet	Cod liver	Cod bile	Cod blood	Passive samplers
PAH metabolite (inkluding OH-pyrene)						1		
EROD					1			
CYP1A					1			
ALA-D							1	
VDSI		8						
Stable isotopes (SIA) $\delta^{15}N$ og $\delta^{13}C$	14				14			
Supplementary analyses								
November 2013 (values indicate sample count)*								
Phthalates					*18*			
DBP (dibutylphthalate),								
DEHP (di2-ethylhexyl phthalat),								
BBP (benzylbutylphthalate),								
DIBP (di-isobutylphthalate)								
HCBD, TBBPA, BPA					*15*			
SCCP, MCCP					*14*			
PFR					*10*			
Nonylphenol					*25*			
PCB					*25*			
PBDE					*25*			

*) Supplementary analyses on MILKYS samples will be performed during the autumn of 2013 and reported in 2014 together with the report on 2013 investigation.

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. Mercury was analysed on a fillet sample from each cod. Furthermore, Biological Effects Methods (BEM) were performed on individual cod (concerned only one station, Inner Oslofjord).

Table 3. Overview of method of analyses (See Appendix B for description of chemical codes).

Name	[CAS-number]	Lab.	LOD	LOQ1	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
cobolt (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, "flexible" accreditation
PCB-52	35693-99-3	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	30 %	Internal method	ISO 17025, "flexible" accreditation
PCB-101	37680-73-2	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
PCB-118	31508-00-6	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	30 %	Internal method	ISO 17025, "flexible" accreditation
PCB-138	35065-28-2	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	30 %	Internal method	ISO 17025, "flexible" accreditation
PCB-153	35065-27-1	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
PCB-180	35065-29-3	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
p-p`-DDT	50-29-3	**NIVA/EFM**		0,2 µg/kg low fat, 4 µg/kg high fat	60 %	Internal method	ISO 17025, "flexible" accreditation
p-p`-DDE	82413-20-5	**NIVA/EFM**		0,05 µg/kg low fat, 1 µg/kg high fat	40 %	Internal method	ISO 17025, "flexible" accreditation
p-p`-DDD	72-54-8	**NIVA/EFM**		0,1 µg/kg low fat, 2 µg/kg high fat	50 %	Internal method	ISO 17025, "flexible" accreditation
PBDEs							
BDE-47	5436-43-1	**NIVA/EFM**		0,005 µg/kg mussels, 0,1 µg/kg high fat	30 %	Internal method	ISO 17025, soon to be accredited
BDE-99	60348-60-9	**NIVA/EFM**		0,01 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE-100	189084-64- 8	**NIVA/EFM**		0,01 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE-126*	366791-32-4	**NIVA/EFM**		0,01 µg/kg mussels	50 %	Internal method	ISO 17025, soon to be accredited
BDE-153	68631-49-2	**NIVA/EFM**		0,02 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE-154	207122-15-4	**NIVA/EFM**		0,02 µg/kg mussels, 0,1 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE-183	207122-16-5	**NIVA/EFM**		0,03 µg/kg mussels, 0,3 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE-196	32536-52-0	**NIVA/EFM**		0,05 µg/kg mussels, 0,3 µg/kg high fat	40 %	Internal method	ISO 17025, soon to be accredited
BDE-209	1163-19-5	**NIVA/EFM**		0,5 µg/kg mussels, 0,5 µg/kg high fat	50 %	Internal method	ISO 17025, soon to be accredited
α, ß, γ-HBCD	134237-α (-50-6), ß (-51-7), γ (-52-8)	**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**	0,5 µg/kg		65 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025
PFOA	335-67-1	**NIVA**	1 µg/kg		70 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025
PFHpA	375-85-9	**NIVA**	0,4 µg/kg		60 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025
PFHxA	307-24-4	**NIVA**	0,4 µg/kg		65 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025
PFOS	1763-23-1	**NIVA**	0,5 µg/kg		25 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025

Name	[CAS-number]	Lab.	LOD	LOQ1	Est. uncertainty	Standard or internal method	Accreditation status
PFBS	29420-49-3	**NIVA**	0,4 µg/kg		30 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025
PFOSA	4151-50-2	**NIVA**	1 µg/kg		45 %	Internal method, validated	Not accredited but follows the rutines and systems of ISO 17025
S/MCCP							
SCCP (C10-C-13)	85535-84-8	**EF-GFA**		0,6-3,5 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
MCCP (C14-C17)	85535-85-9	**EF-GFA**		5-10 ng/g	50 %	Internal method based on AIR OC 147, validated	ISO 17025
Phenols							
Oktylphenol	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
Trifenyltin (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**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tributylphosphate (TBP)	126-73-8	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tri(2-chlorethyl)fosfat (TCEP)	115-96-8	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tri(1-chlor-2-propyl) phosphate (TCPP)	13674-84-5	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tri(1,3-dichlor-2-propyl) phosphate (TDCP)	13674-87-8	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tri(2-butoxyethyl) phosphate (TBEP)	78-51-3	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
triphenylphosphate (TPhP)	115-86-6	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
2-ethylhexsyl-di-phenylphosphate (EHDPP)*	1241-94-7	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tetrakis-(2-chloroethyl)dichlorisopentyldiphosphate (V6)		**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
dibutylfenylfosfat (DBPhP)**	2528-36-1	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
butyldifenylfosfat (BdPhP)**	2752-95-6	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tris(2-etylheksyl)fosfat (TEHP)*	78-42-2	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
tris-o-kresylfosfat (ToCrP)*	78-30-8	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
trikresylfosfat (TCrP)	1330-78-5	**EF-GFA**		10-100 ng/sample with low or no fat.	40 %	Internal method, under developement	ISO 17025
BEM							
EROD		**NIVA**			10-20%	ICES TIMES 23	Not accredited
CYP1A		**NIVA**			10-20%	Standard metode: Goksøyr A. (1991)	Not accredited
ALA-D		**NIVA**			20 %	ICES TIMES 34	Not accredited

2.2.2 Laboratories and brief method descriptions

Several laboratories have been used in performing the chemical analysis since 1981 (cf. Green *et al*. 2008a). However, until 2012 general chemical analyses have been done at NIVA where the two main exceptions are the analyses of dioxins that are carried out by the Norwegian Institute for Air Research (NILU) and analyses of TBT that are carried out by Eurofins. The 2012 samples were largely analysed by Eurofins in Moss and by one of the Eurofins laboratories in Germany (GFA). NIVA was responsible for the PFAS analyses. A brief description of the analytical methods used follows (from Green *et al*. 2008a) below.

Metals from the 2012 investigation were analysed at Eurofins-Moss in 2012 and 2013. Before 2002, these were done using Atomic Absorption Spectrometry (AAS). Biota samples were extracted using nitric acid. Concentrations are determined either by Flame AAS (FAAS, for high concentrations) or Graphite furnace AAS (GAAS, for low concentrations). GAAS was always used for zinc and often for copper determinations.

Since 2002, metals have been determined 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). From 2012/2013 the same techniques were used at Eurofins Moss for metal determinations, according to NS EN ISO 17294-2 and NS 4768 (Hg).

Polychlorinated biphenyls (PCBs) and other chlororganic hazardous substances in biota were analysed at Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology-SINTEF and at NIVA before the analyses of the 2012 samples (2012/2013). Both laboratories have used gas chromatograph, with capillary column, (GC) and an electron capture detector (ECD). Fat content was extracted using a mixture of cyclohexane and acetone on the target tissue. Among the individual PCBs quantified, seven (ΣPCB-7) are commonly used for interpretation of the results[2] (Table 4).

***Table 4**. Suggested PCB-congeners, which are to be quantified in biota (ICES 1986).*

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) have been analysed at NIVA using a gas chromatograph (GC) coupled to a mass-selective detector (MSD) until 2012. The same method was used for the 2012 investigation (2012/2013) at Eurofins Moss. 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.

Organic tin compounds have been determined at Eurofins GFA in 2012/2013 using GC-MS detection. Earlier it has been analyses at NIVA by GC-MSD, except for the years 2001-2002 and 2011 when GALAB (Germany) and Eurofins (Denmark) did the analyses. The other two laboratories used a GC equipped with Atomic Emission Detector (AED), a method comparable to NIVA's.

Analyses of polybrominated diphenylether (PBDE) in cod liver were done at Eurofins Moss in 2012/2013 and at NIVA for earlier investigations. Determinations are made on the fat content of the target tissue using a GC-Negative Chemical Ionization (NCI)-MS.

Analysis of perfluoralkyl compounds (PFAS) in cod liver 2012 were done at NIVA. The general procedures include extractions with solvents using ultrasonic bath before intensive clean up and LC/MS/MS-analysis (ESI negative mode).

[2] Several marine conventions (e.g. OSPAR and HELCOM[2]) use ΣPCB-7 to provide a common basis for PCB assessment.

The transfer from analysing the biota samples at NIVA to analysing them at Eurofins Moss has also included competence transfer from NIVA to Eurofins Moss, and several intercalibrations between the labs.

The new analyses introduced in 2012/2013 were done by Eurofins. Chlorinated paraffins (SCCP (C10-C13) and MCCP (C14-C17)), phosphorus flame-retardant (PFR) and nonyl- and octylphenols which 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 are; liver and fillet(***Table 3***), whereas for the biological effects methods (BEM) liver; blood and bile is used (cf. Table 5). The fish fillet are analysed for mercury content. In addition, the age, sex, and visual pathological state for each individual are 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 published periodically (e.g. Shi *et al*. 2008).

The mussels are analysed for all contaminants including organotin. 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 are analysed for all organotin compounds and biological effects (imposex[3]).

2.3 Biological effects analysis

Five biological effects methods (BEM), including the measurement of OH-pyrene for this investigation, have been applied on an annual basis. Each method in theory is 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 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.

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

***Table 5**. The relevant contaminant-specific biological effects methods applied on an annual basis.*

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	snail soft tissue	organotin

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; 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

[3] Vas Deferens Stage Index

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, after which some modifications have been done. 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 CEMP-programme for 2012 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.

During the period 2002-2011, three stations (four for OH-pyrene) have been sampled for BEM, instead of eight stations as in years prior. After the revision of the programme in 2012 only one station (Inner Oslofjord, st.30B) was investigated. Fifteen individual cod were analysed for biological effects measurements.

2.4 Passive sampling with silicone rubber passive samplers

2.4.1 Principle of passive sampling for hydrophobic contaminants

Passive sampling is based on the diffusive movement of substances from the environmental matrix being sampled into a polymeric device (initially free of the compounds of interest) in which contaminants absorb. For the passive sampling of hydrophobic compounds the best known sampler is the SemiPermeable Membrane Device (SPMD) comprising a low density polyethylene membrane containing a triolein lipid phase (Huckins *et al.*, 2006). Currently, single phase polymeric samplers constructed from material such as low density polyethylene or silicone rubber are used as a result of their robustness (Allan *et al.*, 2009, Allan *et al.*, 2010, Allan *et al.*, 2011). At equilibrium, the mass of a chemical absorbed in the sampling device can be translated into a freely dissolved contaminant concentration in the water that the device was exposed to through K_{sw}, the sampler-water partition coefficient. Passive sampling techniques that allow to derive freely dissolved contaminant concentrations have been the subject of much development over the last two decades (Vrana *et al.*, 2005). For hydrophobic contaminants with $\log K_{ow} > 5\text{-}6$, polymeric samplers have a large capacity. For typical deployment periods of a few weeks, equilibrium between the sampler and water will not be attained for these chemicals. Uptake in the linear mode (i.e. far from equilibrium) is therefore time-integrative for the deployment period in water. The resulting time-integrated freely dissolved concentration can be estimated if *in situ* sampling rates, R_s, equivalent amount of water sampled per unit of time (L d^{-1}) are known. Sampling rates can be estimated from the dissipation of performance reference compounds (PRC), analogues of compounds of interest (but not present in the environment) spiked into the samplers prior to exposure (Booij *et al.*, 1998, Huckins *et al.*, 2002).

Passive sampling based on silicone rubber is increasingly being used for routine monitoring of water and sediment. These have been used within the Tilførselsprogrammet (2009-2013) for monitoring a range of contaminants at Andøya, Bjørnøya and Jan Mayen. Deployments were in most at least 200 days. For the riverine input and discharge programme (2013-), silicone rubber passive samplers have also been chosen. The reason for this choice is that we have recently shown that there is a likely restriction of the sampling of voluminous molecules such as brominated diphenyl ethers when using polyethylene (Allan *et al.*, 2013). This can affect the accurate estimation of sampling rates for these compounds from standard PRCs.

Passive samplers were deployed at three sites, Hvaler, Oslofjord and Ålesund for periods of just under one year and analysed for performance reference compounds (to estimate sampling rates), alkylphenols (octyl and nonylphenols), hexabromocyclododecane (HBCD) and polybrominated diphenyl ethers (PBDEs).

2.4.2 Methodology (field and lab)

Samplers used for this project include silicone rubber passive samplers (for analysis and for specimen banking), low density polyethylene (for specimen banking), and Polar Chemical Integrative Samplers (for specimen banking).

Samplers made of AlteSil silicone rubber (nominal size of 1000 cm^2 and 30 g, strips 100 cm long and 2.5 cm wide) were prepared in the NIVA laboratory following standard procedures. In short, the silicone rubber samplers were placed in a Soxhlet extractor for 24 hour cleaning using ethyl acetate. This step removes a significant amount of non-polymerized oligomers. Samplers were then left to dry before further cleaning with methanol. PRCs (deuterated PAHs and fluoroPCBs) were spiked into the samplers using a methanol-water solution (Booij *et al.*, 2002). Polyethylene membranes were prepared from polyethylene purchased from Brentwoods Plastics Inc. Samplers (1m long and 2.5 cm tubing) were soaked in hexane overnight to remove oligomers and clean the samplers. This step was repeated with fresh hexane. Samplers were then soaked in methanol prior to spiking with PRCs (according to Booij *et al.*, 2002). Onced spiked with PRCs, samplers were kept in the freezer at -20 °C until deployment. POCIS devices were purchased from Exposmeter AB (Sweden).

Two sets of replicate silicone samplers were deployed at each of the three sites (Oslofjord, Ålesund havn and Hvaler) using SPMD canisters and samplers mounted on spider holders. Two control samplers were used to assess potential contamination of the samplers during preparation and deployment procedures and to assess initial PRC concentrations. Triplicate POCIS devices were exposed at each of the three stations (one control sample per site was used). The deployment duration are shown in **Table 6**. All samplers were deployed for just under one year. Exact coordinates for the sampling stations are also given in **Table 6**.

Table 6 *Coordinates for sampling stations, deployment and retrieval dates and exposure times for samplers deployed at the three stations.*

Sampling station	Coordinates	Deployment date	Retrieval date	Exposure time (d)
Oslofjord (*304PP*)	N59° 5' 47.58" E11° 3' 2.628"	08.10.2012	05.09.2013	332
Hvaler (*HPP*)	N59° 5' 47.58" E11° 3' 2.628"	15.11.2012	14.10.2013	333
Ålesund harbour (*APP*)	N59° 5' 47.58" E11° 3' 2.628"	23.11.2012	01.11.2013	343

Once back in the laboratory, all samplers were kept in the freezer at -20 °C until extraction and analysis.

Silicone rubber passive sampling devices were kept at -20 °C until analysis. Replicate samplers (30 g each) and a control from each station were extracted. Additional preparation control samplers and QA spiked samplers were analysed together with exposed samplers. The initial step consisted in cleaning the surface of the samplers with milliQ water and drying before extraction. Samplers were placed in clean glass jars with surrogate standards of substances of interest before extraction with pentane (200 mL) overnight. This extraction was repeated with fresh pentane and pentane extracts were combined. Extracts were reduced and split for the different analyses.

For PRCs and alkylphenols, the extract was cleaned up by gel permeation chromatography (GPC). One fraction of the extract was then analyzed by GC-MS to determine PRC concentrations. The other fraction of the extract was derivatised (with a solution of N,O-bis(trimethylsilyl) trifluoroacetamide and trimethylchlorosilane) before determination of alkyl phenolic substances by GC-MS.

For PBDEs and HBCD, the extract was cleaned up with concentrated sulphuric acid. The extract was then split into two. One fraction of the extract was cleaned up by acetonitrile partitioning before PBDEs determination by GC-MS. The solvent of the second fraction was changed to methanol before determination of HBCD isomers by LC-MS-MS.

2.4.3 Quality assurance: Spiked samplers

A set of silicone rubber passive sampling devices for QA purposes was prepared following a similar procedure to that used for standard samplers. Instead of spiking PRCs, target substances in known amounts were added to the samplers using the methanol-water solution (Booij *et al.*, 2002). Substances added included alkylphenolic substances, polybrominated diphenyl ethers and hexabromocyclododecane isomers.
Once the batch was ready, six QA spiked samplers were randomly selected for extraction and analysis to determine the mean concentration and the reproducibility of the spiking of different samplers. The remaining QA spiked samplers were put into tins and stored in the freezer at -20 °C until use. The table below shows mean concentrations (n = 6) obtained in QA spiked samplers for alkylphenolic substances, HBCD isomers and PBDE congeners. Mean concentrations measured are within 89-120 % of the nominal concentrations across the range of substances spiked into the samplers. Relative standard deviations of amounts spiked into the samplers vary from 4 to 19 % across the range of compounds (Appendix G).

2.4.4 Passive sampling data processing

Freely dissolved concentrations were calculated using the boundary-layer controlled uptake model given in Rusina *et al*. (2010) and using the non-linear least square method to estimate sampling rates as a function of $\log K_{sw}$/MW (Booij and Smedes, 2010) from the performance reference compound data. Polymer-water partition coefficients for PRCs and for alkylphenols were not corrected for temperature or salt content of the water (but can be at a later stage if needs be). For PRCs (deuterated PAHs), K_{sw} values were from Smedes *et al*. (2009). For para-n-octylphenol and para-n-nonylphenol, $\log K_{sw}$ values were 4.43 and 5.08, respectively (unpublished). Correlation of $\log K_{sw}$ values with hexadecane-water partition coefficients (from Cosmotherm software), $\log K_{hdw}$ were used to estimate $\log K_{sw}$ for para-t-octylphenol and para-t-nonylphenol. Ultimately a measured value of K_{sw} for these compounds will be preferable. For PBDEs and HBCD, K_{sw} (not available for these substances) were estimated using the regression of $\log K_{sw}$ with $\log K_{ow}$ for PCBs for AlteSil silicone rubber.

2.5 Information on quality assurance

2.5.1 International intercalibrations

The laboratories 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, these include Round 70 of July-November 2012 and Round 72 of January-April 2013, which both apply to the 2012 samples. These QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this programme. The quality assurance programme is corresponding to the 2011 programme (cf. Green *et al*. 2012).

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.

2.5.2 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.

2.5.3 Comparison between NIVA and Eurofins

There is an agreement of comprehensive cooperation between Eurofins Moss and NIVA to minimize offsets of time trends. All the methods used by Eurofins are similar to the methods used by NIVA, with some minor modifications. Some of the work has been to analyse the same samples to ensure that the results are comparable. Three types of samples were used for this purpose: certified reference materials (SRM), use of in-house standard (*Husstandard*-HSD), when these to sample types were absent, a mini-ring-test was performed. The results are summarized in ***Table 7***. All the details from the comparisons are used in the validations reports from Eurofins Accreditations of the methods. The results can therefore be used in assessments of possible time trends. The result is considered acceptable as long as the difference between laboratories is less than the uncertainty in the method. When this is not the case a comment is provided.

The uncertainty presented in this summary is 2 times the standard deviation which takes into account the low, medium and high levels.

For PCB the results showed good agreement between the two laboratories (***Table 7***). For most of the results the differences were less than 20 %. For some results, the difference was slightly higher but within the uncertainty of Eurofins. There is an exception and it is for PCB 52 in mini ring test for mussels. Here the difference between the labs is 80 %. This is only built on three samples from a sample with low levels and must be considered acceptable.

For DDT, DDE and DDD the results showed good agreement between the two laboratories. For most of the results the differences were less than 30 %. For some results, the difference was slightly higher but within the uncertainty of Eurofins.

For PAHs the results showed good agreement between the two laboratories. For most of the results the difference was less than 30 %. For some results, the difference was slightly higher but within the uncertainty of Eurofins. One exception was fluorene where the difference between the two laboratories was 70%. It was not possible to determine the cause of this, but since both laboratories doing well for fluorene on the SRM sample, it must still be considered to be acceptable for one compound.

Generally the results for PBDEs from the analysis of SRM (CIL EDF2525) were good for both laboratories (Appendix A). The difference between the laboratories in the comparative test is 6-80 %. A Challenge that

was discovered was that the blank values at Eurofins Moss generally were slightly higher than for NIVA for the heaviest BDE like BDE 153, 183 and 209. The general concern that blanks can be contaminated with heavier PBDEs, like BDE209, cannot be neglected.

The results for lipid content showed good agreement between the two laboratories.

The results for As, Cd, Cu, Fe, Pb, Ni and Zn showed good agreement between the two laboratories and for most of the metals the difference are less than 20 %.
For Ag, Co and Sn the results showed good agreement between the two laboratories. Ag shows a difference of 53 %. This is very close to the uncertainty of 50 % and NIVA and Eurofins results are located on either side of the given true value.

The results for Hg showed good agreement between the two laboratories, the difference being less than 20 %.

***Table 7**. Uncertainty related to analyses of contaminants at Eurofins.*

Matrix	Type	Number	Uncertainty Eurofins
PCB			
Fish liver	Ring test	3	30-50%
Fish liver oil	HSD #10	26	30-50%
Mussel tissue	SRM 2974a	9	40-50%
Mussel tissue	HSD #9	10	40-50%
Blue mussel	Ring test	3	40-50%
Lean fish	HSD #8	3	30-50%
DDT, DDE, DDD			
Fish liver	Ring test	3	40-55%
Fish liver oil	HSD #10	26	40-55%
Mussel tissue	SRM 2974a	9	40%
Mussel tissue	HSD #9	10	40%
PAH			
Mussel tissue	SRM 29	7	40-50% (70% Naphthalene)
Mussel tissue	HSD #9	10	40-50% (70% Naphthalene)
PBDE			
Mussel tissue	SRM (CIL-EDF2525)	3	40-80%
Mussel tissue	Ring Test	2	40-80%
Lipid content			
Lean fish	Ring Test	2	10-25%
Fish liver	Ring Test	2	10-25%
Mussel tissue	Ring Test	3	10-25%
As, Cd, Cu, Fe, Pb, Ni, Zn			
Lean fish	SRM (Dorm-3)	2	20-40 %
Fish liver	SRM (Dolt-4)	2	20-40 %
Ag, Co, Sn			
Lean fish	SRM (Dorm-3)	2	20-50 %
Fish liver	SRM (Dolt-4)	2	20-50 %
Hg			
Lean fish	SRM (Dorm-3)	2	20 %
Lean fish	HSD #8	3	30-50%

2.6 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. The national classification system prepared by the Norwegian Environment Agency (*Miljødirektoratet*) has been the most used and in investigations similar to this programme and it is applied here. It is the most complete system and provides assessment criteria for five classes of contamination, where Class I is the best class (lowest concentration). This system is built on presumed background concentrations and the degree above this level. It is currently under revision to accommodate the concern that elevated concentrations of contaminants can be harmful for the environment. This risk-based approach is the basis for EU directives which have defined Environmental Quality Standards (EQS). Exceedences of EQS are interpreted as potentially harmful to the environment and remedial action should be implemented. Two main challenges with the EQS that prevent them from being easily applied are that they are generally not species or tissue specific and they can be in conflict with the national limits. The EQS apply to the whole organism whereas in fish monitoring is generally done on a specific tissue. The EQS can be considerably higher or lower than the national Class II (moderately polluted). For example for hexachlorobenzen (HCB) the EQS is 10 µg/kg w.w., whereas Class I and II are 0.1 and 0.3 µg/kg w.w. for blue mussel, respectively, and 0.2 and 0.5 µg/kg w.w. in cod fillet, respectively; or for mercury the EQS is 20 µg/kg w.w. whereas Class I and II are 40 and 100 µg/kg w.w. for blue mussel, respectively, and 100 and 300 µg/kg w.w. in cod fillet, respectively (cf. ***Table 8*** and Appendix C). These anomalies warrant the need to have clear guidance as to how the EQS should be applied and how to explain the difference in the two systems. Even so, the EQS have been discussed where possible when assessing the results from this programme.

Assessing the risk to human consumption that elevated concentrations of contaminants in seafood might have has not been the task of this programme and hence, the EU foodstuff limits have not been applied.

Focus for the 2012 investigation is on the principle cases where median concentrations exceeded the upper limit to Class I in the environmental quality classification system of the Norwegian Environment Agency (cf. Molvær *et al*. 1997). In addition to this, the EU directives 2008/105/EC and 2013/39/EU where Environmental Quality Standards (EQS) for biota are defined are considered (***Table 8***, **Table 11**). The Norwegian Environment Agency defines most classes on a wet weight basis, the exception being for metals in blue mussel which are on a dry weight basis. The EQS and OSPAR time trend methods of analyses are based on wet weight concentrations. To harmonize the presentation classification and trendanalyses for these results the class limits for metals in blue mussel were unofficially converted to a wet weight basis where needed. The relevant part of the Norwegian Environment Agency system is shown in Appendix C.

The choice of base by OSPAR is 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.

***Table 8**. The Water Framework Directive (WFD) Environmental Quality Standards for "biota"* [1] *(cf. Environmental Quality Standard Directive-2013/39/EU) and the Class I and V (upper limit to insignificant and extreme degree of pollution, respectively) in the environmental classification system of the Norwegian Environment Agency (NEA) (Molvær et al. 1997). Concentrations in µg/kg wet weight.*

Hazardous substance	EQS biota [1]	NEA - blue mussel Class I - V	NEA - cod-liver Class I - V	NEA - cod-fillet Class I - V
Brominated diphenylether [2]	0.0085			
Fluoranthene	30 [3]			
Benzo(a)pryrene	5 [3]	1 - 30		
Benzo(b)fluoranthene	11 [3]			
Benzo(k)fluoranthene	11 [3]			
Benzo(g,h,i,)perylene	11 [3]			
Indeno(1,2,3-cd)-pyrene	11 [3]			
Polyaromatic hydrocarbons (PAH) [4]		50 – 5000		
Hexachlorobenzene (HCB)	10	0.1 - 5	20 - 40	0.2 - 5
Hexachlorobutadiene (HCBD)	55			
Mercury and its compounds	20	40 – 800 [5]		100 – 1000
Dicofol	33			
Perfluorooctane sulfonic acid and its derivatives (PFOS)	9.1			
Dioxins and dioxin-like compounds	0.0065 [6]			
Hexabromocyclododecane (HBCD)	167			
Heptachlor and heptachlorexpoxide	0.0067			

1) Fish unless otherwise stated.
2) Sum of BDE congener numbers 28 (tri), 47 (tetra), 99 (penta), 100 (penta), 153 (hexa) and 154 (hexa)
3) Crustaceans and molluscs. (Monitoring of these PAHs not appropriate for fish)
4) 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.
5) Conversion assuming 20% dry weight.
6) Sum of PCDD+PCSF+PCB-DL TEQ

The system has five classes from Class I, insignificantly polluted, to Class V, extremely polluted. However, the system does not cover all the contaminants for the species and tissues used in CEMP. To assess concentrations not included in the system provisional presumed high background values were used (cf. Appendix C). The factor by which this limit or the Class I limit is exceeded is calculated (cf. Appendix F). High background concentration corresponds to the upper limit to Class I; insignificantly polluted, which in this context has no statistical implications.

The median concentrations are assessed according to the system of the Norwegian Environment Agency, but where this is not possible, presumed high background levels are used. It should be noted that there is in general a need for periodic review and supplement of the list of limits used in the classification system in the light of results from reference localities and introduction of new analytical methods, and/or units. Because of changes in the limits, assessments of presumed high background levels over the years may not correspond.

Recommendations for changes to Class I (cf. Knutzen & Green 2001b, Green & Knutzen 2003) have been taken into account in this report. Revisions to corresponding Classes II-V have not been done, but the Norwegian Environment Agency is considering these recommendations in a current review of their classification system.

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 2012 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 2015 (2021 for Norway) and 2020 at the latest, respectively. 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 8***, **Table 11**). There is also a provision which allows a country to use other EQS in sediment and biota provided these offer the same level of protection as the EQS set for water. It should be noted that application of the EQS set may be in conflict with the best class by the Norwegian Environment Agency system for classification of environmental quality; e.g. lower than the Class I for mercury and higher for Class V for HCB in blue mussel. This has not been resolved and for this report, only the system of the Norwegian Environment Agency will be used.

Proposed background assessment criteria (BAC) for EROD and OH-pyrene (ICES 2011) and VDSI (OSPAR 2005) were used to assess the results (***Table 9***).

Table 9. *Assessment criteria for biological effects measurements using background assessment concentration (BAC) and Environmental assessment criteria (EAC) (ICES 2011, OSPAR 2005).*

Biological effect	Applicable to:	BAC	EAC	Units, method
EROD	cod liver	145	-	pmol/min/ mg microsomal protein
OH-pyrene	cod liver	1.1	35	µg/ml, synchronous scan flurorescence 341/383 nm
VDSI	dog whelk, periwinkle	0.3	2	(OSPAR 2005)

2.7 Statistical time trends analysis

A simple three-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***.

The three 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 null.

The smoothed median for the last three sampling years is linearly projected for the next three years to assess the likelihood of presumed high background levels (not shown in figures).

An estimate of the power of the temporal trend series expressed as the number of years to detect a 10 % change per year with a 90 % power (cf. Nicholson et al. 1997). The fewer the years the easier it is to detect a trend. 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 three years of data and covers the entire period monitored. This fixed means of treating all the datasets may give misleading results especially where non-linear temporal changes are known to occur, such as for HCB in blue mussel from Grenland fjords area (Figure 4).

The reported assessments 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 statistically tests the difference in smoothed annual concentration at the beginning of the time series compared the concentration at the end of the time series. This report presents an assessment in line with the current OSPAR approach.

The term “significant” refers to the results of a statistical analysis used for detecting linear trends in the data and can be found in the tables in Appendix F.

No attempt has been made to compensate for differences in size groups or number of individuals of blue mussel or fish in this study. The exception was with mercury in fish fillet where six data sets in both cod and flatfish in this study showed significant differences between “small” and “large” fish (Appendix F). 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.

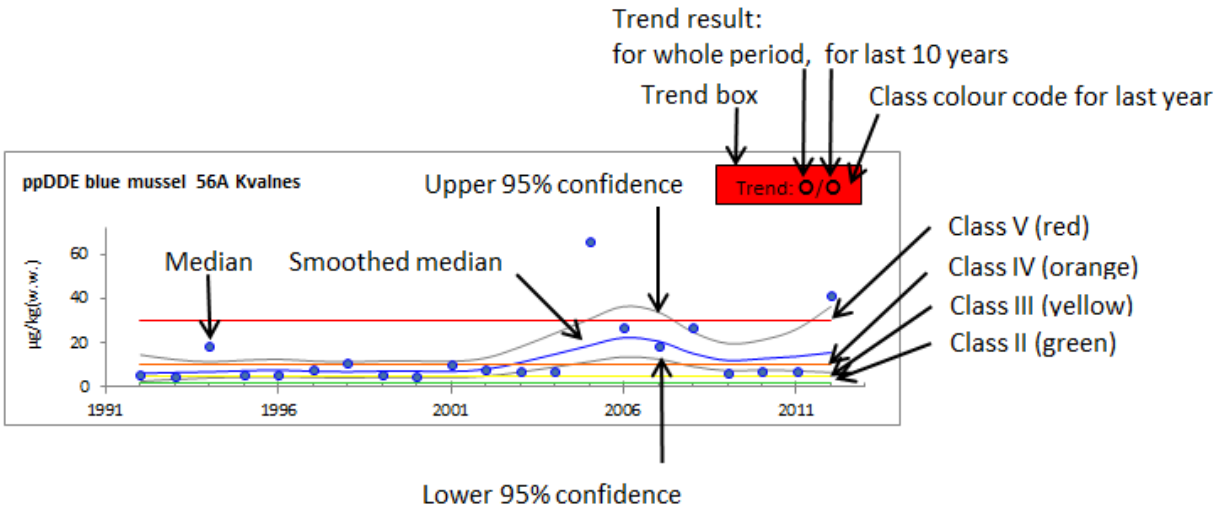


***Figure 4**. Example of time series that indicates the median concentration, running mean of median values (Loess smoother), 95 % confidence intervals. The horizontal lines indicate the lower boundaries to the classes of pollution in the system of the Norwegian Environment Agency : Class II (green line, moderate=upper boundary to Class I (insignificantly polluted, also herein termed as “acceptable”)), III (yellow line, marked), IV (orange line, severe) and V (red line, extreme), or alternatively the Class II boundary is replaced by the upper boundary to provisional "high background level" as in which case no class-boundaries are shown. Further, if there are no classes the background concentration is indicated by a Light grey line. (see text and refer to Appendix C). For biota, trend analyses (shown in the trend box) were done on time series with three or more years and the results, before the slash “/”, 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 period 2002-2011 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. Dark grey indicates concentrations higher than estimated high background levels. Light grey indicates concentrations lower than background levels. Note that scales for the x axis and y axis can vary from figure to figure.*

3. Results and discussion

3.1 General information on measurements

A summary of the levels and trends in contaminants or their effects in Atlantic cod, blue mussel, dog whelk and periwinkle biota along the coast of Norway in 2012 is shown in **Table 11**. More details are given in Appendix F. The trend analyses for the entire monitored period are shown in Appendix F. Unless otherwise stated assessment of trends in the text below refer to long-term trends, i.e. for the whole sampling period, whereas a short term trend refers to the analysis on data for the last 10 years, i.e. 2003-2012.

Time trend analyses were performed on a selection of 30 representative contaminants or their effect (VDSI) where the results included data for 2012 and totalled 272 data series (**Table 10**). In 29 of the 272 cases, concentrations were above what is expected in only diffusely contaminated areas (collectively termed: "over presumed high background concentrations"). The focus of the overview presented below is based on the 272 time series, of which recent and significant trends were registered in 50 cases: 34 (12.5 %) downwards trends and 16 (5.9 %) upwards. Of the 156 cases that could be classified by the system of the Norwegian Environment Agency, 81.4 % were classified as insignificantly polluted, 13.5 % as moderately polluted, 4.5 % as markedly polluted, 0 % as severely polluted and 0.6 % as extremely polluted.

The evaluation of the results focused primarily on those cases where median concentrations in 2012 were over presumed high background level (>Class I, insignificantly polluted, acceptable levels) and where significant upward trends were found and to a lesser degree where there were no significant trends or significant downward trends. The evaluation focused secondarily on cases where median concentrations in 2012 were below presumed high background level (<Class I, insignificantly polluted) in combination with significant upward trends. An overview of trends, classification and median concentrations is presented in Appendix F. The results are presented by classes and with results for observed trend analyses.

It was the intention that 15 cod be sampled at each of 15 stations along the Norwegian coast, however, a catch was made at only 14 stations (**Figure 3**, see also maps in Appendix D). Furthermore, 15 individuals were not obtained at two of these stations (Munkholmen in the Trondheim harbour area and in the Ålesund harbour area, cf. Appendix E). The cod were sampled from October 1 to November 7 2012. All the cod were sampled by local fishermen except for the cod in the Inner Oslofjord (st. 30B) that was collected by NIVA on November 7th 2012 by trawling from the research vessel *F/F Trygve Braarud* owned by University of Oslo. A further complication was that the livers were generally not large enough to accommodate all the analyses planned. This was partly remedied by pooling some of the smaller livers. It was agreed with Norwegian Environment Agency that some of the budget saved could be used to investigate phthlates (not previously included as a parameter) in the cod liver and do analyses in cod fillet on the same contaminants that were analysed in the liver from the same individual. The latter was to see if cod fillet could be used instead of cod liver as an indicator tissue. The results from these extra analyses were not available in time to be included in this report.

Table 10**. Selection of representative contaminants and number of time series assessed for each target species-tissue. The specific results are shown in **Table 11

Contaminant/BEM	Description	Cod, liver	Cod fillet	Blue mussel	Dog whelk, periwinkle	TOTAL
Ag	silver	2		8		10
As	arsenic	0		8		8
Cd	cadmium	6		16		22
Co	cobalt	0		2		2
Cr	chromium	4		8		12
Cu	copper	6		16		22
Hg	mercury	0	6	17		23
Ni	nickel	2		9		11
Pb	lead	6		15		21
Zn	zinc	6		16		22
PCB-7 (CB_S7)	sum of PCB congeners 28+52+101+118+138+153+180	6		14		20
ppDDE (DDEpp)	p,p'-DDE (a DDT metabolite)	1		3		4
BDE47	tetrabromdiphenylether	4				4
BDE100	pentabromdiphenylether	4				4
BDE153	hexabromdiphenylether	4				4
BDE154	hexa bromdiphenylether	4				
BDE196	octa bromdiphenylether	4				
BDE209	decabromdiphenylether	4				
PAHs (P_S)	sum nondicyclic PAHs			6		6
KPAHs (PK_S)	sum carcinogen PAHs			6		6
BKF	benzo[k]fluoranthene			6		6
B[ghi]P	benzo[ghi]perylene			6		6
ICDP	Indeno[1,2,3-cd]pyrene			6		6
B[a]P	benzo[a]pyrene			6		6
FLU	Fluroanthene			6		6
PFOS	perfluorooctanoic sulfonate	4				4
PFBS	Perfluorobutanesulfonic acid	4				
PFNA	Perfluornonanoic acid	4				
TBT	tributyltin (formulation basis)			9		9
VDSI	Vas Deferens Sequence Index				8	8
TOTAL		**75**	**6**	**183**	**8**	**272**

***Table 11**. Overview of samples collected in 2012 with indication of levels and trends in concentrations of contaminants monitored. Classification is based on observed concentrations in cod, blue mussel, dog whelk and periwinkle. Tissues: soft body (SB), muscle (MU), liver (LI) and whole organism (WO). The classification system of the Norwegian Environment Agency is used for biota (Molvær et al. 1997: Classes: I (blue), II (green), III (yellow), IV (orange) and V (red) (see Appendix D). For biota, trend analyses were done on time series with five or more years and the results, before the slash "/", 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 period 2003-2012 and the result is shown after the slash. A small filled square (▪) indicates that chemical analysis has been performed, but either data were insufficient to do a trend analysis or was not presented. Dark grey indicates concentrations higher than estimated high background levels. Light grey indicates concentrations lower than high background levels. Note: Class limits for ΣDDT are used for ppDDE. PBDEs and PFASs with "*" indicate that some assessments are uncertain because of a dominance of values below the detection limit - see main text.*

St.code	St. name	Species	tissue	AG	AS	CD	CO	CR	CU	HG	NI	PB	ZN	PCB-7	pp-DDE	BDE-47	BDE-100*	BDE-153*	BDE-154*	BDE-196*	BDE-209*	PAH	KPAH	BKF	BGHIP	ICDP	BAP	FLU	PFOS*	PFBS*	PFNA*	TBT	VDSI
I023	Singlekalven (south)	Blue mussel	SB	▪/▪	▪/▪	O/↑	▪/▪	▪/▪	O/O	O/↑	▪/▪	O/O	O/O	↓/O		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
I131A	Lastad	Blue mussel	SB	▪/▪	▪/▪	O/O	▪/▪	▪/▪	O/O	O/↑	▪/▪	▪/▪	O/O									O/O	O/O	O/O	O/O	O/O	O/O	O/O					
I301	Akershuskaia	Blue mussel	SB	▪/▪	▪/▪	O/O	▪/▪	▪/▪	O/O	O/↑	▪/▪	↓/O	O/O	↓/O								O/O	O/O	O/O	O/O	O/O	O/O	O/O					
I304	Gåsøya	Blue mussel	SB	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					
I712	Croftholmen	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	↑/↑	▪/▪	▪/▪	▪/▪			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
I965	Moholmen (B5)	Blue mussel	SB	↓/↓	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					
I969	Bjørnbærviken (B9)	Blue mussel	SB	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					
02B	Hvaler area, Kirkøy	Cod	MU							▪/▪																							
02B	Hvaler area, Kirkøy	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪																			
10A2	Skallneset	Blue mussel	SB	O/O	↓/↓	O/O	▪/▪	O/O	O/O	↓/O	O/O	O/O	O/O	↓/O																			
10B	Varangerfjord	Cod	MU							↓/↑																							
10B	Varangerfjord	Cod	LI	▪/▪	▪/▪	↓/O	▪/▪	▪/▪	↓/O		▪/▪	O/O	↓/O	↓/O																			
11G	Brashavn	Dog Whelk	SB																												↓/↓		
11G	Brashavn	Dog Whelk	WO																													O/O	
11X	Brashavn	Blue mussel	SB	▪/▪	▪/▪	O/O	▪/▪	▪/▪	O/O	O/O	▪/▪	O/O	O/O	O/O																			
13BH	Kristiansand harbour	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪									▪/▪	▪/▪	▪/▪		
13BH	Kristiansand harbour	Cod	MU							▪/▪																							
131G	Lastad	Dog Whelk	SB																												↓/↓		
131G	Lastad	Dog Whelk	WO																													↓/↓	
15A	Gåsøy (Ullerø)	Blue mussel	SB	▪/▪	▪/▪	O/O	▪/▪	▪/▪	O/O	O/O	▪/▪	O/↑	O/O	↓/O																			
15B	Ullerø area	Cod	MU							O/O																							
15B	Ullerø area	Cod	LI	▪/▪	▪/▪	O/O	▪/▪	O/O	O/O		▪/▪	↓/O	O/O	O/O																			
15G	Gåsøy (Ullerø)	Dog Whelk	SB																												↓/↓		
15G	Gåsøy (Ullerø)	Dog Whelk	WO																													↓/↓	
22A	Espevær (west)	Blue mussel	SB	O/O	O/O	O/O	▪/▪	O/O	O/O	O/O	O/O	↓/↓	↓/O	↓/O																			
22G	Espevær (west)	Dog Whelk	WO																													↓/↓	
22G	Espevær (west)	Dog Whelk	SB																												↓/↓		
227G1	Melandholmen	Dog Whelk	SB																												↓/↓		
227G1	Melandholmen	Dog Whelk	WO																													↓/↓	
23B	Karihavet area	Cod	MU							O/O																							
23B	Karihavet area	Cod	LI	O/O	▪/▪	↓/↓	▪/▪	O/O	↓/↓		O/O	↓/O	↓/↓	↓/O		↓/O	O/O	O/↑	O/O	O/O	O/O								O/O	↓/↓	O/O		
26A	Hamnen	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
28B	Ålesund	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪												
28B	Ålesund	Cod	MU							▪/▪																							
30A	Gressholmen	Blue mussel	SB	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					
30B	Oslo City area	Cod	MU							↑/↑																							
30B	Oslo City area	Cod	LI	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		
31A	Solbergstrand	Blue mussel	SB	▪/▪	▪/▪	O/O	▪/▪	▪/▪	O/O	↓/O	O/O	↓/O	O/O	O/O																			
36B	Færder area	Cod	MU							O/O																							
36B	Færder area	Cod	LI	▪/▪	▪/▪	O/O	▪/▪	O/O	↓/O		▪/▪	↓/O	↓/O	O/O		↓/O	O/O	O/O	O/O	O/O	O/O								O/O	↓/↓	↓/↓		
36G	Færder	Dog Whelk	WO																													↓/↓	
36G	Færder	Dog Whelk	SB																												↓/↓		
43BH	Tromsø harbour	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪		
43BH	Tromsø harbour	Cod	MU							▪/▪																							
45B2	Hammerfest (harbour)	Cod	MU							▪/▪																							
45B2	Hammerfest (harbour)	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪																			
51A	Byrkjenes	Blue mussel	SB							↓/O				O/O	O/O																		
53B	Inner Sørfjord	Cod	MU							O/O																							
53B	Inner Sørfjord	Cod	LI	▪/▪	▪/▪	O/↓	▪/▪	▪/▪	O/↓		▪/▪	↓/O	O/O	O/O	O/O	O/O	O/O	↑/↑	O/O	O/O	O/O								O/O	↓/↓	↓/↓		
56A	Kvalnes	Blue mussel	SB							O/O				↓/↓	O/O																		

St.code	St. name	Species	tissue	AG	AS	CD	CO	CR	CU	HG	NI	PB	ZN	PCB-7	pp-DDE	BDE-47	BDE-100*	BDE-153*	BDE-154*	BDE-196*	BDE-209*	PAH	KPAH	BKF	BGHIP	ICDP	BAP	FLU	PFOS*	PFBS*	PFNA*	TBT	VDSI
64A	Utne, ytre Sørfjorden (B4)	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪																		
65A	Vikingneset	Blue mussel	SB	▪/▪	▪/▪	🡻/🡻	▪/▪	▪/▪	O/O	O/O	▪/▪	🡻/O	🡻/O	🡻/O	O/O																	
71A	Bjørkøya (Risøyodden)	Blue mussel	SB	🡻/🡻	🡻/🡻	O/🡹	▪/▪	O/O	O/O	🡻/🡹	O/O	O/O	O/O			▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
71B	Grenlandsfjord	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪																				
71B	Grenlandsfjord	Cod	MU							▪/▪																						
71G	Fugløyskjær	Common periwinkle	SB																												O/O	
76A	Risøy	Blue mussel	SB	▪/▪	▪/▪	🡹/O	▪/▪	▪/▪	O/O	O/O	▪/▪	O/O	O/O	🡻/O																		
76G	Risøy	Dog Whelk	SB																												🡻/🡻	
76G	Risøy	Dog Whelk	WO																													🡻/🡻
80BH	Munkholmen	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪		
80BH	Munkholmen	Cod	MU							▪/▪																						
91A2	Ørland, outer Trondheimsfjord	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪											
97A2	Bodø harbour	Blue mussel	SB	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪											
98A2	Husvaagen area	Blue mussel	SB	O/O	O/O	🡹/O	▪/▪	O/O	O/O	O/O	O/O	O/O	O/O	🡻/O		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪					
98B	Skrova Harbour	Cod	MU							▪/▪																						
98B	Skrova Harbour	Cod	LI	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪		▪/▪	▪/▪	▪/▪	▪/▪	▪/▪	▪/▪								▪/▪	▪/▪	▪/▪		
98G	Svolvær	Dog Whelk	WO																													🡻/🡻
98G	Svolvær	Dog Whelk	SB																												🡻/🡻	

3.2 National levels and trends

3.2.1 Mercury (Hg)

Cod fillet

Cod fillet in the Inner Oslofjord was markedly polluted (Class III) by Hg and showed both significant long-term and short-term upward trends (**Table 11, Figure 5***)*. The reason for this increase is not clear. Historical data on entry of mercury to the Inner Oslofjord is not available. Present discharge of mercury to the fjord has however been calculated to be around 7.3 kg/year (Berge *et al*. 2013a). Input from rivers and runoff from urban surfaces are the most important local contributors. It has been suggested that increased wash-out of humus substances in inland water can lead to increased microbial activity in the sediment and increased methylation of mercury (see below). This would make mercury more bioavailable. The amount of particles in the surface water in the Inner Oslofjord has however been reduced (as shown by the increase in secchi depth) over several decades (Berge *et al*. 2013b) and thus do not support the idea that increased wash-out of humus to be an obvious explanation for the increased mercury levels observed in the Inner Oslofjord.

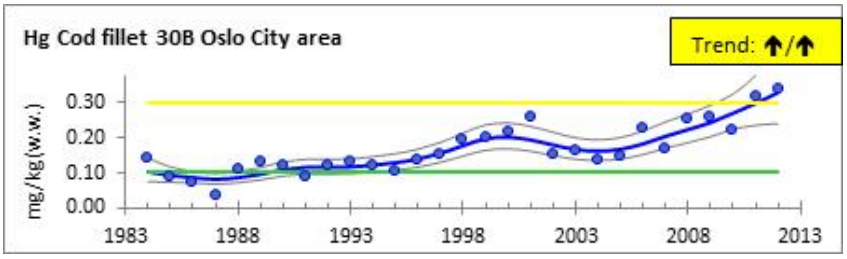


Figure 5*. Median concentrations (mg/kg w.w.) of mercury in cod fillet from 1984 to 2012 in the Inner Oslofjord (st. 30B).*

The cod from Ålesund harbour were markedly polluted (Class III) with mercury in cod filet, but there is insufficient data to do a time trend analysis. Fillet of cod from Karihavet (st. 23 B) on the west coast had increased from insignificantly polluted (Class I) in 2011 to moderately polluted (Class II) by Hg in 2012. The cod from Hvaler area, Grenlandsfjord area and Trondheim harbour were moderately polluted (Class II) with Hg in fillet, but there was insufficient data to do time trend analyses on data from this programme. However, another investigation showed that the Hg in cod fillet was still declining in the Grenlandsfjord during the period from 2008 to 2012, but the level in the Frierfjord was still higher than in 1999 (Ruus *et al*. 2013a). Schøyen *et al*. (2013) also found that cod fillet in the Kristiansand harbour was insignificantly polluted by Hg, but cod from the Topdalsfjord in the Inner Kristiansandsfjord was moderately polluted by Hg. The cod from the Inner Sørfjord were moderately polluted (Class II) with mercury in fillet.

Blue mussel

All blue mussel stations in the Inner and Outer Oslofjord showed background levels of Hg. Gitmark *et al*. (2013) did however find that mussels from Langøya in the Holmestrandfjord in 2012 were up to moderately polluted by Hg. In the Grenlandsfjord area, blue mussel at Bjørkøya (st. 71A) and Croftholmen (st. I712) had increased from being insignificantly polluted (Class I) to being moderately polluted (Class II) by Hg. Blue mussel at Bjørkøya showed a significant upward short-term trend, and a significant downward long-term trend (**Table 11, Figure 6**). Blue mussel at Croftholmen showed both significant long-term and short-term upward trends. Blue mussel at Byrkjenes (st. 51A) had decreased from being moderately polluted (Class II) in 2011 to being insignificantly polluted (Class I) in 2012. The concentrations of metals and mercury in blue mussel in the Sørfjord have decreased significantly during the last 25 years when actions were taken by the local industry (Ruus *et al*. 2013).

Blue mussel at almost all stations in the Kristiansandsfjord in 2012 were insignificantly polluted and the concentrations had decreased slightly compared to 2011 (Schøyen *et al*. 2013). Blue mussel collected in the Sørfjord in 2012 had concentrations of Hg up to markedly polluted, although only slightly higher than the limit of Class II (Ruus *et al*. 2013b).

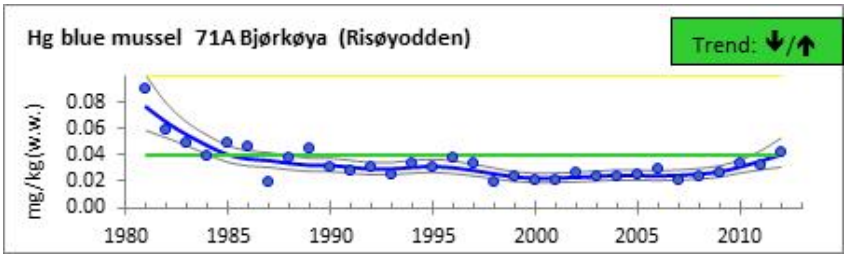


Figure 6. *Median concentrations (mg/kg w.w.) of mercury in blue mussel from 1981 to 2012 in the Grenlandsfjord area (Bjørkøya, st. 71A).).*

Concluding remarks on mercury

It can be noted that the EU has provided Environmental Quality Standard (EQS) for "fish" (cf. ***Table 8***). In this report this EQS has also been applied for blue mussel. The EQS for mercury is 0.02 mg/kg w.w. which is below the upper limit to insignificantly polluted (Class I) for blue mussel (0.04 mg/kg w.w.). The concentrations in blue mussel at Gressholmen (st. 30A) (0.021 mg/kg w.w.) in the Inner Oslofjord, Bjørkøya (st. 71A) (0.042 mg/kg w.w.) in the Grenlandsfjord, Byrkjenes (st.51A) (0.039 mg/kg w.w.), Kvalnes (st. 56A) and Utne (st. 64A) (0.022 mg/kg w.w.) in the Inner to the Outer Sørfjord, and Vikingneset (st. 65A) (0.023 mg/kg w.w.) in the Hardangerfjord were above the EQS applied for blue mussel. Upward trends are always of concern and this warrants a need to continue monitoring.

For this report it is assumed that the EQS for fish are based on analyses on whole fish. Therefore, the EQS cannot be directly compared to concentrations found in different tissues of fish. We have in this study only measured Hg in fillet and have not considered converting fillet to whole fish because this conversion is uncertain. This will probably be an overestimate because Hg accumulates more in the muscle than other tissues (Kwasniak & Falkowska 2012) it is assumed for this exercise that the same concentration is found in all tissue types. If we still compare the results of Hg in cod fillet to the EQS, all the samples in 2012 would have exceeded this value.

OSPAR (2010) found 70-75% reduction in riverine and direct discharges of mercury to the North Sea for the period 1990-2006. There was a predominance of downward significant trends over upward significant trends in concentrations observed for sediment from the North Sea. The OSPAR-results are generally supported by the 2012-investigation. Seven long-term trends were found for Hg in biota. Five significant downward long-term trends were found for blue mussel at Solbergstrand, Bjørkøya, Byrkjenes and Skallneset and in cod fillet in the Varangerfjord. However, two significant upward long-term trends were found in cod fillet in the Inner Oslofjord and blue mussel at Croftholmen in the Grenlandsfjord area, which could be due local conditions in these two perturbed areas. When considering recent trends for both cod and blue mussel. i.e. for the period 2003-2013, significant trends are either not detected or upward (***Figure 7***). The reason for this indication of recent upwards trend that contradicts the general downward trend indicated by the OSPAR has not been determined.

The reason for the upward trend in Hg-concentrations in cod from the inner Oslofjord is unknown. Similar trends have however recently been observed in fish from several lakes in Norway (Fjeld *et al*. 2010). These authors point to observations that the atmospheric deposition of mercury in Southeast Norway has decreased significantly over the last years (Wängberg *et al*. 2010), and thus they expected to find a decrease or unchanged levels in fish. Atmospheric deposition to the seas surrounding Norway is considerably larger that estimates from other sources such as riverine dischages, shipping and offshore installations (Green *et al*. 2013). Possible mechanisms they mention are increased microbial methylation of mercury or contribution from factors that weaken photodemethylation of methylmercury, however, they emphasize that present data do not provide a basis for further reflections on the causes and that it takes long-term monitoring of mercury in fish and related environmental factors to provide the answer to this. In the Oslofjord, there are presently no data to investigate possible changes in input of Hg to the catchment area, or altered trophic links, e.g. a shift in cod diet to prey items with higher Hg content may contribute.

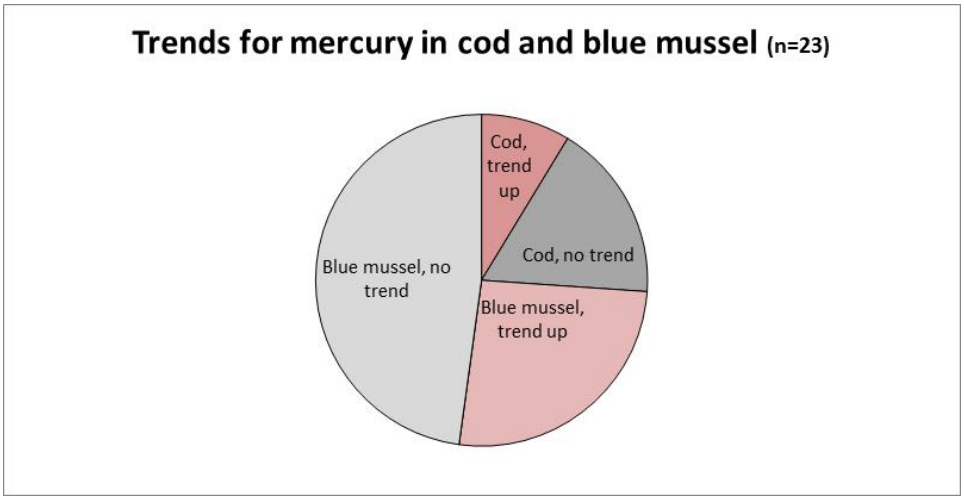


Figure 7. *Frequency of recent trends (2003-2012) for mercury in cod fillet and blue mussel. No downward recent trends were detected.*

3.2.2 Cadmium (Cd)

Cod liver

The observed concentrations were low, i.e. below provisional high background levels (Appendix C). At Færder (st. 36B) there was a significant upward short-term trend in 2012 (with the old statistical method), while there was no significant short term trend in 2011 (**Table 11**) or in 2012 (with the new statistical method), which does indicates no grounds for concern. It is difficult to link this to any local or transboundary change.

Blue mussel

All blue mussel stations were insignificantly polluted (Class I) except for blue mussel at Croftholmen (st. I712) which was moderately polluted (Class II). The concentration of Cd in blue mussel at this station had increased from being insignificantly polluted in 2011. One possible explanation might be that the discharge of Cd to water from local industry in Skien has gradually increased from 0.01 kg pr. year in 2004 to 0.06 kg per year in 2011 and 2012 (www.norskeutslipp.no).

There were significant upward long-term trends in blue mussel at Risøy (st. 76A) and Husvaagen (st. 98A2) and upward short-term trends found in blue mussel at Singlekalven (st. I023) and Bjørkøya (st. 71A) based on the new statistical method. Gitmark *et al.* (2013) found that mussel was up to moderately polluted by Cd at Langøya in the Holmestrandfjord in 2012. Schøyen *et al.* (2013) reported that blue mussel at Odderøy and Svensholmen in the Kristiansandsfjord were insignificantly polluted by Cd in 2012. Ruus *et al.* (2013b) reported that blue mussel in the Sørfjord was up to moderately polluted with Cd.

3.2.3 Lead (Pb)

Cod liver

There were background level concentrations of Pb in cod liver at all stations (**Table 11**). Significant downward long-term trends was found at five stations (Inner Oslofjord, Færder, Ullerø, Inner Sørfjord and Karihavet).

Blue mussel

The presence of Pb in blue mussel exceeded Class I (insignificantly polluted) at one station (Moholmen, st. I965) of the 23 blue mussel stations analysed (**Table 11**). At Moholmen (st. I965) there was an observed significant upward short-term trend in 2012 (with the old statistical method), while no significant trend was observed in 2011. New statistical method for trend analyses applied time series that included 2012 data showed no significant trends, except for an upward short term trend at Gåsøy (st. 15A). We have no knowledge of active sources of Pb in this area. Of the 15 time trend series where there was sufficient data, four of these had significant trends, all downward.

All blue mussel stations in the Inner and Outer Oslofjord had low concentrations of Pb. Gitmark *et al.* (2013) found that mussel was up to moderately polluted by Pb at Langøya in the Holmestrandfjord in 2012. Schøyen *et*

al. (2013) reported that blue mussel at Odderøy in the Kristiansandsfjord was markedly polluted with Pb in 2012, while mussel in the inner fjord was insignificantly polluted and mussel in the outer fjord was moderately polluted. Ruus *et al*. (2013b) found that blue mussel in the Sørfjord was up to moderately polluted by Pb in 2012. The low levels of Pb in cod liver and the significant downward long-term trends at five stations (Inner Oslofjord, Færder, Ullerø, Inner Sørfjord and Karihavet), even in the vicinity of highly populated areas such as Oslo, may indicate that the ban of Pb in gasoline has had a positive effect. EU banned leaded-fuel in road vehicles 1. January 2000, but some countries had banned the fuel beforehand (e.g. Sweden, Germany, Portugal).

Concluding remarks on lead

OSPAR (2010) found 50-80% reduction in riverine and direct discharges of Pb to the North Sea for the period 1990-2006. Of 10 time series for cod or blue mussel observed at coastal stations adjacent to the North Sea stations but distant to point sources of pollution and analysed in the current study, seven showed a significant trend, all downwards, indicating a relatively good correlation with the general trend of the North Sea.

3.2.4 Copper (Cu)

Cod liver

Cod from all stations had concentrations of Cu at background levels. No significant upward trends were found.

Blue mussel

Blue mussel at all stations were insignificantly polluted (Class I) with Cu, and no significant trends were found. Gitmark *et al*. (2013) found that all but one station at Langøya in the Holmestrandfjord had background levels of Cu in 2012. Schøyen *et al*. (2013) reported that blue mussel from September 2012 at Odderøy and Svensholmen in the Kristiansandsfjord were moderately polluted by Cu. Ruus *et al*. (2013b) found that blue mussel in the Sørfjord was insignificantly polluted by Cu in 2012.

3.2.5 Zinc (Zn)

Cod liver

Cod liver from Grenland (st. 71B), Kristiansand harbour (st. 13B), Ålesund (st. 28B) and Skrova (st. 98B) had concentrations that exceeded background levels, but no upward trends were found.

Blue mussel

All blue mussel were insignificantly polluted (Class I) by Zn, and no upward trends were found. Gitmark *et al*. (2013) also found that all mussel stations had low levels of Zn at Langøya in the Holmestrandfjord in 2012. Schøyen *et al*. (2013) found that seven blue mussel stations in the Kristiansandsfjord were insignificantly polluted by Zn in 2012. Ruus *et al*. (2013b) found that blue mussel in the Sørfjord was insignificantly polluted by Zn in 2012.

3.2.6 Silver (Ag)

Wastewater treatment plant discharges and discharges from mine tailings are considered major and important sources of silver to the aquatic environment (Tappin *et al*. 2010). The incorporation of silver nanoparticles into consumer products is of clear concern in terms of inputs to wastewater treatment plants (Nowack 2010). Silver 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 silver in both wastewater treatment plant effluent and sludge due to its increasing use in nanoparticle form in consumer products. Recent studies have shown that much of the silver entering wastewater treatment plants is incorporated into sludge as silver sulphide nanoparticles (Ag_2S), although little is known about the 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).

Cod liver

The environmental classifications system does not include Ag in cod. No significant upward trends were found. The highest concentration (5 mg/kg w.w.) was found in cod from the Inner Oslofjord. This 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. The second highest concentration (1.455 mg/kg w.w.) was found in cod liver from Ålesund (st. 28B). The lowest concentration (0.004 mg/kg w.w.) was found in Karihavet on the west coast (st. 23B). There are no historical data on the amounts of silver entering the Inner Oslofjord. The use of silver (nano-silver) as an antibacterial agent in some textiles and consumer products may be a possible explanation for the relatively high concentrations observed in the Inner Oslofjord. Effects of use of nano-silver are also most likely to be first observed in densely populated area with several wastewater treatment plants like the Inner Oslofjord.

Blue mussel
All blue mussel were insignificantly polluted (Class I) by Ag, and there were no significant upward trends. This was also reported by Schøyen *et al.* (2013) in mussels from seven stations in the Kristiansandsfjord in 2012.

3.2.7 Arsenic (As)

Cod liver
Relevant values for background levels of As are not available for cod. No significant upward trends were found.

Blue mussel
All blue mussel were insignificantly polluted (Class I) by As and no significant upward trends were found.

Gitmark *et al.* (2013) observed that blue mussel was up to moderately polluted by As at Langøya in the Holmestrandfjord in 2012. Schøyen *et al.* (2013) found that five of seven blue mussel stations in the Kristiansandsfjord were moderately polluted by As.

3.2.8 Nickel (Ni)

Cod liver
The environmental classifications system does not include Ni in cod.

Blue mussel
All blue mussel were insignificantly polluted (Class I) by Ni. Significant upward long-term and short-term trends were found at Gåsøya (st. I304) in the Inner Oslofjord. All blue mussel stations in the Inner and Outer Oslofjord showed acceptable (background) levels of Ni. Gitmark *et al.* (2013) did however observe that mussel was up to severely polluted by Ni at one station at Langøya in the Holmestrandfjord in 2012. Blue mussel in the Ranfjord was up to markedly polluted with Ni (Øxnevad and Bakke 2013). Schøyen *et al.* (2013) found that blue mussel was insignificantly polluted by Ni in the Kristiansandsfjord, except for Svensholmen where blue mussel was moderately polluted.

3.2.9 Chromium (Cr)

Cod liver
Relevant values for background levels of Cr are not available for cod. No significant upward trends were found.

Blue mussel
All blue mussel stations were insignificantly polluted (Class I) by Cr and no significant trends were found. Gitmark *et al.* (2013) found that mussels at one station at Langøya in the Holmenstrandfjord were up to extremely polluted by Cr. Blue mussel from Moholmen and Rauberget in the Ranfjord were respectively markedly and severely polluted with Cr (Øxnevad and Bakke 2013). Schøyen *et al.* (2013) found that six blue mussel stations in the Kristiansandsfjord had background levels of Cr and that one station in the outer fjord was moderately polluted by Cr.

3.2.10 Cobalt (Co)

Cod liver
Relevant values for background levels of Co are not available for cod. No significant trends could be observed.

Blue mussel

There were significant upward long-term and short-term trends at both Moholmen (st. I965) and Bjørnbærviken (st. I969) with the new statistical method for time trend analyses, whereas with the old statistical method no significant trends were detected (for time series up to and including 2011 data). Both stations are located in the Inner Ranfjord. A review of discharges to this area did not include Co (www.norskeutslipp.no). There is no classification for Co in blue mussel.

3.2.11 Tributyltin (TBT)

Concentrations of TBT in dog whelk (*Nucella lapillus*)

There were no changes in trends from 2011 to 2012, and the trends were still downward. Significant downward long-term and short-term trends were found at all stations: Færder (st. 36G), Risøy (st. 76G), Lista at Gåsøy/Ullerø (st. 15G), Lastad (st. 131G), Melandsholmen (st. 227G1), Espevær (st. 22G) Svolvær (st. 98G) and Brashavn (st. 11G). The concentrations of TBT were low (<6.31 µg/kg w.w.) as in the previous years. The highest organotin level was found at Melandsholmen/Flatskjær close to Haugesund (6.31 µg/kg w.w.) on the west coast of Norway.

Concentrations of TBT in common periwinkle (*Littorina littorea*)

There were no changes in trends from 2011 to 2012. There were no significant trends of TBT at Fugløyskjær in the Grenland area. The concentration of TBT was 2.11 µg/kg w.w.

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

The effects from TBT were low (VDSI<1.19) at all eight stations investigated in 2012. There were significant downward trends at all the stations except for at Brashavn where no significant trend was found and where VDSI values have been low during the whole monitoring period. The VDSI in dog whelk from the Svolvær area had decreased from 0.65 in 2011 to 0.33 in 2012. At Melandholmen in The Karmsundet the VDSI was 1.96 in 2011 and 1.19 in 2012. At Espevær the VDSI was 0.52 in 2011 and 0.07 in 2012. No effects (VDSI=0) were found at Færder, Risøy, Gåsøy/Ullerø, Lastad and Brashavn. These results were below the OSPARs Background Assessment Criteria (BAC=0.3) (OSPAR 2009). The VDSI was 1.19 at Melandsholmen and 0.33 at Svolvær. These results were over BAC but below the OSPARs Ecotoxicological Assessment Criteria (EAC=2) (OSPAR 2009).

Concluding remarks on TBT

The results show that the Norwegian legislation banning application of organotins on ships shorter than 25 meters in 1990 and longer than 25 meters in 2003 has been effective in reducing imposex in dog whelk populations. Some of the previously effected gastropod populations have also re-established. The international convention that was initiated by the International Maritime Organization (IMO) did not only ban application of organotins on ships after 2003 but also stated that organotins 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 in the whole monitoring period. It was a clear decline in VDSI as well as TBT at nearly all stations between 2003 and the total ban in 2008 (***Figure 8*** and ***Figure 9***). The exceptions being for VDSI for snails from Varangerfjord and periwinkles from the Grenlandsfjord area. In the Varangerfjord the VDSI has remained low (<0.3) for the entire investigation period. 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 10***.

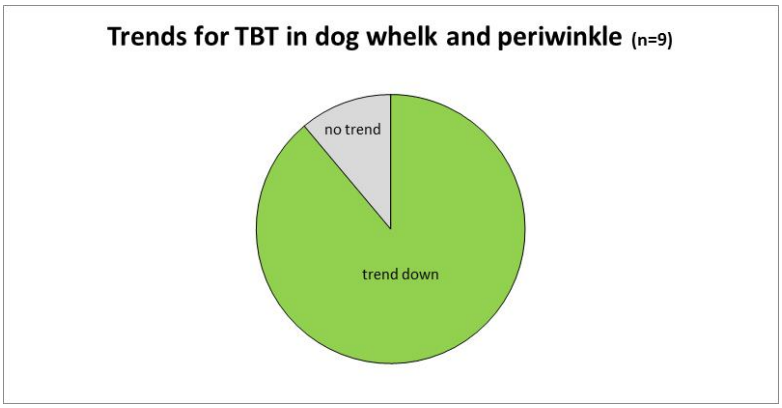


Figure 8. *Frequency of trends for TBT in dog whelk and periwinkle. No upward trends were detected.*

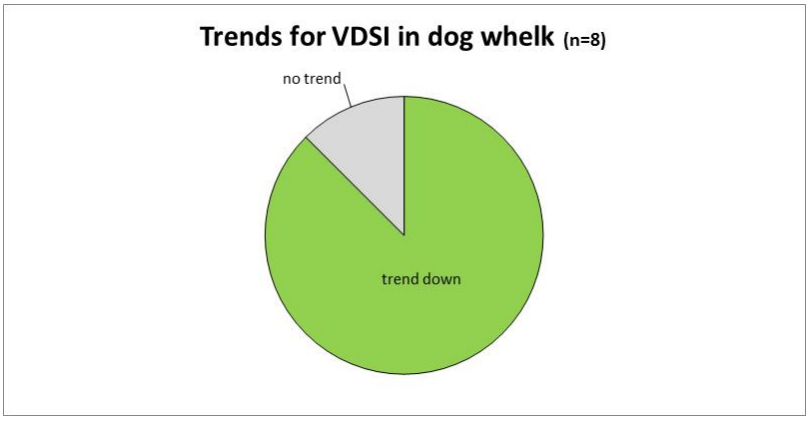


Figure 9. *Frequency of trends for VDSI in dog whelk. No upward trends were detected.*

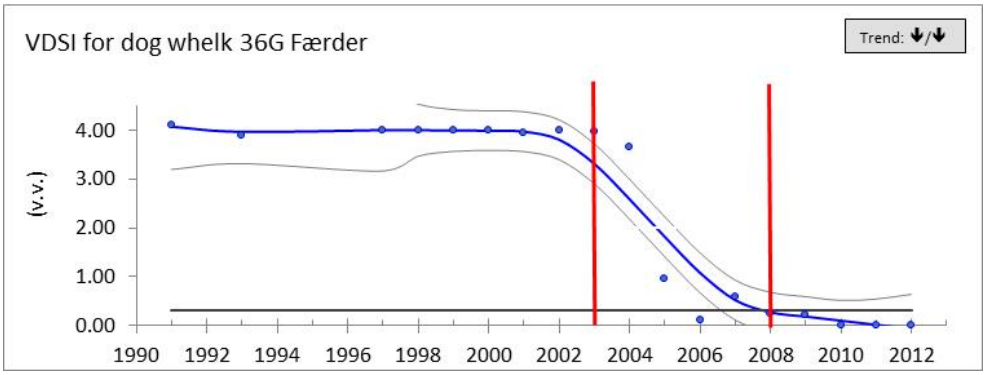


Figure 10. *Change in VDSI for dog whelk from Færder (st.36G). The vertical red line indicates the initial ban of TBT in 2003 and total ban in 2008.*

3.2.12 Polychlorinated biphenyls (ΣPCB-7)

Cod liver

Cod liver from the Inner Oslofjord (***Figure 11***) and Hammerfest harbour area were markedly polluted with PCBs, but there were no upward trends. There were downward trends for PCB-7 in cod liver from the Varangerfjord and Karihavet. Cod liver from the Inner Sørfjord (st. 53B) was now only insignificantly polluted (Class I) in 2012 as compared to moderately polluted (Class II) in 2011. However, Ruus *et al.* (2013) found that cod liver from the Inner Sørfjord was moderately polluted with PCB-7. Cod liver was moderately polluted by PCB-7 in the Kristiansand harbour. Schøyen *et al.* (2013) also found that both cod fillet and liver were up to moderately polluted in the Kristiansandsfjord in 2012. The cod from the Hammerfest harbour were markedly polluted (Class III) with ΣPCB-7 in liver, 1586 µg/kg w.w. Only the median concentration in the Inner Oslofjord was higher (3065 µg/kg w.w.). The cod from the Ålesund harbour area was moderately polluted with ΣPCB-7 in liver. Whereas the liver of cod from the Trondheim harbour area was insignificantly polluted (Class I) with ΣPCB-7. There is insufficient data to do a time trend analysis for the Hammerfest, Ålesund and Trondheim data.

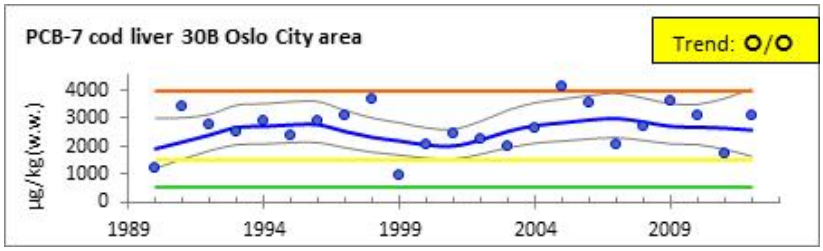


Figure 11. *Median concentrations (mg/kg w.w.) of PCB-7 in cod liver from 1990 to 2012 in the Inner Oslofjord (st. 30B).).*

Blue mussel
There were 11 downward trends and no upward trends for PCB-7 in blue mussel. There were no changes in classes except for blue mussel at Gressholmen (st. 30A) in the Inner Oslofjord which was moderately polluted (Class II) in 2012 but were insignificantly polluted (Class I) in 2011.

Concluding remarks on ΣPCB-7

The concentration of ΣPCB-7 in cod liver from the Inner Oslofjord was 3065 µg/kg w.w., over 48 % higher than the four other harbour stations where ΣPCB-7 was measured (Ålesund and Trondheim, Tromsø and Hammerfest harbours). Historical data on entry of PCB to the Inner Oslofjord is not available. Present entry of PCB to the fjord has however been calculated to be around 3.3 kg/year (Berge *et al.* 2013a). Run-off from urban surfaces is the most important contributor (2.1 kg/year). It is also anticipated that sediments in the fjord store much of the historic inputs of PCB to the fjord. Parts of the Inner Oslofjord are densely populated with much urban activities. The high concentrations of PCB observed in cod liver are probably related to these activities, as well as reduced water exchange with the Outer fjord.

Altogether the results show that the concentrations of PCBs have decreased in both cod and blue mussel. In Norway PCBs has been prohibited since 1980, but leakage from old products may still be a source of contamination. Production and new use of PCBs is also prohibited internationally through the ECE-POPs protocol and the Stockholm Convention.

3.2.13 Dichlorodiphenyldichloroethylene (ppDDE)

Cod liver
There were no significant trends for ppDDE in cod liver in the Inner Sørfjord (st. 53B) which wsa the only station investigated for this parameter.

Blue mussel
No significant trends for ppDDE in mussels were observed. Blue mussel at Byrkjenes (st. 51A) in the Inner Sørfjord was insignificantly polluted (Class I) by ppDDE in 2011 but had increased to moderately polluted (Class II) in 2012. Blue mussel at Kvalnes (st. 56A) in the Mid Sørfjord was markedly polluted (6.9 µg/kg, Class III) by ppDDE in 2011 and had increased to extremely polluted (41.79 µg/kg, Class V, ***Figure 12***) in 2012. Blue mussel at the new station Utne (st. 64A) was markedly polluted.

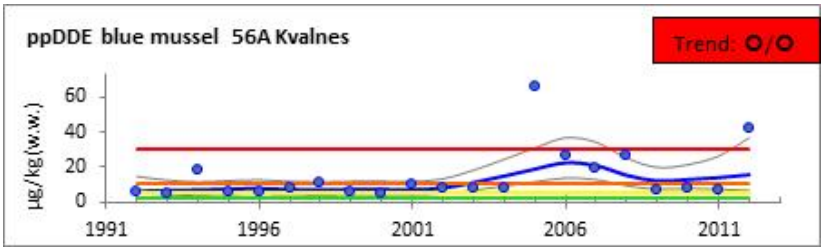


Figure 12. *Median concentrations (mg/kg w.w.) of ppDDE in blue mussel from 1981 to 2012 in the Grenlandsfjord area (Bjørkøya, st. 71A).*

Concluding remarks on ppDDE
Ruus *et al.* (2013b) found that concentrations of ∑DDT in blue mussel were classified as extremely polluted at the two stations Kvalnes in the Mid Sørfjord and Utne in the Outer Sørfjord in 2012. At the other stations, concentrations in mussel could be classified as moderately to markedly polluted. This study also showed that the average ΣDDT-concentration in cod liver from the Sørfjord was moderately polluted in 2012.

The Sørfjord area has a considerable number of fruit 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 have been prohibited in Norway since 1970. Green *et al.* (2004a) concluded that the source of ppDDE was uncertain. Analyses of supplementary stations between Kvalnes and Krossanes in 1999 indicated that there could be several sources (Green *et al.*

2001). A more intensive investigation in 2002 with seven sampling stations confirmed that there were two main areas with high concentrations north of Kvalnes and near Urdheim south of Krossanes (Green *et al.* 2004a). 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) set out 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, 2010a, 2011, 2012a). There was high variability in the concentrations of ΣDDT in replicate samples from Utne, indicating that the station is affected by DDT-compounds in varying degree, dependent on local conditions. The highest concentrations of ppDDE in sediment were observed in Mid Sørfjord (Green *et al.* 2010b).

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

3.2.14 Polycyclic aromatic hydrocarbons (PAHs)

Blue mussel

The presence of PAHs in blue mussel exceeded Class I (insignificantly polluted) at three of the 10 blue mussel stations. No significant trends were observed. Blue mussel at Akershuskaia (st. I301) was moderately polluted (Class II) in 2011 and was markedly polluted (Class III) in 2012. Mussel at Moholmen (st. I965) was markedly polluted in 2011, and moderately polluted in 2012.

The EQS (2013/39/EC) for fluoranthene (30 µg/kg w.w.) was exceeded at Akershuskaia (st. I301) (73 µg/kg w.w.) a three-fold increase from 2011, and Bjørnbærviken (st. I969) (34 µg/kg w.w.), a 55% increase from 2011. The median concentration in blue mussel at Moholmen (st. I965) decreased to below this limit; from 55 µg/kg w.w. in 2011 to 29 µg/kg w.w. 2012.

Gitmark *et al.* (2013) found that mussel was up to moderately polluted by PAHs at one station at Langøya in the Holmestrandfjord in 2012. Schøyen *et al.* (2013) reported that blue mussel at four stations in Kristiansandsfjorden were moderately polluted in 2012. Remedial action has been implemented to reduce the impact of PAHs in this area. Four blue mussel stations in the Ranfjord were moderately polluted and one station (Toraneskaia) was markedly polluted with PAHs (Øxnevad & Bakke 2013). The Ranfjord has received discharges of PAHs from local industry for a number of years, but an overview for 2011 and 2012 was not found (www.norskeutslipp.no). This overview did indicate about a 50% reduction after 2001, however no trends were detected for PAHs in blue mussels for the period 1995 (Bjørnbærviken) or 2001 (Moholmen) to 2012.

3.2.15 Sum carcinogenic polycyclic aromatic hydrocarbons (KPAHs)

Blue mussel

The concentration of the potentially most carcinogenic PAHs (KPAHs, cf. Appendix B) in blue mussel exceeded Class I (insignificantly polluted) at three of 10 stations, but no significant trends were observed. Blue mussel from Bjørnbærviken (st. I969) in the Ranfjord was insignificantly polluted (Class I) in 2011 and was moderately polluted (Class II) in 2012.

Gitmark *et al.* (2013) found that mussel was up to markedly polluted by KPAH at Langøya in the Holmestrandfjord in 2012. Schøyen *et al.* (2013) reported that blue mussel at Odderøy and Svensholmen in the Kristiansandsfjord were markedly polluted by KPAH in 2012.

3.2.16 Benzo[a]pyrene B[a]P

Blue mussel

The presence of B[a]P in blue mussel exceeded Class I (insignificantly polluted) at three of the 10 blue mussel stations. No significant trends were found.

The highest concentration (6.1 µg/kg w.w.) was found at Moholmen (st. I965) in the Ranfjord where the mussel was markedly polluted by B[a]P. The second (3 µg/kg w.w.) and third highest (2.8 µg/kg w.w.) concentrations were found at Akershuskaia (st. I301) in the Inner Oslofjord and Bjørnbærviken (st. I969) in Ranfjorden where the mussel was moderately polluted.

The EQS (2013/39/EC) for B[a]P is 5 ng/g=µg/kg and was only exceeded at Moholmen (st. I965) (6.1 µg/kg) which indicates acceptable conditions to the this criteria.

Gitmark *et al.* (2013) found that mussel was up to moderately polluted by B[a]P at Langøya in the Holmestrandfjord in 2012. Schøyen *et al.* (2013) reported that blue mussel at the former CEMP-stations Odderøy and Svensholmen were markedly polluted by B[a]P in the Kristiansandsfjord in 2012.

High concentrations in the Oslofjord and Ranfjord are most likely related to harbour and industrial activities.

3.2.17 Polybrominated diphenyl ethers (PBDEs)

Cod liver

Polybrominated diphenyl ethers (PBDEs) have been investigated annually in cod liver since 2005. In the Inner Oslofjord cod have also been analysed for PBDE in samples collected in 1993, 1996 and 2001. Samples for similar analyses were also collected from the Færder area in 1993 and 1996, and samples from Karihavet on the West Coast in 1996 and 2001. In 2012, PBDEs were analysed in cod from nine stations (see **Table 11**). Of the PBDEs only congeners BDE47, BDE100, BDE154, BDE183 and BDE196 were over the detection limit in at least half the samples from each station. Tetrabromodiphenyl ether (BDE47) was the dominant congener and was highest in the Inner Oslofjord (40 µg/kg w.w.). The lowest concentration was found in Lofoten at Bjørnerøya (1.5 µg/kg w.w.) in the Lofoten area. BDE47 in cod liver from the Trondheim harbour was 38 µg/kg w.w. The only significant recent trend for these five PBDEs was downward for pentabromodiphenyl ether (BDE100) in the Inner Oslofjord. BDE100 was the second most dominant PBDE (**Table 11**).

Table 12 *Median concentrations (µg/kg w.w.) standard deviations of PBDE congeners in cod liver, 2012. The shaded values indicate cases where more than half of the samples were below the detection limit.*

Component name	**BDE47**		**BD100**		**BDE126**		**BDE153**		**BDE154**		**BDE183**		**BDE196**		**BDE209**	
	µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.	
	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.
Inner Oslofjord (st. 30B)	40.00	68.70	12.00	17.77	0.10	0.08	0.10	0.04	2.90	1.90	0.53	0.50	1.24	2.21	0.50	0.00
Færder (st. 36B)	4.70	2.91	1.35	0.74	0.10	0.00	0.10	0.02	0.76	0.52	0.30	0.20	1.53	2.08	0.50	0.00
Kristiansand harbour (st. 13BH)	11.00	11.19	2.70	1.99	0.10	0.00	0.10	0.07	0.27	1.31	0.30	0.10	1.29	0.65	0.50	0.00
Inner Sørfjord (st. 53B)	13.00	8.10	1.90	1.94	0.10	0.01	0.10	0.20	0.61	1.31	0.34	0.39	0.97	2.37	0.50	0.00
Karihavet area (st. 23B)	4.20	3.65	1.06	0.93	0.10	0.00	0.10	0.01	0.55	0.54	0.30	0.54	0.30	2.18	0.50	0.00
Ålesund (st. 28B)	9.40	4.34	2.30	0.80	0.10	0.00	0.10	0.58	1.50	0.75	0.30	0.01	0.44	1.83	0.50	0.00
Trondheim harbour (st. 80BH)	37.95	28.63	6.52	5.65	0.10	0.00	0.10	0.58	1.07	0.75	0.48	0.23	2.84	1.64	0.50	0.00
Bjørnerøya (st. 98B1)	1.50	0.78	0.34	0.31	0.10	0.04	0.10	0.30	0.21	0.14	0.30	0.21	0.30	1.50	0.50	0.00
Tromsø harbour (st. 43BH)	9.60	4.60	3.20	0.79	0.10	0.00	0.10	0.04	0.69	0.21	0.30	0.01	0.32	0.73	0.50	0.00

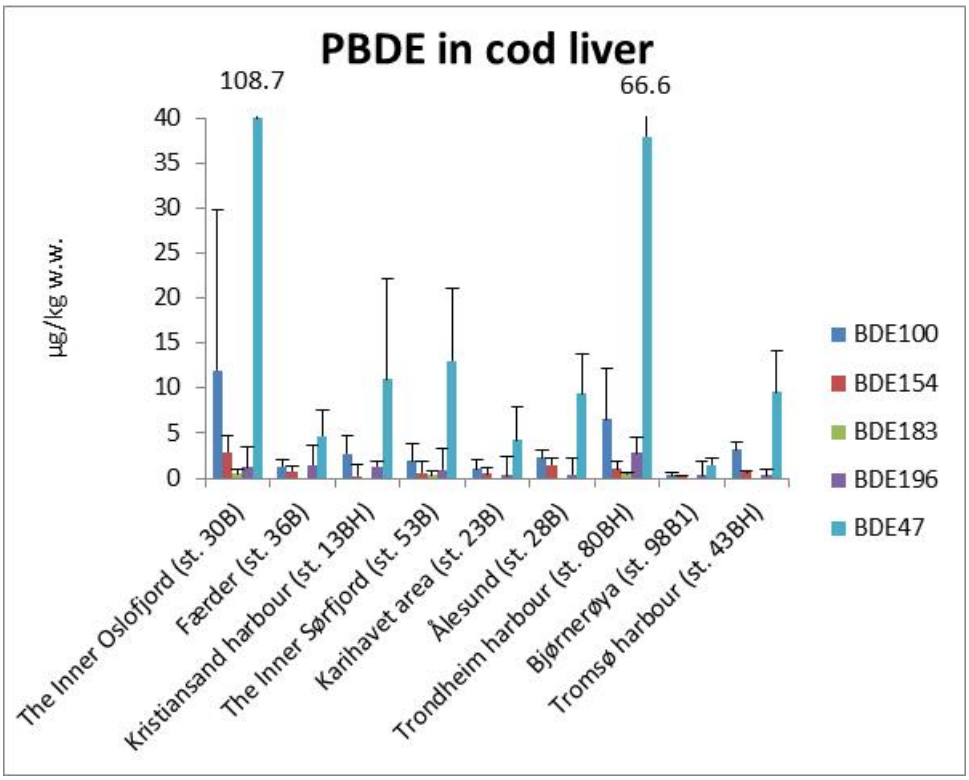


***Figure 13**. Median concentrations (µg/kg w.w.) of PBDEs in cod liver in 2012. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the median.*

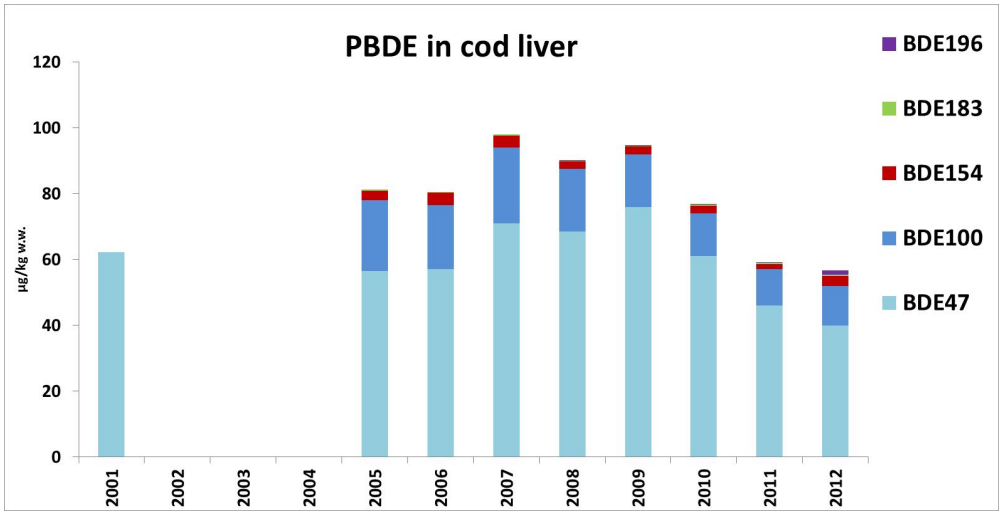


***Figure 14.** Median concentrations (µg/kg w.w.) of PBDEs in cod liver from 2001 to 2012 in the Inner Oslofjord (st. 30B).).*

Blue mussel

PBDEs were investigated in blue mussel for the first time in 2012. Only congeners BDE47, BDE100 and BDE209 had concentrations above the detection limit for half or more of the samples at a station (**Table 13**, ***Figure 15***, **Table 11**). The most dominant congener was BDE209 when it was detected. This was the case for mussels from the Inner Oslofjord and Bodø harbour. However it should be noted that the detection limit for this congener is about ten times higher than for the other two congeners. BDE47 was found at all eight stations and BDE100 was detected at all but two. For both of these congeners the highest median concentration was found in mussels from Bodø harbour. No significant trends were found.

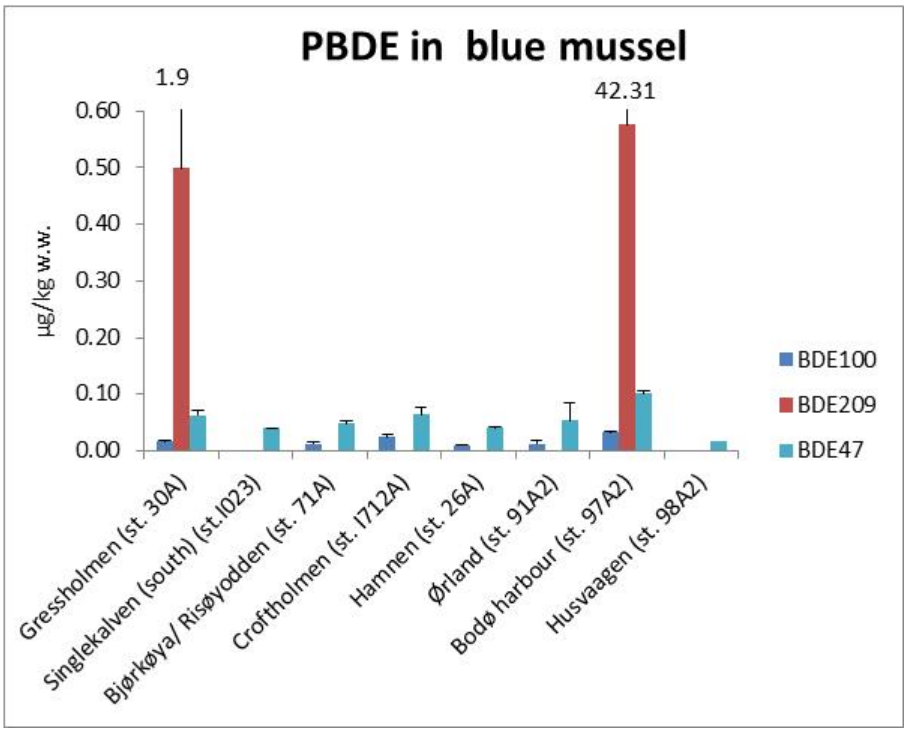


***Figure 15**. Median concentrations (µg/kg w.w.) of PBDEs in blue mussel in 2012. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the median.*

Concluding remarks on PBDEs

The EQS (2013/39/EC) for brominateddiphenylethers is the sum of the concentrations of congener numbers 28, 47, 99, 100, 153 and 154. The concentration of just PBDE47 in cod liver exceeded this threshold by at least a factor of 100 in median concentrations in cod liver at any station and by at least a factor of two for blue mussel at any station. These results indicate that the EQS might be too high to be a useful criteria to judge the condition of biota with respect to this contaminant.

Parts of the Inner Oslofjord are densely populated with much urban activities including use of PBDE in certain products. The high concentrations of PBDE observed in cod are probably related to these activities, as well as reduced water exchange with the Outer fjord.

PBDE in cod liver from Grenlandsfjord decreased during the period 2008-2012 (Ruus *et al*. 2013a), but MILKYS sampling only began in 2012 and cannot confirm this trend.

Median concentrations for the sum of PBDE found at presumed reference stations like Svolvær, Færder, Utsira and Bømlo-Sotra indicate that a high background level in diffusely contaminated areas might be around 30 µg/kg w.w. for cod liver (Fjeld *et al*. 2005). This is higher than the sum of the medians BDE47, -100, -154, -183, and -196n found at MILKYS cod stations in Færder, Kristiansand, Karihavet, Inner Sørfjord, Ålesund, Bjørnerøya in Lofoten and Tromsø (cf. ***Figure 13***) and higher than the average concentrations found at two cod stations in the North Sea (14.6 and 15.4 µg/kg w.w.) (Green *et al*. 2011) and three cod stations in the Norwegian Sea (5.89, 12.9 and 19 µg/kg w.w.) (Green *et al*. 2012). It cannot be disregarded that this high

background concentration might be too high. The median found in the Inner Oslofjord for just BDE47 was 40 µg/kg w.w., which was within the interval for sum PBDE of 37-112 µg/kg w.w. found in other contaminated areas (Fjeld *et al*. 2005, Berge *et al*. 2006). Bakke *et al*. (2007b) found a range of mean concentrations of sum of PBDE in remote areas to be 3.4-29.0 µg/kg w.w.

The congeners BDE47 and BDE 100 were observed to be most dominant if the two results for BDE209 in blue mussel are disregarded. The low concentrations of BDE99 are probably due to the debromination to BDE47. 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).

Table 13 Median concentrations (µg/kg w.w.) *standard deviations* of PBDE congeners in blue mussel, 2012. *The shaded values indicate cases where more than half of the samples were below the detection limit.*

Component name	BDE47		BD100		BDE126		BDE153		BD154		BDE183		BDE196		BDE209	
	µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.	
	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.
Gressholmen (st. 30A)	0.063	0.01	0,016	0,002	0,010	0,000	0.014	0.000	0.014	0.000	0.024	0.001	0.048	0.001	0.499	1.400
Singlekalven (south) (st.I023)	0.040	0.00	0,012	0,001	0,011	0,000	0.017	0.000	0.017	0.000	0.028	0.001	0.055	0.001	0.554	0.013
Bjørkøya/ Risøyodden (st. 71A)	0.049	0.00	0,013	0,002	0,010	0,000	0.015	0.000	0.015	0.000	0.024	0.001	0.048	0.001	0.482	0.010
Croftholmen (st. I712A)	0.064	0.01	0,024	0,005	0,010	0,001	0.014	0.001	0.014	0.001	0.024	0.002	0.048	0.004	0.478	0.035
Hamnen (st. 26A)	0.041	0.00	0,010	0,000	0,009	0,001	0.013	0.001	0.013	0.001	0.022	0.002	0.044	0.004	0.437	0.037
Ørland (st. 91A2)	0.054	0.03	0,013	0,006	0,009	0,006	0.013	0.008	0.013	0.008	0.022	0.014	0.044	0.028	0.440	0.276
Bodø harbour (st. 97A2)	0.101	0.00	0,032	0,003	0,009	0,000	0.013	0.000	0.013	0.000	0.022	0.009	0.045	0.018	0.576	41.736
Husvaagen (st. 98A2)	0.018		0,009		0,009		0.014		0.014		0.024		0.047		0.471	

3.2.18 Perfluoralkyl compounds (PFAS)

Cod liver

Perfluroalkyl compounds (PFAS) have in this monitoring programme been analysed in cod liver annually since 2005. Samples from 1993 have also been analysed for PFAS from the Inner Oslofjord and Karihavet. In 2012, these compounds were analysed in cod liver from eight stations (**Table 11** and ***Figure 16***).

The median concentration of perfluoroctonoic sulphonate (PFOS) was highest at Færder in the Outer Oslofjord (6.7 µg/kg w.w.) and lowest in the Tromsø harbour (0.5 µg/kg w.w.) **Table 11**. There were no significant upward trends for PFOS found at any of the eight stations.

Perfluorooctane sulphonamide (PFOSA) had a maximum median concentration of 10 µg/kg w.w. in the Inner Oslofjord and a minimum at Trondheim, Bjørnerøya and Tromsø (1 µg/kg w.w.). No significant upward trends were found.

The concentration of PFOSA was higher than PFOS in the Inner Oslofjord and Færder (***Figure 17)***. The median concentrations of the remaining PFAS were below the detection limit with the exception of perfluorononanoic acid (PFNA) and perfluorooctanoic acid (PFOA) in the inner Oslofjord (**Table 14, Table 11**). There will be a national ban on PFOA by 1 June 2014[4]. Of the four time series with sufficient data for a time trend analysis, one station (Karihavet) had a significant trend, downward

Concluding remarks on PFAS

The EQS (2013/39/EC) for PFOS was not exceeded at any station. The only significant trends for PFOS or PFOSA were significant downward long-term and short-term trends for PFOS in Tromsø harbour. There is insufficient historical data on PFAS loads to relate to help explain the trends found.

Parts of the Inner Oslofjord are densely populated with much urban activities including use of PFOSA in certain products. The high concentrations of PFOSA observed in cod are probably related to these activities, as well as reduced water exchange with the Outer fjord.

The level of PFAS in cod liver remained stable in the Grenlandsfjord during the period 2009-2012 (Ruus *et al.* 2013a).

Median concentrations of PFOS in cod from presumed reference stations like Svolvær, 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.* 2007b). All concentrations observed in in the current study were lower. The highest concentrations were found at Færder (6.7 µg/kg w.w.) and in the Inner Oslofjord (st. 30B).

PFOS was the dominant PFAS in cod liver in the Inner Oslofjord in 2009 (median 48 µg/kg w.w.) compared with PFOSA (41.5 µg/kg w.w.). In 2010 and 2011, PFOSA dominated (18 and 19 µg/kg w.w., respectively) more than PFOS (16 and 5 µg/kg w.w., respectively). The average concentration of PFOS in cod from two stations in the North Sea was 1.55 and 0.95 µg/kg w.w. (Green *et al.* 2011b) and from three stations in the Norwegian Sea was 0.75, 0.82 and 11 µg/kg w.w. (Green *et al.* 2012). Schøyen and Kringstad (2011) analysed PFAS in cod blood samples from the same individuals which were analysed in the CEMP-programme in 2009 from the Inner Oslofjord (Green *et al.* 2010b). They found that PFOSA was the most dominant PFAS-compound with a median level 6 times higher than for PFOS. The median level of PFOSA in cod blood was about 5 times higher than in liver. 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.

Fjeld *et al.* (2011) found only PFOS and PFOSA in quantifiable amounts in the three fish species brown trout (*Salmo trutta)*, smelt (*Osmerus eperlanus*) and vendace (*Coregonus albula*) in lake Mjøsa for the period 2008-2010. In 2011 Fjeld *et al.* (2012) also detected PFOA, PFDcA and PFUnA in addition to PFOS and PFOSA. PFOS was found to be the dominant compound in all three species.

[4] http://www.regjeringen.no/nb/dokumentarkiv/stoltenberg-ii/md/Nyheter-og-pressemeldinger/nyheter/2013/norge-gar-foran-med-forbud-mot-miljogift.html?id=735702

Table 14 Median concentrations (µg/kg w.w.) *standard deviations* of the PFAS-compounds PFOS, PFOSA, PFNA and PFOA analysed in cod liver in 2012. *The shaded values indicate cases where more than half of the samples were below the detection limit.*

Component name	PFBS		PFDCA		PFDCS		PFHpA		PFHxA		PFHXS		PFNA		PFOA		PFOS		PFOSA		PFUDA	
	µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.	
	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.
Inner Oslofjord (st. 30B)	0.30	0.00	1.00	0.45	1.00	0.38	0.30	0.00	0,30	0,00	0.00	0.00	0.40	0.08	1.00	0.00	6.50	3.91	10.00	8.64	0.00	1.16
Færder (st. 36B)	0.20	0.00	0.45	0.09	0.30	0.00	0.30	0.00	0,20	0,00	0.00	0.00	0.32	0.12	0.80	0.00	6.70	3.07	6.90	2.33	0.00	0.00
Kristiansand harbour (st. 13BH)	0.20	0.00	0.50	0.00	1.00	0.00	0.30	0.00	0,20	0,00	0.00	0.00	0.50	0.03	0.50	0.00	3.00	0.76	3.59	1.07	0.00	0.17
Inner Sørfjord (st. 53B)	0.20	0.00	0.50	0.24	1.00	0.00	0.30	0.00	0,20	0,00	0.00	0.01	0.50	0.82	0.50	0.21	0.82	1.53	0.92	1.03	0.00	0.24
Karihavet area (st. 23B)	0.20	0.00	0.40	0.05	0.30	0.00	0.30	0.00	0,20	0,00	0.00	0.02	0.30	0.17	0.80	0.00	2.00	1.35	1.30	0.77	0.00	0.00
Trondheim harbour (st. 80BH)	0.30	0.00	0.80	0.00	0.50	0.00	0.40	0.00	0,30	0,03	0.00	0.00	1.00	0.00	1.00	0.00	0.55	0.23	1.00	1.08	0.00	0.31
Skrova harbour (st. 98B)	0.40	0.00	0.80	0.00	1.00	0.00					0.00	0.00	1.00	0.00	1.00	0.00	1.12	0.98	1.00	0.37	0.00	0.00
Tromsø harbour (st. 43BH)	0.40	0.00	0.80	0.00	1.00	0.00	0.50	0.00	0,40	0,00	0.00	0.00	1.00	0.00	1.00	0.00	0.50	0.03	1.00	0.00	0.00	0.00

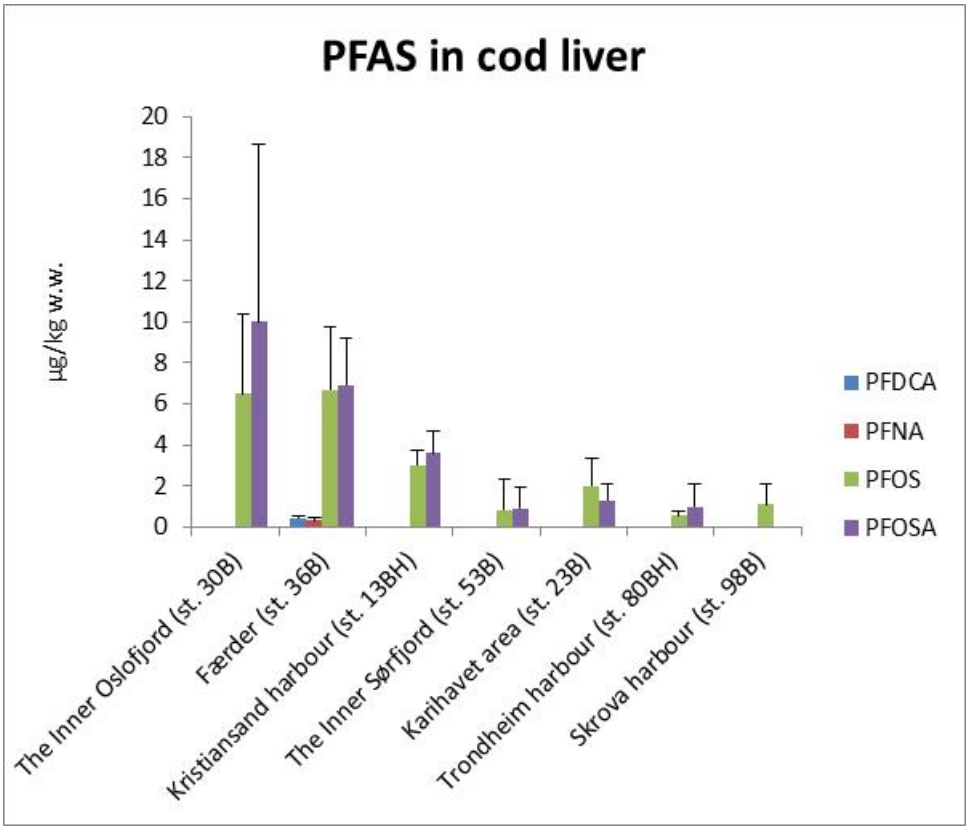


***Figure 16**. Median concentrations (µg/kg w.w.) of PFAS in cod liver in 2012. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the median.*

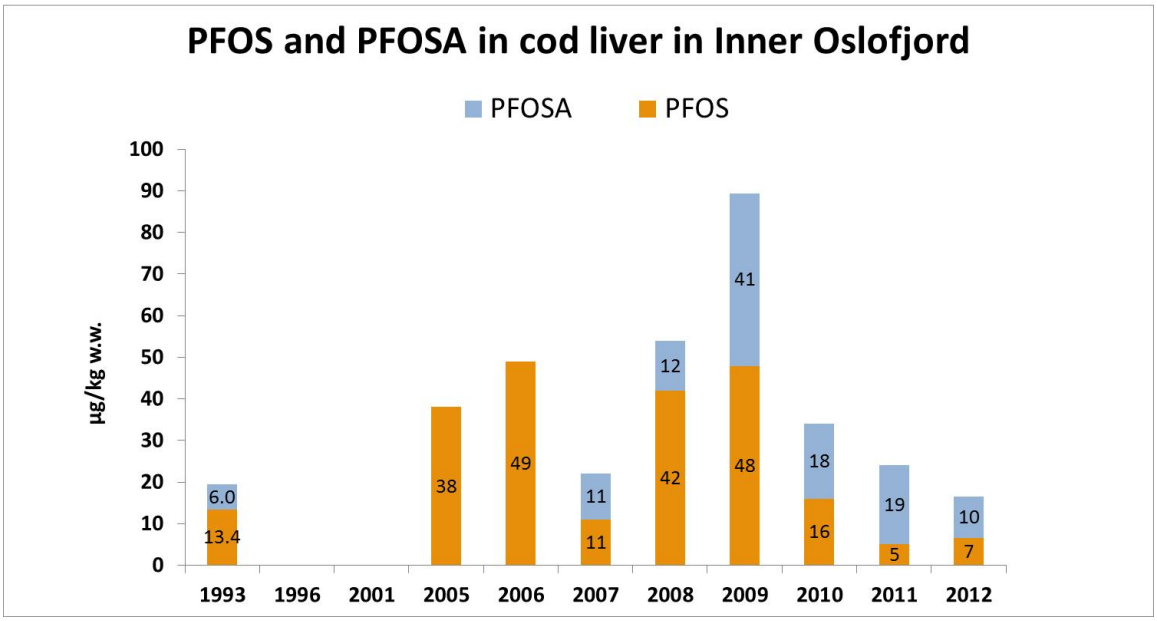


***Figure 17**. Median concentrations (µg/kg w.w.) of PFOS and PFOSA in cod liver from 1993 to 2012 in the Inner Oslofjord (st. 30B).*

3.3 New contaminants

3.3.1 Hexabromcyclododecane (HBCD)

HBCD is a persistent pollutant with a high potential for bioaccumulation. HBCD is one of the substances identified as priority hazardous substances **(**Directive 2013/39/EU) but the EQS was not exceeded by any median. Cod from the Oslo city area had the highest concentration of HBCD in the liver (**Figure 18**). HBCD is here the sum of the α–, β–, and γ–diastereomers. The median concentration of HBCD in cod liver from the Oslo city area was 24.9 µg/kg, but there was considerable variation (**Table 15**). Parts of the Inner Oslofjord are densely populated driving urban activities which could apply HBCD in certain products. The high concentrations of HBCD observed in cod are probably related to these activities, as well as to reduced water exchange with the Outer fjord.

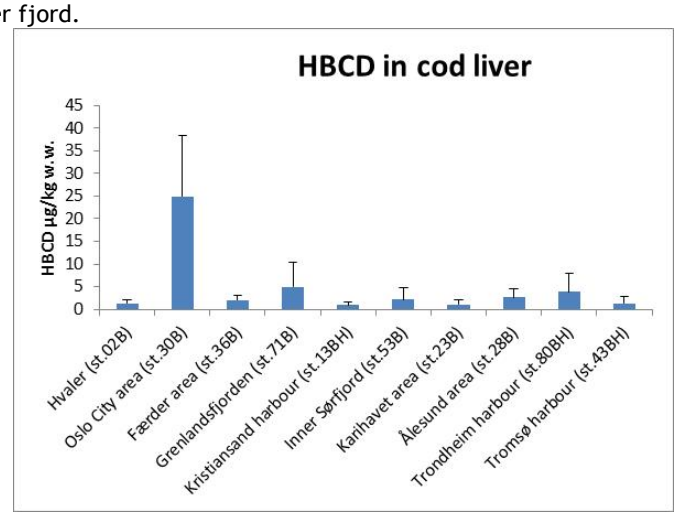


***Figure 18**. Median concentration of HBCD (sum of the α–, β–, and γ–diastereomers)in cod liver in 2012. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the median.*

Table 15. Median concentration with standard deviation of HBCD (sum of the α–, β–, and γ–diastereomers) in cod liver and blue mussel. The shaded values indicate where over half of the cases were below the limit of detection.

Area	Tissue	HBCD µg/kg w.w.	s.d.
Oslo City area (Inner Oslofjord)	Cod liver	24.90	13.47
Færder area	Cod liver	2.09	1.05
Hvaler	Cod liver	1.36	0.68
Grenlandsfjord	Cod liver	5.01	5.24
Kristiansand harbour	Cod liver	0.91	0.67
Karihavet area	Cod liver	0.89	0.96
Inner Sørfjord	Cod liver	1.22	1.84
Ålesund area	Cod liver	1.13	1.87
Trondheim harbour	Cod liver	3.83	3.99
Tromsø harbour	Cod liver	1.32	1.57
Skrova harbour	Cod liver	0.83	0.44
Gressholmen, Inner Oslofjord	Blue mussel	0.023	0.016
Singlekalven, Hvaler	Blue mussel	0.026	0
Croftholmen, Grenlandsfjord	Blue mussel	0.024	0.006
Bjørkøya, Grenlandsfjord	Blue mussel	0.052	0.012
Hamnen, Førdefjord	Blue mussel	0.067	0.021
Ørland, outer Trondheimsfjord	Blue mussel	0.054	0.016
Bodø harbour	Blue mussel	0.020	0
Husvaagen, Svolvær	Blue mussel	0.056	0.016

Considering only α–HBCD, which was the most dominant diastereomers, concentrations in cod liver were significantly higher in the Inner Oslofjord than elsewhere (Tukey-Kramer HSD test) (**Figure 19**). Furthermorewere about-100 times higher than concentrations in blue mussel on a wetweight basis (compare **Figure 19** and **Figure 20**). The difference was smaller on a lipid basis. There are some indications of biomagnification for specific diastereomers of HBCD (Haukås, 2009).

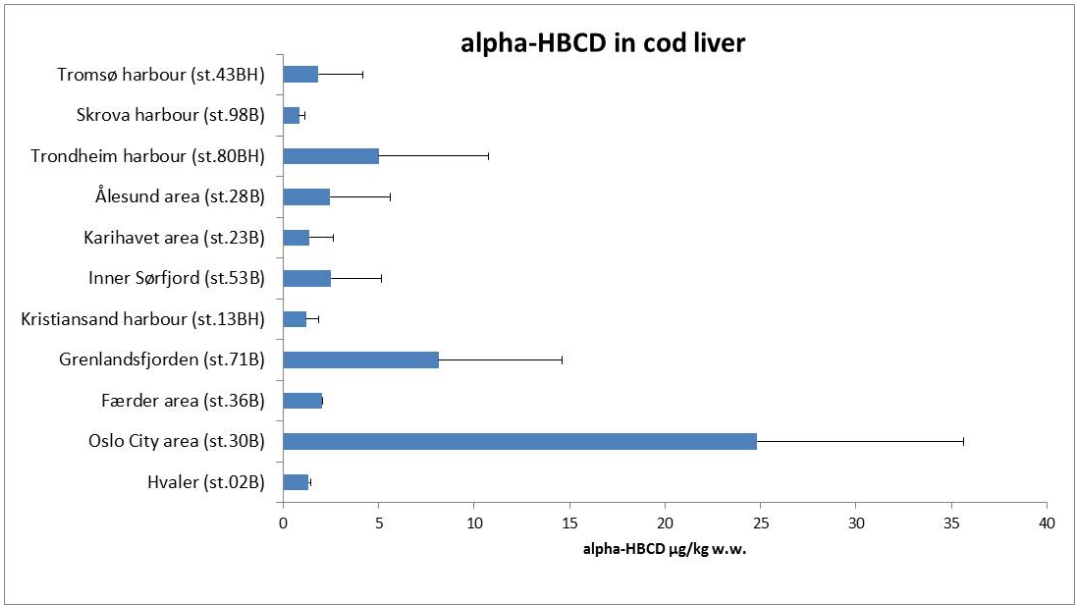


***Figure 19**. Mean concentration of α–HBCD in cod liver in 2012. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the mean.*

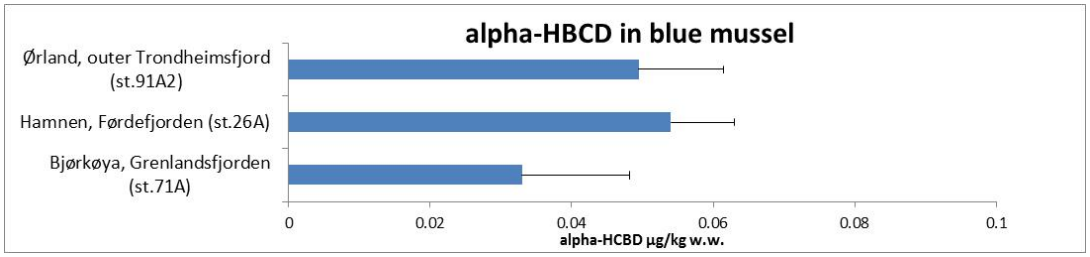


***Figure 20**. Mean concentration of α–HBCD in blue mussel in 2012. Only the results are shown where concentrations were above the detection limit for half or more of the samples. The error bar indicates one standard deviation above the mean.*

3.3.2 Chlorinated paraffins (SCCP and MCCP)

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}). All chlorinated paraffins are listed as "priority substances" for the Water Framework Directive. 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 can not be excluded

The concentration of SCCP in cod liver ranged from 12 to 91 µg/kg w.w., with highest concentration in cod from Ålesund (***Figure 21***, ***Table 16***). Reth *et al.* (2005) found similar levels of SCCP in cod from the North Sea and the Baltic Sea in the range of 19 to 143 ng/g w.w.. The concentrations found in the current investigation seem to be on the same level. Results from urban area are frequently higher than other areas.

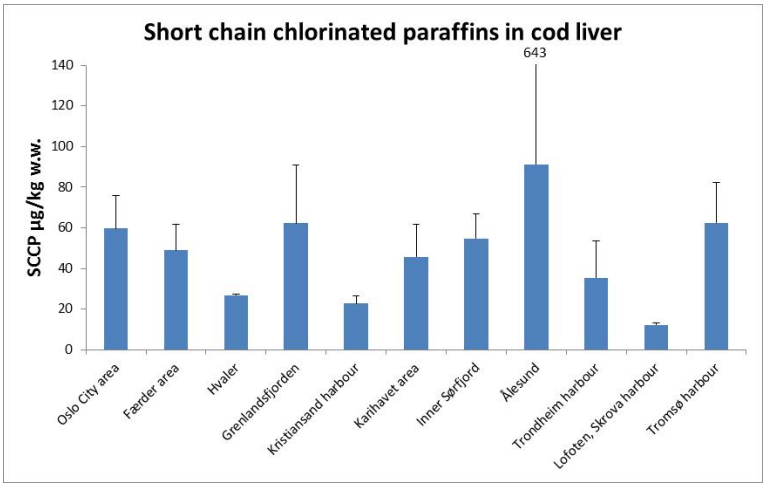


Figure 21. *Median concentration of SCCP in cod liver in 2012. The error bar indicates one standard deviation above the median.*

The concentration of SCCP in blue mussel ranged from 1.49 to 17.0 µg/kg w.w. The highest concentration was found in blue mussel from Hamnen, in the outer part of the Førdefjord (**Figure 22**).

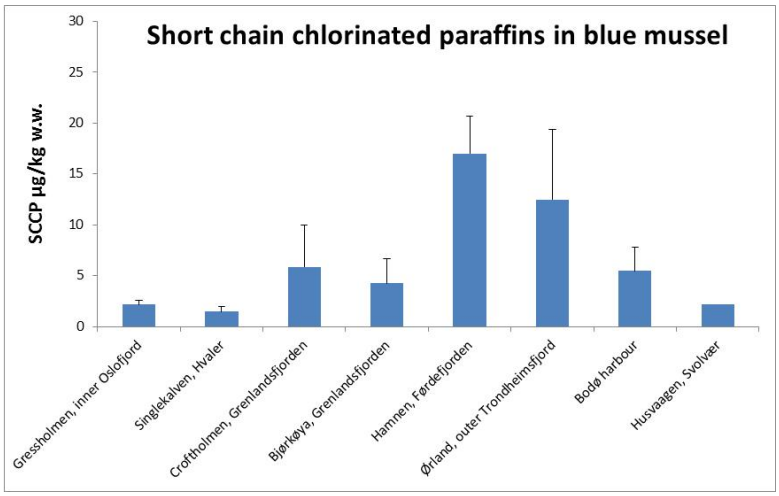


Figure 22. *Median concentration of SCCP in blue mussel in 2012. The error bar indicates one standard deviation above the median.*

***Table 16**. Median concentration with standard deviation of SCCP in cod liver and blue mussel.*

Area	Tissue	SCCP µg/kg w.w.	s.d.
Oslo City area	Cod liver	59.70	16.14
Færder area	Cod liver	48.92	12.80
Hvaler	Cod liver	26.85	0.64
Grenlandsfjord area	Cod liver	62.19	28.70
Kristiansand harbour	Cod liver	22.70	3.90
Karihavet area	Cod liver	45.80	15.93
Inner Sørfjord	Cod liver	54.75	11.95
Ålesund	Cod liver	91.14	551.90
Trondheim harbour	Cod liver	35.50	18.25
Lofoten, Skrova harbour	Cod liver	12.23	0.92
Tromsø harbour	Cod liver	62.45	20.01
Gressholmen, Inner Oslofjord	Blue mussel	2.16	0.45
Singlekalven, Hvaler	Blue mussel	1.49	0.45
Croftholmen, Grenlandsfjord area	Blue mussel	5.87	4.09
Bjørkøya, Grenlandsfjord area	Blue mussel	4.25	2.43
Hamnen, Førdefjord	Blue mussel	17	3.72
Ørland, outer Trondheimsfjord	Blue mussel	12.5	6.91
Bodø harbour	Blue mussel	5.47	2.34
Husvaagen, Svolvær	Blue mussel	2.18	0.00

Cod from the inner Sørfjord had the highest concentration of MCCPs in liver with 931.5 µg/kg wet weight (**Figure 23**, **Table 17**). It was statistically higher than every other station but Trondheim harbour and Færder (ANOVA, means compared in Tukey-Kramer HSD test). The other concentrations ranged from 32.3 to 131.0 µg/kg wet weight. Reth *et al.* (2005) found levels of MCCP in cod from the North Sea and the Baltic Sea in the range of 32 to 106 ng/g wet weight. The levels found in inner Sørfjord seem to be very much higher than found elsewhere (**Figure 23**). MCCPs are used in metal machinery as working fluids, but are also added to plastics, such as PVC, to increase flexibility, and to rubber to reduce flammability. 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 found in imported products. There is, however, considerable uncertainty about the quantities used in products in Norway. The source of the MCCPs in the Sørfjord is unknown, but there are several metal related industries as well as a hydroelectric power plant located in this fairly restricted area with fairly slow water exchange.

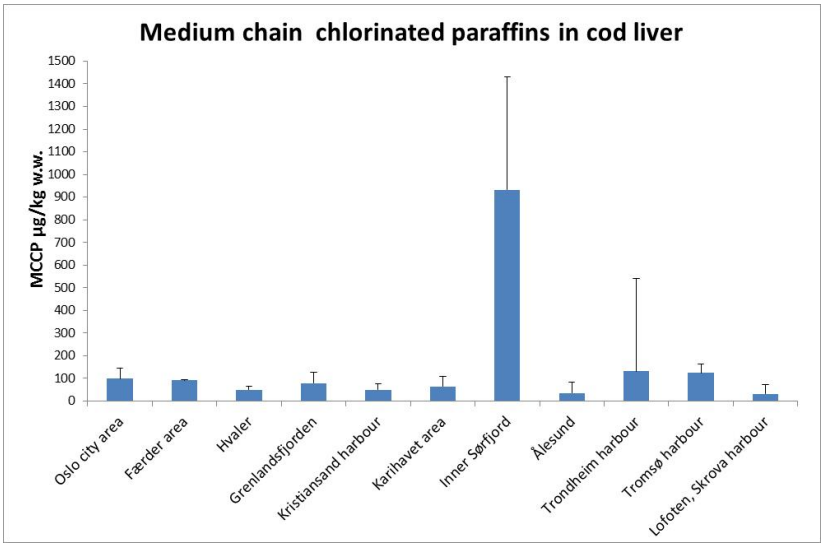


Figure 23. Median concentration of MCCPs in cod liver in 2012. The error bar indicates one standard deviation above the median.

The concentration of MCCPs in blue mussel was lower than in cod, and ranged from 2.4 to 17.9 µg/kg w.w. Blue mussel from Bodø harbour had the highest concentration of MCCPs (**Figure 24**). These results warrant further investigations of possible biomagnifying properties of MCCPs as concluded by Houde *et al.* (2008).

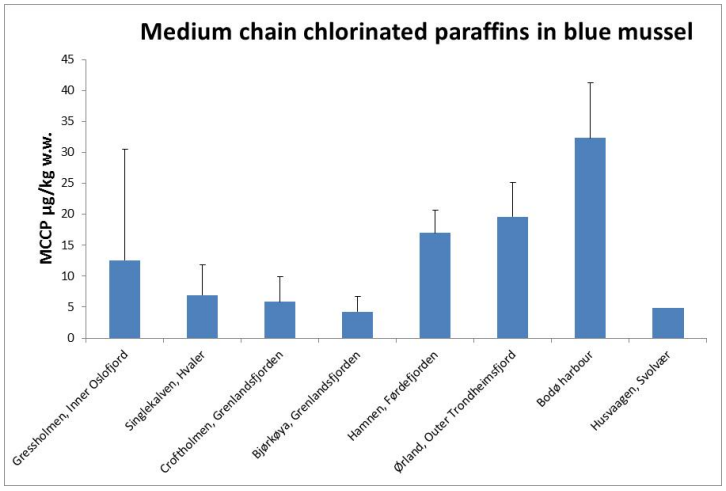


***Figure 24**. Median concentration of MCCPs in blue mussel in 2012. The error bar indicates one standard deviation above the median.*

***Table 17**. Median concentrations with standard deviation of MCCPs in cod and blue mussel in 2012.*

Area	Tissue	MCCP µg/kg w.w.	s.d.
Oslo city area (Inner Oslofjord)	Cod liver	99.50	46.3
Færder area	Cod liver	91.43	3.0
Hvaler	Cod liver	50.23	13.6
Grenlandsfjord area	Cod liver	79.45	47.4
Kristiansand harbour	Cod liver	49.40	25.3
Karihavet area	Cod liver	65.00	43.0
Inner Sørfjord	Cod liver	931.47	498.1
Ålesund	Cod liver	35.87	46.0
Trondheim harbour	Cod liver	131.00	411.0
Tromsø harbour	Cod liver	124.33	39.2
Skrova harbour	Cod liver	32.38	40.9
Gressholmen, Inner Oslofjord	Blue mussel	12.60	17.9
Singlekalven, Hvaler	Blue mussel	6.95	4.9
Croftholmen, Grenlandsfjord area	Blue mussel	5.87	4.1
Bjørkøya, Grenlandsfjord area	Blue mussel	4.25	2.4
Hamnen, Førdefjord	Blue mussel	17.00	3.7
Ørland, Outer Trondheimsfjord	Blue mussel	19.60	5.5
Bodø harbour	Blue mussel	32.30	8.9
Husvaagen, Svolvær	Blue mussel	4.86	0.0

3.3.3 Organophosphorus flame retardants (PFRs)

Many of the PFRs are persistent and bioaccumulative. 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), tricresyl phosphate (TCrP) and triphenylphosphate (TPhP). TCEP is classified as harmful to reproduction. Some of the PFRs are suspected to be carcinogenic (TBP, TCEP and TDCP). TCEP is listed as "priority substance" for the Water Framework Directive. 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). However there is no registered used of these substances and there is considerable uncertainty as to the quantities used in products in Norway.

For the 2012-investigation only 2-ethylhexyl-di-phenylphosphate (EHDPP) was detected in one cod in a sample of ten from Tromsø harbour (8.91 µg/kg w.w.) (Table 18). Tri(1-chloro-2-propyl)phosphate (TCPP) was detected at only four blue mussel stations. In three of these TCPP was detected in all three replicates (mean+/-one standard deviation): 0.98+/-0.29µg/kg w.w. at Bjørkøy (st.71A, Grenlandsfjord area), 0.88+/-0.31µg/kg w.w. at Croftholmen (st.I712, Grenlandsfjordene) and 1.02+/-0.12µg/kg w.w. at Hammen (st.26A, West coast). These values were close to the limit of detection which varied generally from 0.7 to 1.4 µg/kg w.w., the exception was 4.3 µg/kg w.w. for three replicates at one station.

Table 18.Median concentrations with standard deviation of PFRs in cod liver in 2012. The shaded areas indicate values below the detection limit. Only one individual for EHDPP was about this limit (see text).

Parameter code	Component name	Oslo city area		Færder area		Hvaler		Grenlands Fjorden		Kristiansand harbour		Karihavet		Inner Sørfjorden		Trondheim harbour		Lofoten. Skrova		Tromsø harbour	
		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.		µg/kg w.w.	
		median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.	median	S.d.
EHDPP	2-ethylhexyl diphenyl phosphate	11.7	6.88	10.6	13.34	7.4	0.18	13.0	13.93	36.7	14.37	10.6	13.03	67.5		14.4	8.63	13.7	0.50	11.5	9.58
TBEP	tris(2-butoxyethyl) phosphate	54.4	12.16	47.8	8.70	50.2	4.67	51.6	26.63	63.7	21.73	83	40.85	49.7		113.1	56.35	45.1	2.40	60.3	27.63
TBP	tributyl phosphate	12	2.69	10.6	1.92	12.4	6.72	11.5	4.49	8.2	0.87	10.1	1.30	11		14.2	26.26	9.4	0.29	12.6	9.01
TCEP	tris(chloroethyl) phosphate	429	95.89	376.4	68.59	258.2	58.69	407.0	174.22	315	53.78	361	46.85	392		507.6	221.03	334.9	9.90	387.4	178.74
TCPP	tris(1-chloropropan-2-yl) phosphate	10.4	2.32	9.1	1.68	7.6	0.38	10.2	5.47	7.6	1.30	8.9	2.44	9.5		13.3	5.27	8.3	0.04	9.7	4.42
TCRP	tricresyl phosphate	887	606.97	685.0	9.90	358.7	207.18	822.6	778.22	1920	913.79	295	270.70	3160		432.0	398.56	913.8	818.12	708.4	1023.31
TDCP	tris(1.3-dichloropropan-2-yl) phosphate	26.5	5.95	23.3	4.17	21.6	4.46	25.2	10.94	19.5	3.31	22.3	2.89	24.2		39.8	25.04	20.6	0.64	24.8	12.22
TEHP	tris(2-ethylhexyl)phosphate	147	70.84	363.5	130.11	123.7	20.51	109.2	216.19	571	36.30	216	161.87	380		148.0	158.21	300.4	61.52	115.5	412.85
TIBP	tris(2-methylpropyl) phosphate	47.1	10.54	41.4	7.50	46.0	21.43	44.7	19.18	45	13.40	39.6	5.11	43		55.8	28.51	36.8	1.13	44.1	19.77
TOCRP	o-Trikresylphosphate	709	158.27	622.9	113.14	786.9	222.74	673.5	280.26	521	88.95	597	77.09	648		864.7	349.84	553.9	16.97	664.4	416.47
TPHP	triphenyl phosphate	29.5	6.59	29.6	11.10	22.5	9.76	29.2	16.81	28	7.62	24.8	3.21	26.9		44.4	34.67	23.1	0.71	27.6	12.29

3.3.4 Bisphenol A (BPA)

Bisphenol A is derived from epoxy resins and polycarbonate plastics (Belfroid *et al.*2002). It has a very high volume world production 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.

Occassional high concentrations of bisphenol A were found in cod from impacted areas of Grenlandsfjord and the Oslo city area (**Figure 25**). Occassional high values were also found at Færder area and Karihavet area which are presumably remote from point sources of BPA. However, the variability was high in these areas and median concentrations showed only small differences. Hence, no conclusion can be drawn regarding possible differences between stations. The reason for this high variability is unknown but suggests the need for further investigations of BPA along the Norwegian coast.

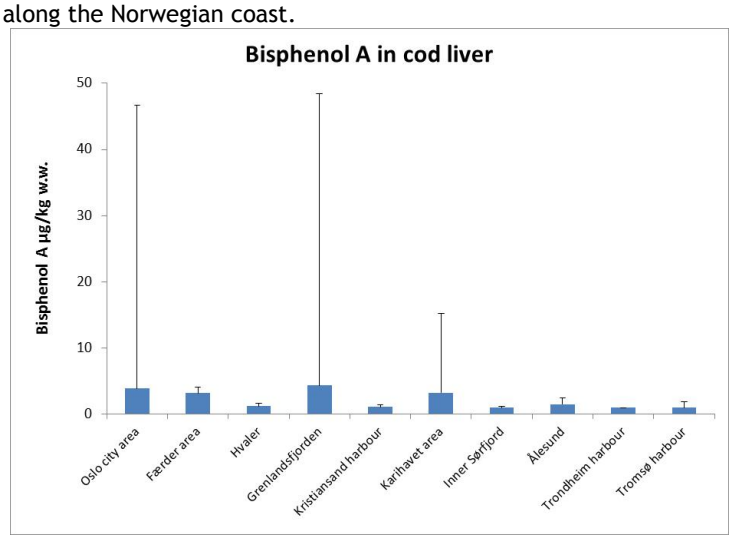


***Figure 25**. Median concentration of bisphenol A in cod liver in 2012. More than half of the observations were below the limit of detection at Inner Sørfjord, Trondheim harbour and Tromsø harbour. The error bar indicates one standard deviation above the median.*

Blue mussel from Ørland and Husvaagen in Svolvær had high concentrations of BPA, higher than what was found in cod liver (**Figure 26**). We have no knowledge of active sources in either of these areas.

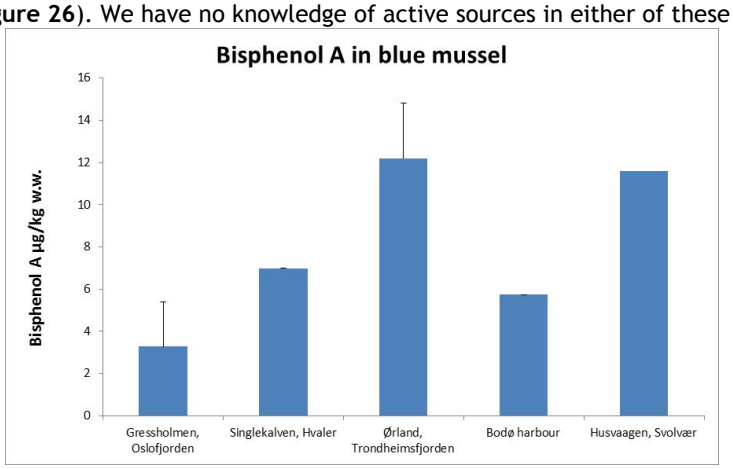


***Figure 26**. Median concentration of bisphenol A in blue mussel in 2012. The error bar indicates one standard deviation above the median.*

3.3.5 Tetrabrombisphenol A (TBBPA)

Tetrabrombisphenol A is a brominated flame retardant. TBBPA is an endocrine disruptor and immunotoxicant.

Concentrations of TBBPA found in cod liver were below the limit of detection for all samples except one. The exception being one (of five) fish from the Inner Oslofjord that had a concentration of 0.771 µg/kg w.w. The detection limit in cod liver and blue mussel ranged from 0.0464 to0.315 µg/kg w.w.

.

3.4 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 (in the regard bile metabolites are included). 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. ICES 2011).

3.4.1 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. Detection methods for OH-pyrene have been improved two times since the initiation of these analyses in the CEMP programme. In 1998, the wavelength for measurement of light absorbance of the support/normalisation parameter biliverdine was changed to 380 nm. In 2000, the use of single-wavelength fluorescence for quantification of OH-pyrene was replaced with HPLC separation proceeding fluorescence detection. 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 is 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 2012 the median concentration of OH-pyrene metabolites in bile from cod in the Inner Oslofjord (st. 30B) were about 25 % lower than the 2011-concentration. No significant temporal trend could be observed over the last 10 years (Appendix F). Median OH-pyrene bile concentration in 2012 was above the ICES/OSPAR assessment criterion (background assessment criteria, BAC). Note that the unit of the assessment criterion is ng/ml, without normalization to absorbance at 380nm.

PAHs are measured in blue mussel from the Inner Oslofjord (stations 30A, I301, I304). The changes in concentrations in mussels (st. 30A) visually correlated moderately well to the changes in OH-pyrene in cod from the same area (st. 30B), based on visual inspection of the directions of the annual concentration changes. These results indicate general changes in PAH exposure in this fjord area, since cod and blue mussel apparently experience similar alterations in PAH exposure, despite biological differences. Blue mussel is a sessile, filtering organism in surface water, while cod is mobile, living in deeper part of the fjord and exposed to PAHs both through food and through direct partitioning from water (over respiratory surfaces).

3.4.2 ALA-D in blood cells

Inhibited activity of ALA-D indicates the influence of lead contamination. Although ALA-D inhibition is lead-specific, it is not possible to rule out interference by other metals or organic contaminants.

In 2012, ALA-D activities in the blood of cod from the Inner Oslofjord (st. 30B) were about one third the activity measured in 2011. No significant temporal trends could be observed over the last 10 years (Appendix F). However, the median concentration of lead in cod liver decreased from 2011 to 2012.

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), Karihavet in the Bømlo-Sotra area (st. 23B), and Varangerfjord (st. 10B; only data to 2001, not shown) (Appendix F). No reference stations were monitored in 2012. As mentioned (chapter 2.3), the lower activities of ALA-D in cod from the Inner Oslofjord compared to the reference station (basis for comparison prior to 2007 and in 2009-2011) indicate the contamination of lead. The higher concentrations of lead in cod liver are generally observed in the Inner Oslofjord, though with a relatively large individual variation.

3.4.3 EROD-activity and amount of CYP1A protein 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 2012, median EROD-activity in liver of cod from the Inner Oslofjord (30B) was about one third the activity measured in 2011. Since 2000, the median EROD-activity has been higher in the Inner Oslofjord compared to the reference station on the west coast (Karihavet, st. 23B), but this station was not monitored in 2012. No significant temporal trends could be observed for EROD in cod liver, and median EROD-activities were below the ICES/OSPAR assessment criterion (background assessment criteria, BAC) at all stations.

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). It has been shown that generally higher activity occurs at more contaminated stations (Ruus *et al*. 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.

CYP1A protein levels in 2012 in the Inner Oslofjord were lower than the level in 2011, as was observed for the EROD activities. No significant temporal trends in CYP1A protein content could be observed. It was previously shown that CYP1A protein levels (as EROD) were higher in the Inner Oslofjord, compared to the Sørfjord and Karihavet (not monitored in 2012), with the possible explanation that the exposure to PCBs was higher in the Inner Oslofjord than in the Sørfjord and Karihavet (Green *et al*. 2012). It was earlier also observed, however, that EROD activities apparently were not significantly influenced by a substantial increase in cod liver PCB content (Ruus *et al*. 2006). Berge *et al*. (2012) also found higher values in the Inner Oslofjord compared to the Outer Oslofjord. An explanation (besides the adaptation hypothesis) may be that the inducing effect of specific contaminants may be inhibited by other contaminants present (e.g. dioxins or PAHs).

3.5 Monitoring of contaminants with passive samplers

Sampling rates were low, particularly considering the surface area of the samplers (1000 cm^2). The standard errors on the estimation of sampling rates were at most 10 % (***Table 19***). Sampling rates were lowest for samplers deployed in Oslofjord and highest in Ålesund. Sampling rates ranged from 2.0 L d^{-1} for the least hydrophobic substances (e.g. 4-t-octylphenol) to 0.13 L d^{-1} for the most hydrophobic substances (e.g BDE-209). These sampling rates are lower than those obtained with the same type of silicone rubber samplers as part of the Tilførselprogrammet (Allan *et al.*, 2011; Allan *et al.*, 2012).

The extraction and analysis of two QA spiked samplers together with this batch of exposed passive samplers resulted in amount per samplers close to those determined in the initial batch of six QA spiked samplers (Appendix G).

Table 19 *Estimated sampling rates, R_s for AlteSil silicone rubber samplers (1000 cm^2, 30 g) deployed at three sites for > 300 days.*

	Site					
	Hvaler		Oslofjord		Ålesund harbour	
	Replicate 1	Replicate 2	Replicate 1	Replicate 2	Replicate 1	Replicate 2
β_{sil} ($L^{1.08}$ $kg^{0.08}$ d^{-1})*	1.1	1.5	0.77	1.1	3.6	3.4
+/-	0.1	0.1	0.02	0.04	0.2	0.07
R_s (L d^{-1}) at $logK_{sw}$ = 5	0.45	0.58	0.30	0.43	1.41	1.36
+/-	0.04	0.04	0.01	0.01	0.07	0.03

*According to Booij and Smedes (2010) and Rusina et al. (2010): $R_s = \beta_{sil} K_{sw}^{-0.08}$

As shown in ***Table 20***, most compounds were below limits of detection. In the case of 4-t-OP, 4-t-NP, γ-HBCD, and BDE-209, non-negligible amounts of these substances were measured in field control samplers. This affected limits of detection for these compounds. Overall limits of detection depend on the quality of sampler preparation, contamination during sampler extraction and analysis, and instrumental limits of detection.

Significant absorption of para-t-nonylphenol (4-t-NP in the table) could be observed for samplers from Oslofjord and a freely dissolved concentration of 11 ng L^{-1} was estimated. This value is at the WFD EQS level (Appendix G) of 0.01 μg L^{-1} for octylphenol. All other alkyphenols were below limits of detection with these ranging from 2 to 20 ng L^{-1} for para-t-octylphenol and para-t-nonylphenol and 0.03-0.11 ng L^{-1} for para-n-octylphenol and para-n-nonylphenol, respectively. No other alkylphenol measurements have been undertaken using silicone rubber samplers until now. Sack and Lohmann (2011) used LDPE to sample these substances and were able to measure freely dissolved concentrations of t-octylphenol in the low ng L^{-1} range (3-11 ng L^{-1}) in Narragansett Bay, a small and heavily urbanized bay (US) with a surrounding population of two million inhabitants.

The technical mixture of HBCD is mainly composed of the γ-isomer (80-85 %), while α-HBCD and β-HBCD account for 8 and 6 % of the mixture, respectively. Expectedly, β-HBCD was below limits of detection (with these in the range 2-5 pg L^{-1}). Field control sampler contamination with γ-HBCD resulted in increased limits of detection (4-28 pg L^{-1}). Concentrations in exposed samplers were not significantly higher than those in the field control samplers. Freely dissolved concentrations of the α-isomer of HBCD of 12 and 3.9 pg L^{-1} were estimated for the Oslofjord and Ålesund sites, respectively. GC-MS analysis of extracts (sum of all isomers) from silicone samplers exposed at Jan Mayen (Allan *et al.*, 2012) as part of the Tilførselsprogrammet showed that concentrations of HBCD in these samplers were below limits of detection. While passive air sampling of HBCD has been undertaken, passive sampling in water has not been reported (to the author's knowledge).

Most PBDEs were found below limits of detection. The exposure of samplers for almost a year resulted in the accumulation of significant amounts of many different brominated substances rendering the quantification of specific PBDEs challenging. A freely dissolved concentration of 19 pg L^{-1} for BDE-47 was estimated for the Oslofjord (data not corrected for temperature or salinity). This value is higher than those obtained for silicone rubber samplers exposed at Andøya (4.8 pg L^{-1}), Bjørnøya (6-7 pg L^{-1}) or Jan Mayen (0.27 pg L^{-1}) during the Tilførselsprogrammet (Allan *et al.*, 2011; Allan *et al.*, 2012). Freely dissolved concentrations of PBDE congeners measured during the RiverPOP programme (2008-2011) were generally in the low pg L^{-1} range or

below for rivers such as the Drammenselva and Glomma (Allan *et al.*, 2009; Allan *et al.*, 2010; Allan *et al.*, 2011) and generally an order of magnitude below the estimate for the Oslofjord.

Table 20 *Freely dissolved concentrations measured with silicone rubber samplers exposed at three sites for over 300 days.*

Substances		**Freely dissolved contaminant concentrations**		
Sites	**Unit**	**Hvaler**	**Oslofjord**	**Ålesund harbour**
Alkylphenols				
4-t-OP	ng L^{-1}	< 20[a]	< 20[a]	< 20[a]
4-t-NP	ng L^{-1}	< 4[a]	**11 (54)**[b,c]	< 2[a]
4-n-OP	ng L^{-1}	< 0.03	< 0.03	< 0.03
4-n-NP	ng L^{-1}	< 0.05	< 0.07	< 0.11
HBCD				
α-HBCD	pg L^{-1}	< 4	**12 (77)**[b]	**3.9 (32)**[b]
β-HBCD	pg L^{-1}	< 4	< 5	< 2
γ-HBCD	pg L^{-1}	< 4	< 29[a]	< 8[a]
PBDEs				
BDE-47	pg L^{-1}	<14	**19 (6)**[b]	< 13.3
BDE-99	pg L^{-1}	< 8	< 10	< 3
BDE-100	pg L^{-1}	< 8	< 10	< 3
BDE-126	pg L^{-1}	< 22	< 10	< 12
BDE-153	pg L^{-1}	< 9	< 6	< 10
BDE-154	pg L^{-1}	< 17	< 6	< 10
BDE-183	pg L^{-1}	< 3	< 4	< 2
BDE-196	pg L^{-1}	< 3	< 4	< 2
BDE-209	pg L^{-1}	< 47[a]	< 63[a]	< 19[a]

[a]Limit of detection calculated from 3 times the average of amounts found in the field controls (n = 3) and sampler-specific sampling rates.
[b]Relative percent difference of replicate measurements (%) given in brackets
[c]Amounts found in exposed samplers higher than 3 times the amounts found in field controls

3.6 Analysis of stable isotopes

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 (15N). The relative increase of 15N over 14N (δ15N) 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) that give the factor of increase in concentrations of contaminants, and have 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 21**). It is anticipated that statistical temporal analyses may be applied to perform more "refined" assessments, when the "MILKYS" stable isotope database is further expanded. The δ15N 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 δ15N, since this will warrant further scrutiny of the contaminant's potential to biomagnify.

For selected contaminants (BPA, TCEP, MCCP and TBBPA), $\delta^{15}N$ has been plotted against concentration 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 e.g. the concentration of mercury increase with $\delta^{15}N$ among individuals of the same species (more specifically tusk; *Brosme brosme*) in the Sørfjord (Ruus *et al*. 2013). For that reason, also concentrations of mercury, as well as CB153 (another compound with known biomagnifying properties), is plotted against δ15N in cod. The data material for Hg and CB153 is larger (more individuals analysed per station), than for BPA, TCEP, MCCP and TBBPA.

There were no great differences in $\delta^{13}C$ between mussels or fish from the different areas. Furthermore, there were no major differences in $\delta^{15}N$ between cod from different locations, with some exceptions, indicating that the different populations surveyed can be placed on approximately the same trophic level. As mentioned, an increase in $\delta^{15}N$ of 3 to 5 ‰ represent a step of one full trophic level, while the differences observed were generally lower. 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 must be mentioned, however, that differences in e.g. mercury content in tusk from Sørfjord area could be partly attributed to small differences in trophic position/$\delta^{15}N$ (less than one full trophic level) (Ruus *et al*. 2013).

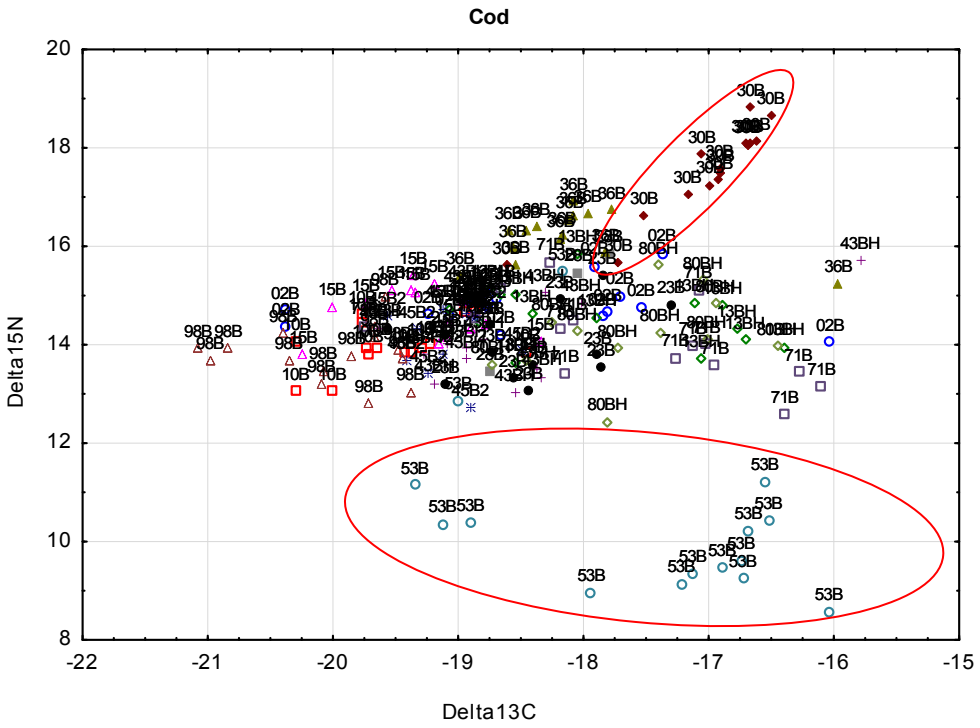
Table 21. Summary of analyses of stable isotopes: $\delta^{13}C$ and $\delta^{15}N$ and C:N ratio, in blue mussel and cod, 2012. Statistics shown are count (n), mean and standard deviation.

	Blue mussel									Atlantic Cod								
	$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$			W% C/N			$\delta^{13}C_{VPDB}$			$\delta^{15}N_{AIR}$			W% C/N		
Station ID	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.	n	mean	st.dev.
presumed more impacted, summary >>	**21**	**-19.76**	**0.79**	**21**	**6.48**	**2.41**	**21**	**4.24**	**0.21**	**121**	**-17.98**	**1.04**	**121**	**14.28**	**2.01**	**121**	**2.96**	**0.08**
02B										15	-18.41	1.14	15	14.78	0.48	15	3.00	0.03
13B										15	-17.85	0.92	15	14.59	0.59	15	2.97	0.02
28B										4	-18.38	0.54	4	14.94	1.05	4	2.80	0.17
30A	3	-18.52	0.09	3	8.43	0.35	3	4.14	0.25									
30B										15	-17.05	0.55	15	17.49	0.95	15	3.00	0.04
43B2										15	-18.61	0.89	15	14.18	0.81	15	2.99	0.02
45B2										15	-19.02	0.28	15	14.26	0.63	15	2.97	0.04
51A	3	-20.08	0.01	3	2.75	0.24	3	4.63	0.04									
53B										15	-17.53	1.11	15	10.43	1.78	15	2.99	0.03
56A	3	-19.67	0.18	3	2.98	0.43	3	4.25	0.15									
71A	3	-19.95	0.14	3	7.11	0.04	3	4.26	0.06									
71B										15	-17.61	1.05	15	14.11	0.83	15	2.96	0.12
80B										12	-17.61	0.69	12	14.20	0.83	12	2.81	0.05
I023	3	-20.59	0.08	3	8.60	0.37	3	4.06	0.02									
I304	3	-18.80	0.13	3	7.95	0.11	3	4.21	0.19									
I712	3	-20.68	0.10	3	7.56	0.10	3	4.14	0.15									
presumed less impacted, summary >>	**21**	**-21.55**	**0.95**	**21**	**6.62**	**1.06**	**21**	**4.31**	**0.30**	**75**	**-19.09**	**0.90**	**75**	**14.55**	**1.03**	**75**	**2.95**	**0.14**
10B										15	-19.52	0.51	15	13.99	0.50	15	2.92	0.18
11X	3	-22.82	0.35	3	6.27	0.08	3	4.34	0.07									
15A	3	-21.07	0.26	3	8.59	0.19	3	4.05	0.07									
15B										15	-19.27	0.48	15	14.64	0.51	15	3.00	0.04
22A	3	-21.38	0.20	3	7.04	0.06	3	3.97	0.18									
23B										15	-18.50	0.60	15	14.14	0.73	15	2.77	0.13
26A2	3	-20.48	0.02	3	4.92	0.02	3	4.70	0.04									
36B										15	-18.11	0.68	15	16.20	0.49	15	3.00	0.03
91A2	3	-20.57	0.09	3	6.25	0.11	3	4.71	0.10									
97A2	3	-21.72	0.13	3	7.01	0.14	3	4.21	0.18									
98A2	3	-22.83	0.47	3	6.29	0.17	3	4.16	0.08									
98B2										15	-20.04	0.57	15	13.79	0.54	15	3.04	0.03
Grand Total	**42**	**-20.65**	**1.25**	**42**	**6.55**	**1.84**	**42**	**4.27**	**0.26**	**196**	**-18.41**	**1.13**	**196**	**14.38**	**1.70**	**196**	**2.96**	**0.11**

Although there were generally no major differences in $\delta^{15}N$ between cod from different locations, cod from the Sørfjord (station 53B) stand out with particularly low $\delta^{15}N$ signature. The same is shown for mussels from the same area (stations 51A and 56 A), indicating that the $\delta^{15}N$ -baseline of the food web in the Sørfjord is lower. The reason for this is unknown, but a higher influence of allochthonous nitrogen is possible. Likewise, isotope signatures of both fish and mussel from the Oslofjord are among the highest observed (**Figure 27**) indicating a high baseline (and not a higher trophic position of the Oslofjord cod).

The overall range in $\delta^{15}N$ in mussels (all locations considered) is larger than for cod and the reason for this is unknown.

a



b

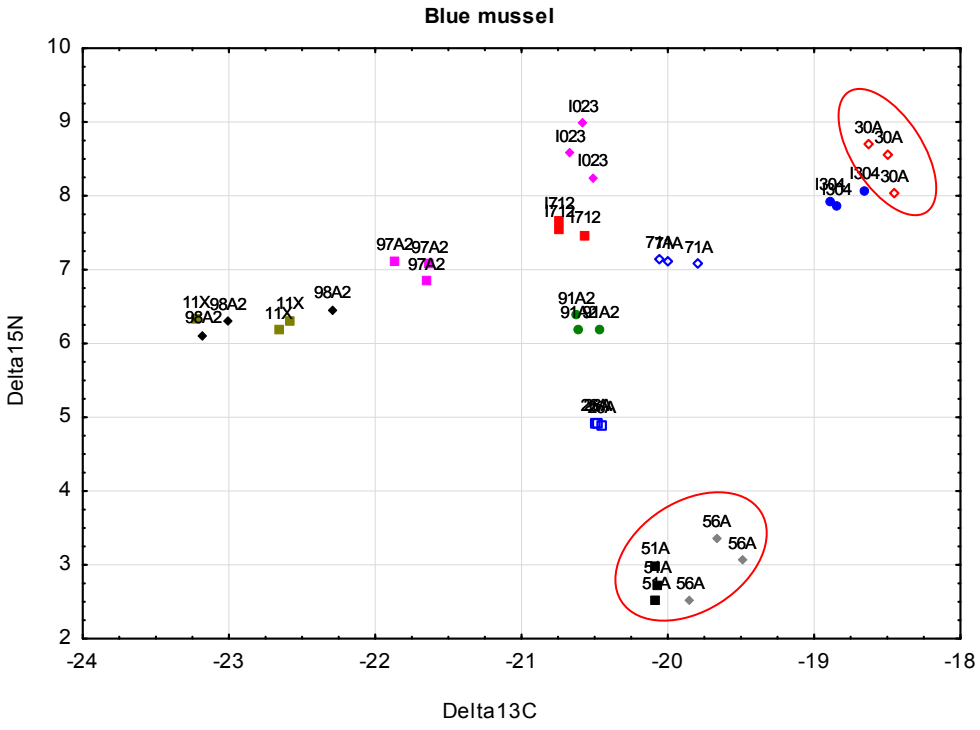


Figure 27. *$\delta^{13}C$ plotted against $\delta^{15}N$ in for cod (a) and blue mussel (b). Station codes are superimposed. Red ellipses indicate cod and blue mussel from the Inner Oslofjord and the Sørfjord, respectively.*

Plotting $\delta^{15}N$ against the 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], with very poor goodness-of-fit; R^2=0,022; P=0,039; Figure 2), However, this is likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high Hg-exposure as well as high $\delta^{15}N$ in cod from 30B, and low $\delta^{15}N$ baseline at 53B). A linear regression excluding stations 53B and 30B produced no significant result. However, from **Figure 28**, 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 four stations (23B, 28B, 30B and 45B2).

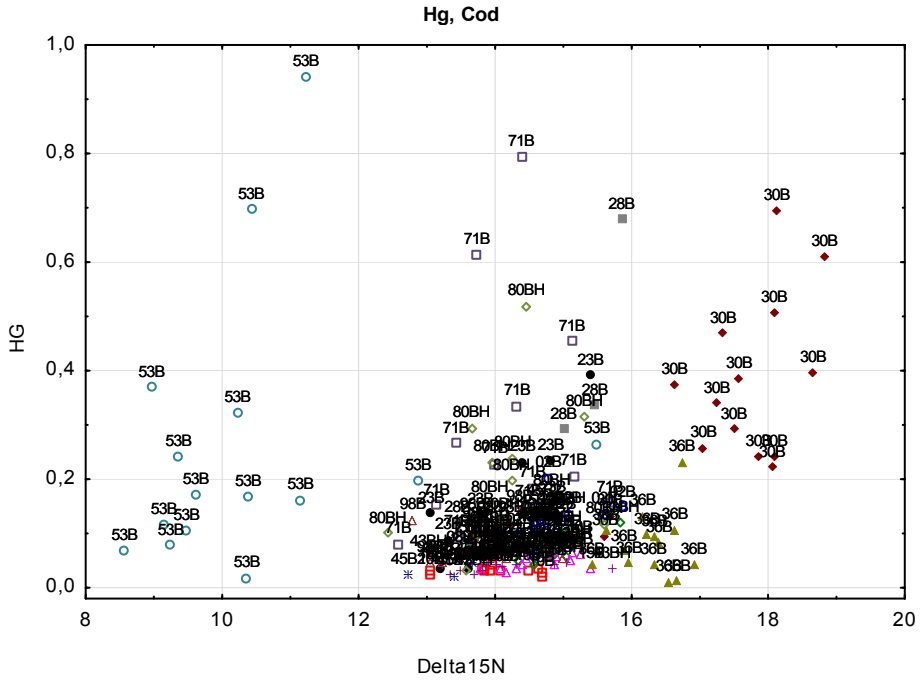


***Figure 28**. $\delta^{15}N$ plotted against the concentration of Hg in cod. Station codes are superimposed.*

Plotting $\delta^{15}N$ against the concentration of CB153 in cod could suggest higher concentrations in individuals with higher $\delta^{15}N$ (significant linear regression between $\delta^{15}N$ and Log[CB153]; R^2=0,15; P=0,000001; **Figure 29**), However, this is most likely partly a result of different exposure, as well as difference in isotopic signature (baseline) among stations (high CB153-exposure as well as high $\delta^{15}N$ in cod from 30B, and low CB153 exposure as well as low $\delta^{15}N$ baseline at 53B). A linear regression excluding stations 53B and 30B still produced significant result (P=0,0007), but with a very poor goodness-of-fit (R^2=0,092). Linear regressions isolated for each station produced significant positive linear relationships between $\delta^{15}N$ and Log[CB153] for two stations (28B and 43BH).

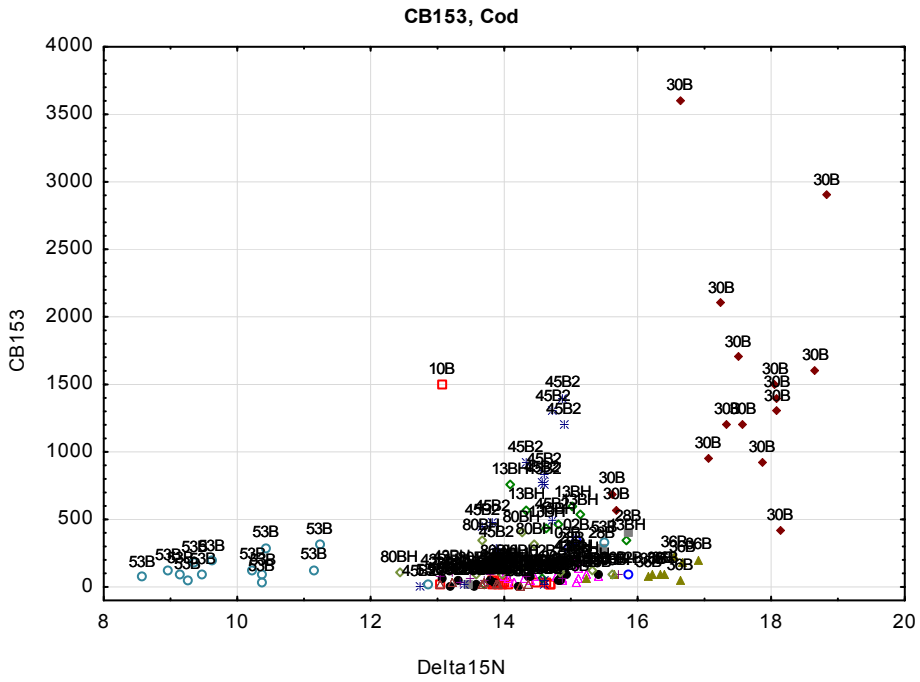


Figure 29. *δ^{15}N plotted against the concentration of CB153 in cod. Station codes are superimposed.*

Plotting δ^{15}N against the concentration of BPA in cod gives no indication of higher concentrations in individuals with higher δ^{15}N, but merely indicates stations with the highest exposure (71B, 23B and one sample from 30B), as well as the above mentioned difference in isotopic signature among stations (**Figure 30**).

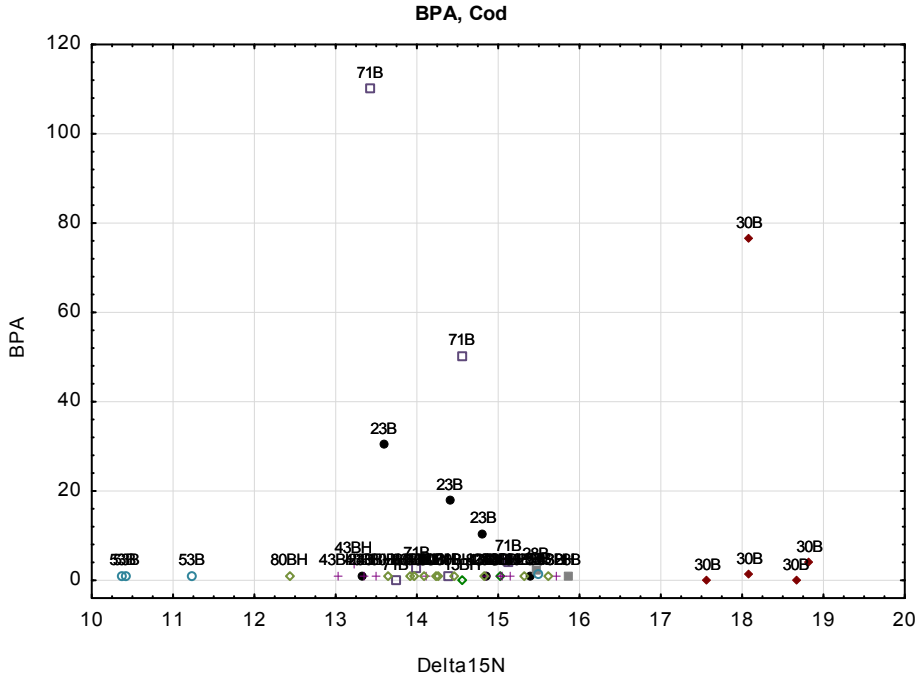


Figure 30. *δ^{15}N plotted against the concentration of BPA in cod. Station codes are superimposed.*

Plotting δ^{15}N against the concentration of MCCP in cod gives no indication of higher concentrations in individuals with higher δ^{15}N, but merely indicates stations with the highest exposure (53B and 80BH), as well as the above mentioned difference in isotopic signature among stations (**Figure 31**).

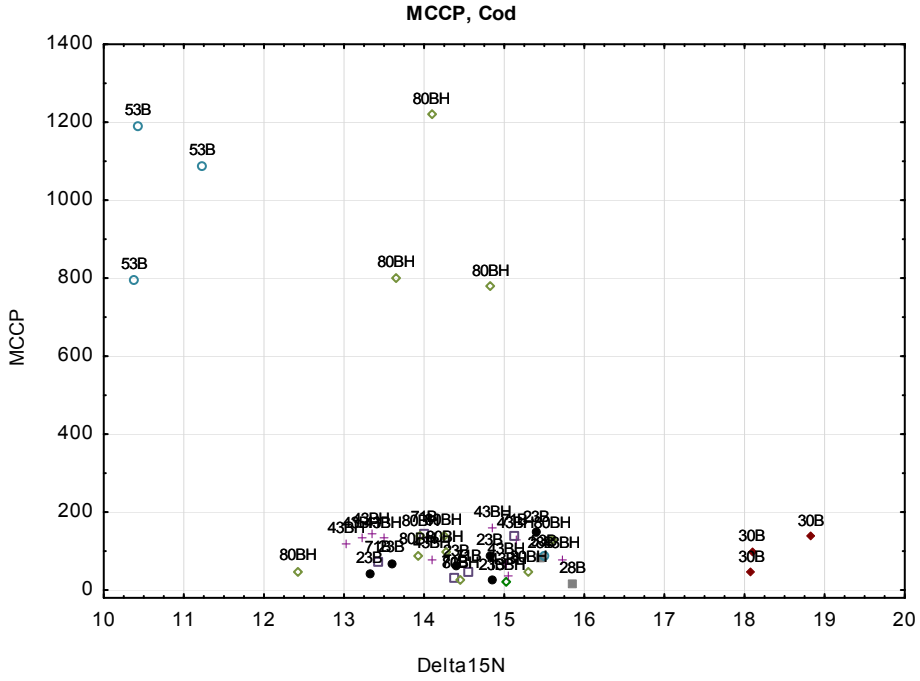


Figure 31. *δ^{15}N plotted against the concentration of MCCP in cod. Station codes are superimposed.*

4. Conclusions

This programme examines long term changes for legacy contaminants in biota along the coast of Norway in both polluted and in areas remote from point sources. In addition, the programme includes supplementary analyses of some emerging contaminants. As such, the programme provides a basis for assessing the state of the environment for the coastal waters with respect to contaminants. The main conclusions were:

- Most trends are downwards, predominantly for metals, including TBT and its effect, but also PCBs.
- The decrease in TBT can be related to legislation banning this substance
- Significant increase in mercury was found in cod from the Inner Oslofjord, but there is currently no evidence to explain this trend.
- PBDEs, predominantly BDE47, was highest in the Inner Oslofjord and the Trondheim harbour area.
- Blue mussel from one station in the Sørfjord was extremely polluted with DDE, presumably related to the earlier use of DDT as pesticide in this orchard district.
- The dominant hexabromcyclododecane (α–HBCD) in cod liver was highest in the Inner Oslofjord, probably related to urban activities
- Medium chain-chlorinated paraffins (MCCP) were significantly higher in cod liver from the Inner Sørfjord compared to other cod-stations.
- Concentrations of flame retardants (PFRs) were not detected or low (EHDPP and TCPP).
- The variability of bisphenol A among individual cod was quite high and no conclusions could be drawn.

5. References

Titles translated to English in square brackets [ ] are not official.

2000/60/EC. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. [Water Framework Directive]. http://www.europa.eu.int/comm/environment/water/water-framework/inde_en.html.

2008/105/EC. Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council.

2008/56/EC. Directive 2000/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy. [Marine Strategy Framework Directive]. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0056:EN:NOT.

2013/39/EU. Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy. Replaces 2008/105/EC. Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council.

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

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.

Allan, I., Fjeld, E., Garmo, Ø., Langford, K., Kringstad, A., Bratsberg, E., Kaste, Ø., 2009. RiverPOP: Measuring concentrations of persistent organic pollutants and trace metals in Norwegian rivers RiverPOP: Måle konsentrasjoner av persistente organiske forurensende stoffer og metaller i norske elver, . Klif-report TA2521/2009, p. 112.

Allan, I.J., Booij, K., Paschke, A., Vrana, B., Mills, G.A., Greenwood, R., 2009. Field Performance of Seven Passive Sampling Devices for Monitoring of Hydrophobic Substances. Environmental Science & Technology 43, 5383-5390.

Allan, I., Garmo, Ø., Harman, C., Kringstad, A., E., B., 2010. RiverPOP 2009: Measuring concentrations of persistent organic pollutants and trace metals in Norwegian rivers. . Klif-report TA2662/2010, p. 39.

Allan, I.J., Harman, C., Kringstad, A., Bratsberg, E., 2010. Effect of sampler material on the uptake of PAHs into passive sampling devices. Chemosphere 79, 470-475.

Allan, I.J., Aas, W., Green, N.W., Bæk, K., Christensen, G., Breivik, K., 2011. Tilførselsprogrammet: 2010: Passive air and water sampling at Andøya, Bjørnøya and Jan Mayen, 2009-2010. Klif-report TA2808/2011. p 53.

Allan, I.J., Ranneklev, S.B., 2011. Occurrence of PAHs and PCBs in the Alna River, Oslo (Norway). Journal of Environmental Monitoring 13, 2420-2426.

Allan, I., Bæk, K., Kringstad, A., Bratsberg, E., Høgfeldt, A., Ranneklev, S.B., Harman, C., Garmo, Ø., 2011. RiverPOP 2010. Measurement of trace contaminants in the Glomma River and some recommendations from RiverPOP projects (2008-2011). . Klif-report TA-2760/2011, p. 33.

Allan, I.J., Aas, W., Langford, K., Christensen, G., Green, N.W., Breivik, K., Bæk, K., Ranneklev, S., 2012. Tilførselsprogrammet: Passive air and water sampling at Andøya, Bjørnøya and Jan Mayen, Klif-report TA2937/2012. p 32.

Allan, I.J., Harman, C., Ranneklev, S.B., Thomas, K.V., Grung, M., 2013. Passive sampling for target and nontarget analyses of moderately polar and nonpolar substances in water. Environmental Toxicology and Chemistry 32, 1718-1726.

ASMO, 1994. Draft assessment of temporal trends monitoring data for 1983-91: Trace metals and organic contaminants in biota. Environmental Assessment and Monitoring Committee (ASMO). Document ASMO(2) 94/6/1.

Bakke, T., Breedveld, G., Källqvist,T., Oen, A., Eek, E., Ruus, A., Kibsgaard, A., Helland, A., Hylland, K. 2007a.Veileder for klassifisering av miljøkvalitet i fjorder og kystvann. Revidering av klassifisering av metaller og organiske miljøgifter i vann og sedimenter. SFT TA 2229/2007. Statens Forurensningstilsyn, Oslo. 12pp. ISBN 978-82-7655-537-0.

Bakke, T., Fjeld, E., Skaare, B.B., Berge, J.A, Green, N., Ruus, A., Schlabach, M., Botnen, H. 2007b. *Kartlegging av metaller og utvalgte nye organiske miljøgifter 2007. Krom, arsen, perfluoralkylstoffer, dikoretan, klorbenzener, pentaklorfenol, HCBD og DEHP.* [Mapping of metals and selected new organic contaminants 2006. Chromium, Arsenic, Perfluorated substances, Dichloroethane, Chlorinated benzenes, Pentachlorophenol, HCBD and DEHP.] Norwegian Pollution Control Authority (SFT) report no. 990/2007 (TA-2284/2007). NIVA report no. 5464-2007. 105pp. + annexes. ISBN 978-82-577-5199-9.

Belfroid, A., van Velzen, M., van der Horst, B., Vethaak, D., 2002. Occurrence of bisphenol A in surface water and uptake in fish: evaluation of field measurements. *Chemosphere* 49(2992:97-103.

Berge, J., Schlabach, M., Fagerhaug, A., Rønneberg, J.E., 2006. *Kartlegging av utvalgte miljøgifter i Åsefjorden og omkringliggende områder. Bromerte flammehemmere, klororganiske forbindelser, kvikksølv og tribromanisol.* [Screening of selected contaminants in Åsefjord and vicinity. Brominated flame retardants2004. Brominated flame retardants, organic compounds, mercury and tribromanisol. Norwegian Pollution Control Authority (SFT) report no. 946/2006 (TA-2146/2006). NIVA report no. 5132-2006. 73pp. + annexes. ISBN 978-82-577-4843-9.

Berge, J.A., Amundsen, R, Fredriksen, L., , Bjerkeng, B, Gitmark, J,., Holt, Haande, S., Hylland, K., Johnsen, T.M., Kroglund, T., Ledang. A.B., Lendrink, A., Lømsland, E.R., Norli, M., Magnusson, J., Rohrlack, T., Sørensen, K., Wisbech, C. 2013a. Overvåking av Indre Oslofjord i 2012 – Vedleggsrapport. NIVA-rapport nr 6534, 142s.

Berge, J.A., Ranneklev, S., Selvik, J.R. og Steen, A.O., 2013b. Indre Oslofjord – Sammenstilling av data om miljøgifttilførsler og forekomst av miljøgifter i sediment. NIVA-rapport nr. 6565, 122s.

Bjerkeng, B., Green, N. W., 1994. Shell length and metal concentrations in mussels (Mytilus edulis). Report of the Working Group on Statistical Aspects of Environmental Monitoring, St. Johns 26-29, April 1994. International Council for the Exploration of the Sea. C.M. 1994 ENV:6 Annex 11.

Booij, K., Sleiderink, H.M., Smedes, F., 1998. Calibrating the uptake kinetics of semipermeable membrane devices using exposure standards. Environmental Toxicology and Chemistry 17, 1236-1245.

Booij, K., Smedes, F., 2010. An Improved Method for Estimating in Situ Sampling Rates of Nonpolar Passive Samplers. Environmental Science & Technology 44, 6789-6794.

Booij, K., Smedes, F., van Weerlee, E.M., 2002. Spiking of performance reference compounds in low density polyethylene and silicone passive water samplers. Chemosphere 46, 1157-1161.

Brooks, S.J., Farmen, E., 2013. The distribution of the mussel *Mytilus* spedes along the Norwegian coast. *Journal of Shellfish Research*. 32(2:265-270.

Farmen, E., Mikkelsen, H.N., Evensen, Ø., Einset, J., Heier, L.S., Rosseland, B.O., Salbu, B., Tollefsen, K.E., Oughton, D.H., 2012. Acute and sub-lethal effects in juvenile Atlantic salmon exposed to low µg/L concentrations of Ag nanoparticle. *Aquatic Toxicology* 108:78-84.

Fjeld, E., Schlabach, M., Berge, J.A., Green, N., Egge, T., Snilsberg, P., Vogelsang, C., Rognerud, S., Kãllberg, G., Enge, E.K., Borge, A., Gundersen, H., 2005. *Kartlegging av utvalgte nye organiske miljøgifter 2004. Bromerte flammehemmere, perfluorerte forbindelser, irgarol, diuron, BHT og dicofol.* Screening of selected new organic contaminants 2004. Brominated flame retardants, perfluorinated compounds, irgarol, diuron, BHT and dicofol. Norwegian Pollution Control Authority (SFT) report no. 927/2005 (TA-2096/2005). NIVA report no. 5011-2005. 97pp + annexes. ISBN 978-82-577-4710-6.

Fjeld, E., Rognerud, S., Christensen, G., Dahl-Hanssen, G., Braaten, H.F.V., 2010. Environmental survey of mercury in perch, 2010. Klima- and forurensnings direktoratet TA no. 2737/2010. Norwegian Institute for Water Research, report no. 6090-2010. 28 pp.. 978-82-577-5825-7.

Fjeld, E., Enge, E. K., Rognerud, S., Rustadbakken, A. Løvik, J. E. 2012. Environmental contaminants in fish and zooplankton from Lake Mjøsa, 2011. Monitoring report 1115/2012 TA no. 2889/2012. Norwegian Institute for Water Research project 12003. Report no. 6357-2012. 63 pp. ISBN no. 987-82-577-6092-2.

Flint, S., Markle, T., Thomopson, S., Wallace, E., 2012. Bisphenol A exposure, effects, and policy: A wildliffe perspective. *Journal of Environmental Management* 104(2012:19-34.

Følsvik, N., Berge J.A., Brevik E.M., Walday, M. 1999. Quantification of organotin compounds and determination of Imposex in populations of dog whelk (*Nucella lapillus*) from Norway. *Chemosphere*. 38 (3): 681-691.

Fryer, R., Nicholson, M., 1999. Using smoother for comprehensive assessments of contaminant time series in marine biota. ICES Jounral of Marine Science, 56: 779-790.

Gibbs, P.E., Bryan, G.W., Pascoe, P.L., Burt, G.R., 1987. The use of the Dog-whelk, *Nucella lapillus*, as an indicator of tributyltin (TBT) contamination. J. mar. biol. Ass. U.K. (1987), 67:507-523.

Gitmark, J., Green, N., Beylich, B., Borgersen, G., Høgåsen, T. 2013. Overvåking NOAH Langøya 2012. Miljøgifter i blåskjell, sedimentundersøkelser samt marinbiologiske registreringer. NIVA-rapport L. nr. 6466-2013. 69 p. ISBN 978-82-577-6201-8.

Green, N.W., 1989. The effect of depuration on mussels analyses. Report of the 1989 meeting of the working group on statistical aspects of trend monitoring. The Hague, 24-27 April 1989. ICES-report C.M.1989/E:13 Annex 6:52-58.

Green, N.W., Bjerkeng B., Berge J.A., 1996. Depuration (12h) of metals, PCB and PAH concentrations by blue mussel (*Mytilus edulis*). Report of the Working Group on the Statistical Aspects of Environmental Monitoring. Stockholm 18-22 March 1996. ICES C.M.1996/D:1 Annex 13:108-117.

Green, N.W., Dahl, I., Kringstad, A., og Schlabach, 2008a. Joint Assessment and Monitoring Programme (JAMP). Overview of analytical methods 1981-2007. Norwegian Pollution Control Authority, Monitoring report no.1016/2008 TA no. 2370/2007. NIVA-rapport 5563-2008, 96 pp. ISBN no. 978-82-577-5298-9.

Green, N.W., Knutzen, J., 2003. Organohalogens and metals in marine fish and mussels and some relationships to biological variables at reference localities in Norway. *Marine Pollution Bulletin* 46(3):362-374.

Green, N.W., Ruus, 2008. Joint Assessment and Monitoring Programme (JAMP). *Overvåking av miljøgifter i marine sedimenter og organismer 1981-2006.* Norwegian Pollution Control Authority, Monitoring report no. 1018/2008 TA no. 2372/2008. Norwegian Institute for Water Research projects 80106, 25106, 26106, and 27106 and report no. 5565-2008, 93 pp. ISBN no. 978- 82-577-5300-9.

Green, N.W., Ruus, A., Bakketun, Å., Håvardstun, J., Rogne, Å.G., Schøyen, M., Tveiten, L., Øxenvad, S., 2007. Joint Assessment and Monitoring Programme (JAMP). National Comments regarding the Norwegian Data for 2005. Norwegian Pollution Control Authority, Monitoring report no. 974/2006 TA no. 2214/2006. Norwegian Institute for Water Research projects 80106, 25106, and 26106 and report no. 5315-2006, 191 pp. ISBN no. 82-577-5047-6. Also as Trends and Effects of Substances in the Marine Environment (SIME), Hamburg 6-8 March 2007. SIME 07/02/Info.3-E.

Green, N.W., Schøyen, M., Øxnevad, S., Ruus, A., Høgåsen, T., Beylich, B., Håvardstun, J., Rogne, Å.G., Tveiten, L., 2010b. Coordinated environmental monitoring programme (CEMP). Levels, trends and effects of hazardous substances in fjords and coastal waters-2009. Norwegian Pollution Control Authority, Monitoring report no. 1079/2010 TA no. 2716/2010. Norwegian Institute for Water Research project 10106 and report no. 6048-2010, 287 pp. ISBN no. 978- 82-577-5783-0.

Green, N.W., Heldal, H.E., Måge, A., Aas, W., Gäfvert, T., Schrum, C., Boitsov, S., Breivik, K., Iosjpe, M, Yakushev, K., Skogen, M., Høgåsen, T., Eckhardt, S., Christiansen, A.B., Daae, K.L., Durand D., Debloskaya, E., 2011b. Tilførselsprogrammet 2010. Overvåking av tilførsler og miljøtilstand i Nordsjøen. Klima og forurensningsdirektoratet (Klif) Rapport TA 2810/2011. Norsk institutt for vannforskning (NIVA) rapport nr. 6187-2011. 251 pp. ISBN 978-82-577-5922-3.

Green, N.W., Heldal, H.E., Måge, A., Aas, W., Gäfvert, T., Schrum, C., Boitsov, S., Breivik, K., Iosjpe, M, Yakushev, K., Skogen, M., Høgåsen, T., Eckhardt, S., Christiansen, A.B., Daae, K.L., Durand D., Ledang, A.B., Jaccard, P.F., 2012. Tilførselsprogrammet 2011. Overvåking av tilførsler og miljøtilstand i Norskehavet. Klima og forurensningsdirektoratet (Klif) Rapport TA 2935/2012. Norsk institutt for vannforskning (NIVA) rapport nr. 6360-2012. 251 pp. ISBN 978-82-577-6095-3.

Green N.W., Heldal, H.E., Måge, A., Aas, W., Gäfvert, T., Schrum, C., Boitsov, S., Breivik, K., Iosjpe, M, Yakushev, K., Skogen, M., Høgåsen, T., Eckhardt, S., Christiansen, A.B., Daae, K.L., Durand, D., Ledang A.B., 2013. Tilførselsprogrammet 2012. Overvåking av tilførsler og miljøtilstand i Barentshavet og Lofotenområdet. Klima og forurensningsdirektoratet (Klif) SPFO-rapport 1146/2013, TA 3042/2013. Norsk institutt for vannforskning (NIVA) rapport nr. 6544-2013. 149 sider. ISBN 978-82-577-6279-7.

Green, N.W., Schøyen, M., Øxnevad, S., Ruus, A., Høgåsen, T., Beylich, B., Håvardstun, J., Rogne, Å.G., Tveiten, L., 2012. Hazardous substances in fjords and coastal waters-2011. Levels, trends and effects. Long-term monitoring of environmental quality in Norwegian coastal waters. Climate and Pollution Agency/Klima- og forurensningsdirektoratet, Klif, Monitoring report no. 1132/2012 TA no. 2974/2012. Norwegian Institute for Water Research project 12106 and report no. 6432-2012, 264 pp. ISBN no. 978-82-577-6167-7.

HASEC 2012. Meeting of the Hazardous Substances and Eutrophication Committee (HASEC). Oslo, 27 February – 2 March 2012.OSPAR. Document HASEC 12/131-E – Summary Record. Convention for the Protection of the Marine Environment of the North-East Atlantic. (see also HASEC document 12/2/09).

Hauke, M., 2009. Fate and dynamics of hexabromocyclododecane (HBCD) in marine ecosystems. PhD dissertation. Department of Biology, Faculty of Mathematics and Natural Sciences, University of Oslo. 29 pp. + appendices.

Houde, M., Muir, D. C.G, Tomy, G.T., Whittle, D.M., Teixeira, C., Moore, S., 2008. Bioaccumulation and trophic magnification of short- and medium-chain chlorinated paraffins in food webs from Lake Ontario and Lake Michigan. *Envionmental Science and Technology* 2008: 42:3893-3899.

Huckins, J.N., Petty, J.D., Lebo, J.A., Almeida, F.V., Booij, K., Alvarez, D.A., Clark, R.C., Mogensen, B.B., 2002. Development of the permeability/performance reference compound approach for in situ calibration of semipermeable membrane devices. Environmental Science & Technology 36, 85-91.

Huckins, J. N.; Petty, J. D.; Booij, K., *Monitors of organic chemicals in the environment: Semipermeable membrane devices.* Springer: New York, 2006.

Hylland, K., Ruus, A., Grung, M., Green N. 2009. Relationships between physiology, tissue contaminants, and biomarker responses in Atlantic Cod (*Gadus morhua* L.). *Journal of Toxicology and Environmental Health-Part A*, 72:226-233.

ICES TIMES 13. Galgani, F., and Payne, J.F. 1991. Biological effects of contaminants: microplate method for measurement of ethoxyresorufin-O-deethylase (EROD) in fish. 11 pp.

ICES TIMES 23. Stagg, R., and McIntosh, A. 1998. Biological effects of contaminants: Determination of CYP1A-dependent mono-oxygenase activity in dab by fluorimetric measurement of EROD activity. 16 pp..

ICES TIMES 24. Gibbs, P.E. 1999. Biological effects of contaminants: Use of imposex in the dog whelk, (*Nucella lapillus*) as a bioindicator of tributyltin (TBT) pollution. 29 pp.

ICES TIMES 34. Hylland, K. 2004. Biological effects of contaminants: Quantification of d-aminolevulinic acid dehydratase (ALA-D) activity in fish blood. ICES Techniques in Marine Environmental Sciences. 9pp.

ICES, 1992. ICES Environmental data reporting formats, Version 2.1-January 1992.

ICES, 1996. ICES Environmental Data Reporting Formats. Version 2.2, revision 2-July 1996.

ICES. 2011. Report of the Study Group on Integrated Monitoring of Contaminants and Biological Effects (SGIMC), 14–18 March 2011, Copenhagen, Denmark. ICES CM 2011/ACOM:30. 265 pp.

Kim, B., Park, C.S., Murayama, M., Hochella, M.F. 2010. Discovery and charatcterisation of silver sulfide nanoparticles in final sewage sludge products. Environmental Science and Technology 44: 7509-7514.

Knutzen, J., Green, N.W., 1995. Bakgrunnsnivåer av en del miljøgifter i fisk, blåskjell og reker. Data fra utvalgte norske prøvesteder innen den felles overvåking under Oslo-/Paris-kommisjonene 1990-1993. [Background levels of some micropollutants in fish, the blue mussel and shrimps. Data from selected Norwegian sampling sites within the joint monitoring of the Oslo-/Paris Commissions 1990-1993]. Norwegian Pollution Control Authority, Monitoring report no. 594/95 TA no. 1173/1995. NIVA project O-80106/E-91412, (report no. 3302) 105 pp. ISBN no. 82-577-2678-8.

Knutzen, J., Green, N.W., 2001a. Tiltaksorienterte miljøundersøkelser i Sørfjorden og Hardangerfjord 2000. Delrapport 2. Miljøgifter i organismer. [Investigation of micropollutants in the Sørfjord and Hardangerfjord 2000. Report 2. Contaminants in organisms.] Norwegian Pollution Control Authority, Monitoring report no. 836/01. TA no. 1833/2001. NIVA project O-800309, (report no. 4445-2001) 51 pp. ISBN no. 82-577-4091-8.

Kwasniak, J., Flakowska, L., 2012. Mercury distribution in muscles and internal organs of the juvenile and adult Baltic cod (*Gadus morhua callarias* Linnaeus, 1758).

Layman, C. A.; Araujo, M. S.; Boucek, R.; Hammerschlag-Peyer, C. M.; Harrison, E.; Jud, Z. R.; Matich, P.; Rosenblatt, A. E.; Vaudo, J. J.; Yeager, L. A.; Post, D. M.; Bearhop, S., Applying stable isotopes to examine food-web structure: an overview of analytical tools. Biological Reviews 2012, 87, 545-562.

Molvær, J., Knutzen, J., Magnusson, J., Rygg, B., Skei J., Sørensen, J., 1997. Klassifisering av miljøkvalitet i fjorder og kystfarvann. Veiledning. *Classification of environmental quality in fjords and coastal waters. A guide*. Norwegian Pollution Control Authority. TA no. TA-1467/1997. 36 pp. ISBN 82-7655-367-2.

Nicholson, M.D, Fryer, R.J., Larsen, J.R., 1998. Temporal trend monitoring: A robust method for analysing trend monitoring data, ICES Techniques in Marine Envrionmental Sciences, No.20 September 1998.

Nicholson, M.D., Fryer N.W., & Green, N.W., 1994. Focusing on key aspects of contaminant trend assessments. Report of the 1994 meeting of the Working Group on the Statistical Aspects of Environmental Monitoring. St. Johns 26-29 April 1994. Annex 7:65-67.

Nicholson, M.D., Fryer, R.J., Mawell, D.M., 1997. A study of the power of various methods for detecting trends. ICES CM 1997/Env.11.

Nicholson, M.D., Green, N.W., & Wilson, S.J., 1991. Regression models for assessing trends in cadmium and PCBs in cod livers from the Oslofjord. Marine Pollution Bulletin 22(2):77-81.

Nowack, B. 2010. Nanosilver revisited downstream. Science 330: 1054-1055.

OSPAR, 1998. OSPAR OSPAR Strategy with regard to Hazardous Substances. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. Meeting of the OSPAR Commission (OSPAR). Sintra, 23-27 June, 1998. Summary Record Annex 34 (Reference no. 1998-16). 22 pp.

OSPAR, 2003b, JAMP [Joint Assessment and Monitoring Programme] Guidelines Contaminant-specific biological Effects Monitoring. OSPAR Commission, ref.no. 2003-10. 38 pp.

OSPAR, 2005. North Sea Pilot Project on Ecological Quality Objectives. Background document on the Ecological Quality Objective on imposex in dog whelks *Nucella lapillus*. OSPAR publication number 2005/247. ISBN 1-904426-86-7.

OSPAR, 2007. OSPAR Coordinated Environmental Monitoring Programme (CEMP). OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. OSPAR Commission. Reference no.: 2007-1. 25pp.

OSPAR, 2009. JAMP [Joint Assessment and Monitoring Programme] Guidelines for Monitoring Contaminants in Biota. OSPAR Commission, ref.no. 1992-2. 98 pp.

OSPAR, 2010. OSPAR, 2010. Quality Status Report 2010. OSPAR Commission. London. 176 pp (publication 497/2010). The OSPAR Commission encourages the hyperlinking to the QSR 2010 website: http://qsr2010.ospar.org.

Post, D. M., Using stable isotopes to estimate trophic position: Models, methods, and assumptions. Ecology 2002, 83, 703-718.2

Reth, M., Zencak, Z. & Oehme, M., 2005. First study of congener group patterns and concentrations of short- and medium-chain chlorinated paraffins in fish from the North and Baltic Sea. Chemosphere58: 847-854.

Rusina, T. P.; Smedes, F.; Koblizkova, M.; Klanova, J., Calibration of Silicone Rubber Passive Samplers: Experimental and Modeled Relations between Sampling Rate and Compound Properties. *Environmental Science & Technology* **2010,** *44,* (1), 362-367.

Ruus, A., Bakke, T., Bjerkeng, B, Knutsen, H. 2013a. Overvåking av miljøgifter i fisk og skalldyr fra Grenlandsfjordene 2012. *Monitoring of contaminants in fish and shellfish from Grenlandsfjordene 2012*. Miljødirektoratet-rapport, M-8/2013, SPFO 1151/2013. NIVA-rapport L. nr. 6571-2013. 81 p. ISBN 978-82-577-6306-0.

Ruus, A. Green, N., Maage, A., Amundsen, C. E., Schøyen, M., Skei, J. 2010. Post World War II orcharding creates present day DDT-problems in The Sørfjord (Western Norway) – A case study. Marine Pollution Bulletin 60 (2010) 1856-1861. 6 pp.

Ruus, A., Hylland, K., Green, N., 2003. Joint Assessment and Monitoring Programme (JAMP). Biological Effects Methods, Norwegian Monitoring 1997-2001. Norwegian Pollution Control Authority, Monitoring report no. 869/03 TA no. 1948/2003. Norwegian Institute for Water Research project 80106, report no. 4649-2003, 139 pp. ISBN no. 82-577-4313-5.

Ruus, A., Kvassnes, A. J. S., Ledang, A. B., Green, N. W., Schøyen, M. 2013b. Overvåking av miljøforholdene i Sørfjorden 2012. Metaller i vannmassene, Oksygen, nitrogen og fosfor i vannmassene, Miljøgifter i organismer. *Monitoring of environmental quality in the Sørfjord 2012. Metals in the water masses, Oxygen, nitrogen and phosphorus in the water masses, Contaminants in organisms.* Miljødirektoratet-rapport, M-15/2013. SPFO 1150/2013. NIVA rapport, L. nr. 6549-2013. 107 p. ISBN 978-82-577-6284-1.

Sacks, V.P., Lohmann, R., 2011. Development and Use of Polyethylene Passive Samplers To Detect Triclosans and Alkylphenols in an Urban Estuary. Environmental Science & Technology 45, 2270-2277.

Schøyen, M., Håvardstun, J., Øxnevad, S., Borgersen, G., Høgåsen, T., Oug, E. 2013. Overvåking av miljøgifter i Kristiansandsfjorden i 2012. Undersøkelse av blåskjell, torsk, taskekrabbe, sedimenter og bløtbunnsfauna. Monitoring of contaminants in Kristiansandsfjorden in 2012. Investigations of blue mussel, cod, edible crab, sediments and soft bottom fauna. NIVA rapport, L. nr. 6540-2013. 353 p. ISBN 978-82-577-6275-9.

Schøyen, M. and Kringstad, A. 2011. Perfluoroalkyl compounds (PFCs) in cod blood and liver from the Inner Oslofjord (2009). NIVA O-11257. Notat nr. N-45/11. 20 s.

SIME, 2004a. OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic. Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (SIME) London (Secretariat) 24-26 February 2004. SIME 04/6/1-E [JAMP implementation], 9 pp.

Smedes, F., Geertsma, R.W., van der Zande, T., Booij, K., 2009. Polymer-Water Partition Coefficients of Hydrophobic Compounds for Passive Sampling: Application of Cosolvent Models for Validation. Environmental Science & Technology 43, 7047-7054.

Thomas, K.V., Langford, K.H., Muthanna, T., Schlabach, M., Enge, E.K., Borgen, A., Ghebremskel, M., Gundersen, G., Leknes, H., Uggerud, H., Haglund, P., Liao, Z., Liltved, H. 2011. Occurrence of selected organic micropllutants and silver at wastewater treatment plants in Norway. The Norwegian Climate and Pollution Agency report no. 2784/2011.

Van den Berg, M., L. Birnbaum, A.T.C. Bosveld, B. Brunström, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, F.X.R. van Leeuwen, A.K.D. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Wærn and T. Zacharewski 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Hlth. Perspect. 106:775-792.

Van der Veen, I., de Boer, J., 2012. Phosphorus flame retardants: Properties, production, environmental occurrence, toxicity and analysis. *Chemosphere* 88(2012):1119-1153.

Vrana, B.; Mills, G. A.; Allan, I. J.; Dominiak, E.; Svensson, K.; Knutsson, J.; Morrison, G.; Greenwood, R., Passive sampling techniques for monitoring pollutants in water. *Trac-Trends in Analytical Chemistry* **2005,** *24*, (10), 845-868.

WGSAEM, 1993. The length effect on contaminant concentrations in mussels. Section 13.2. in the Report of the Working Group on Statistical Aspects of Environmental Monitoring, Copenhagen, 27-30 April 1993. International Council for the Exploration of the Sea. C-M- 1993/ENV:6 Ref.: D and E, 61 pp.

Wängberg, J.G., Spry, D.J., 1996. Toxicological significance of mercury in freshwater fish, pp. 297-339 in: Beyer, W.N., Heinz, G.H., Redmon-Norwood, A.W., eds. *Environmental contaminants in wildlife: interpreting tissue concentrations*, Lewis Publisher, Boca Raton, Fl.

Øxnevad, S., Bakke, T. 2013. Kartlegging av miljøgifter i sedimenter og blåskjell I indre Ranfjorden I 2012. Risikovurdering av forurenset sediment utenfor kaiområdene. NIVA-report 6483-2013.

Appendix A
Quality assurance programme

Information on Quality Assurance

The laboratories have participated in the QUASIMEME international intercalibration exercises and other SLPs relevant to chemical and imposex analyses. For chemical analyses, these include Round 70 of July-November 2012 and Round 72 of January-April 2013, which both apply to the 2012 samples. These QUASIMEME exercises included nearly all the contaminants as well as imposex analysed in this programme. The quality assurance programme is corresponding to the 2011 programme (cf. Green *et al*. 2012).

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 CDSI 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 17025:2005.

Summary of quality control results
Standard Reference Materials (SRM) as well as in-house reference materials were analysed regularly (***Table 22***). Fish protein (DORM-4) or dogfish liver (DOLT-4) was used as SRM for the control of the determination of metals. The SRM for determination of PBDEs was fish fillet (EDF2525). For determination of PCBs, DDTs, PAHs and chlorinated paraffins, QUASIMEME biota samples with known true value was applied. The HBCDs were determined using *Folkehelsa* reference material, halibut from 2009. For bisphenols nonyl-/octylphenols and chlorinated phosphates, spiked blank samples or spiked vegetable oil were used as internal reference materials.

The results for QUASIMEME-Round 70 (July-November 2012) and Round 72 (January-May 2013) apply to the 2012 samples. Overall, the results are good and mostly within the uncertainty limits of deviation from the true value with only a few exceptions.

ROUND 66

- QOR108BT (no. 1) and QOR109BT (no. 2) for PCB in biota
  The results were acceptable and within the uncertainty limits of the method with only a few exceptions.
- QPH063BT (no. 1) and QPH064BT (no. 2) for PAH in biota
  The results were acceptable and within the uncertainty limits of the method with only a few exceptions.

***Table 22**. Summary of the quality control of results for the 2011 biota samples analysed in 2011-2012. The Standard Reference Materials (SRM) were DOLT-4* (dogfish liver) for fish liver, DORM-4* (fish protein) for blue mussel and fish fillet, EDF2525** (fish fillet) for fish, and QUASIMEME samples and in-house reference materials. In addition, a spiked fish liver sample was analysed for recovery.*
The SRMs and in-house reference materials were analysed in series with the MILKYS samples. Tissue types were: mussel soft body (SB), fish liver (LI) and fish fillet (MU). SRMs and HSDs were measured several times (N) over a number of weeks (W).

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
Ag	**Silver**	LI	DOLT-4	0.93 ± 0.07	31	28	0,82	0,32
As	**Arsenic**	LI	DOLT-4	9.66 ± 0.62	31	59	10	0.73
Cd	**Cadmium**	LI	DOLT-4	24.3 ± 0.8	27	59	24.2	2.18
Co	**Cobalt**	LI	DOLT-4	0.25[1)]	26	28	0.23	0.022
Cr	**Chromium**	LI	DOLT-4	1.4[1)]	26	28	1.3	0.32
Cu	**Copper**	LI	DOLT-4	31.2 ± 1.1	31	59	30.7	3.21
Hg	**Mercury**	LI	DOLT-4	2.58 ± 0.22	18	59	2.39	0.51
Ni	**Nickel**	LI	DOLT-4	0.97 ± 0.11	26	28	1.0	0.28
Pb	**Lead**	LI	DOLT-4	0.16 ± 0.04	31	59	0.14	0.074
Sn	**Tin**	LI	DOLT-4	0.17[1)]	26	28	0.18	0.067
Zn	**Zinc**	LI	DOLT-4	116 ± 6	36	59	124	10.69
As	**Arsenic**	**SB**	DORM-4	6.80 ± 0.64	25	39	6.45	0.35
Cd	**Cadmium**	**SB**	DORM-4	0.306 ± 0.015	25	39	0.30	0.028
Cr	**Chromium**	**SB**	DORM-4	1.87 ± 0.16	25	39	1.87	0.35
Cu	**Copper**	**SB**	DORM-4	15.9 ± 0.9	25	39	14.7	1.16
Hg	**Mercury**	**SB**	DORM-4	0.410 ± 0.055	23	34	0.4	0.044
Ni	**Nickel**	**SB**	DORM-4	1.36 ± 0.22	26	39	1.33	0.22
Pb	**Lead**	**SB**	DORM-4	0.416 ± 0.053	25	39	0.39	0.071
Sn	**Tin**	**SB**	DORM-4	0.056 ± 0.010	14	18	0.064	0.058
Zn	**Zinc**	**SB**	DORM-4	52.2 ± 3.2	25	39	50.9	3.97
BDE100	**2,2',4,4',6-Pentabromodiphenylether**	**MU**	EDF2525	1.720 ±0.566	7	2	1.40	0.157
BDE153	**2,2',4,4'5,5'-Hexabromodiphenylether**	**MU**	EDF2525	2.030 ± 0.506	7	2	1.62	0.224
BDE154	**2,2',4,4',5,6'-Hexabromodiphenylether**	**MU**	EDF2525	2.550 ± 1.000	7	2	4.30	0.466
BDE47	**2,2',4,4',-Tetrabromodiphenylether**	**MU**	EDF2525	9.080 ± 2.620	7	2	10.08	1.31
BDE99	**2,2',4,4',5-Pentabromodiphenylether**	**MU**	EDF2525	2.280 ± 0.472	7	2	2.11	0.177
BDE183	**2,2',3,4,4,5',6-Heptabromodiphenylether**	**MU**	EDF2525	0.137 ± 0.050	7	2	0.08	0.069
BDE209	**Decabromodiphenylether**	**MU**	EDF2525	0.545 ± 0.0020	7	2	m	m
CB101	**PCB congener CB-101**	MU	QOR110BT	3.25	5	4	3.25	0.143
CB118	**PCB congener CB-118**	MU	QOR110BT	2.20	5	4	2.40	0.079
CB138	**PCB congener CB-138**	MU	QOR110BT	4.46	5	4	6.49	0.175
CB153	**PCB congener CB-153**	MU	QOR110BT	7.93	5	4	8.56	0.231
CB180	**PCB congener CB-180**	MU	QOR110BT	0.48	5	4	0.55	0.015
CB209	**PCB congener CB-209**	MU	QOR110BT					
CB28	**PCB congener CB-28**	MU	QOR110BT	0.37	5	4	0.43	0.062
CB52	**PCB congener CB-52**	MU	QOR110BT	1.11	5	4	1.41	0.047
DDEPP	**4.4'-DDE**	MU	QOR110BT	1.4	5	4	1.87	0.113
TDEPP	**4.4'-DDD**	MU	QOR110BT	0.59	5	4	0.54	0.067
DDTPP	**4.4'-DDT**	MU	QOR110BT	0.14 [1)]	5	4	0.06	0.063
α-HBCD	**α-Hexabromocyclododecane**	MU, LI	*Folkehelsa* RM (Halibut 2009)	980 ± 170	6	m	872	116
ß-HBCD	**ß-**	MU,	*Folkehelsa*	8.6 ± 2.5	6	m	16	6

Code	Contaminant	Tissue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
	Hexabromocyclododecane	LI	RM (Halibut 2009)					
γ-HBCD	γ-Hexabromocyclododecane	MU, LI	*Folkehelsa* RM (Halibut 2009)	65 ± 52	6	m	66	28
CB101	PCB congener CB-101	LI	QOR108BT	63.7	13	7	68.55	7.91
CB118	PCB congener CB-118	LI	QOR108BT	69.9	13	7	77.29	8.45
CB138	PCB congener CB-138	LI	QOR108BT	204.77	13	7	204.07	22.8
CB153	PCB congener CB-153	LI	QOR108BT	219	13	7	235.18	28.14
CB180	PCB congener CB-180	LI	QOR108BT	45.5	13	7	45.59	6.11
CB28	PCB congener CB-28	LI	QOR108BT	10.5	13	7	10.2	1.43
CB52	PCB congener CB-52	LI	QOR108BT	23.7	13	7	25.8	2.83
DDEPP	4.4'-DDE	LI	QOR108BT	1.4	13	7	83.1	95.03
DDTPP	4.4'-DDT	LI	QOR108BT	26.7	13	7	28.46	10.63
TDEPP	4.4'-DDD	LI	QOR108BT	0.83*ikke sertifisert	1	1	1.09	
ACNE	Acenaphthene	SB	QPH065BT	0.77	5	3	0.71	0.277
ACNLE	Acenaphthylene	SB	QPH065BT	0.45	5	3	0.82	0.102
ANT	Anthracene	SB	QPH065BT	0.75	5	3	1.99	0.148
BAP	benzo[a]pyrene	SB	QPH065BT	1.50	5	3	1.85	0.549
BBJF	Benzo(b+j)flouranthene[2)]	SB	QPH065BT	4.99	5	3	5.12	1.593
BKF	benzo[k]fluoranthene	SB	QPH065BT	2.00	5	3	2.88	0.577
BAA	benzo[a]anthracene	SB	QPH065BT	5.26	5	3	5.45	0.148
CHR	Chrysene	SB	QPH065BT	7.19	5	3	6.74	1.139
DBA3A	Dibenz[a,h]anthracene	SB	QPH065BT	0.43	5	3	0.47	0.218
FLE	Fluorene	SB	QPH065BT	1.59	5	3	0.58	0.205
FLU	Fluoranthene	SB	QPH065BT	13.8	5	3	17.65	1.523
ICDP	indeno[1,2,3-cd]pyrene	SB	QPH065BT	1.52	5	3	1.17	0.469
NAP	Naphthalene	SB	QPH065BT	5.05	5	3	5.78	0.569
PA	Phenanthrene	SB	QPH065BT	8.18	5	3	9.03	1.13
PYR	Pyrene	SB	QPH065BT	11.1	5	3	15.2	1.037
	Tetrabromobisphenol-A	MU, LI	Internal RM (olive oil)	m	10		25	*1*
	Bisphenol-A	MU, LI	Internal RM (spiked blank sample)	m	34		39.3	m
SCCP	C10-C13 Chlorinated paraffines	MU, LI	IVMCPQ2011	18.5	3		19.7	*2.3*
MCCP	C13-C17 Chlorinated paraffines	MU, LI	IVMCPQ2011	m	m		m	m
	Octylphenol	MU, LI	Internal RM (spiked blank sample)					
	Nonylphenol	MU, LI	Internal RM (spiked blank sample)					
TIBP	Triisobutylphosphate	VO	Spiked vegetable oil	69.57	12	3	69,91	6,38
TBP	Tributylphosphate	VO	Spiked vegetable oil	65,22	12	3	63,61	1,91
TCEP	Tris(2-chloroethyl)phosphate	VO	Spiked vegetable oil	65,22	12	3	60,94	5,04
TCPP	Tris(2-chloro-isopropyl)phosphate	VO	Spiked vegetable oil	69,57	12	3	66,99	4,26
TDCP	Tris(1,3-chloro-isopropyl)phosphate	VO	Spiked vegetable oil	65,22	12	3	61,12	7,73
TBEP	Tris(2-butoxyethyl)phosphate	VO	Spiked vegetable oil	65,22	12	3	60,37	18,84

Code	Contaminant	Tis-sue type	SRM type	SRM value confidence interval	N	W	Mean value	Standard deviation
TPhP	**Triphenylphosphate**	VO	Spiked vegetable oil	65,22	12	3	70,57	3,29
EHDPP	**2-Ethylhexyl-diphenylphosphate**	VO	Spiked vegetable oil	65,22	12	3	65,07	3,27
TEHP	**Tris(2-ethylhexyl) phosphate**	VO	Spiked vegetable oil	65,22	12	3	60,76	5,88
ToCrP	**o-Tricresylphosphate**	VO	Spiked vegetable oil	65,22	12	3	65,78	5,60
TCrP	**Tricresylphosphate**	VO	Spiked vegetable oil	65,22	12	3	70,89	8,25
MBT	**Monobutyltinn**	snail	BCR646 freshwater sediment	610 ± 240	24		587	61
DBT	**Dibutyltin**		BCR646	770 ± 180	24		547	116
TBT	**Tributyltin**		BCR646	480 ± 160	24		443	34
TpPhT	**Triphenyltin**		BCR646	29 ± 22	24		34	6
PFBS	**Perfluorobutane sulphonate**	LI		100 %[3)]			105	6
PFHxA	**Perfluorohexane acid**	LI		100 %[3)]			106	5
PFHpA	**Perfluoroheptane acid**	LI		100 %[3)]			104	9
PFOA	**Perfluorooctane acid**	LI		100 %[3)]			104	9
PFNA	**Perfluorononane acid**	LI		100 %[3)]			115	11
PFOS	**Perfluorooctane sulphonate**	LI		100 %[3)]			101	6
PFOSA	**Perfluorooctane sulphone amide**	LI		100 %[3)]			101	3
PFHxS	**Perfluorohexanoic sulphonate**	LI		100 %[3)]			98	3
PFDcA	**Perfluorodecanoic acid (=PFDA)**	LI		100 %[3)]			102	5
PFUdA	**Perfluordecanoic acid (=PFUnA)**	LI		100 %[3)]			100	6
PFDcS	**Perfluorodecanoic sulphonate**	LI		100 %[3)]			85	28

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

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

*** National Institute of Standards & Technology (NIST).

**** CIL, US.

1) Not certified value.

2) Calculated from separate values for **Benzo(b)fluoranthene** and **Benzo(j)fluoranthene.**

3) Recovery of spiked control sample

Appendix B
Abbreviations

Abbreviation[1]	English	*Norwegian*	Param. group
ELEMENTS			
Al	aluminium	*aluminium*	I-MET
As	arsenic	*arsen*	I-MET
Cd	cadmium	*kadmium*	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
Li	lithium	*litium*	I-MET
Mn	manganese	*mangan*	I-MET
Ni	nickel	*nikkel*	I-MET
Pb	lead	*bly*	I-MET
Pb210	lead-210	*bly-210*	I-RNC
Se	selenium	*selen*	I-MET
Sn	tin	*tinn*	I-MET
Ti	titanium	*titan*	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	Monobutyltin	*Monobutyltinn*	O-MET
DBTIN	Dibutyltin	*dibutyltinn*	O-MET
TBTIN	Tributyltin (=TBT*0.40984)	*tributyltinn* (=TBT*0.40984)	O-MET
MPTIN	monophenyltin	*monofenyltinn*	O-MET
DPTIN	diphenyltin	*difenyltinn*	O-MET
TPTIN	triphenyltin	*trifenyltinn*	O-MET
PAHs			
PAH	polycyclic aromatic hydrocarbons	*polysykliske aromatiske hydrokarboner*	
ACNE [3]	acenaphthene	*acenaften*	PAH
ACNLE [3]	acenaphthylene	*acenaftylen*	PAH
ANT [3]	anthracene	*antracen*	PAH
BAA [3, 4]	benzo[*a*]anthracene	*benzo[a]antracen*	PAH
BAP [3, 4]	benzo[*a*]pyrene	*benzo[a]pyren*	PAH
BBF [3, 4]	benzo[*b*]fluoranthene	*benzo[b]fluoranten*	PAH
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]	dibenzopyrenes	*dibenzopyren*	PAH
DBT	dibenzothiophene	*dibenzothiofen*	PAH
DBTC1	C_1-dibenzothiophenes	*C_1-dibenzotiofen*	PAH
DBTC2	C_2-dibenzothiophenes	*C_2-dibenzotiofen*	PAH

Abbreviation[1]	English	*Norwegian*	Param. group
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]	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	*Sammebetegnelse for naftalen, fenantren og dibenzotiofens*	PAH
PA [3]	phenanthrene	*fenantren*	PAH
PAC1	C_1-phenanthrenes	*C_1-fenantren*	PAH
PAC2	C_2-phenanthrenes	*C_2-fenantren*	PAH
PAC3	C_3-phenanthrenes	*C_3-fenantren*	PAH
PAM1	1-methylphenanthrene	*1-metylfenantren*	PAH
PAM2	2-methylphenanthrene	*2-metylfenantren*	PAH
PADM1	3,6-dimethylphenanthrene	*3,6-dimetylfenantren*	PAH
PADM2	9,10-dimethylphenanthrene	*9,10-dimetylfenantren*	PAH
PER	perylene	*perylen*	PAH
PYR [3]	pyrene	*pyren*	PAH
DI-Σn	sum of "n" dicyclic "PAH"s (footnote 2)	*sum "n" disykliske "PAH" (fotnote 2)*	
P-Σn/P_S	sum "n" PAH (DI-Σn not included, footnote 3)	*sum "n" PAH (DI-Σn ikke inkludert, fotnot 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 (foreldret 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

Abbreviation[1]	English	*Norwegian*	Param. group
CB101	CB101 (IUPAC)	*CB101 (IUPAC)*	OC-CB
CB105	CB105 (IUPAC)	*CB105 (IUPAC)*	OC-CB
CB110	CB110 (IUPAC)	*CB110 (IUPAC)*	OC-CB
CB118	CB118 (IUPAC)	*CB118 (IUPAC)*	OC-CB
CB126 [5]	CB126 (IUPAC)	*CB126 (IUPAC)*	OC-CB
CB128	CB128 (IUPAC)	*CB128 (IUPAC)*	OC-CB
CB138	CB138 (IUPAC)	*CB138 (IUPAC)*	OC-CB
CB149	CB149 (IUPAC)	*CB149 (IUPAC)*	OC-CB
CB153	CB153 (IUPAC)	*CB153 (IUPAC)*	OC-CB
CB156	CB156 (IUPAC)	*CB156 (IUPAC)*	OC-CB
CB169 [5]	CB169 (IUPAC)	*CB169 (IUPAC)*	OC-CB
CB170	CB170 (IUPAC)	*CB170 (IUPAC)*	OC-CB
CB180	CB180 (IUPAC)	*CB180 (IUPAC)*	OC-CB
CB194	CB194 (IUPAC)	*CB194 (IUPAC)*	OC-CB
CB209	CB209 (IUPAC)	*CB209 (IUPAC)*	OC-CB
CB-Σ7	CB: 28+52+101+118+138+153+180	*CB: 28+52+101+118+138+153+180*	
CB-ΣΣ	Sum of CBs, includes CB-Σ7	*sum CBer, inkluderer CB-Σ7*	
TECBW	Sum of CB-toxicity equivalents after WHO model, see **TEQ**	*Sum CB- toksitets ekvivalenter etter WHO modell, se **TEQ***	
TECBS	Sum of CB-toxicity equivalents after SAFE model, see **TEQ**	*Sum CB-toksitets ekvivalenter etter SAFE modell, se **TEQ***	
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- toksitets ekvivalenter etter Nordisk modell, se **TEQ***	
TCDDI	Sum of TCDD-toxicity equivalents after international model, see **TEQ**	*Sum TCDD-toksitets ekvivalenter etter internasjonale modell, se **TEQ***	
PESTICIDES			
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
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-dichloro-2,2-bis-(4-chlorophenyl)ethylene*	*diklordifenyldikloretylen (hovedmetabolitt av DDT)* *1,1-dikloro-2,2-bis-(4-klorofenyl)etylen*	OC-DD
DDT	dichlorodiphenyltrichloroethane 1,1,1-trichloro-2,2-bis-(4-chlorophenyl)ethane	*diklordifenyltrikloretan* *1,1,1-trikloro-2,2-bis-(4-klorofenyl)etan*	OC-DD
DDEOP	o,p'-DDE	*o,p'-DDE*	OC-DD
DDEPP	p,p'-DDE	*p,p'-DDE*	OC-DD
DDTOP	o,p'-DDT	*o,p'-DDT*	OC-DD
DDTPP	p,p'-DDT	*p,p'-DDT*	OC-DD
TDEPP	p,p'-DDD	*p,p'-DDD*	OC-DD
DDTEP	p,p'-DDE + p,p'-DDT	*p,p'-DDE + p,p'-DDT*	OC-DD
DD-nΣ	sum of DDT and metabolites, n = number of compounds	*sum DDT og metabolitter, n = antall forbindelser*	OC-DD
HCB	hexachlorobenzene	*heksaklorbenzen*	OC-CL
HCHG	Lindane γ HCH = gamma hexachlorocyclohexane (γ BHC = gamma benzenehexachloride, outdated synonym)	*Lindan* *γ HCH = gamma heksaklorsykloheksan (γ BHC = gamma benzenheksaklorid, foreldret 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*	

Abbreviation[1]	English	*Norwegian*	Param. group
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
BDE-28	2,4,4'-tribromodiphenyl ether	*2,4,4'-tribromdifenyleter*	OC-BR
BDE-47	2,2',4,4'-tetrabromodiphenyl ether	*2,2',4,4'-tetrabromdifenyleter*	OC-BR
BDE-49*	2,2',4,5'- tetrabromodiphenyl ether	*2,2',4,5'- tetrabromdifenyleter*	OC-BR
BDE-66*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE-71*	2,3',4',6- tetrabromodiphenyl ether	*2,3',4',6- tetrabromdifenyleter*	OC-BR
BDE-77	3,3',4,4'-tetrabromodiphenyl ether	*3,3',4,4'-tetrabromdifenyleter*	OC-BR
BDE-85	2,2',3,4,4'-pentabromodiphenyl ether	2,2',3,4,4'-pentabromdifenyleter	OC-BR
BDE-99	2,2',4,4',5-pentabromodiphenyl ether	*2,2',4,4',5-pentabromdifenyleter*	OC-BR
BDE-100	2,2',4,4',6-pentabromodiphenyl ether	*2,2',4,4',6-pentabromdifenyleter*	OC-BR
BDE-119	2,3',4,4',6-pentabromodiphenyl ether	*2,3',4,4',6-pentabromdifenyleter*	OC-BR
BDE-138	2,2',3,4,4',5'-hexabromodiphenyl ether	*2,2',3,4,4',5'-heksabromdifenyleter*	OC-BR
BDE-153	2,2',4,4',5,5'-hexabromodiphenyl ether	*2,2',4,4',5,5'-heksabromdifenyleter*	OC-BR
BDE-154	2,2',4,4',5,6'-hexabromodiphenyl ether	*2,2',4,4',5,6'-heksabromdifenyleter*	OC-BR
BDE-183	2,2',3,4,4',5',6-heptabromodiphenyl ether	*2,2',3,4,4',5',6-heptabromdifenyleter*	OC-BR
BDE-196	2,2',3,3',4,4',5',6-octabromodiphenyl ether	*2,2',3,3',4,4',5',6-octabromdifenyleter*	OC-BR
BDE-205	2,2',3,3',4,4',5,5',6'-nonabromodiphenyl ether	*2,2',3,3',4,4',5,5',6'-nonabromdifenyleter*	OC-BR
BDE-209	Decabromodiphenyl ether	*Dekabromdifenyleter*	OC-BR
BDE5S	Sum of BDE -85, -99, -100, -119	Sum av BDE -85, -99, -100, -119	OC-BR
BDESS	Sum of all BDEs	Sum av alle BDEer	OC-BR
HBCD	Hexabromocyclododecane	Heksabromsyklododekan	OC-BR
TBBPA	Tetrabrombisphenol A	Tetrabrombisfenol A	OC-CP
BPA	Bisphenol A	Bisfenol A	OC-CP
PFAS	perfluorinated alkylated substances	perfluoralkylertestoffer	
PFBS	perfluorobutane sulfonate	perfluorbutan sulfonat	PFAS
PFHxA	perfluorohexanoic acid	perfluorhexansyre	PFAS
PFHpA	perfluoroheptanoic acid	perfluorheptansyre	PFAS
PFOA	perfluorooctanoic acid	perfluoroktansyre	PFAS
PFNA	perfluorononanoic acid	perfluornonansyre	PFAS
PFOS	perfluoroctanoic sulfonate	perfluoroktansulfonat	PFAS
PFOSA	perfluoroctanesulfonic amide	perfluoroktansulfonamid	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}	
[not defined]	Alkylphenol	Akylfenoler	
[not defined]	Octylphenol	Oktylfenol	
[not defined]	Nonylphenol	Nonylfenol	
PFR	**Phosphorus Flame Retardants**	**Fosforflammehemmera**	
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*	
Delta15N	$\delta^{15}N$	$\delta^{15}N$	
Delta13C	$\delta^{13}C$	$\delta^{13}C$	
[not defined]	Trichlosan	Triklosan	
[not defined]	Dodecylfenol	Dodecylfenol	
	Phtalates	**Phtalater**	
DBP	Dibutylphthalate	Dibutylftalat	
DEHP	Di(2-ethylhexyl)-phthalate	Di(2-etylhexyl)-ftalate	
BBP	Benzylbutylphthalate	Benzylbutylftalat	
DIBP	Diisobutylphthalate	Diisobutylftalat	
[not defined]	Duiron	Durion	
[not defined]	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
VSDI	Vas Deferens Sequence Index		BEM

Abbreviation[1]	English	*Norwegian*	Param. group
INSTITUTES			
EFDH	Eurofins [DK]	*Eurofins [DK]*	
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 forluftforskning*	
NIVA	Norwegian Institute for Water Research	*Norsk institutt for vannforskning*	
SERI	Swedish Environmental Research Institute	*Institutionen för vatten- och luftvårdsforskning*	
SIIF	Fondation for Scientific and Industrial Research at the Norwegian Institute of Technology-SINTEF (a division, previously: Center for Industrial Research SI)	*Stiftelsen for industriell og teknisk forskning ved Norges tekniske høgskole- SINTEF (en avdeling, tidligere: Senter for industriforskning SI)*	
VETN	Norwegian Veterinary Institute	*Veterinærinstituttet*	
VKID	Water Quality Institute [DK]	*Vannkvalitetsintitutt [DK]*	

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

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

[3]) Indicates the sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic), so that the Klif 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 inlcludes Chrysene as cancerogenic and hence, KPAH with Chrysene should not be used in Klif's classification system for this sum-variable (Molvær *et al.* 1997).

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

*) 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
Classification of environmental quality

***Table 23**. Norwegian Environment Agency classification system of contaminants in blue mussel and fish (Molvær et al. 1997) and proposed revisions (shaded) for Class I concentrations (Knutzen & Green 2001b) used in this report.*

Contaminant			Classification (upper limit for Classes I-IV) *Degree of pollution*				
			I *Insignificant*	II *Moderate*	III *Marked*	IV *Severe*	V *Extreme*
Blue mussel							
Arsenic (As)	mg/kg	w.w. [2)]	10	30	70	140	>140
	mg/kg	d.w.	50	150	350	700	>700
Cadmium (Cd)	mg/kg	w.w. [2)]	0.4	1	4	8	>8
	mg/kg	d.w.	2	5	20	40	>40
Copper (Cu)	mg/kg	w.w. [2)]	2	6	20	40	>40
	mg/kg	d.w.	10	30	100	200	>200
Chromium (Cr)	mg/kg	w.w. [2)]	0.2	1	3	10	>10
	mg/kg	d.w.	1	5	15	50	>50
Lead (Pb)	mg/kg	w.w. [2)]	0.6	3	8	20	>20
	mg/kg	d.w.	3	15	40	100	>100
Mercury (Hg)	mg/kg	w.w. [2)]	0.04	0.1	0.3	0.8	>0.8
	mg/kg	d.w.	0.2	0.5	1.5	4	>4
Nickel (Ni)	mg/kg	w.w. [2)]	1	5	10	20	>20
	mg/kg	d.w.	5	25	50	100	>100
Silver (Ag)	mg/kg	d.w.	0.3	1	2	5	>5
Zinc (Zn)	mg/kg	w.w. [2)]	40	80	200	500	>500
	mg/kg	d.w.	200	400	1000	2500	>2500
TBT [1)]	mg/kg	d.w.	0.1	0.5	2	5	>5
∑PCB-7	µg/kg	w.w.	3 [5)]	15	40	100	>100
		d.w. [2)]	15 [2)]	75	200	500	>500
∑DDT [11)]	µg/kg	w.w.	2	5	10	30	>30
		d.w. [2)]	10	25	50	150	>150
∑HCH [12)]	µg/kg	w.w.	1	3	10	30	>30
		d.w. [2)]	5	15	50	150	>150
HCB	µg/kg	w.w.	0.1	0.3	1	5	>5
		d.w. [2)]	0.5	1.5	5	25	>25
∑PAH [13)]	µg/kg	w.w.	50	200	2000	5000	>5000
		d.w. [2)]	250	1000	10000	25000	>25000
∑KPAH	µg/kg	w.w.	10	30	100	300	>300
		d.w. [2)]	50	150	500	1500	>1500
B[*a*]P	µg/kg	w.w.	1	3	10	30	>30
		d.w. [2)]	5	15	50	150	>150
$TE_{PCDF/D}$ [3)]	µg/t [4)]	w.w.	0.2	0.5	1.5	3	>3
Cod, fillet							
Mercury (Hg)	mg/kg	w.w.	0.1	0.3	0.5	1	>1
∑PCB-7	µg/kg	w.w.	3 [6)]	20	50	150	>150
∑DDT [11)]	µg/kg	w.w.	1	3	10	25	>25
∑HCH [12]	µg/kg	w.w.	0.3 [7)]	2	5	15	>15
HCB	µg/kg	w.w.	0.2	0.5	2	5	>5
$TE_{PCDF/D}$	ng/kg	w.w.	< 0.1	0.3	1	2	> 2
Cod, liver							
∑PCB-7	µg/kg	w.w.	500	1500	4000	10000	>10000
∑DDT [11)]	µg/kg	w.w.	200 [8)]	500	1500	3000	>3000
∑HCH [12)]	µg/kg	w.w.	30 [9)]	200	500	1000	>1000
HCB	µg/kg	w.w.	20	50	200	400	>400
$TE_{PCDF/D}$ [3)]	µg/t [4)]	w.w.	10 [10)]	40	100	300	>300
Flounder, fillet							
∑PCB-7	µg/kg	w.w.	<5	20	50	150	>150
∑DDT [11)]	µg/kg	w.w.	<2	4	15	40	>40
∑HCH [12)]	µg/kg	w.w.	<1	3	10	30	>30
HCB	µg/kg	w.w.	<0.2	0.5	2	5	>5
$TE_{PCDF/D}$	ng/kg	w.w.	<0.1	0.3	1	3	>3

[1)] Tributyltin on a formula basis

[2]) Conversion assuming 20% dry weight

[3]) TCDDN (Appendix B)

[4]) µg/t = µg/ton = g/1000 kg (Appendix B)

[5]) Blue mussel-ΣPCB7: Decrease limit from 4 to 3

[6]) Cod fillet-ΣPCB7: Decrease limit from 5 to 3

[7]) Cod fillet-ΣHCH: Decrease limit from 0.5 to 0.3

[8]) Cod liver-ΣDDT: Proposal to either increase limit from 200 to 300 or, preferably, replace ΣDDT with p,p'-DDE and keep the limit (Knutzen & Green 2001b)

[9]) Cod liver-ΣHCH: Decrease limit from 50 to 30

[10]) Cod liver: TEPCDD/PCDF: Decrease limit from 15 to 10

[11]) Used in this investigation also for ppDDE

[12]) Used in this investigation also for γ-HCH (lindane)

[13]) The sum of tri- to hexacyclic PAH compounds named in EPA protocol 8310 minus naphthalene (dicyclic)-totalling 15 compounds, so that the Klif classification system can be applied

***Table 24**. Provisional "high background levels" of selected contaminants, in **mg/kg dry weight** (blue mussel) and **mg/kg wet weight** (blue mussel and fish) used in this report. The respective "high background" limits are from Knutzen & Skei (1990) with mostly minor adjustments (Knutzen & Green 1995, 2001b; Molvær et al. 1997, Green & Knutzen 2003), except for dab where the suggested limit is based on CEMP-data (Knutzen & Green 1995). Especially uncertain values are marked with "?".*

Cont.	Blue mussel [1]		Cod [1]		Flounder [1]		Dab [1]		Plaice [1]	
			liver	fillet	liver	fillet	liver	fillet	liver	fillet
	mg/kg d.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.	mg/kg w.w.
Lead	3.0 [2)]	0.6 [3)]	0.1		0.3 ?		0.3 ?		0.2 ?	
Cadmium	2.0 [2)]	0.4 [3)]	0.3		0.3 ?		0.3 ?		0.2 ?	
Copper	10 [2)]	2 [3)]	20		10 ?		30 ?		10 ?	
Mercury	0.2 [2)]	0.04 [3)]		0.1 [2)]		0.1		0.1		0.1
Zinc	200 [2)]	40 [3)]	30		50 ?		60 ?		50 ?	
∑PCB-7 [8)]	0.015[3,9)]	0.003[2 9)]	0.50 [2)]	0.003[9)]	0.1	0.003 [9)]	0.5	0.005 [9)]	0.05 ?	0.004 [9)]
ppDDE	0.010 [3)]	0.002 [6)]	0.2 [9)]		0.03	0.001 [9)]	0.1	0.002 [9)]	0.01 ? [6)]	0.001 [9)]
γ HCH	0.005 [3)]	0.001 [6)]	0.03 [9)]	0.0003[9)]	0.01	0.0003[9)]	0.03	0.0005 [9)]	0.005 ?[6)]	0.0003[9)]
HCB	0.0005 [3)]	0.0001 [2)]	0.02 [2)]		0.005	0.0001[9)]	0.01	0.0002 [9)]	0.005 ?	0.0002[9)]
TCDDN	0.000001 [3)] 0.0000002 [2)]		0.00001 [9)]							

[1]) Respectively: *Mytilus edulis*, *Gadus morhua*, *Platichthys flesus* and *Limanda limanda*

[2]) From the Norwegian Environment Agency Class I ("good") (Molvær *et al.* 1997)

[3]) Conversion assuming 20% dry weight

[4]) Approximately 25% of ΣPCB-7 (Knutzen & Green 1995)

[5]) 1.5-2 times 75% quartile (cf. Annex B in Knutzen & Green 1995)

[6]) Assumed equal to limit for ΣDDT or ΣHCH, respectively, from the Norwegian Pollution Control Authority Environmental Class I ("good") (Molvær *et al.* 1997). Hence, limits for ppDDE and γHCH are probably too high (lacking sufficient and reliable reference values)

[7]) Mean plus 2 times standard deviation (cf. Annex B in Knutzen & Green 1995)

[8]) Estimated as sum of 7 individual PCB compounds (CB-28, -52, -101, -118, -138, -153 and -180) and assumed to be ca. 50% and 70% of total PCB for blue mussel and cod/flatfish, respectively

[9]) Flounder liver: Decrease limit from 5 to 3 and from 2 to 1 for ΣPCB7 and p,p-DDE, respectively, with regard to revisions suggested by Knutzen & Green (2001b) and Green & Knutzen (2003)

Appendix D
Map of stations

Nominel station positions 1981-2012
(cf. Appendix E)

Appendix D (cont.) Map of stations

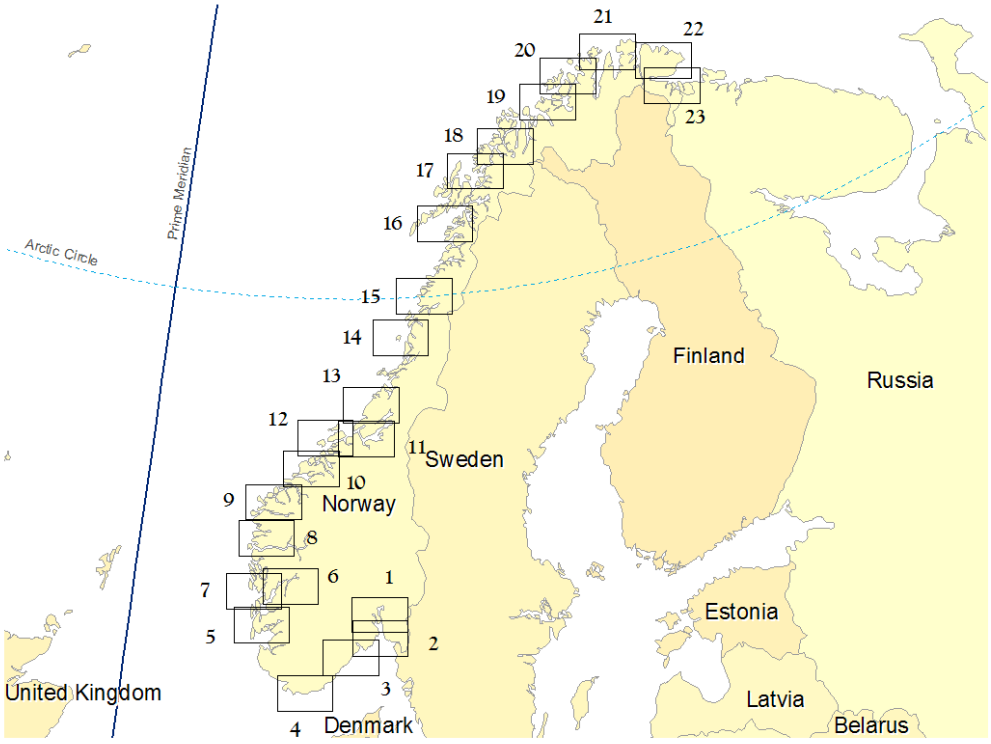
NOTES

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.

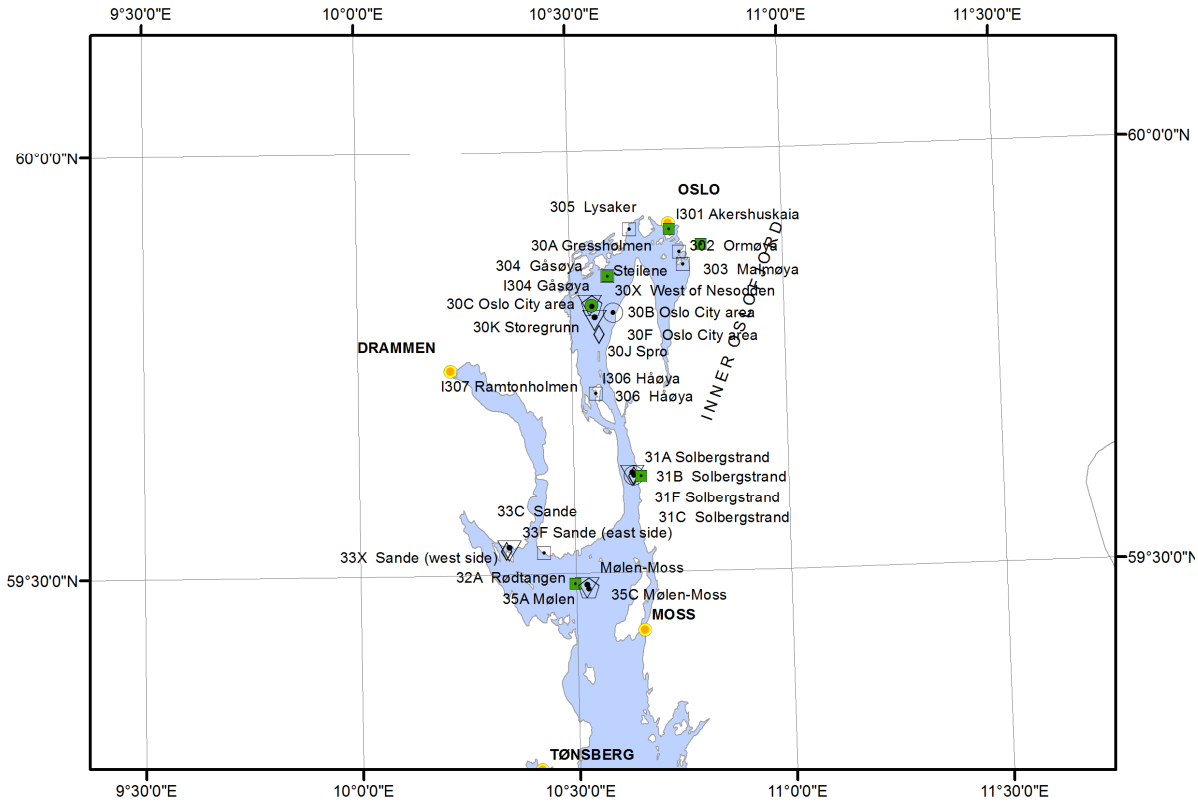
The following symbols and codes apply:

All years	2012	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	

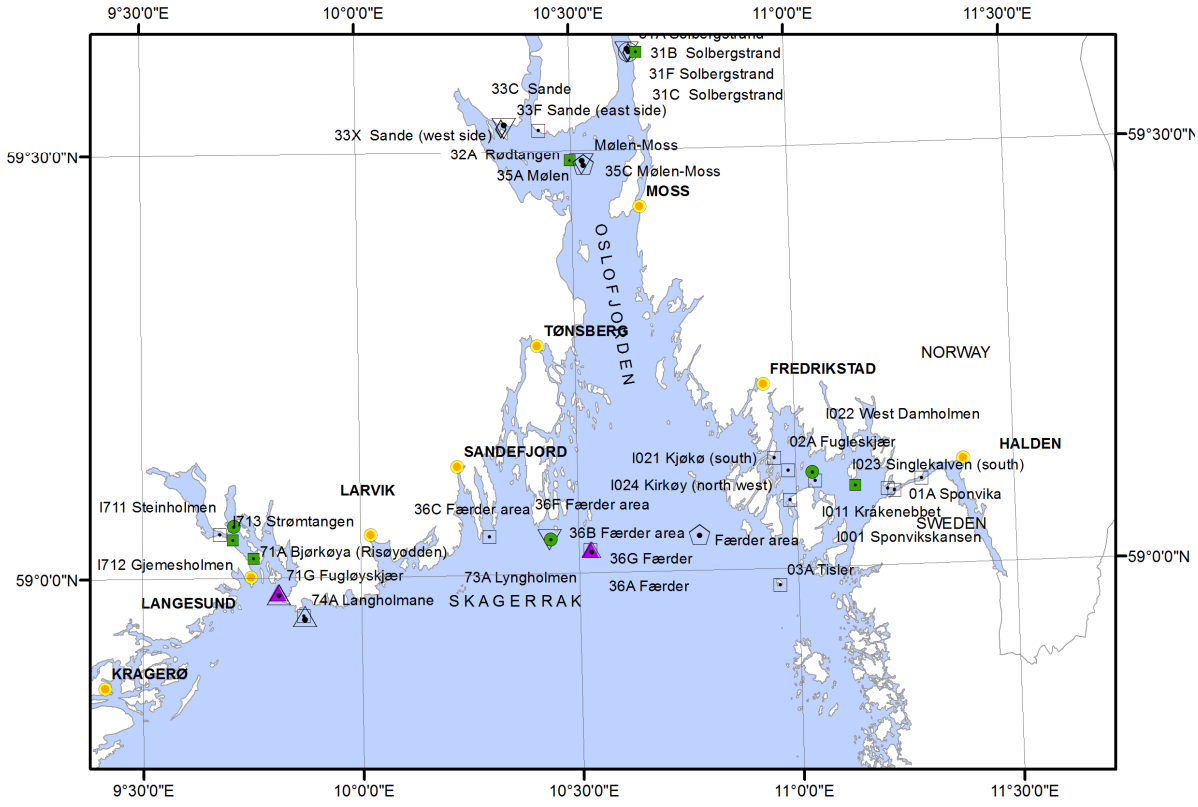
1) Supplementary station used in the blue mussel pollution (I) or reference (R) index of the Norwegian Environment Agency (cf. Green *et al*. 2011).



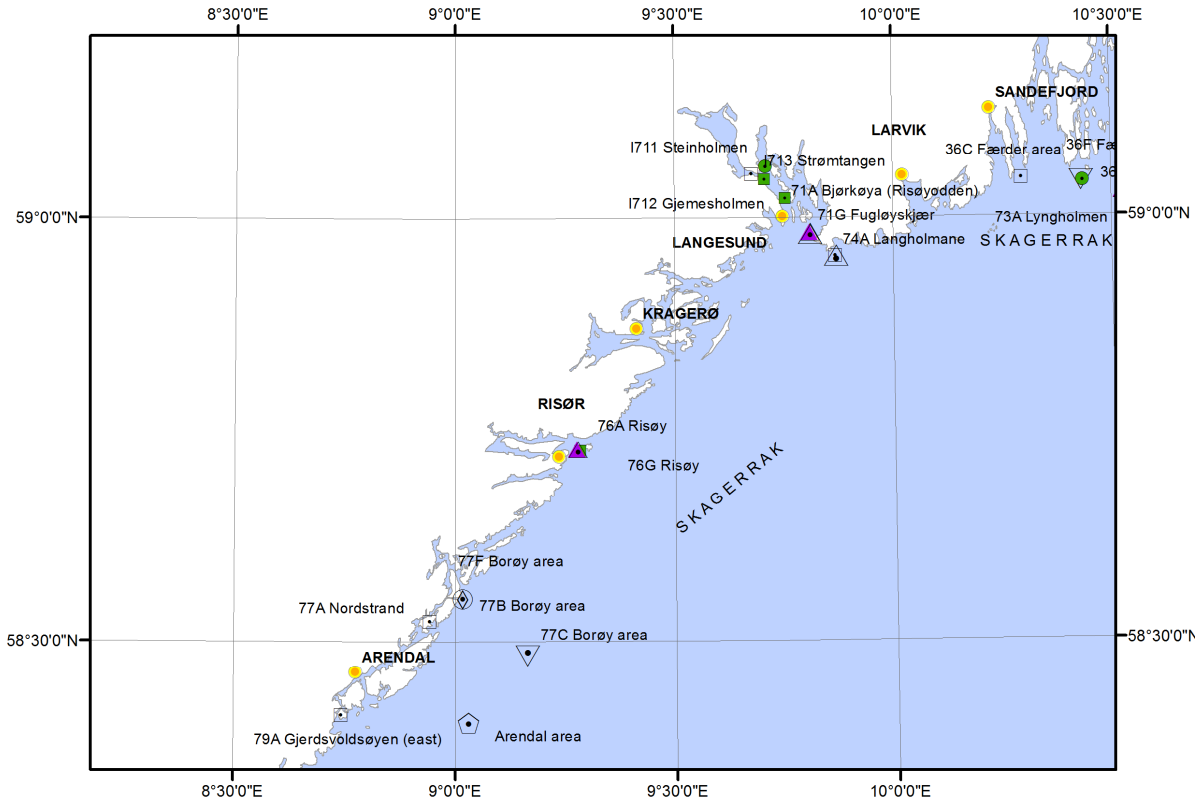
MILKYS stations Norway. Numbers indicate map reference that follow.
Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
60°0'0"N
59°30'0"N
OSLO
305 Lysaker
I301 Akershuskaia
30A Gressholmen
302 Ormøya
304 Gåsøya
Steilene
303 Malmøya
I304 Gåsøya
30X West of Nesodden
30C Oslo City area
30B Oslo City area
30K Storegrunn
30F Oslo City area
30J Spro
DRAMMEN
I306 Håøya
I307 Ramtonholmen
306 Håøya
INNER OSLOFJORD
31A Solbergstrand
31B Solbergstrand
31F Solbergstrand
31C Solbergstrand
33C Sande
33F Sande (east side)
33X Sande (west side)
Mølen-Moss
32A Rødtangen
35A Mølen
35C Mølen-Moss
MOSS
TØNSBERG

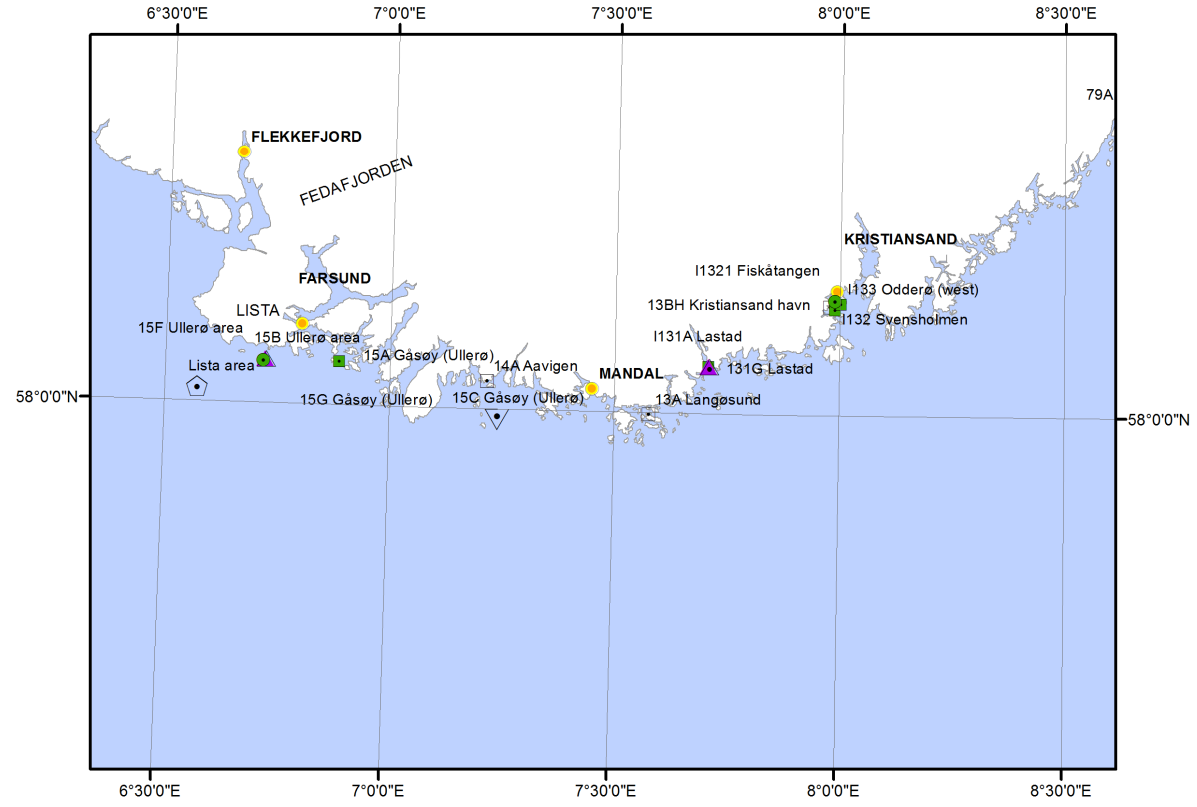
MAP 1


9°30'0"E
10°0'0"E
10°30'0"E
11°0'0"E
11°30'0"E
59°30'0"N
59°0'0"N
31B Solbergstrand
31F Solbergstrand
31C Solbergstrand
33C Sande
33F Sande (east side)
33X Sande (west side)
Mølen-Moss
32A Rødtangen
35A Mølen
35C Mølen-Moss
MOSS
OSLOFJORDEN
TØNSBERG
NORWAY
FREDRIKSTAD
I022 West Damholmen
02A Fugleskjær
HALDEN
I023 Singlekalven (south)
SANDEFJORD
I021 Kjøkø (south)
I024 Kirkøy (north west)
01A Sponvika
LARVIK
I711 Steinholmen
36C Færder area
36F Færder area
I011 Krakenebbet
SWEDEN
I713 Strømtangen
36B Færder area
Færder area
I001 Sponvikskansen
71A Bjørkøya (Risøyodden)
I712 Gjemesholmen
36G Færder
03A Tisler
71G Fugløyskjær
73A Lyngholmen
36A Færder
LANGESUND
74A Langholmane
SKAGERRAK
KRAGERØ

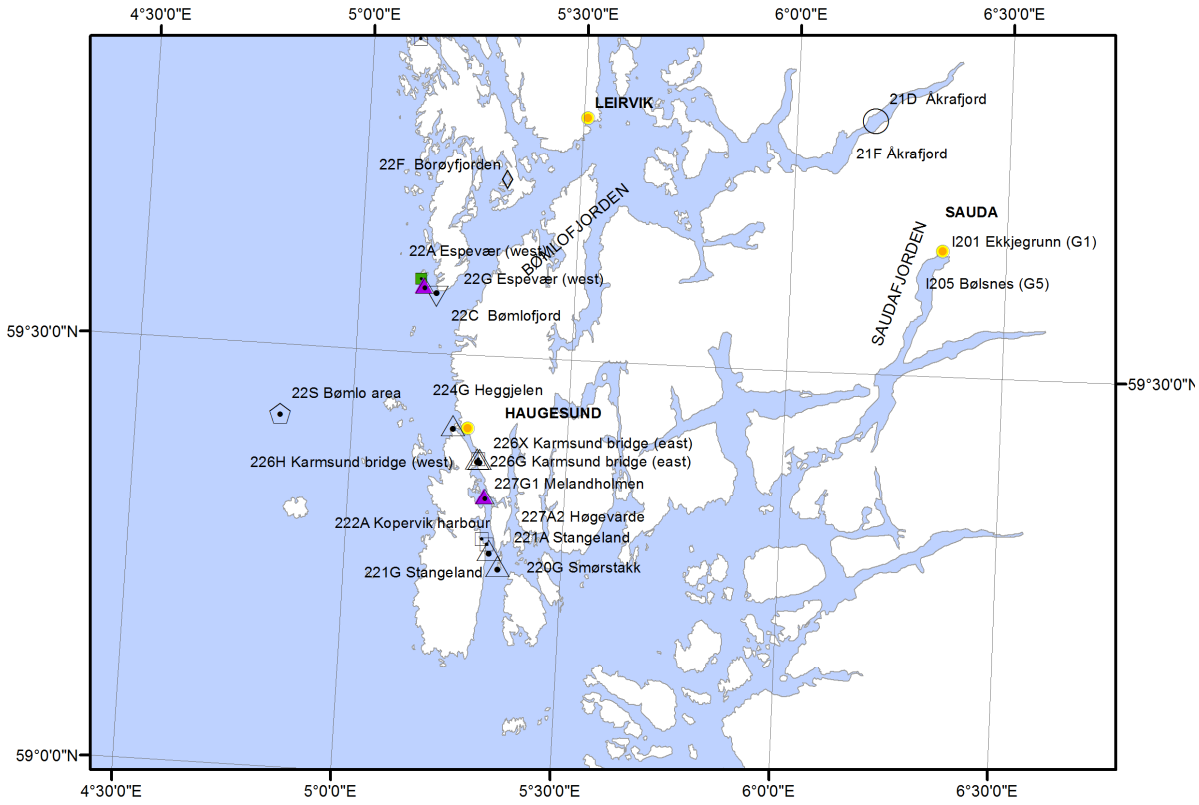
MAP 2


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
I711 Steinholmen
I713 Strømtangen
36C Færder area
71A Bjørkøya (Risøyodden)
I712 Gjemesholmen
71G Fugløyskjær
73A Lyngholmen
LANGESUND
74A Langholmane
SKAGERRAK
KRAGERØ
RISØR
76A Risøy
76G Risøy
77F Borøy area
77A Nordstrand
77B Borøy area
77C Borøy area
ARENDAL
79A Gjerdsvoldsøyen (east)
Arendal area

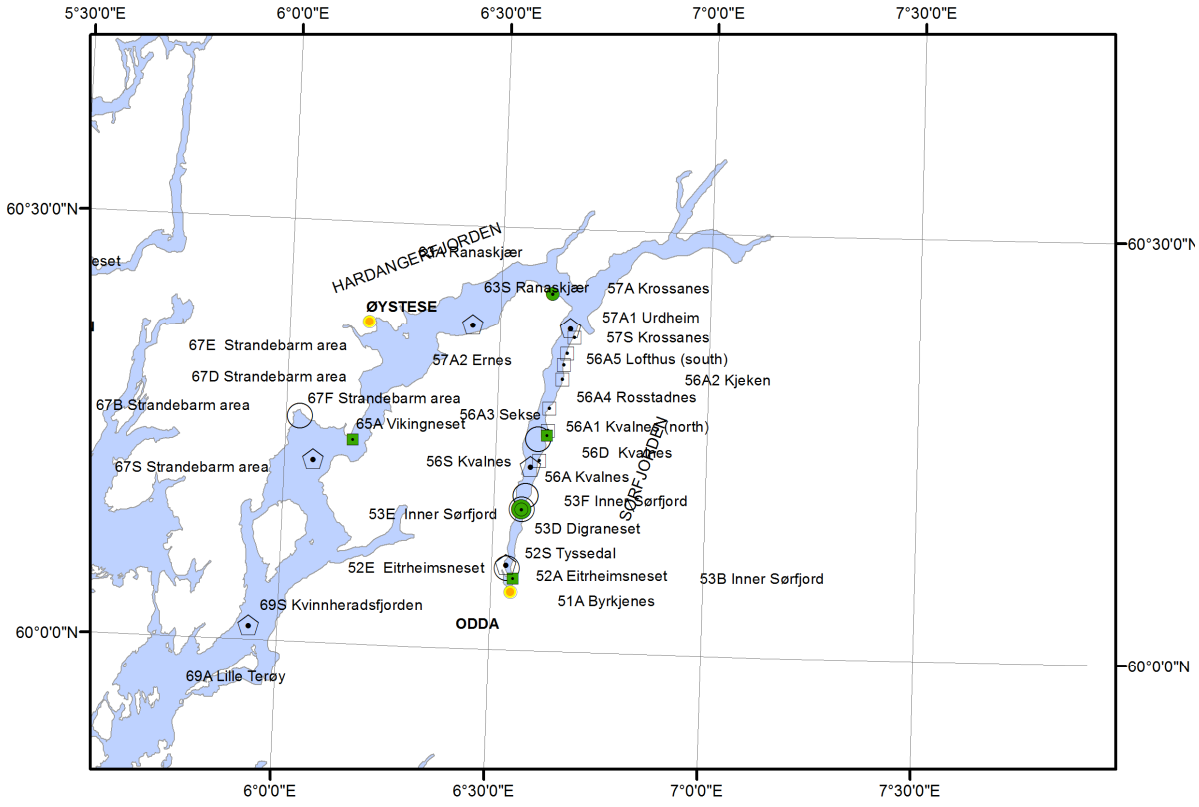
MAP 3


6°30'0"E
7°0'0"E
7°30'0"E
8°0'0"E
8°30'0"E
58°0'0"N
79A
FLEKKEFJORD
FEDAFJORDEN
KRISTIANSAND
I1321 Fiskåtangen
I133 Odderø (west)
13BH Kristiansand havn
I132 Svensholmen
FARSUND
LISTA
15F Ullerø area
15B Ullerø area
I131A Lastad
Lista area
15A Gåsøy (Ullerø)
14A Aavigen
131G Lastad
MANDAL
15G Gåsøy (Ullerø)
15C Gåsøy (Ullerø)
13A Langøsund

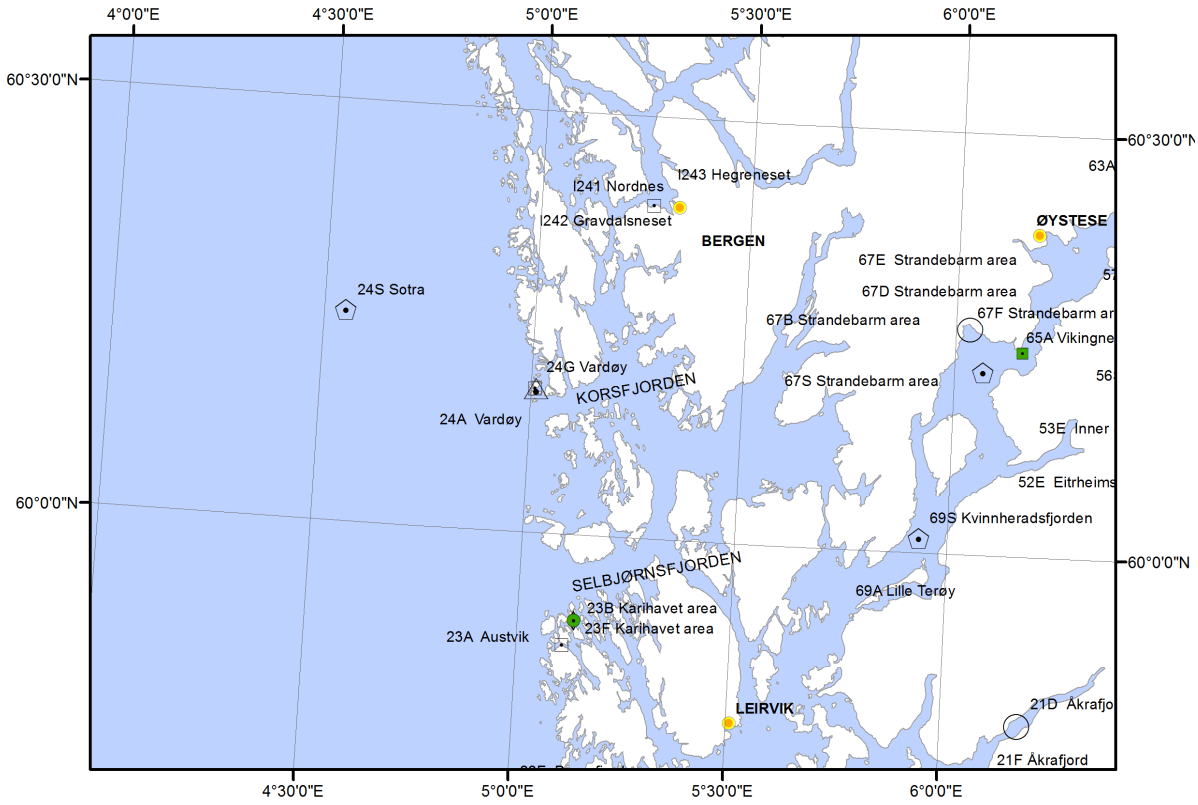
MAP 4


4°30'0"E
5°0'0"E
5°30'0"E
6°0'0"E
6°30'0"E
59°30'0"N
59°0'0"N
LEIRVIK
21D Åkrafjord
21F Åkrafjord
22F Borøyfjorden
BØMLOFJORDEN
SAUDA
SAUDAFJORDEN
I201 Ekkjegrunn (G1)
I205 Bølsnes (G5)
22A Espevær (west)
22G Espevær (west)
22C Bømlofjord
22S Bømlo area
224G Heggjelen
HAUGESUND
226X Karmsund bridge (east)
226H Karmsund bridge (west)
226G Karmsund bridge (east)
227G1 Melandholmen
222A Kopervik harbour
227A2 Høgevarde
221A Stangeland
221G Stangeland
220G Smørstakk

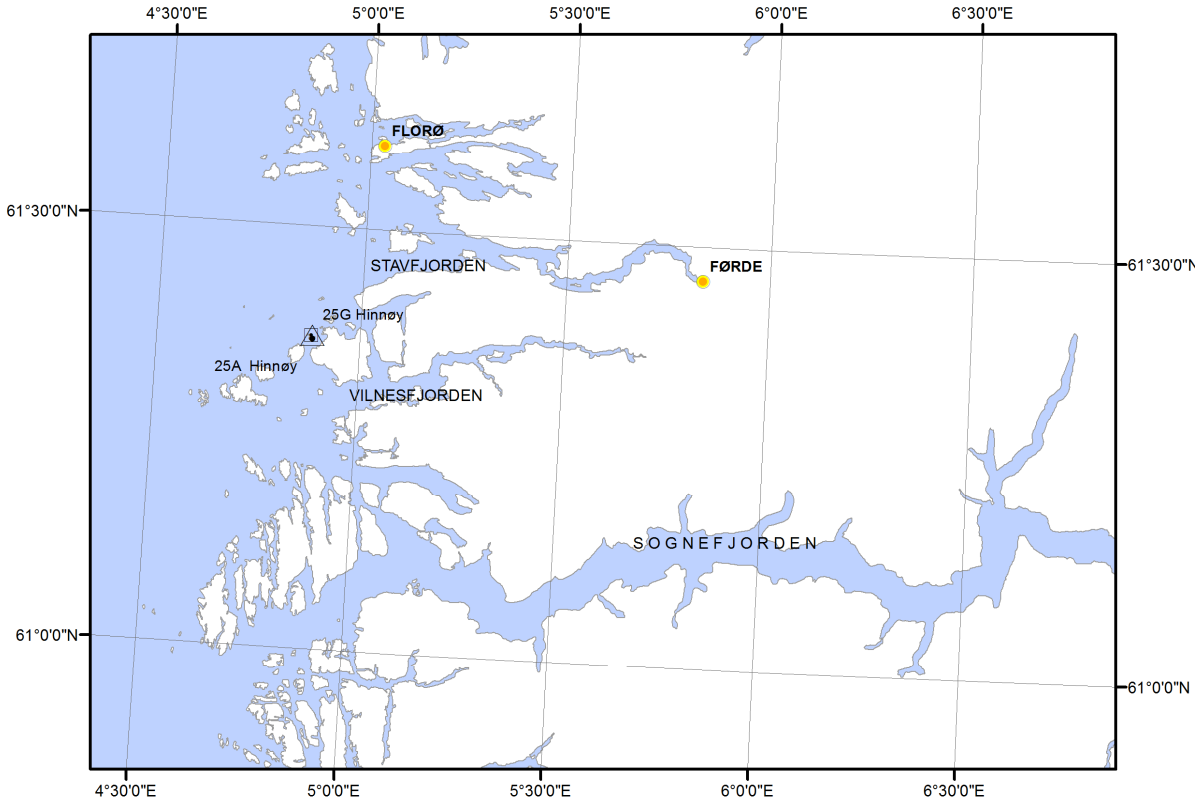
MAP 5


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
HARDANGERFJORDEN
63A Ranaskjær
63S Ranaskjær
57A Krossanes
ØYSTESE
57A1 Urdheim
57S Krossanes
67E Strandebarm area
57A2 Ernes
56A5 Lofthus (south)
67D Strandebarm area
56A2 Kjeken
67F Strandebarm area
56A4 Rosstadnes
67B Strandebarm area
56A3 Sekse
65A Vikingneset
56A1 Kvalnes (north)
56D Kvalnes
67S Strandebarm area
56S Kvalnes
56A Kvalnes
SØRFJORDEN
53F Inner Sørfjord
53E Inner Sørfjord
53D Digraneset
52S Tyssedal
52E Eitrheimsneset
52A Eitrheimsneset
53B Inner Sørfjord
51A Byrkjenes
69S Kvinnheradsfjorden
ODDA
69A Lille Terøy

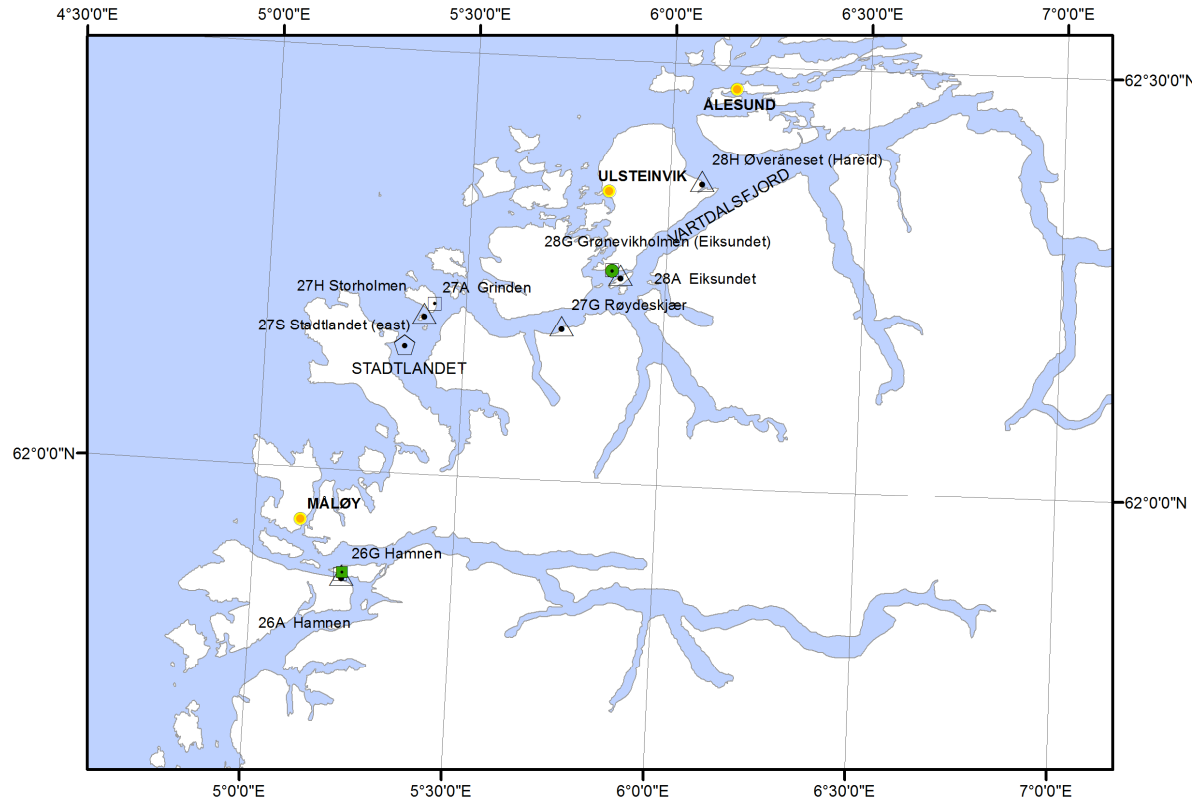
MAP 6


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
1243 Hegreneset
1241 Nordnes
1242 Gravdalsneset
BERGEN
ØYSTESE
67E Strandebarm area
67D Strandebarm area
67B Strandebarm area
67S Strandebarm area
24S Sotra
24G Vardøy
24A Vardøy
KORSFJORDEN
53E Inner
52E Eitrheims
69S Kvinnheradsfjorden
SELBJØRNSFJORDEN
69A Lille Terøy
23B Karihavet area
23F Karihavet area
23A Austvik
LEIRVIK
21F Åkrafjord

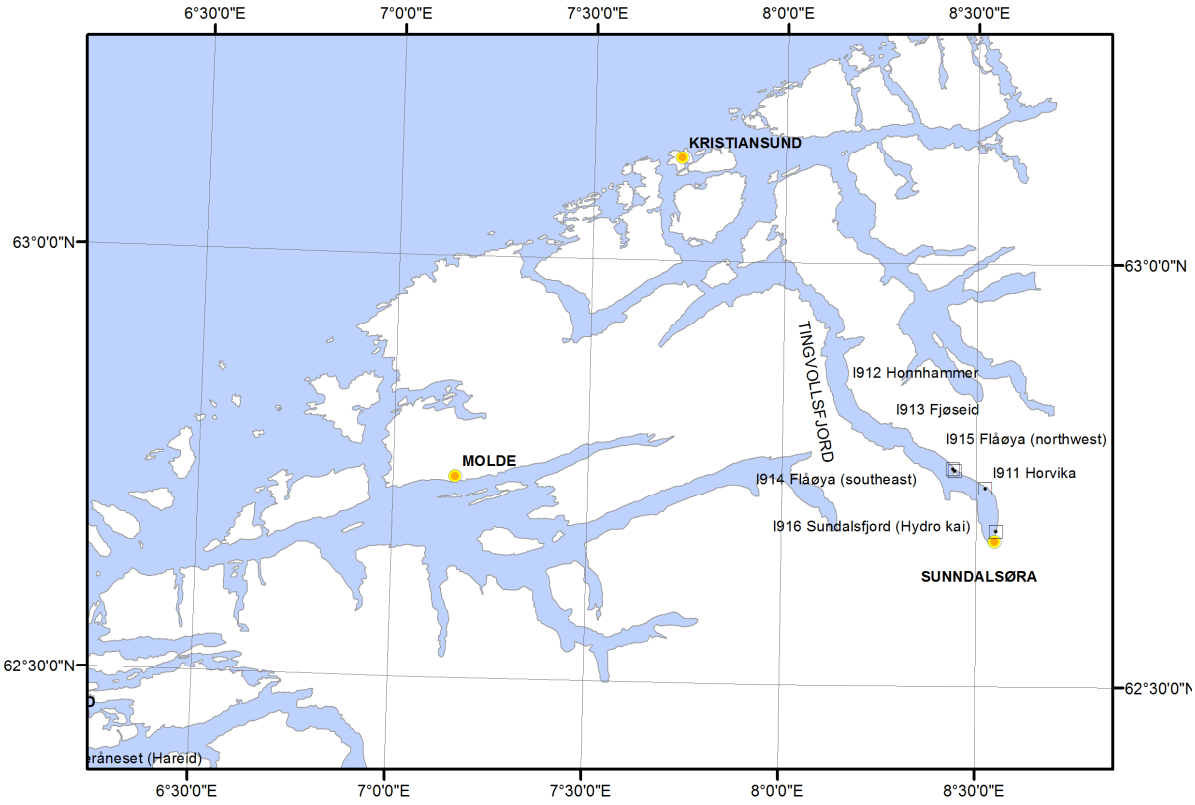
MAP 7


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
STAVFJORDEN
FØRDE
25G Hinnøy
25A Hinnøy
VILNESFJORDEN
SOGNEFJORDEN

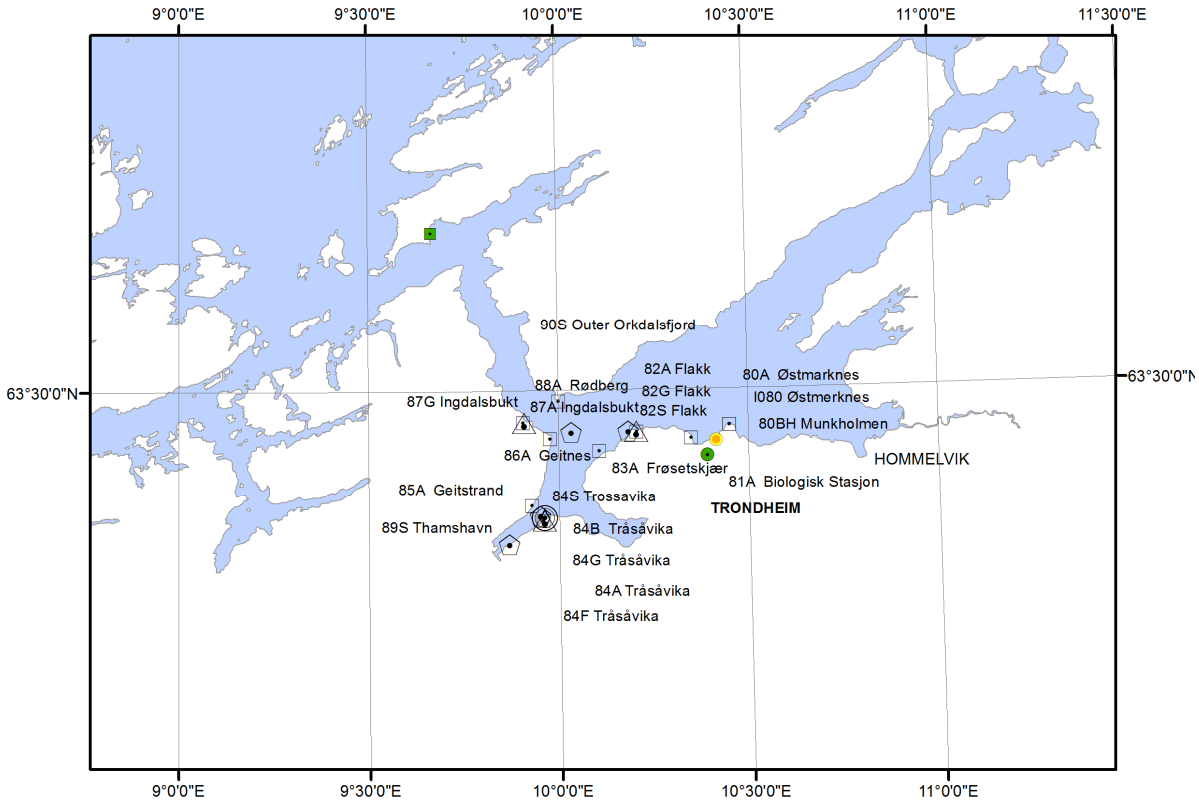
MAP 8


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
28H Øveråneset (Hareid)
ULSTEINVIK
VARTDALSFJORD
28G Grønevikholmen (Eiksundet)
28A Eiksundet
27H Storholmen
27A Grinden
27G Røydeskjær
27S Stadtlandet (east)
STADTLANDET
MÅLØY
26G Hamnen
26A Hamnen

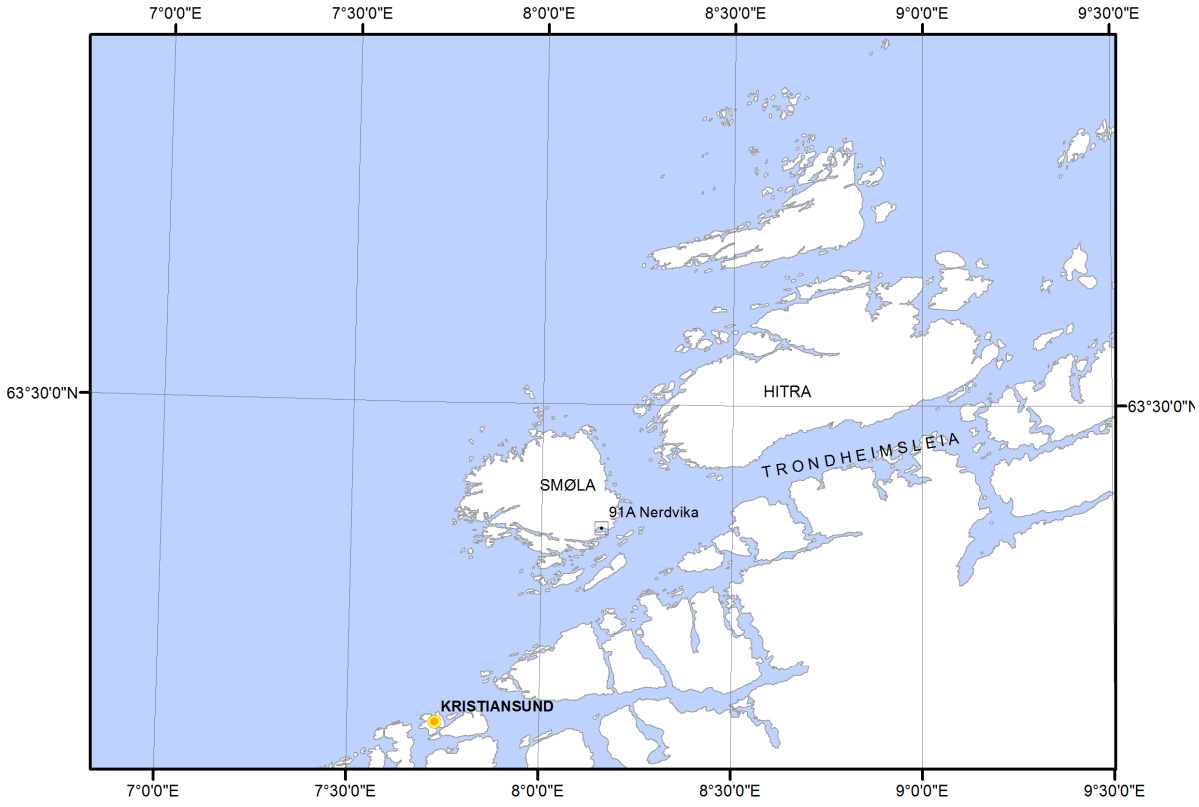
MAP 9


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
TINGVOLLSFJORD
I912 Honnhammer
I913 Fjøseid
I915 Flåøya (northwest)
I911 Horvika
MOLDE
I914 Flåøya (southeast)
I916 Sundalsfjord (Hydro kai)
SUNNDALSØRA

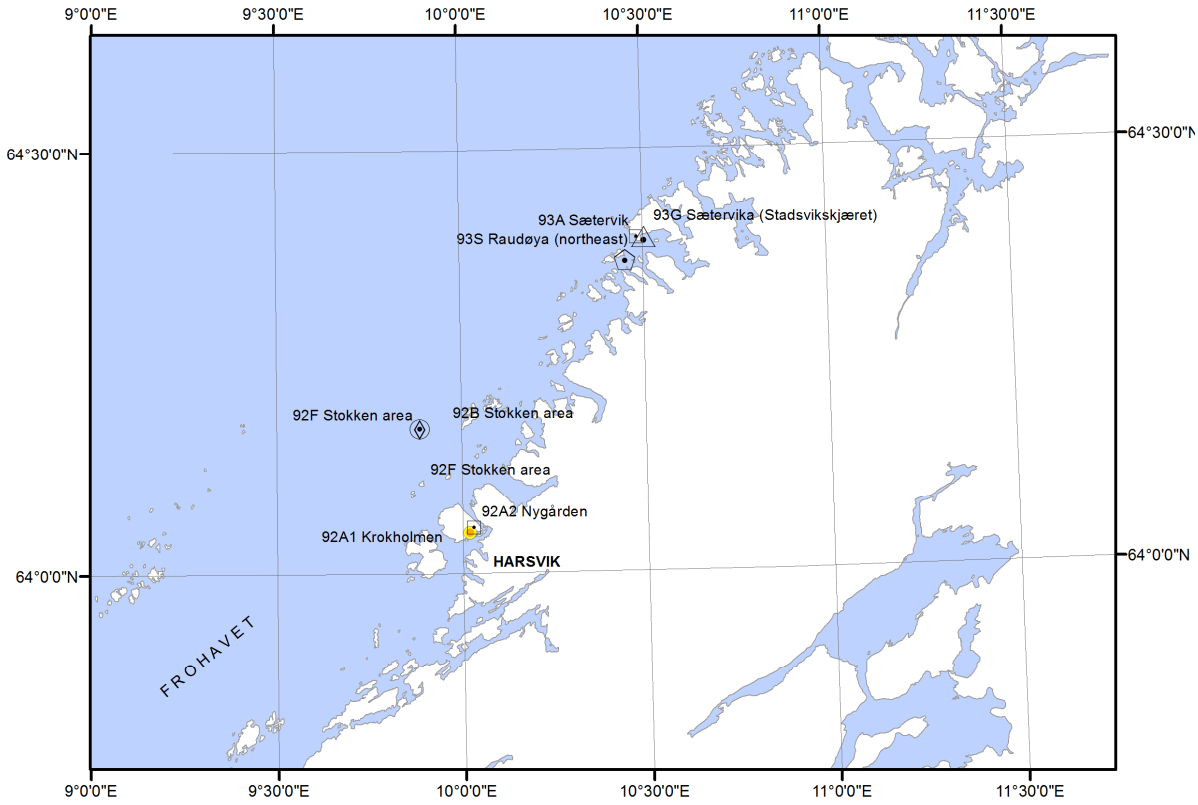
MAP 10


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
90S Outer Orkdalsfjord
82A Flakk
80A Østmarknes
88A Rødberg
82G Flakk
I080 Østmerknes
87G Ingdalsbukt
87A Ingdalsbukt
82S Flakk
80BH Munkholmen
86A Geitnes
83A Frøsetskjær
HOMMELVIK
85A Geitstrand
84S Trossavika
81A Biologisk Stasjon
TRONDHEIM
89S Thamshavn
84B Tråsåvika
84G Tråsåvika
84A Tråsåvika
84F Tråsåvika

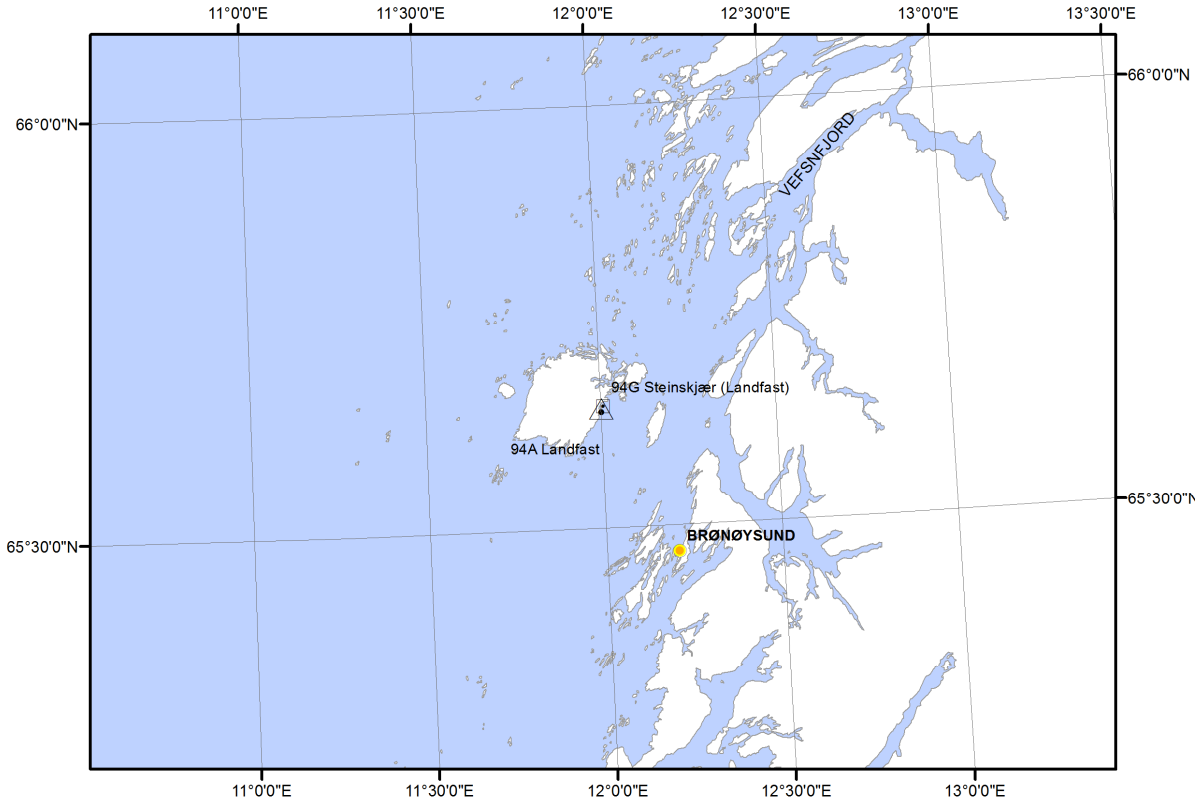
MAP 11


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
HITRA
TRONDHEIMSLEIA
SMØLA
91A Nerdvika
KRISTIANSUND

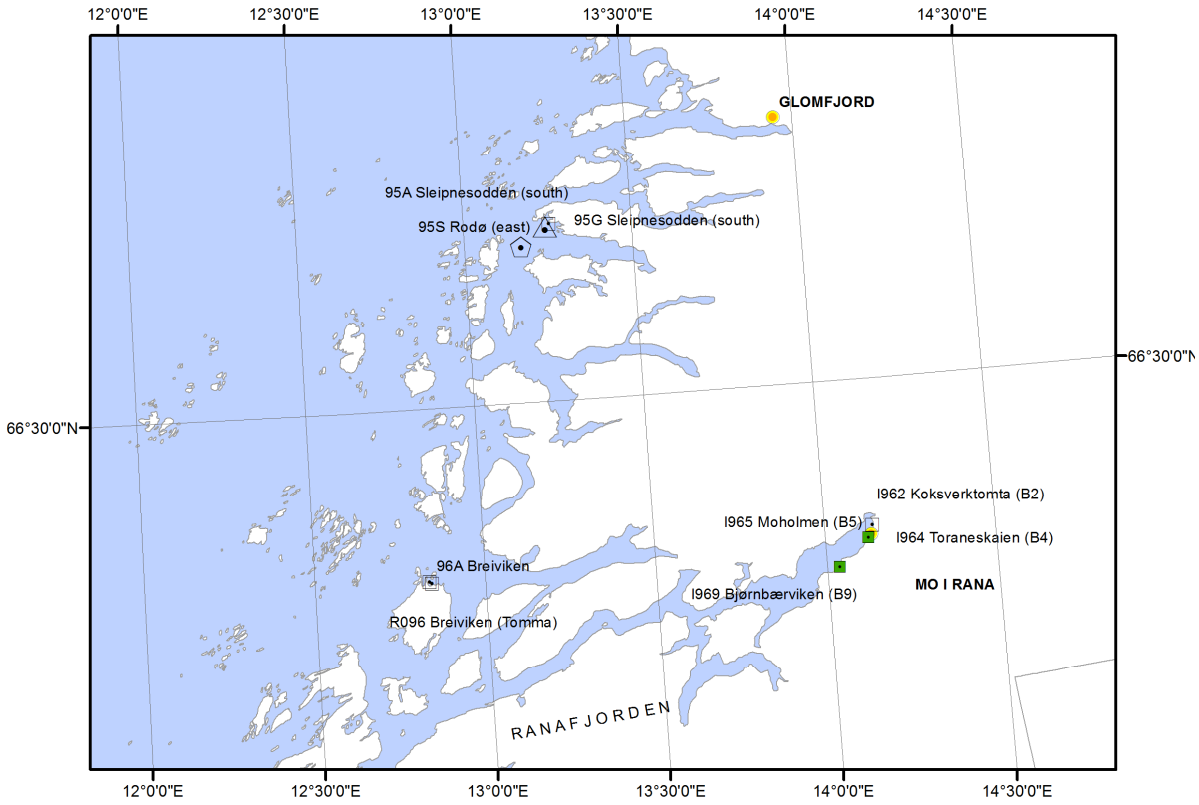
MAP 12


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)
93S Raudøya (northeast)
92F Stokken area
92B Stokken area
92F Stokken area
92A2 Nygården
92A1 Krokholmen
HARSVIK
FROHAVET

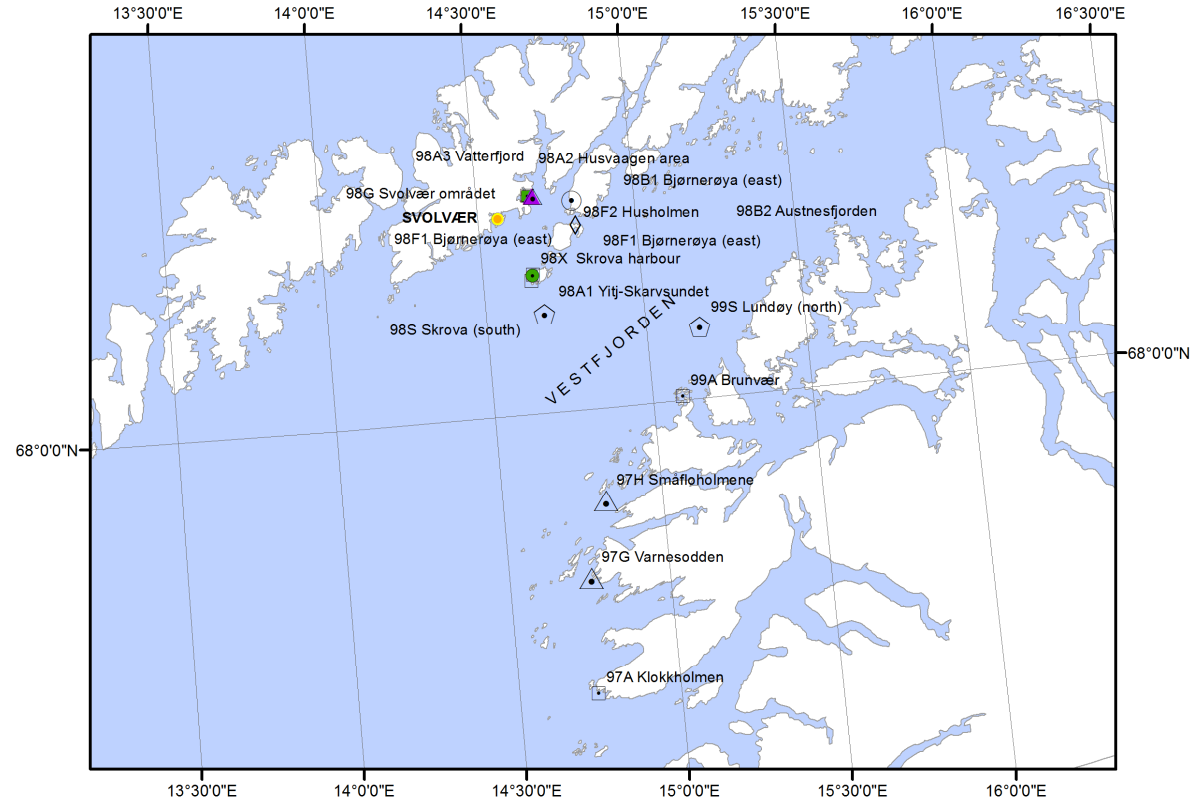
MAP 13


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
VEFSNFJORD
94G Steinskjær (Landfast)
94A Landfast
BRØNØYSUND

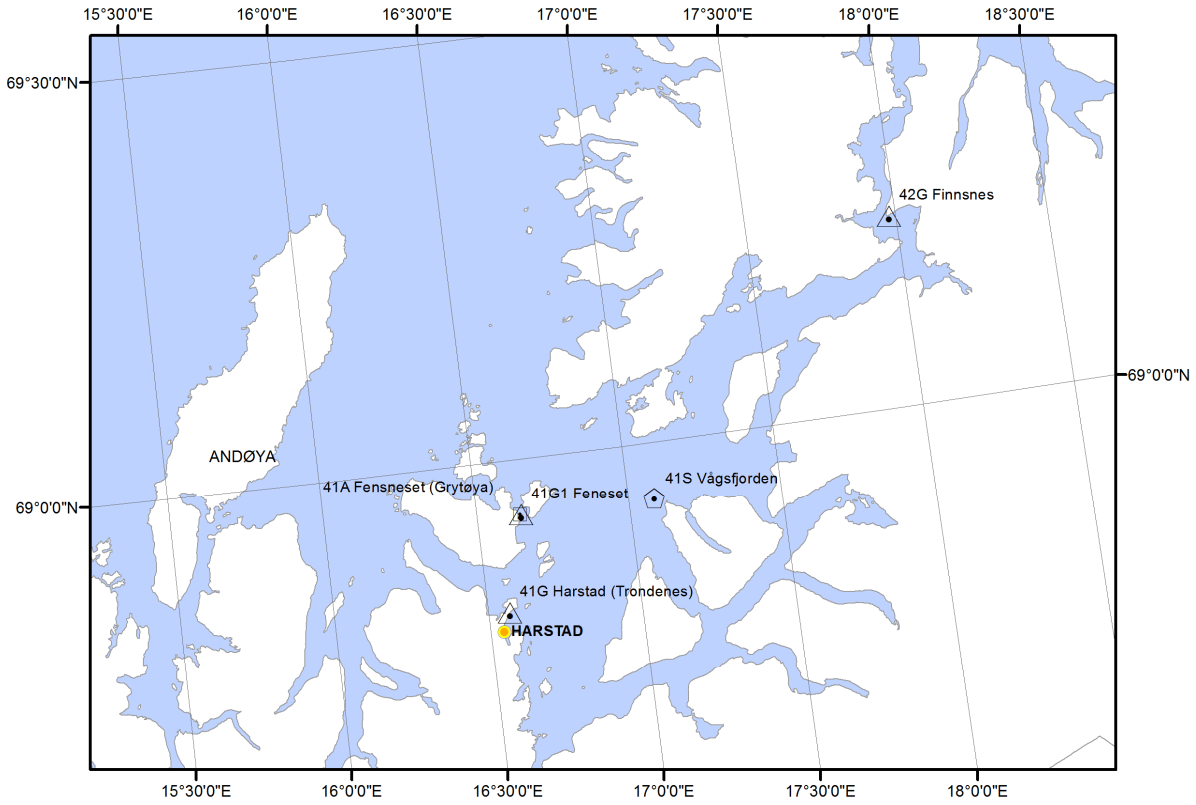
MAP 14


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
95A Sleipnesodden (south)
95S Rodø (east)
95G Sleipnesodden (south)
I962 Koksverktomta (B2)
I965 Moholmen (B5)
I964 Toraneskaien (B4)
96A Breiviken
MO I RANA
I969 Bjørnbærviken (B9)
R096 Breiviken (Tomma)
RANAFJORDEN

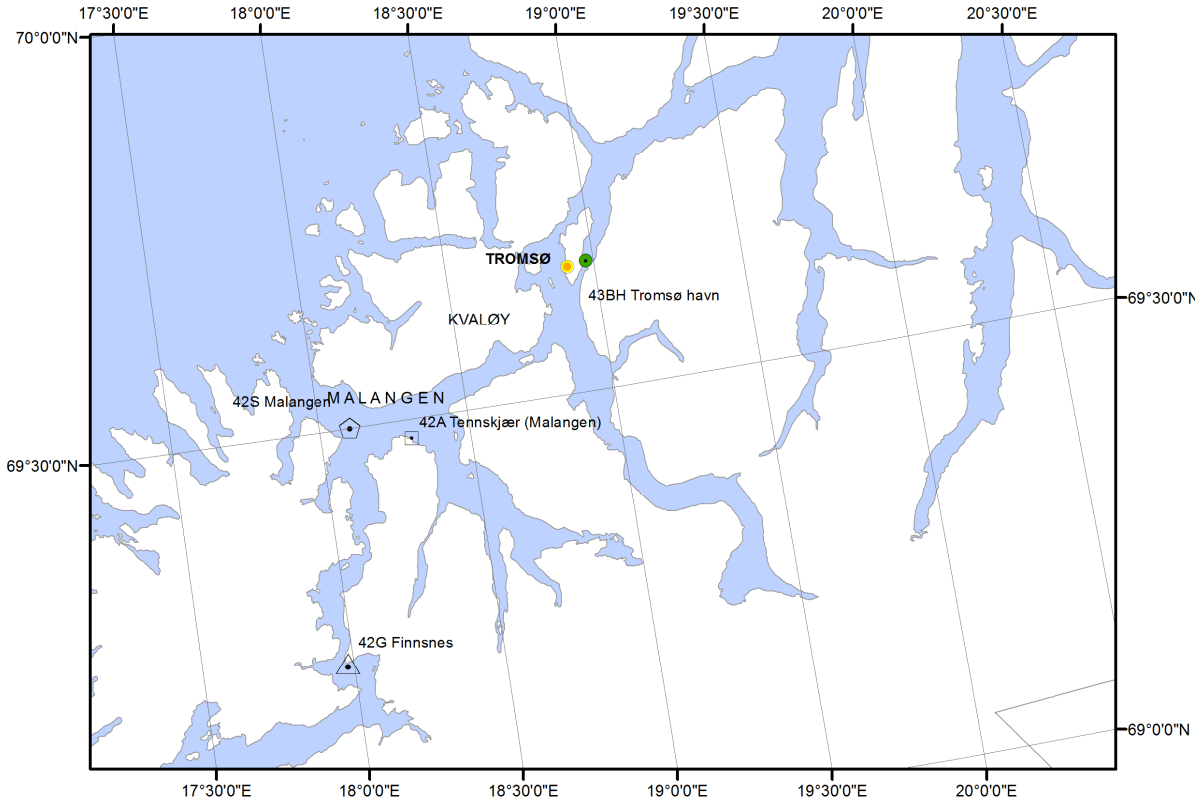
MAP 15


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
98A3 Vatterfjord
98A2 Husvaagen area
98B1 Bjørnerøya (east)
98G Svolvær området
SVOLVÆR
98F2 Husholmen
98B2 Austnesfjorden
98F1 Bjørnerøya (east)
98F1 Bjørnerøya (east)
98X Skrova harbour
98A1 Yitj-Skarvsundet
99S Lundøy (north)
98S Skrova (south)
VESTFJORDEN
99A Brunvær
97H Smafloholmene
97G Varnesodden
97A Klokkholmen

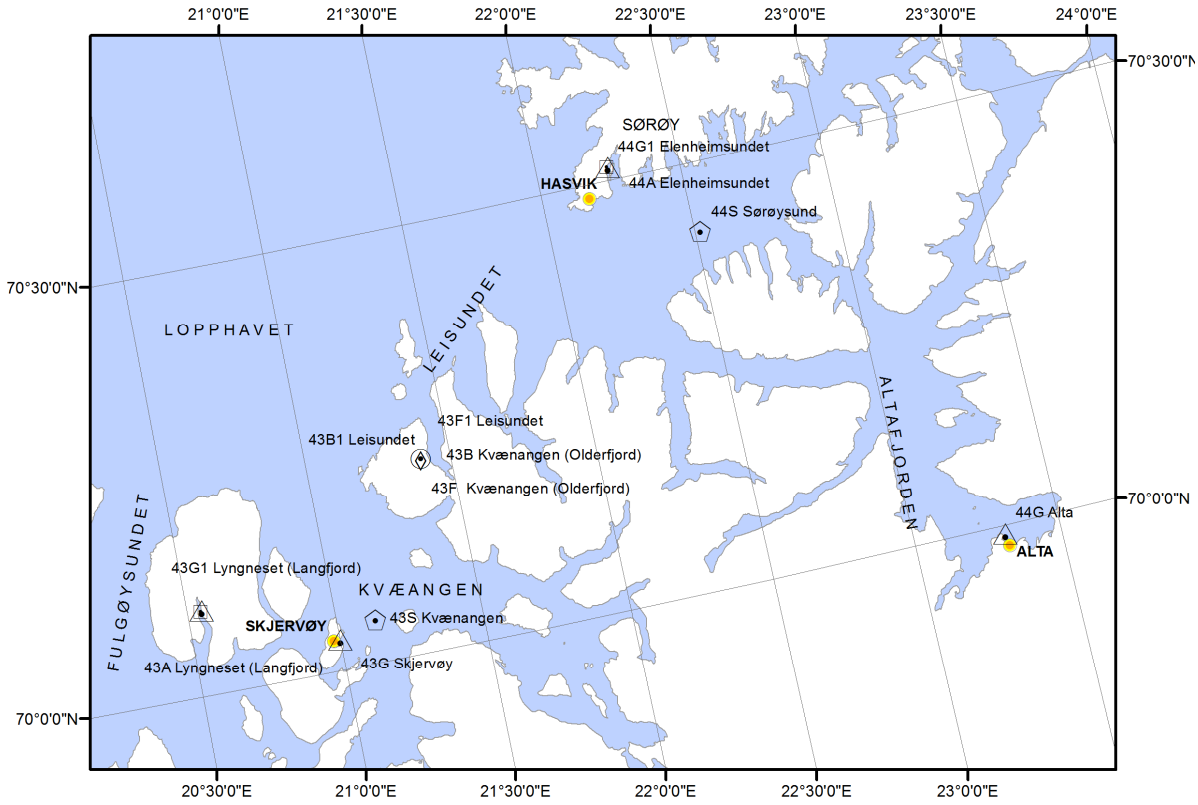
MAP 16


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
ANDØYA
41A Fensneset (Grytøya)
41G1 Feneset
41S Vågsfjorden
41G Harstad (Trondenes)
HARSTAD

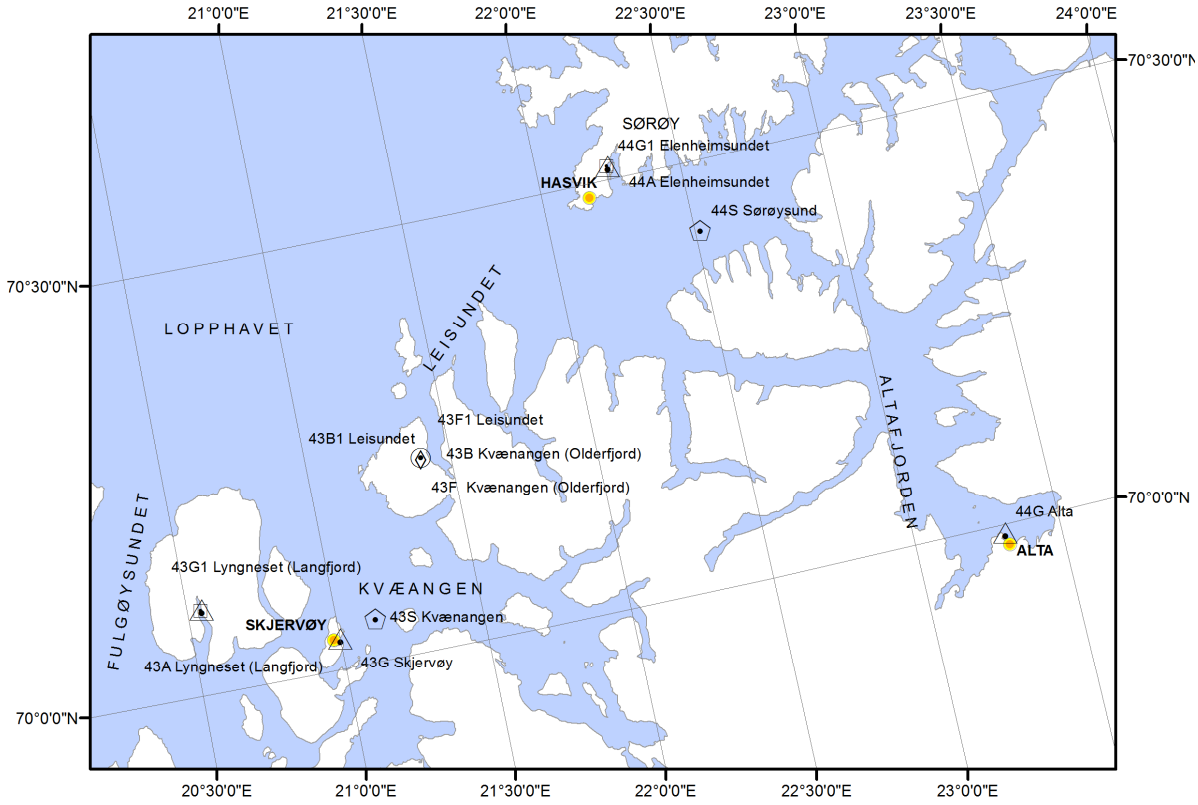
MAP 17


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
43BH Tromsø havn
KVALØY
42S Malangen
MALANGEN
42A Tennskjær (Malangen)
42G Finnsnes

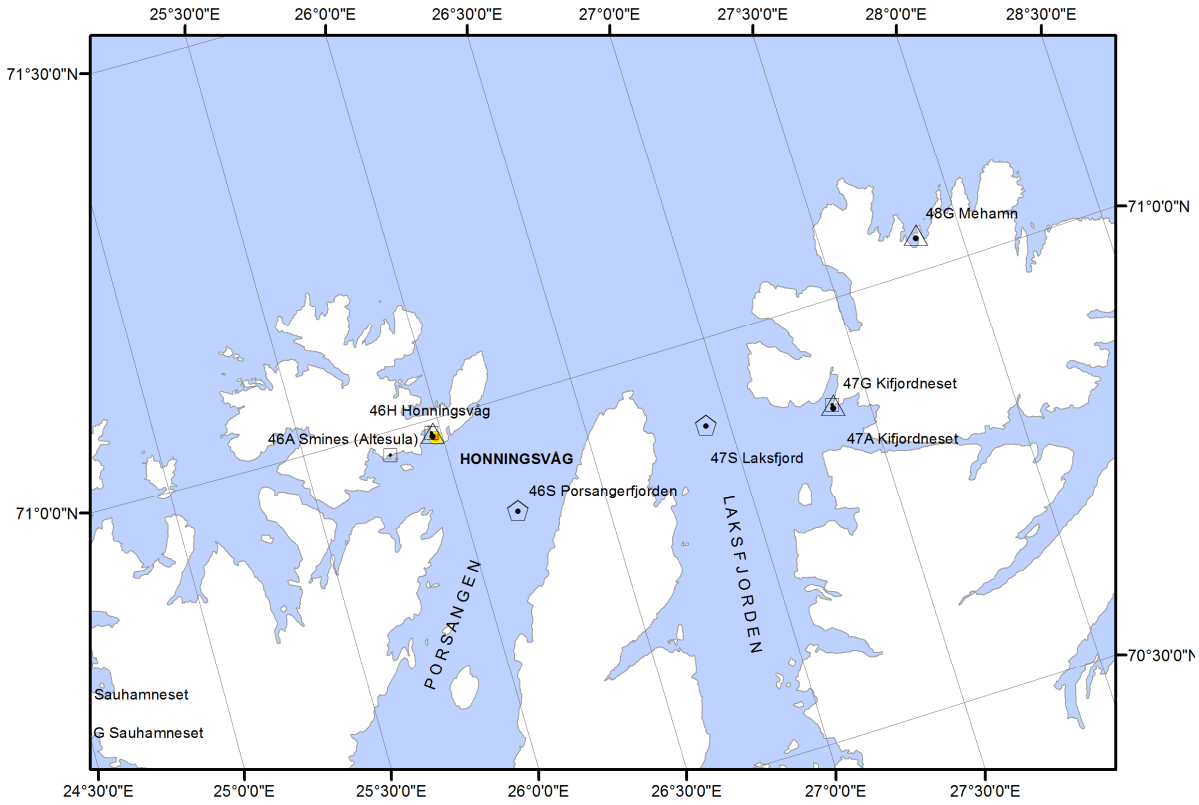
MAP 18


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
SØRØY
44G1 Elenheimsundet
HASVIK
44A Elenheimsundet
44S Sørøysund
LOPPHAVET
LEISUNDET
ALTAFJORDEN
43F1 Leisundet
43B1 Leisundet
43B Kvænangen (Olderfjord)
43F Kvænangen (Olderfjord)
44G Alta
ALTA
FULGØYSUNDET
43G1 Lyngneset (Langfjord)
KVÆANGEN
43S Kvænangen
SKJERVØY
43A Lyngneset (Langfjord)
43G Skjervøy

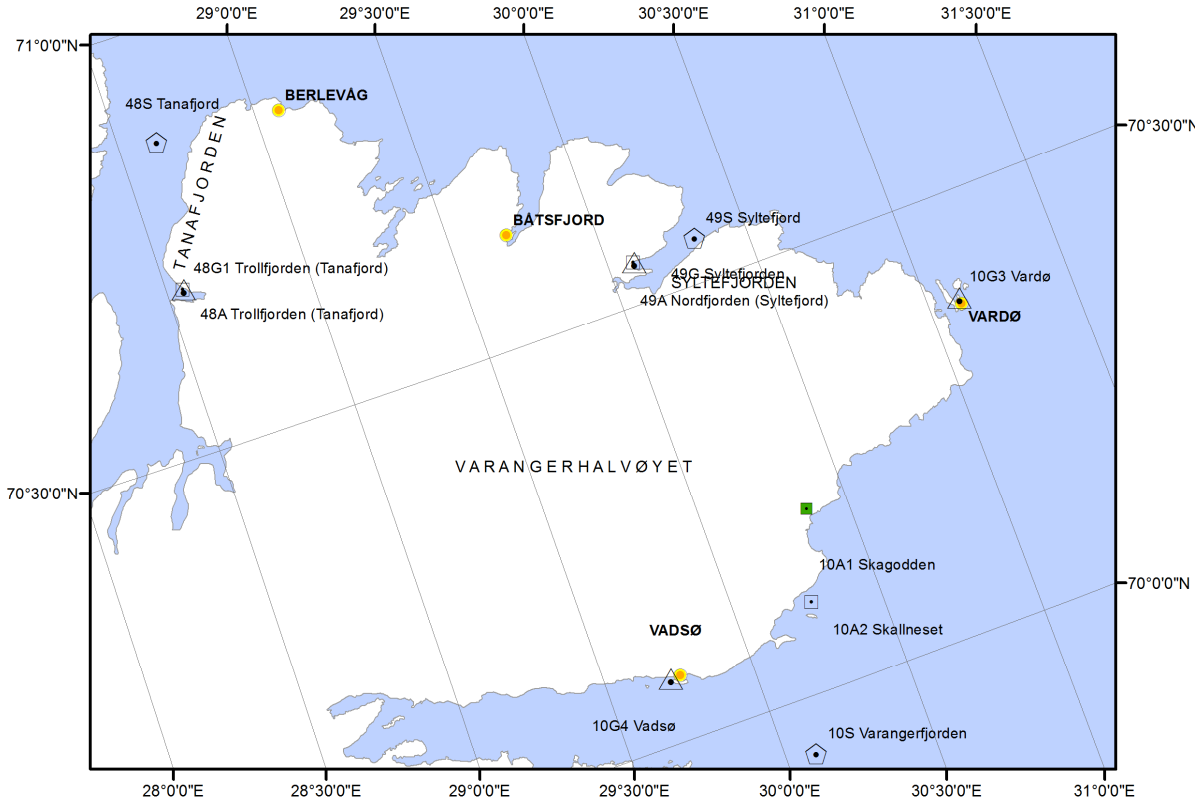
MAP 19


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
SØRØY
44G1 Elenheimsundet
HASVIK
44A Elenheimsundet
44S Sørøysund
LOPPHAVET
LEISUNDET
ALTAFJORDEN
43F1 Leisundet
43B1 Leisundet
43B Kvænangen (Olderfjord)
43F Kvænangen (Olderfjord)
44G Alta
ALTA
FULGØYSUNDET
43G1 Lyngneset (Langfjord)
KVÆANGEN
43S Kvænangen
SKJERVØY
43A Lyngneset (Langfjord)
43G Skjervøy

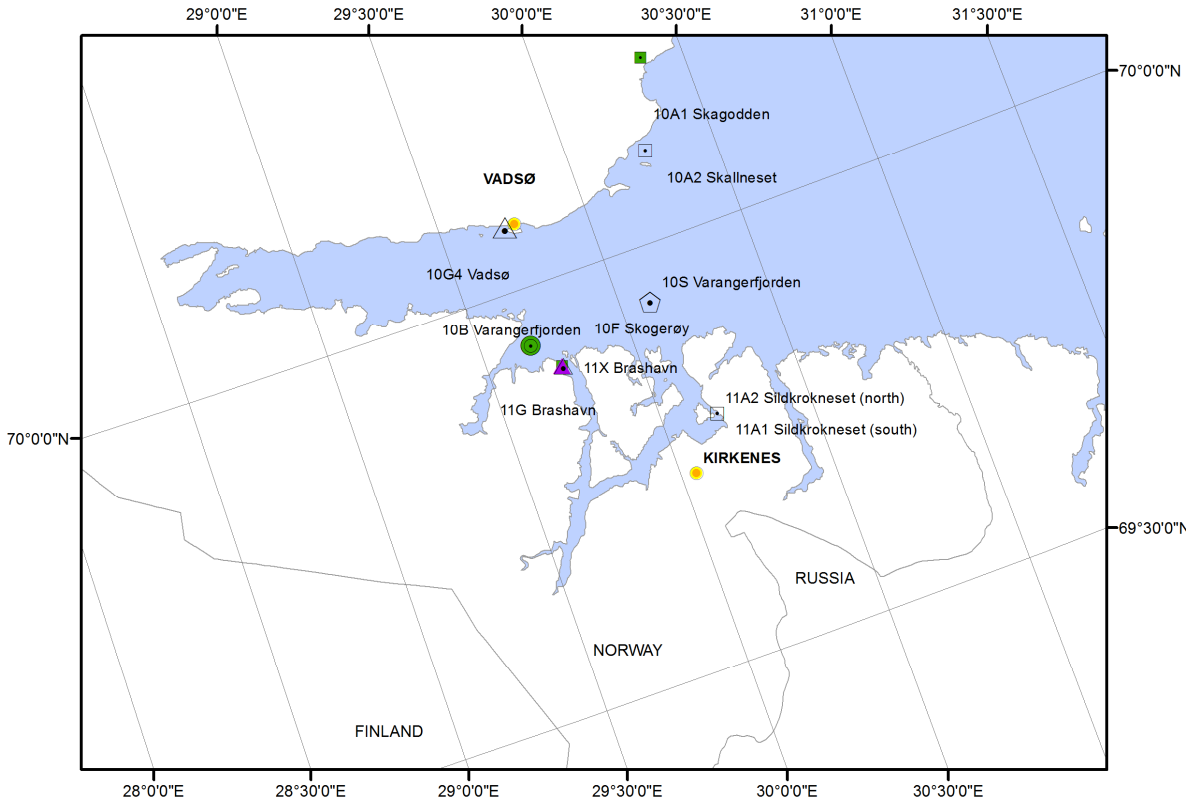
MAP 20


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
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
48G Mehamn
47G Kifjordneset
47A Kifjordneset
46H Honningsvåg
46A Smines (Altesula)
HONNINGSVÅG
47S Laksfjord
46S Porsangerfjorden
PORSANGEN
LAKSFJORDEN
Sauhamneset
G Sauhamneset

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
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
48S Tanafjord
BERLEVÅG
TANAFJORDEN
BATSFJORD
49S Syltefjord
48G1 Trollfjorden (Tanafjord)
48A Trollfjorden (Tanafjord)
49G Syltefjorden
SYLTEFJORDEN
49A Nordfjorden (Syltefjord)
10G3 Vardø
VARDØ
VARANGERHALVØYET
10A1 Skagodden
10A2 Skallneset
VADSØ
10G4 Vadsø
10S Varangerfjorden

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
10A1 Skagodden
10A2 Skallneset
VADSØ
10G4 Vadsø
10S Varangerfjorden
10B Varangerfjorden
10F Skogerøy
11X Brashavn
11G Brashavn
11A2 Sildkrokneset (north)
11A1 Sildkrokneset (south)
KIRKENES
RUSSIA
NORWAY
FINLAND

MAP 23

Appendix E
Overview of materials and analyses 2011-2012

Nominal station positions are shown on maps in Appendix D

Me-Blue Mussel (*Mytilus edulis*)
Nl-Dog whelk (*Nucella lapillus*)
Gm-Atlantic cod (*Gadus morhua*)
Fl-flat fish:
Megrim (*Lepidorhombus whiff-iagonis*)
Dab (*Limanda limanda*)
Flounder (*Platichthys flesus*)

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

myear:
2011t - samples taken in 2011
2012p – samples planned in 2012
2012t – samples taken in 2012

Overview follows on next page

Parameter-group codes (See Appendix B for descriptions of codes):

code	Description	Me-SB	NI-SB	Gm-BI	Gm-BL	Gm/Ff-LI	Gm/Ff-MU
I-MET	Cd, Cu, Pb, Zn	x				x	
I-MET	Hg	x					x
ISOTO	$\delta^{15}N$ and $\delta^{13}C$	x				x	
O-BR	PBDE [4)]		x			x [3)]	
O-MET	TBT [1)]	x	x			x [3)]	
OC-CB	PCBs [2)]	x				x	x
OC-CL	HCB	x				x	x
OC-CP	SCCP, MCCP						
OC-DD	DDT, DDE, DDD	x				x	x
OC-HC	α-, γ-HCH	x				x	x
OC-DX	Dioxins [3)]	x					
OC-PF	PFAS [5)]					x [3)]	
PAH	PAHs [6)]	x					
PFR	PFRs [7)]						
PHC	PHCs [8)]						
BE [9)]	Biological effects met.		Impo-sex	OH-pyrene	ALA-D	EROD-activity, CYP1A [10)]	

[1)] Includes: DBTIN, DPTIN, MBTIN, MPTIN, TBTIN, TPTIN

[2)] Includes a selection of the congeners: CB-28,-52,-101,-105,-118,-138,-153,-156,-180, 209, 5-CB, OCS and, when dioxins are analysed, the non-orto-PCBs, i.e. CB-77, -81, -126, -169

[3)] Includes: CDD1N, CDD4X, CDD6P, CDD6X, CDD9X, CDDO, CDF2N, CDF2T, CDF4X, CDF6P, CDF6X, CDF9P, CDF9X, CDFDN, CDFDX, CDFO,TCDD

[4)] Polybrominated diphenyl ethers (PBDE), 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,

[5)] Includes: PFNA, PFOA, PFHpA, PFHxA, PFOS, PFBS, PFOSA

[6)] Includes (with NPDs): ACNE, ACNLE, ANT, BAP, BBJF, BEP, BGHIP, BKF. BAA. CHR, DBA3A, DBT, DBTC1, DBTC2, DBTC3, FLE, FLU, ICDP, NAP, NAPC1, NAPC2, NAPC3, PA, PAC1, PAC2, PAC3, PER, PYR.

[7)] PFR – Phosphorus Flame Retardants and includes a selection of: TIBP, TBP, TCEP, TCPP, TDCP, TBEP, TPhP, EHDPP, V6, DBPhP, BdPhP, TEHP, ToCrP, TCrP

[8)] PHC – phenols including BPA, TBBPA

[9)] Biological effects methods

[10)] Cod only

***Appendix E**. Sampling and analyses for 2011-2012 -biota.*

myear	STATION _CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2011t	15B	Ullerø area	58.05	6.7166667	GADU MOR	BI	25													19		
2011t	23B	Karihavet area	59.9	5.1333333	GADU MOR	BI	25													25		
2011t	30B	Oslo City area	59.816667	10.55	GADU MOR	BI	25													17		
2012p	30B	Oslo City area	59.8167	10.5500	GADU MOR	BI	15													15		
2012t	30B	Oslo City area	59.816667	10.55	GADU MOR	BI	15													15		
2011t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	BI	25													25		
2011t	23B	Karihavet area	59.9	5.1333333	GADU MOR	BL	25													25		
2011t	30B	Oslo City area	59.816667	10.55	GADU MOR	BL	25													25		
2012p	30B	Oslo City area	59.8167	10.5500	GADU MOR	BL	15													15		
2012t	30B	Oslo City area	59.816667	10.55	GADU MOR	BL	15													15		
2011t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	BL	25													25		
2012p	02B	Hvaler area, Kirkøy north	59.1125	11.0388	GADU MOR	LI	15	15		15	15		15								15	15
2012t	02B	Hvaler area, Kirkøy north	59.1125	11.038833	GADU MOR	LI	17	6		2	6		2								2	2
2011t	10B	Varangerfjord	69.933333	29.666667	GADU MOR	LI	25	25			25	25		25		25						
2012p	10B	Varangerfjord	69.9333	29.6667	GADU MOR	LI	15	15			15											
2012t	10B	Varangerfjord	69.933333	29.666667	GADU MOR	LI	15	15			15											
2011t	13BH	Kristiansand harbour	58.135	7.988	GADU MOR	LI	25	25		25	25	25		25		25	25					
2012p	13BH	Kristiansand harbour	58.1350	7.9880	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	13BH	Kristiansand harbour	58.135	7.988	GADU MOR	LI	17	11		11	11		4				7				4	4
2011t	15B	Ullerø area	58.05	6.7166667	GADU MOR	LI	25	25		25	25	25		25		25	25					
2012p	15B	Ullerø area	58.0500	6.7167	GADU MOR	LI	15	15			15											
2012t	15B	Ullerø area	58.05	6.7166667	GADU MOR	LI	15	15			15											
2011t	23B	Karihavet area	59.9	5.1333333	GADU MOR	LI	25	25		25	25	25		25		25	25			25		
2012p	23B	Karihavet area	59.9000	5.1333	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	23B	Karihavet area	59.9	5.1333333	GADU MOR	LI	15	15		15	15		6				11				6	6
2012p	28B	Ålesund area, Hundsvær	62.2517	5.8640	GADU MOR	LI	15	15		15	15		15								15	15
2012t	28B	Ålesund area, Hundsvær	62.251667	5.864	GADU MOR	LI	4	4		4	4		2								1	2
2011t	30B	Oslo City area	59.816667	10.55	GADU MOR	LI	25	25		25	25	25		25		25	25			25		
2012p	30B	Oslo City area	59.8167	10.5500	GADU MOR	LI	15	15		15	15		15				15			15	15	15

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2012t	30B	Oslo City area	59.816667	10.55	GADU MOR	LI	15	15		15	15		5				13			15	5	5
2011t	36B	Færder area	59.0405	10.435833	GADU MOR	LI	25	25		25	25	25		25		25	25					
2012p	36B	Færder area	59.0405	10.4358	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	36B	Færder area	59.0405	10.435833	GADU MOR	LI	17	12		12	12		2				11				2	2
2011t	43BH	Tromsø harbour	69.653	18.974	GADU MOR	LI	25	25		25	25	25		25		25	25					
2012p	43BH	Tromsø harbour	69.6530	18.9740	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	43BH	Tromsø harbour	69.653	18.974	GADU MOR	LI	15	15		15	15		10				15				10	10
2012p	45B2	Hammerfest (harbour)	70.7000	24.4833	GADU MOR	LI	15	15			15											
2012t	45B2	Hammerfest (harbour)	70.7	24.483333	GADU MOR	LI	15	15			15											
2011t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	LI	25	25		25	25	25		25		25	25			25		
2012p	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	LI	15	15		15	15		4	15			14				4	4
2011t	67B	Strandebarm area	60.266667	6.0333333	GADU MOR	LI	2	2			2	2		2		2						
2012p	71B	Grenlandsfjord, Breviks omr.	59.0612	9.7097	GADU MOR	LI	15	15		15			15								15	15
2012t	71B	Grenlandsfjord, Breviks omr.	59.061167	9.7096667	GADU MOR	LI	16	13		7			7								7	7
2011t	80BH	Munkholmen	63.422	10.3915	GADU MOR	LI	15	15		15	15	15		15		15	15					
2012p	80BH	Munkholmen	63.4220	10.3915	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	80BH	Munkholmen	63.422	10.3915	GADU MOR	LI	12	12		12	12		11				11				11	11
2011t	92B	Stokken area	64.171333	9.8873333	GADU MOR	LI	24															
2012p	96B	Sandesjøen harbour	66.0345	12.6055	GADU MOR	LI	15	15			15											
2011t	98B1	Bjørnerøya (east)	68.246667	14.803333	GADU MOR	LI	25	25		25	25	25		25		25	25					
2012p	98B	Skrova Harbour	68.1640	14.6570	GADU MOR	LI	15	15		15	15		15				15				15	15
2012t	98B	Skrova Harbour	68.164	14.657	GADU MOR	LI	17	11		11	11		2				6				2	
2012p	02B	Hvalerbassenget, Kirkøy nord	59.1125	11.0388	GADU MOR	MU	15	15	15													
2012t	02B	Hvalerbassenget, Kirkøy nord	59.1125	11.038833	GADU MOR	MU	15	15	15													
2011t	10B	Varangerfjord	69.933333	29.666667	GADU MOR	MU	30	25			5	5		5		5						
2012p	10B	Varangerfjord	69.9333	29.6667	GADU MOR	MU	15	15	15													
2012t	10B	Varangerfjord	69.933333	29.666667	GADU MOR	MU	15	15	15													
2011t	13BH	Kristiansand harbour	58.135	7.988	GADU MOR	MU	30	25			5	5		5		5						
2012p	13BH	Kristiansand harbour	58.1350	7.9880	GADU MOR	MU	15	15	15													
2012t	13BH	Kristiansand harbour	58.135	7.988	GADU MOR	MU	15	15	15													
2011t	15B	Ullerø area	58.05	6.7166667	GADU MOR	MU	30	25			5	5		5		5						

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2012p	15B	Ullerø area	58.0500	6.7167	GADU MOR	MU	15	15	15													
2012t	15B	Ullerø area	58.05	6.7166667	GADU MOR	MU	15	15	15													
2011t	23B	Karihavet area	59.9	5.1333333	GADU MOR	MU	30	25			5	5		5		5						
2012p	23B	Karihavet area	59.9000	5.1333	GADU MOR	MU	15	15	15													
2012t	23B	Karihavet area	59.9	5.1333333	GADU MOR	MU	15	15	15													
2012p	28B	Ålesund, omr. ved Hundsvær	62.2517	5.8640	GADU MOR	MU	15	15	15													
2012t	28B	Ålesund, omr. ved Hundsvær	62.251667	5.864	GADU MOR	MU	4	4	4													
2011t	30B	Oslo City area	59.816667	10.55	GADU MOR	MU	30	25			5	5		5		5						
2012p	30B	Oslo City area	59.8167	10.5500	GADU MOR	MU	15	15	15													
2012t	30B	Oslo City area	59.816667	10.55	GADU MOR	MU	15	15	15													
2011t	36B	Færder area	59.0405	10.435833	GADU MOR	MU	30	25			5	5		5		5						
2012p	36B	Færder area	59.0405	10.4358	GADU MOR	MU	15	15	15													
2012t	36B	Færder area	59.0405	10.435833	GADU MOR	MU	15	15	15													
2011t	43BH	Tromsø harbour	69.653	18.974	GADU MOR	MU	30	25			5	5		5		5						
2012p	43BH	Tromsø harbour	69.6530	18.9740	GADU MOR	MU	15	15	15													
2012t	43BH	Tromsø harbour	69.653	18.974	GADU MOR	MU	15	15	15													
2012p	45B2	Hammerfest (harbour)	70.7000	24.4833	GADU MOR	MU	15	15	15													
2012t	45B2	Hammerfest (harbour)	70.7	24.483333	GADU MOR	MU	15	15	15													
2011t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	MU	30	25			5	5		5		5						
2012p	53B	Inner Sørfjord	60.1667	6.5667	GADU MOR	MU	15	15	15													
2012t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	MU	15	15	15													
2011t	67B	Strandebarm area	60.266667	6.0333333	GADU MOR	MU	2	2			2	2		2		2						
2012p	71B	Grenlandsfjord, Breviks omr.	59.0612	9.7097	GADU MOR	MU	15	15	15													
2012t	71B	Grenlandsfjord, Breviks omr.	59.061167	9.7096667	GADU MOR	MU	15	15	15													
2011t	80BH	Munkholmen	63.422	10.3915	GADU MOR	MU	18	15			3	3		3		3						
2012p	80BH	Munkholmen	63.4220	10.3915	GADU MOR	MU	15	15	15													
2012t	80BH	Munkholmen	63.422	10.3915	GADU MOR	MU	12	12	12													
2012p	96B	Sandesjøenharbour	66.0345	12.6055	GADU MOR	MU	15	15	15													
2011t	98B1	Bjørnerøya (east)	68.246667	14.803333	GADU MOR	MU	30	25			5	5		5		5						
2012p	98B	Skrova Harbour	68.1640	14.6570	GADU MOR	MU	15	15	15													
2012t	98B	Skrova Harbour	68.164	14.657	GADU MOR	MU	15	15	15													
2011t	15B	Ullerø area	58.05	6.7166667	GADU MOR	WO	30															

myear	STATION _CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2011t	23B	Karihavet area	59.9	5.1333333	GADU MOR	WO	30															
2011t	30B	Oslo City area	59.816667	10.55	GADU MOR	WO	30															
2012t	30B	Oslo City area	59.816667	10.55	GADU MOR	WO	15															
2011t	53B	Inner Sørfjord	60.166667	6.5666667	GADU MOR	WO	30															
2011t	21F	Åkrafjord	59.75	6.1166667	LEPI WHI	LI	3	3			3	3		3		3						
2011t	67F	Strandebarm area	60.267	6.033	LEPI WHI	LI	2	2			2	2		2		2						
2011t	21F	Åkrafjord	59.75	6.1166667	LEPI WHI	MU	3	3			3	3		3		3						
2011t	67F	Strandebarm area	60.267	6.033	LEPI WHI	MU	2	2			2	2		2		2						
2011t	15F	Ullerø area	58.05	6.7166667	LIMA LIM	LI	5	5			5	5		5		5						
2011t	36F	Færder area	59.066667	10.383333	LIMA LIM	LI	3	3			3	3		3		3						
2011t	15F	Ullerø area	58.05	6.7166667	LIMA LIM	MU	5	5			5	5		5		5						
2011t	36F	Færder area	59.066667	10.383333	LIMA LIM	MU	3	3			3	3		3		3						
2011t	10A2	Skallneset	70.208333	30.358333	MYTI EDU	SB	3	3			3	3		3		3						
2012p	10A2	Skallneset	70.2083	30.3583	MYTI EDU	SB	3	3			3											
2012t	10A2	Skallneset	70.208333	30.358333	MYTI EDU	SB	3	3			3											
2011t	11X	Brasharbour	69.898667	29.744167	MYTI EDU	SB	3	3			3	3		3		3			2			
2012p	11X	Brasharbour	69.8987	29.7442	MYTI EDU	SB	3	3	3		3											
2012t	11X	Brasharbour	69.898667	29.744167	MYTI EDU	SB	3	3	3		3											
2011t	15A	Gåsøy (Ullerø)	58.051167	6.886	MYTI EDU	SB	3	3			3	3		3		3			2			
2012p	15A	Gåsøy (Ullerø)	58.0512	6.8860	MYTI EDU	SB	3	3	3		3											
2012t	15A	Gåsøy (Ullerø)	58.051167	6.886	MYTI EDU	SB	3	3	3		3											
2011t	227A2	Høgevarde	59.326	5.3175	MYTI EDU	SB	3	3			3	3		3		3			2			
2011t	22A	Espevær (west)	59.586667	5.1416667	MYTI EDU	SB	3	3			3	3		3		3			2			
2012p	22A	Espevær (west)	59.5867	5.1417	MYTI EDU	SB	3	3	3		3											
2012t	22A	Espevær (west)	59.586667	5.1416667	MYTI EDU	SB	3	3	3		3											
2012p	26A	Hamnen (Måløy)	61.8783	5.2267	MYTI EDU	SB	3	3	3	3	3		3								3	3
2012t	26A	Hamnen	61.878333	5.2266667	MYTI EDU	SB	3	3	3	3	3		3								3	
2011t	30A	Gressholmen	59.886667	10.809667	MYTI EDU	SB	3	3			3	3		3	2	3		3	3			
2012p	30A	Gressholmen	59.8867	10.8097	MYTI EDU	SB	3	3	3	3	3		3					3			3	3
2012t	30A	Gressholmen	59.886667	10.809667	MYTI EDU	SB	4	3	3	3	4		3					3			3	3
2011t	31A	Solbergstrand	59.615	10.656667	MYTI EDU	SB	3	3			3	3		3		3						
2012p	31A	Solbergstrand	59.6150	10.6567	MYTI EDU	SB	3	3			3											

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2012t	31A	Solbergstrand	59.615	10.656667	MYTI EDU	SB	3	3			3											
2011t	35A	Mølen	59.488167	10.498	MYTI EDU	SB	3	3			3	3		3		3		1	1			
2011t	36A	Færder	59.027167	10.5255	MYTI EDU	SB	3	3			3	3		3		3			2			
2012p	36A	Færder	59.0272	10.5255	MYTI EDU	SB	3	3	3	3	3		3					3			3	3
2011t	51A	Byrkjenes	60.085	6.5516667	MYTI EDU	SB	3	3			3	3		3		3						
2012p	51A	Byrkjenes	60.0850	6.5517	MYTI EDU	SB	3	3	3		3			3								
2012t	51A	Byrkjenes	60.085	6.5516667	MYTI EDU	SB	3	3	3		3			3								
2011t	52A	Eitrheimsneset	60.096667	6.5366667	MYTI EDU	SB	3	3			3	3		3		3						
2011t	56A	Kvalnes	60.255167	6.62	MYTI EDU	SB	3	3			3	3		3		3						
2012p	56A	Kvalnes	60.2552	6.6200	MYTI EDU	SB	3	3	3		3			3								
2012t	56A	Kvalnes	60.255167	6.62	MYTI EDU	SB	3	3	3		3			3								
2011t	57A	Krossanes	60.420833	6.7421667	MYTI EDU	SB	3	3			3	3		3		3						
2011t	63A	Ranaskjær	60.418333	6.4083333	MYTI EDU	SB	3	3			3	3		3		3						
2012p	64A	Utne, ytre Sørfjord (B4)	60.4237	6.6222	MYTI EDU	SB	3	3			3			3								
2012t	64A	Utne, ytre Sørfjord (B4)	60.423667	6.6221667	MYTI EDU	SB	3	3			3			3								
2011t	65A	Vikingneset	60.241667	6.16	MYTI EDU	SB	3	3			3	3		3		3						
2012p	65A	Vikingneset	60.2417	6.1600	MYTI EDU	SB	3	3			3			3								
2012t	65A	Vikingneset	60.241667	6.16	MYTI EDU	SB	3	3			3			3								
2011t	69A	Lille Terøy	59.979833	5.7558333	MYTI EDU	SB	3	3			3	3		3		3						
2011t	71A	Bjørkøya (Risøyodden)	59.023333	9.7536667	MYTI EDU	SB	3	3			3	3		3	2	3			2			
2012p	71A	Bjørkøya (Risøyodden)	59.0233	9.7537	MYTI EDU	SB	3	3	3	3			3					3			3	3
2012t	71A	Bjørkøya (Risøyodden)	59.023333	9.7536667	MYTI EDU	SB	3	3	3	3			3					3			3	
2011t	76A	Risøy	58.726667	9.2833333	MYTI EDU	SB	3	3			3	3		3	2	3			2			
2012p	76A	Risøy	58.7267	9.2833	MYTI EDU	SB	3	3			3											
2012t	76A	Risøy	58.726667	9.2833333	MYTI EDU	SB	3	3			3											
2012p	91A2	Ørland, ytre Trondheimsfjord	63.6875	9.6678	MYTI EDU	SB	3	3	3	3	3		3								3	3
2012t	91A2	Ørland, ytre Trondheimsfjord	63.6875	9.6678333	MYTI EDU	SB	3	3	3	3	3		3								3	1
2012p	97A2	Bodø harbour	67.2950	14.3880	MYTI EDU	SB	3	3	3	3	3		3								3	3
2012t	97A2	Bodø harbour	67.295	14.388	MYTI EDU	SB	4	3	3	3	4		3								3	3
2011t	98A2	Husvaagen area	68.257667	14.663833	MYTI EDU	SB	3	3			3	3		3		3			2			
2012p	98A2	Husvaagen area	68.2577	14.6638	MYTI EDU	SB	3	3	3	3	3		3					3			3	3
2012t	98A2	Husvaagen area	68.257667	14.663833	MYTI EDU	SB	3	3	3	3	3		3					3			3	3

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2011t	I023	Singlekalven (south)	59.095	11.136667	MYTI EDU	SB	3	3			3	3		3		3						
2012p	I023	Singlekalven (south)	59.0950	11.1367	MYTI EDU	SB	3	3	3	0	3		0					0			0	0
2012p	I024	Kirkøy (north west)	59.0800	10.9863	MYTI EDU	SB	3	3	3	3	3		3					3			3	3
2012t	I023	Singlekalven (south)	59.095	11.136667	MYTI EDU	SB	5	3	3	3	5		3					3			3	3
2011t	I131A	Lastad	58.0555	7.7086667	MYTI EDU	SB	3	3			3	3		3		3		3	3			
2012p	I131A	Lastad	58.0555	7.7087	MYTI EDU	SB	3	3										3				
2012t	I131A	Lastad	58.0555	7.7086667	MYTI EDU	SB	3	3										3				
2011t	I132	Svensholmen	58.125	7.9888333	MYTI EDU	SB	1	1			1	1		1	1	1		1	1			
2011t	I133	Odderøy	58.131667	8.0016667	MYTI EDU	SB	3	3			3	3		3	2	3		3	3			
2011t	I201	Ekkjegrunn (G1)	59.644167	6.3563333	MYTI EDU	SB	3	3										3	3			
2011t	I205	Bølsnes (G5)	59.591667	6.3001667	MYTI EDU	SB	3	3										3	3			
2011t	I241	Nordnes	60.400667	5.3016667	MYTI EDU	SB	3	3			3	3		3		3						
2012p	I241	Nordnes	60.4007	5.3017	MYTI EDU	SB	3	3		3	3		3								3	3
2011t	I243	Hegreneset	60.415333	5.3048333	MYTI EDU	SB	3	3			3	3		3		3						
2011t	I301	Akershuskaia	59.905333	10.736333	MYTI EDU	SB	3	3			3	3		3		3		3	3			
2012p	I301	Akershuskaia	59.9053	10.7363	MYTI EDU	SB	3	3			3							3				
2012t	I301	Akershuskaia	59.905333	10.736333	MYTI EDU	SB	3	3			3							3				
2011t	I304	Gåsøya	59.851333	10.589	MYTI EDU	SB	3	3			3	3		3		3		3	3			
2012p	I304	Gåsøya	59.8513	10.5890	MYTI EDU	SB	3	3	3		3							3				
2012t	I304	Gåsøya	59.851333	10.589	MYTI EDU	SB	3	3	3		3							3				
2011t	I306	Håøya	59.713333	10.555167	MYTI EDU	SB	3	3			3	3		3		3		3	3			
2011t	I307	Ramtonholmen	59.7445	10.522833	MYTI EDU	SB	3	3			3	3		3		3		3	3			
2011t	I712	Croftholmen	59.045333	9.7068333	MYTI EDU	SB	4	3			4	3		3	2	3			2			
2012p	I712	Croftholmen	59.0453	9.7068	MYTI EDU	SB	3	3	3	3			3					3			3	3
2012t	I712	Croftholmen	59.045333	9.7068333	MYTI EDU	SB	3	3	3	3			3					3			3	
2011t	I713	Strømtangen	59.050333	9.6916667	MYTI EDU	SB	3	3			3	3		3	1	3			2			
2011t	I912	Honnhammer	62.853333	8.1616667	MYTI EDU	SB	3											3	3			
2011t	I913	Fjøseid	62.809833	8.2746667	MYTI EDU	SB	3											3	3			
2011t	I964	Toraneskaien	66.321667	14.132833	MYTI EDU	SB	3	3										3	3			
2011t	I965	Moholmen (B5)	66.312	14.125833	MYTI EDU	SB	3	3										3	3			
2012p	I965	Moholmen (B5)	66.3120	14.1258	MYTI EDU	SB	3	3										3				
2012t	I965	Moholmen (B5)	66.312	14.125833	MYTI EDU	SB	3	3										3				

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2011t	I969	Bjørnbærviken (B9)	66.279833	14.0355	MYTI EDU	SB	3	3										3	3			
2012p	I969	Bjørnbærviken (B9)	66.2798	14.0355	MYTI EDU	SB	3	3										3				
2012t	I969	Bjørnbærviken (B9)	66.279833	14.0355	MYTI EDU	SB	3	3										3				
2011t	71G	Fugløyskjær	58.9825	9.8083333	LITT LIT	SB	1												1			
2011t	71G	Fugløyskjær	58.9825	9.8083333	LITT LIT	WO	1													1		
2012p	71G	Fugløyskjær	58.9825	9.8083	LITT LIT	SB	1												1			
2012t	71G	Fugløyskjær	58.9825	9.8083333	LITT LIT	SB	1												1		1	1
2011t	11G	Brasharbour	69.898667	29.744167	NUCE LAP	SB	52												1			
2012p	11G	Brasharbour	69.8987	29.7442	NUCE LAP	SB	1												1			
2012t	11G	Brasharbour	69.898667	29.744167	NUCE LAP	SB	52												1		1	1
2011t	131G	Lastad	58.0555	7.7086667	NUCE LAP	SB	30												1			
2012p	131G	Lastad	58.0555	7.7087	NUCE LAP	SB	1												1			
2012t	131G	Lastad	58.0555	7.7086667	NUCE LAP	SB	46												1		1	1
2011t	15G	Gåsøy (Ullerø)	58.051667	6.7216667	NUCE LAP	SB	52												1			
2012p	15G	Gåsøy (Ullerø)	58.0517	6.7217	NUCE LAP	SB	1												1			
2012t	15G	Gåsøy (Ullerø)	58.051667	6.7216667	NUCE LAP	SB	52												1		1	1
2011t	227G1	Melandholmen	59.3335	5.315	NUCE LAP	SB	52												1			
2012p	227G1	Melandholmen (Flatskjær)	59.3335	5.3150	NUCE LAP	SB	1												1			
2012t	227G1	Melandholmen	59.3335	5.315	NUCE LAP	SB	52												1		1	1
2011t	22G	Espevær (west)	59.579167	5.1483333	NUCE LAP	SB	52												1			
2012p	22G	Espevær (west)	59.5792	5.1483	NUCE LAP	SB	1												1			
2012t	22G	Espevær (west)	59.579167	5.1483333	NUCE LAP	SB	52												1		1	1
2011t	36G	Færder	59.027167	10.5255	NUCE LAP	SB	52												1			
2012p	36G	Færder	59.0272	10.5255	NUCE LAP	SB	1												1			
2012t	36G	Færder	59.027167	10.5255	NUCE LAP	SB	52												1		1	1
2011t	76G	Risøy	58.728	9.276	NUCE LAP	SB	52												1			
2012p	76G	Risøy	58.7280	9.2760	NUCE LAP	SB	1												1			
2012t	76G	Risøy	58.728	9.276	NUCE LAP	SB	52												1		1	1
2011t	98G	Svolvær området	68.256667	14.676667	NUCE LAP	SB	52												1			
2012p	98G	Svolvær området	68.2567	14.6767	NUCE LAP	SB	1												1			
2012t	98G	Svolvær området	68.256667	14.676667	NUCE LAP	SB	52												1		1	1
2012p	71G	Fugløyskjær	58.9825	9.8083	LITT LIT	WO	1													60		

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2011t	11G	Brasharbour	69.898667	29.744167	NUCE LAP	WO	53													53		
2012p	11G	Brasharbour	69.8987	29.7442	NUCE LAP	WO	1													60		
2012t	11G	Brasharbour	69.898667	29.744167	NUCE LAP	WO	53													53		
2011t	131G	Lastad	58.0555	7.7086667	NUCE LAP	WO	31													31		
2012p	131G	Lastad	58.0555	7.7087	NUCE LAP	WO	1													60		
2012t	131G	Lastad	58.0555	7.7086667	NUCE LAP	WO	47													47		
2011t	15G	Gåsøy (Ullerø)	58.051667	6.7216667	NUCE LAP	WO	53													53		
2012p	15G	Gåsøy (Ullerø)	58.0517	6.7217	NUCE LAP	WO	1													60		
2012t	15G	Gåsøy (Ullerø)	58.051667	6.7216667	NUCE LAP	WO	53													53		
2011t	227G1	Melandholmen	59.3335	5.315	NUCE LAP	WO	53													53		
2012p	227G1	Melandholmen (Flatskjær)	59.3335	5.3150	NUCE LAP	WO	1													60		
2012t	227G1	Melandholmen	59.3335	5.315	NUCE LAP	WO	53													53		
2011t	22G	Espevær (west)	59.579167	5.1483333	NUCE LAP	WO	53													53		
2012p	22G	Espevær (west)	59.5792	5.1483	NUCE LAP	WO	1													60		
2012t	22G	Espevær (west)	59.579167	5.1483333	NUCE LAP	WO	53													53		
2011t	36G	Færder	59.027167	10.5255	NUCE LAP	WO	53													53		
2012p	36G	Færder	59.0272	10.5255	NUCE LAP	WO	1													60		
2012t	36G	Færder	59.027167	10.5255	NUCE LAP	WO	53													53		
2011t	76G	Risøy	58.728	9.276	NUCE LAP	WO	53													53		
2012p	76G	Risøy	58.7280	9.2760	NUCE LAP	WO	1													60		
2012t	76G	Risøy	58.728	9.276	NUCE LAP	WO	53													53		
2011t	98G	Svolvær området	68.256667	14.676667	NUCE LAP	WO	53													53		
2012p	98G	Svolvær området	68.2567	14.6767	NUCE LAP	WO	1													60		
2012t	98G	Svolvær området	68.256667	14.676667	NUCE LAP	WO	53													53		
2011t	33F	Sande (east side)	59.528333	10.35	PLAT FLE	LI	5	5			5	5		5		5						
2011t	53F	Inner Sørfjord	60.167	6.567	PLAT FLE	LI	1	1			1	1		1		1						
2011t	67F	Strandebarm area	60.267	6.033	PLAT FLE	LI	3	3			3	3		3		3						
2011t	33F	Sande (east side)	59.528333	10.35	PLAT FLE	MU	5	5			5	5		5		5						
2011t	53F	Inner Sørfjord	60.167	6.567	PLAT FLE	MU	1	1			1	1		1		1						
2011t	67F	Strandebarm area	60.267	6.033	PLAT FLE	MU	3	3			3	3		3		3						
2011t	10F	Skogerøy	69.916667	29.85	PLEU PLA	LI	2	2			2	2		2		2						
2011t	98F2	Husholmen	68.219	14.808	PLEU PLA	LI	5	5			5	5		5		5						

myear	STATION_CODE	STATION_NAME	Latitude	Longitude	specie	tissue	Antallprøver	I-MET	ISOTO	O-BR	OC-CB	OC-CL	OC-CP	OC-DD	OC-DX	OC-HC	O-FL	O-PAH	O-MET	BE	PFR	PHC
2011t	10F	Skogerøy	69.916667	29.85	PLEU PLA	MU	2	2			2	2		2		2						
2011t	98F2	Husholmen	68.219	14.808	PLEU PLA	MU	5	5			5	5		5		5						

Appendix F
Temporal trend analyses of contaminants and biomarkers in biota 1981-2012

This Appendix is provided as an EXCEL file separate from this report but described below.

Median concentrations only shown for the period 2002-2012

Sorted by alphabetically by contaminant (and unit), species and area/station:

Code descriptions are given in Appendix B

Mercury (Hg)
Cadmium (Cd)
Lead (Pb)
Copper (Cu)
Zinc (Zn)
Silver (Ag)
Arsenic (As)
Nickel (Ni)
Chromium (Cr)
Cobalt (Co)
Barium (Ba)
TBT (Tributyltin)

Sum PCB-7 or **CB_S7** (CB: 28+52+101+118+138+153+180)
DDEPP (ppDDE)
PAH-16 (sum carcinogen PAHs, cf. Appendix B)
KPAH (sum of PAHs, dicyclic "PAHs" not included, cf. Appendix B)
B[a]P (benzo[*a*]pyrene)
PBDE (Sum brominated flame retardants)
PFOS (perfluoroctanoic sulphonate**)**
H-pyrene or PYR10 (Pyrene metabolite)
ALA-D (δ-amino levulinic acid dehydrase inhibition)
EROD-activity (Cytochrome P4501A-activity)
CYP1A (relative amount of Cytochrome P4501A protein)
VDSI (measurement of imposex)

CEMP-stations
MYTI EDU-Blue Mussel (*Mytilus edulis***)**
LITT LIT-Common periwinkle (*Littorina littorea***)**
NUCE LAP-Dog whelk (*Nucella lapillus***)**
GADU MOR-Atlantic cod (*Gadus morhua***)**

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

(continues on next page)

OC Overconcentration expressed as quotient of median of last year and upper limit to presumed “high background” ("m" missing background value)
SD Standard deviation for last year

Power (long) POWER; estimated number of years to detect a hypothetical situation of 10% trend a year with a 90% power – for the entire sampling period.
First Yr (long) First year in time series for entire sampling period
Last Yr (long) Last year in time series for entire sampling period
No.Yrs (long) Number of years in time series for entire sampling period

Power (short) POWER; estimated number of years to detect a hypothetical situation of 10% trend a year with a 90% power – for the entire sampling period.
First Yr (short) First year in time series for the last 10-year-sampling period
Last Yr (short) Last year in time series for the last 10-year-sampling period
No. Yrs (short) Number of years in time series for the last 10-year-sampling period

Trend Indication of levels and trends in concentrations of contaminants monitored. Classification is based on observed median concentrations in cod, flatfish and blue mussel. The classification system of the Norwegian Environment Agency is used for biota (Molvær et al. 1997: Classes: I (blue), II (green), III (yellow), IV (orange) and V (red) (see Appendix D). For biota, trend analyses were done on time series with three or more years and the results, before the slash “/”, 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 period 2002-2011 and the result is shown after the slash. A small filled square (▪) indicates that chemical analysis has been performed, but either data were insufficient to do a trend analysis or was not presented. Dark grey indicates concentrations higher than estimated high background levels. Light grey indicates concentrations lower than high background levels. Note: Class limits for ΣDDT are used for ppDDE, and the Class limits for ΣHCH are used for HCHG.

The analyses are done on wet weight basis

Supplementary analyses on wet weight basis

Supplementary analyses on lipid weight basis

Note on detection limit: half of the limit is used.

Appendix G
Passive sampling result-tables

The table below (***Table 25***) shows mean contaminant concentrations (n = 6) measured in QA spiked samplers, relative standard deviations and a comparison with nominal (expected) concentrations. Relative standard deviations are in the range of 4-21 % depending on the substance and most mean values are close to nominal concentrations

Table 25 *Mean concentrations of substances of interest measured in six QA spiked silicone rubber samplers (including % relative standard deviation, n = 6) and nominal concentrations.*

Substance	Nominal concentration ng g^{-1} silicone	Mean concentration ng g^{-1} silicone (n = 6)	Relative standard deviation (%) (n = 6)
Alkyphenols			
4-t-OP	65	79	12
4-t-NP	260	289	10
4-n-OP	65	72	18
4-n-NP	65	64	4
HBCD			
α-HBCD	11	10.8	13
β-HBCD	11	11.5	13
γ-HBCD	11	9.8	19
PBDEs			
BDE 47	4.8	4.5	9
BDE-99	4.8	4.4	12
BDE-100	3.6	3.0	8
BDE-126	2.4	2.3	11
BDE-153	2.4	2.2	14
BDE-154	2.4	2.0	15
BDE-183	2.4	2.2	21
BDE-196	2.4	1.7	20
BDE-209	4.8	4.1	18

4-t-OP: para-t-octylphenol; 4-t-NP : para-t-nonylphenol; 4-n-OP: para-n-octylphenol; 4-n-NP : para-n-nonylphenol
HBCD: Hexabromocyclododecane
PBDE: Polybrominated diphenyl ether

As part of the batch of analysis of samplers from the 2012-2013 survey, two QA spiked samplers were analysed for substances of interest. This will allow us to gauge the performance of the extraction and analysis over time. The table below (***Table 26***) show the contaminant concentrations measured in two QA spiked samplers. For most substances concentrations measured are very close to the mean concentrations from the six QA spiked samplers analysed previously. Differences between concentrations of 4-t-OP and BDE-183 in these QA spiked samplers and respective mean concentrations (from six samplers) are slightly larger than for other substances. This will allow us to build control charts.

Table 26 *Comparison of concentrations of substances of interest measured in the two QA spiked samplers with data from the initial evaluation of the QA spiked samplers.*

Substance	Mean concentration in ng g^{-1} (% RSD)*	QA Spike 1 (ng g^{-1})	QA Spike 2 (ng g^{-1})
Alkyphenols			
4-t-OP	79 (12)	103	121
4-t-NP	289 (10)	258	271
4-n-OP	72 (18)	61	63
4-n-NP	64 (4)	59	60
HBCD			
α-HBCD	2.5 (11)	2.4	2.4
β-HBCD	2.7 (13)	2.0	2.2
γ-HBCD	2.3 (21)	2.0	2.2
PBDEs			
BDE 47	4.5 (9)	5.0	4.4
BDE-99	4.4 (12)	4.4	4.0
BDE-100	3.0 (8)	3.0	3.0
BDE-126	2.3 (11)	2.2	2.3
BDE-153	2.2 (14)	1.9	2.1
BDE-154	2.0 (15)	1.7	1.8
BDE-183	2.2 (21)	1.4	1.5
BDE-196	1.7 (20)	1.5	1.5
BDE-209	4.1 (18)	3.2	3.5

4-t-OP: para-t-octylphenol; 4-t-NP : para-t-nonylphenol; 4-n-OP: para-n-octylphenol; 4-n-NP : para-n-nonylphenol
HBCD: Hexabromocyclododecane
PBDE: Polybrominated diphenyl ether
*Mean concentration in the first six QA spiked samplers

The table below (***Table 27***) shows Water Framework Directive Environmental Quality Standards for substances of interest for the passive sampling work. These have been set for the "Whole Water" (as opposed to passive samplers measuring the freely dissolved concentration).

Table 27 *Annual average and maximum acceptable concentration environmental quality standard set by the European Union's Water Framework Directive (published in 2013).*

	Water Framewor Directive EQS ($\mu g\ L^{-1}$)	
	AA-EQS	**MAC-EQS**
Octylphenol*	0.01	Not applicable
Nonylphenol**	0.3	2.0
PBDEs***		0.014
HBCD	0.0008	0.05

*with CAS number 1806-26-4 (including compound with CAS number 140-66-9)
**with CAS number 25154 (including compounds with CAS numbers 104-40-5 and84852-15-3)
***only tetra, penta, hexa and heptabromodiphenyl ether (CAS numbers 40088-47-9, 32534-81-9, 36483-60-0, 68928-80-3)

Miljødirektoratet
Telefon: 03400/73 58 05 00 | Faks: 73 58 05 01
E-post: post@miljodir.no
Nett: www.miljødirektoratet.no
Post: Postboks 5672 Sluppen, 7485 Trondheim
Besøksadresse Trondheim: Brattørkaia 15, 7010 Trondheim
Besøksadresse Oslo: Strømsveien 96, 0602 Oslo

Overvåkingsprogrammmet skal gi informasjon om tilstanden og utviklingen av forurensningssituasjonen, og påvise eventuell uheldig utvikling på et tidlig tidspunkt. Programmet skal dekke myndighetenes informasjonsbehov om forurensningsforholdene, registrere virkningen av iverksatte tiltak for å redusere forurensningen, og danne grunnlag for vurdering av nye tiltak. Miljødirektoratet er ansvarlig for gjennomføringen av overvåkningsprogrammet.

M-69/2013
ISBN 978-82-577-6317-6