Statlig program for forurensningsovervåking

Norwegian State Pollution Monitoring Programme
Long-term monitoring of environmental quality in
Norwegian coastal waters

NATIONAL COMMENTS REGARDING THE NORWEGIAN DATA FOR 2008

1017
2008

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Abstract

This report is part of the Norwegian contribution to OSPAR's Joint Assessment and Monitoring Programme (JAMP) of which of which OSPAR's Coordinated Environmental Monitoring Programme (CEMP) is based. JAMP 2006 included the monitoring of contaminants in sediment (10), blue mussel (52), dogwhelk (21), cod (10) and flatfish (10) along the coast of Norway from Oslo to Varangerfjord. The results showed elevated, in a few cases up to severely contaminated, levels of contaminants in the inner Oslofjord (PCBs, mercury and lead in cod; PCBs in blue mussel), and Sørfjord and Hardangerfjord (DDT, lead, cadmium and mercury in blue mussel; mercury and DDT in cod). The results from the remaining stations showed low or moderate levels of contamination in 2006. Considering the whole monitoring period (1984-2006), a significant upward trend was found for mercury in cod from the inner Oslofjord. A significant downward trend was found for lead in blue mussel from Sørfjord/Hardangerfjord. The "Pollution" index was between "moderate" and "marked", a level less polluted than in 2005. The "Reference" index was between "insignificant" and "moderate" as before. Contamination of organotin in blue mussel and imposex in dogwhelk were still apparent, however, there is some indication of downward trends. The results from studies using biological effects methods in cod are also discussed.

4 keywords, Norwegian	4 keywords, English
1. Miljøgifter	1. Contaminants
2. Organismer	2. Organisms
3. Marin	3. Marine
4. Norge	4. Norway

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WORKING GROUP ON CONCENTRATIONS, TRENDS AND EFFECTS OF SUBSTANCES IN THE MARINE ENVIRONMENT (SIME)

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JOINT ASSESSMENT AND MONITORING PROGRAMME (JAMP)

NATIONAL COMMENTS REGARDING

THE NORWEGIAN DATA FOR 2006

Oslo, 25. December 2007

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Foreword

This report presents the Norwegian national comments on the 2006 investigations for the Joint Assessment and Monitoring Programme (JAMP). JAMP is administered by the Oslo and Paris Commissions (OSPAR) and their Environmental Assessment and Monitoring Committee (ASMO). JAMP receives guidance from the International Council for the Exploration of the Sea (ICES). ASMO has delegated implementation of part of the programme to the Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (SIME). The Norwegian 2006 investigations are directed to particular JAMP issues relating to contaminants and implemented by SIME. JAMP replaced Joint Monitoring Programme (JMP) in 1995 and has been an integral part of OSPAR's Coordinated Environmental Monitoring Programme (CEMP) since 1998.

The Norwegian JAMP for 2005 was carried out by the Norwegian Institute for Water Research (NIVA) by contract from the Norwegian Pollution Control Authority (SFT), (NIVA contractO-6, O-26106, O-27106).

The Norwegian contribution to the JMP/JAMP was initiated by SFT in 1981 as part of the national monitoring programme. It now comprises three areas: the Oslofjord and adjacent areas (Hvaler-Singlefjord area and Langesundsfjord, 1981-), Sørfjord/Hardangerfjord (1983-84, 1987-) and Orkdalsfjord area (1984-89, 1991-93, 1995-96, 2004-05).

Since the North Sea Task Force Monitoring Master Plan was implemented in 1990, additional areas have also been monitored. These include: Arendal, Lista and Bømlo-Sotra areas. On the initiative of SFT and NIVA "reference" or merely diffusely contaminated areas from Bergen to Lofoten have been monitored since 1992 and from Lofoten to the Norwegian-Russian border from 1994.
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***Reader's guide**. There is currently no OSPAR agreement as to the format for comments, however, to maintain consistency and completeness the Norwegian contribution is presented in accordance with the earlier agreed standardised format (ASMO 1997, Annex 12). Following the SIME meeting in Edinburgh, 11-13 February, 2008, the full report in PDF-format can be downloaded from either of two websites: the SFT's website and using SFT's TA-number at http://www.sft.no/publikasjonerforside____10990.aspx or from NIVA's website at http://www.niva.no/symfoni/infoportal/portenglish.nsf and doing a search on the "løpenr", which is the NIVA-report number for this report.*

***Acknowledgments.** Thanks are due to many colleagues at NIVA, especially: Lise Tveiten, Merete Schøyen, Åse Kristine Rogne, Sigurd Øxnevad, Jarle Håvardstun, for field work, sample preparations and data entry; Alfhild Kringstad,Olav Bøyum, Torgunn Sætre, and their colleagues for organic analyses; Bente Hiort Lauritzen and her colleagues for metal analyses; Randi Romstad and her colleagues for biological effects measurements, Gunnar Severinsen, Ling Shi and Tore Høgåsen for data programme management and operation; and to the authors Anders Ruus (biological effects methods), Mats Walday (organotin), and Eva Hagebø and her colleagues (analytical quality assurance). Thanks go also to the numerous fishermen and their boat crews for which we have had the pleasure of working with.*

Oslo, 25 December 2007.

Norman W. Green
Project co-ordinator

Contents

1. General Details

1.1. Executive Summary / Sammendrag

The Norwegian JAMP 2006 included the monitoring of micropollutants (contaminants) in sediment (10 stations), blue mussel (52 stations), dogwhelks (21 stations), cod (10 stations) and flatfish (10 stations) from Oslo in the south-east along the coast of Norway to the Varangerfjord in the north-east. The mussel sites include supplementary stations for the Norwegian Index programme, The results showed several cases of elevated levels of contaminants, i.e. higher than Class I (*insignificantly*[1] polluted) in the Norwegian Pollution Control Authority's (SFT's) classification system (or over provisional "high background"). The major cases were found in:

- Part of JAMP area 26 - Oslofjord was contaminated with PCBs and to a lesser extent mercury and lead. In particular cod liver from the inner Oslofjord was *markedly* polluted with PCB (Class III). A significant downward trend was found for PCBs in blue mussel from the inner Oslofjord. A significant upward trend was found for mercury in cod fillet from both "large" and "small" individuals and for cadmium in cod liver from the inner Oslofjord 1984-2006;
- JAMP areas 63 and 62 - Sørfjord and Hardangerfjord was contaminated with DDT, lead and cadmium. Blue mussel was up one class to *extremely* polluted (Class V) with DDT, and as before, *markedly* polluted with lead and cadmiumCod, was *moderately* polluted (Class II) with mercury and DDT, as before. A significant downward trend was found for lead in blue mussel at one station in Hardangerfjord 1987-2006, and also for cadmium at three stations in Sørfjord over the same period.
- Part of JAMP area 26 – Langesundsfjord has been an area of concern partly due to elevated concentrations of HCB in blue mussel. In 2002, 2003, 2004 and 2006 the blue mussel was *insignificantly* or *moderately* polluted (Class I and II). In 2005 the blue mussel were *markedly* polluted. A downward trend was found for the period 1990-2006.

Two environmental indices have been applied annually since 1995 to assess the levels of contamination in blue mussel from "polluted" and "reference" areas. In 2006 the Pollution Index result was between *moderate* and *marked* (class II-III). This was one level down compared to 2005. The Reference Index was between *insignificantly* and *moderately* polluted (Class I-II), as before.

The biological effect parameters OH-pyrene (pyrene metabolite; marker for PAH exposure), δ-aminolevulinic acid dehydrase (ALA-D; marker for lead exposure), and cytochrome P4501A (EROD-activity; marker for planar hydrocarbons, such as certain PCBs/PCNs, PAHs and dioxins) were determined in cod from four stationsalong the coast from the Oslofjord, Karihavet and Sørfjord. In 2006, the Oslofjord showed the highest levels of OH-pyrene and EROD-activity. With regard to EROD-activity, the same result has been obtained in some, but not all, of the preceding years. The amount of CYP1A protein was however consistently higher in the Oslofjord than the Sørfjord and the Karihavet, 2003-2006. Results for ALA-D indicated exposure of cod to lead in the inner Oslofjord and inner Sørfjord.

The presence of organotin (TBT) in Norwegian waters was still a problem in 2006, most evident close to harbours, but also at stations remote from known point-sources. Concentrations of organotin were elevated in blue mussel and dogwhelk, and biological effects from TBT were found in dogwhelk from all eight stations except for one. Eight of the twelve timeseries for TBT in blue mussel 1997-2006 showed significant downward trends. There was also a downward trend in effects of TBT in dogwhelk found at three stations. These results may be an indication that regulatory action has lead to an improvement in the investigated areas.

[1] Corresponds to Norwegian term *ubetydelig*, and has no statistical implications in this context.

Sammendrag

*JAMP (*Joint Assessment and Monitoring Programme*) er et internasjonalt program for miljøovervåking av kystfarvann. Norge er et av tolv land som gjennom Oslo-Pariskonvensjonen (OSPAR) har forpliktet seg til å delta i dette felles overvåkingsprogrammet. Programmet i Norge startet i 1981 og hovedmålsettingen er å overvåke miljøgifter i påvirkede områder og ellers langs hele norskekysten. Resultatene fra de minst påvirkede områdene benyttes for å angi "bakgrunnsnivåer". Resultatene rapporteres årlig.*

I 2006 omfattet JAMP undersøkelse av sediment (10 stasjoner), blåskjell (52, inkludert de til SFTs forurensningsindeks og til overvåking av TBT), purpursnegl (21 stasjoner), torsk (10 stasjoner) og flatfisk (10 stasjoner) langs kysten fra Oslofjorden til Varangerfjorden . Resultatene tydet på forhøyede konsentrasjoner av miljøgifter, dvs. mer enn Klasse I i SFTs klassifiseringssystem, eller over antatt "høyt bakgrunnsnivå". Disse tilfellene ble registrert i:

- *Oslofjorden med inntil Kl.III for PCB og mindre forurenset med hensyn til kvikksølv og bly. Torskelever fra indre Oslofjord var markert forurenset med PCB (Kl.III). Det ble også funnet signifikant økende trender for kvikksølv i torskefilet fra både "store" og "små" individer og for kadmium i torskelever fra indre Oslofjord 1984-2006;*
- *Sørfjorden og Hardangerfjorden med opp til Kl.V for DDE og Kl.III for bly og kadmium i blåskjell, og Kl.II for kvikksølv og DDE i torsk. Det ble funnet en signifikant avtagende trend for bly i blåskjell på en stasjon i Hardangerfjorden 1987-2006, og for kadmium på tre stasjoner i Sørfjorden.*
- *Langesundfjorden har vært et område med bl.a. høye konsentrasjoner av HCB i blåskjell. Forurensningsnivået fra 2002 til 2004 og 2006 har vært ubetydelig eller moderat (Kl.I eller II), men i 2005 var blåskjellene markert forurenset (Kl.III). En avtagende trend ble funnet for perioden 1990-2006.*

SFTs blåskjell-forurensningsindeks og blåskjell-referanseindeks har blitt brukt årlig siden 1995 på en gruppe "forurensede-" og "referanse-" fjordområder. Forurensningsindeksen for 2006 viste "moderat" til "markert" forurensning. Dette var en lavere klasse en som i 2005. Referanseindeksen har klassifisert sin gruppe mellom "lite" og "moderat" forurenset i hele perioden.

Følgende biologiske effekt-parametre ble undersøkt i torsk fra tre-fire stasjoner langs kysten fra indre Oslofjord til Hardanger: OH-pyren (pyren-metabolitt; markør for PAH-eksponering), δ-aminolevulinsyre dehydrase (ALA-D; markør for bly-eksponering), og aktivitet av cytokrom P4501A (EROD; markør for plane hydrokarboner, slik som spesifikke PCB/PCN, PAH og dioksiner). Oslofjorden viste de høyeste OH-pyren-nivåene. OH-pyren nivåene i indre Oslofjord var høyere en på de andre stasjonene. Resultatene for ALA-D indikerte bly-eksponering for torsk fra indre Oslofjord og indre Sørfjord. Høyest EROD-aktivitet ble observert i indre Oslofjord. Tidligere år har vist at EROD-aktivitet i fisk fra Oslofjorden og Sørfjorden ikke er konsistent høyere enn på andre, antatt mindre forurensede stasjoner, selv om dette er observert enkelte år. Derimot var mendgen CYP1A protein konsekvent høyere i Oslofjorden enn i Sørfjorden og Karihavet, 2003-2006.

Effekter av organotin (bl.a. TBT) kunne fortsatt registreres i 2006, tydeligst i havner eller i områder med mye skipstrafikk, men også på stasjoner som var antatt lite påvirket. Konsentrasjoner av TBT i blåskjell og purpursnegl var forhøyet, og virkning av TBT (imposex) ble registrert på samtlige stasjoner unntatt en. Åtte av tolv tidstrender for TBT i blåskjell perioden 1997-2006 var avtakende. Det ble funnet en signifikant nedadgående trend for imposex på tre stasjoner.Disse resultatene kan kanskje tyde på at forbud mot bruk av TBT som begroingshindrende middel på båter har ført til forbedring i de undersøkte områdene.

1.2. Introduction

The Norwegian contribution to the "Joint Assessment and Monitoring Programme (JAMP) was initiated by the Norwegian Pollution Control Authority (SFT) and is integrated with SFT's State Pollution Monitoring Programme. The procedures and practice of JAMP has also provided a basis for other investigations of interest to SFT but not necessarily requested by JAMP (e.g. SFT's Index Programme (Pollution and Reference Indices), chapter 1.3.8).

JAMP is administered by the Oslo and Paris Commissions (OSPAR) and since 1998, parts of JAMP have formed and integral part of OSPAR's Coordinated Environmental Monitoring Programme (CEMP).

Data are submitted to ICES using the integrated environmental reporting format 3.2.1 (www.ices.dk/env/repfor/), and screening using the their DATSU programme (www.ices.dk/datacentre/datsu/). The Norwegian JAMP data can be currently relevant to 4 purposes in the database: *temporal trends*, *spatial distribution*, *effects of hazardous substances*, and to a lesser degree the *risk to human health*. The former three are obligatory .

This report focuses on issues and situations in Norway concerning contaminants and considered of interest to the implementation of JAMP and CEMP (Table 1). It should be noted that these issues are being revised (cf., MON 2001).
The chapter structure of this report for the first and second level is according to an earlier agreed format (ASMO 1997, Annex 12) which *inter alia* presents results before methodology. No new format for reporting National Comments has been agreed by OSPAR, however, each country is obliged to ensure that their respective experts are as familiar as possible with the detail of their national submissions (ASMO 2007). In this regard, the format that of Norway has chosen for National Comments has served this purpose.

Table 1. CEMP-products relevant for the Norwegian JAMP (cf., OSPAR 2007, SIME 2004b).

Subject	CEMP products [6]	Recent Norwegian contribution
Mandatory		
Hg, Cd and Pb	AA-2, HA-5, HA-6	2006: Levels in sediment (cf., Green *et al.* 2000) 2006: Levels and trends in biota (annual investigations since 1981, Chapter **1.3**) 2006: INDEX for blue mussel from selected stations (annual investigations since 1995, cf. Chapter **1.3.8**)
PCBs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8) 2006: Levels in sediment and biota (Chapter 1.3)
PAHs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8) 2006: Levels in sediment and biota (Chapter 1.3)
TBT	AA-2, HA-5, HA-6	2006: Levels and trends in blue mussel and snails (annual investigations since 1997, cf. Chapter 1.5) 2006: Levels in sediment (Chapter 1.3)
TBT effects	AA-2, HA-4, HM-3	2006: IMPOSEX in snails (annual investigations since 1997, cf. Chapter 1.5)
Voluntary		
BFR [1]	AA-2, HA-5, HA-6	2006: in cod (annual investigations since 2005, cf. Chapter 1.6)
Planar PCBs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 2002, Chapter 1.8)
Alkylated PAHs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8) 2006: Levels in sediment and biota (Chapter 1.3)
PFOS [2]	AA-2, HA-5, HA-6	2006: in cod (annual investigations since 2005, cf. Chapter 1.7)
Dioxins [3]	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 2002, Chapter 1.8)
Specific BEM [4]	AA-2, HA-4, HM-3	2006: OH-pyrene, ALA-D in cod (annual investigations since 1997, cf. Chapter 1.4) 2006: IMPOSEX in snails (annual investigations since 1997, cf. Chapter 1.5)
General BEM [5]	AA-2, HA-4, HM-3	2006: EROD-activity in cod (annual investigations since 1997, cf. Chapter 1.4)

[1]) Certain Brominated Flame Retardents
[2]) Perfluoroctylsulfonate
[3]) Polychlorinated dibenzodioxins and furans
[4]) PAH- and Metal-Specific Biological Effects
[5]) General Biological Effects
[6]) From SIME 2004b:

AA-2 An assessment in 2010 of the quality status of the OSPAR maritime area and of its sub-regions.

HA-4 A more elaborated assessment by 2009 of biological effects of hazardous substances in the maritime area;

HA-5 An assessment by 2009 of temporal trends and (where relevant/feasible) spatial distribution for the hazardous substances where periodic sampling and analysis is undertaken, in particular under CAMP, CEMP and RID;

HA-6 A general assessment by 2009 of the development in the quality status of the maritime area in relation to hazardous substances that should take into account the results of the assessments under HA-1 and HA-5, HA-2 and HA-4 and HA-3, and the results of any screening of levels of substances in the marine environment covered by HM-3;

HM-3 When appropriate, identification of the likely impacts on the marine environment of substances recorded, inter alia, in source inventories, or identified by screening methods.

1.3. Information on measurements

An overview of JAMP stations in Norway is shown in the tables in Appendix E and maps in Appendix G. The stations and sample counts relevant to the 2006 investigations are noted in the tables in Appendix E. Data reports have been published recently for sediment 1986-2006, biota 1981-2006, biological effects (Shi *et al.* 2008).

Blue mussel was sampled at 52 stations (including supplementary stations for Index and TBT), dogwhelk at 21, cod at 10 , flatfish at 10 and sediment at 10 stations from the border to Sweden in the south to the border to Russia in the north. Generally, blue mussel are not abundant on the exposed coastline from Lista (south Norway) to the North of Norway. A number of samples were collected from dock areas, buoys or anchor lines.

This chapter focuses on the principle cases where *median* concentrations exceeded provisional "high background" ("normal"). The median concentration can be derived from the tables in Appendix I or figures in Appendix J, taking into consideration the year and whether the concentration is on a wet weight or dry weight basis. Where possible, these medians are classified according to the Norwegian Pollution Control Authority's (SFT's) **environmental quality classification system** (cf. Molvær *et al.* 1997). An extract of the system that is applied in this report is shown in Table 6 and Table 5 and includes unofficial conversion to other bases. The system does not cover all of the analysed contaminants for for all of the analysed species-tissues, however provisional "high background" concentrations have been determined and these are listed in Table 7. "High background" concentrations set the upper limit for Class I in SFT's system. The factor by which concentrations exceeded “high background” is termed **overconcentration**. "High background" concentration corresponds to the upper limit to Class I; “slightly” or “insignificantly” polluted, which in this context has no statistical implications. Below, the median concentrations are assessed according to the SFT system, but where this is not possible, overconcentrations are used. The term "significant" refers to the results of a statistical analysis of linear trends shown in Appendix I. More details concerning these terms and methods can be found in chapter 2.1.2.

1.3.1. Oslofjord area

Blue mussel from the inner Oslofjord were moderately polluted with ΣPCB-7 (SFT's Class II, Figure 1A). Cod liver from the inner Oslofjord was markedly polluted with ΣPCB-7 (Class III, Figure 2A). The median concentration in cod liver was 3550 µg/kg w.w., about 15% lower than the 2005 value which was the highest recorded median concentration since JAMP-monitoring started in 1990. Nearly all the cod collected during this period have been collected in the Vestfjord area west of Steilene. The range found in 2006 was 219-7409 µg/kg w.w. The fillet from the same fish were moderately polluted with ΣPCB-7 as it has been since 2000 (Class II, Figure 2C). Cod liver and fillet from the outer Oslofjord was moderately polluted with regard to ΣPCB-7 (Færder, st.36B, Figure 2B).

In 1994, and renewed in 2005, the Norwegian Food Safety Authority (*Mattilsynet*, earlier referred to as SNT) advised not to consume liver of cod from the inner Oslofjord (north of Mølen - st.35A, see Map 1 in Appendix G) due to concerns about PCB contamination (cf. Table 3).

A significant linear *downward* trend was detected (see method description in chapter 2.1.3) for ΣPCB-7 in blue mussel from the inner Oslofjord (30A and 31A Figure 1A, B) for the period 1988 to 2006.

Power analyses (see chapter 2.1.3) indicated that a hypothetical trend of 10% change per year in ΣPCB-7 concentration in the blue mussel from the mid and inner Oslofjord would take 12 to 14 years to be detected with 90% significance (Appendix I).

The fillet of "small"[1] (42-48 cm) and “large” cod (50-78 cm) from the inner Oslofjord in 2006 were moderately polluted with mercury; second and third highest since monitoring started in 1984 (Class II, Figure 3A, B). A significant *upward* trend was detected for the period 1984-2006 for both size groups. No significant trend was found for the period 1998-2006. Considering the entire period, the power, indicated as number of years to detect a hypothetical 10% change per year for mercury in cod fillet from either station, was slightly better for “small” fish (11 years) than “large” fish (13 years) (cf. Appendix I). Concentrations of mercury were significantly higher in "large" cod compared to "small" cod.

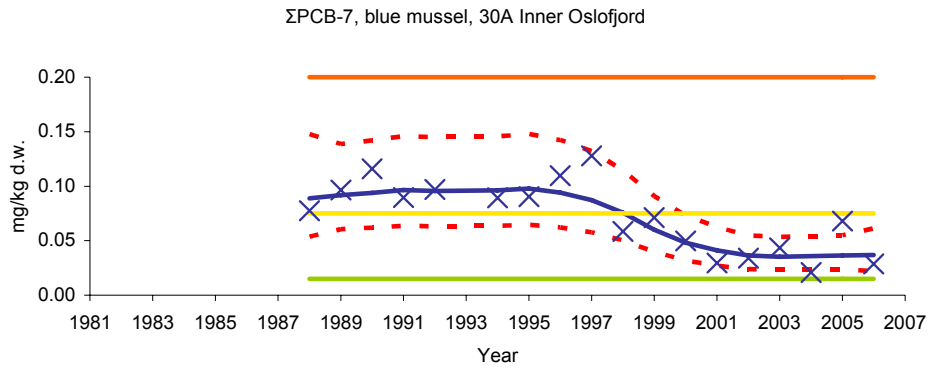
Median concentration of lead in cod liver from the inner Oslofjord (30B) 2006 was 0.1 mg/kg w.w.. This was less than the concentration found in 2005 and a fifth of the 2002 value; the second highest found during the entire period (1990-2006). “High background” for this metal is 0.1 mg/kg w.w. Blue mussel from one station in the inner Oslofjord (st. 30A) were moderately polluted with respect to lead in 2006.

The SFT's environmental quality classification system does not include cadmium and lead in cod liver.

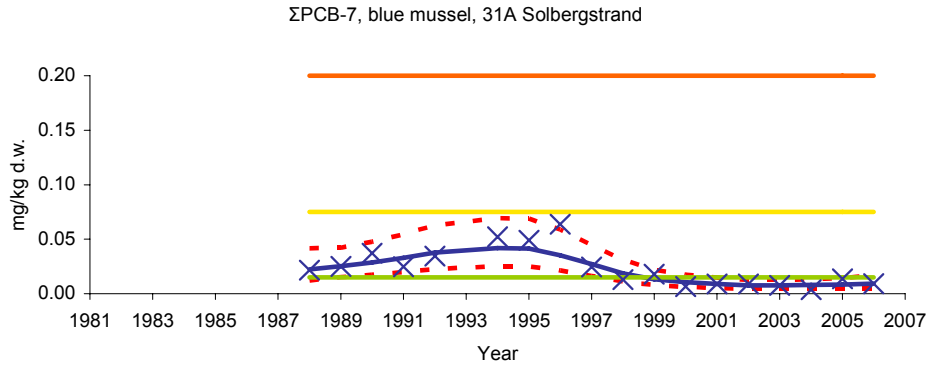
It should be noted that the Index programme indicated moderate concentrations of TBT in blue mussel from a station located in the inner Oslofjord (see chapter 1.3.8).

[1] The size of "small" and "large" cod depends on the station-year catch, and hence may vary (see section 2.1.3. The range given is the lower and upper quartile of the median lengths of the "small" or "large" fish.

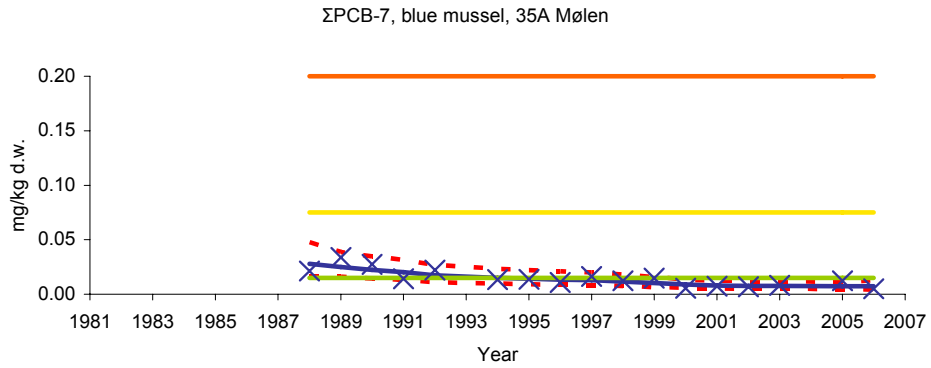
A



B



C



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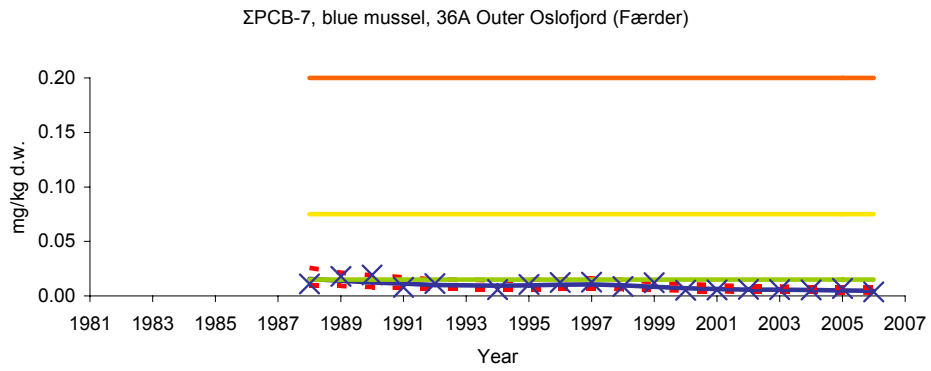


Figure 1. Median ΣPCB-7 (sum of PCB 28, 52, 101, 118, 138, 153 and 180) concentration in blue mussel (*Mytilus edulis*) from inner (st.30A) to outer (st.36A) Oslofjord. (cf. Appendix G and Appendix I, and and key in Figure 21).

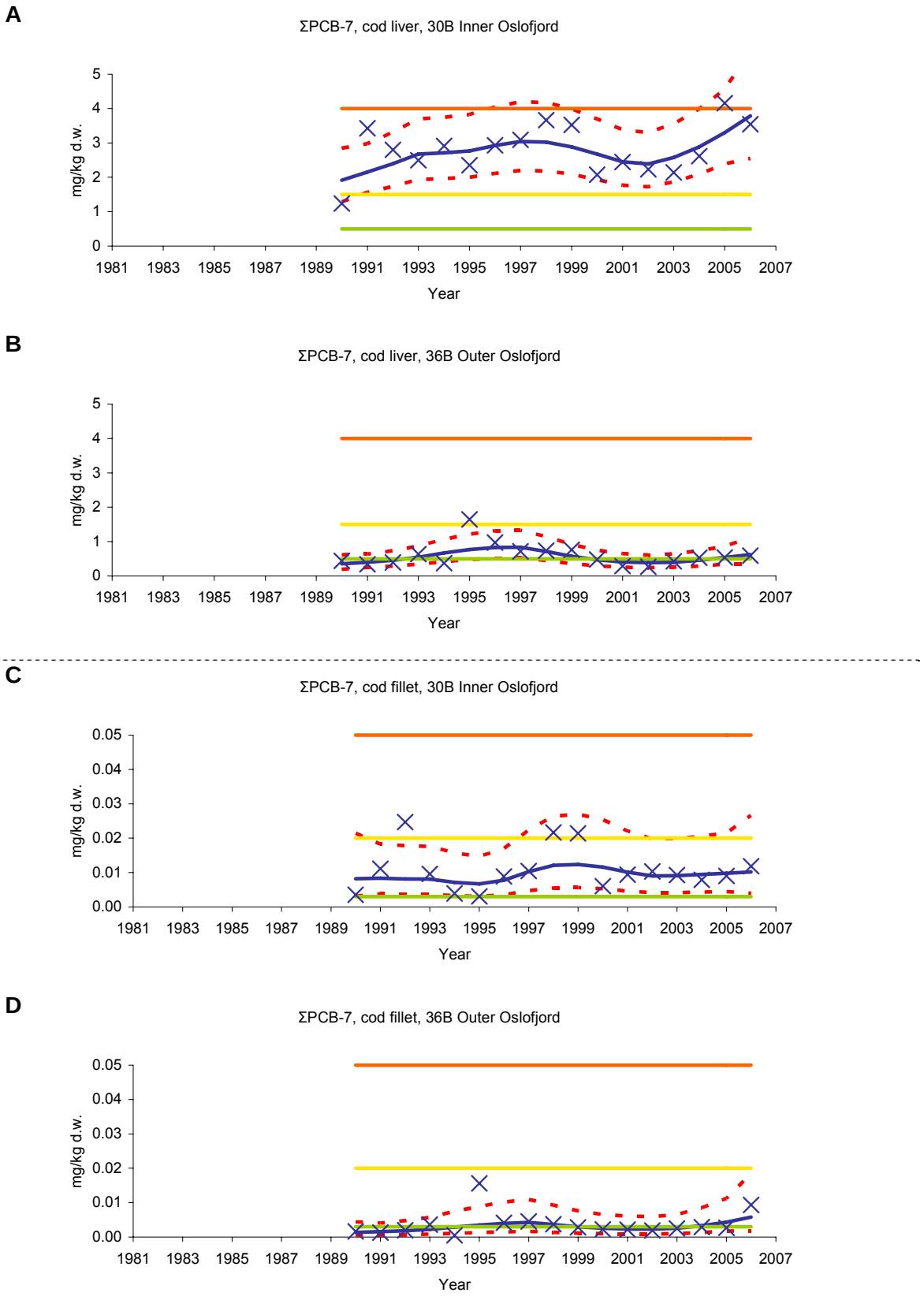


Figure 2. Median ΣPCB-7 (sum of PCB 28, 52, 101, 118, 138, 153 and 180) concentration in liver and fillet of cod (*Gadus morhua*) from the inner (st.30B) to outer (st.36B) Oslofjord. (cf. Appendix G and Appendix I, and key in Figure 21).

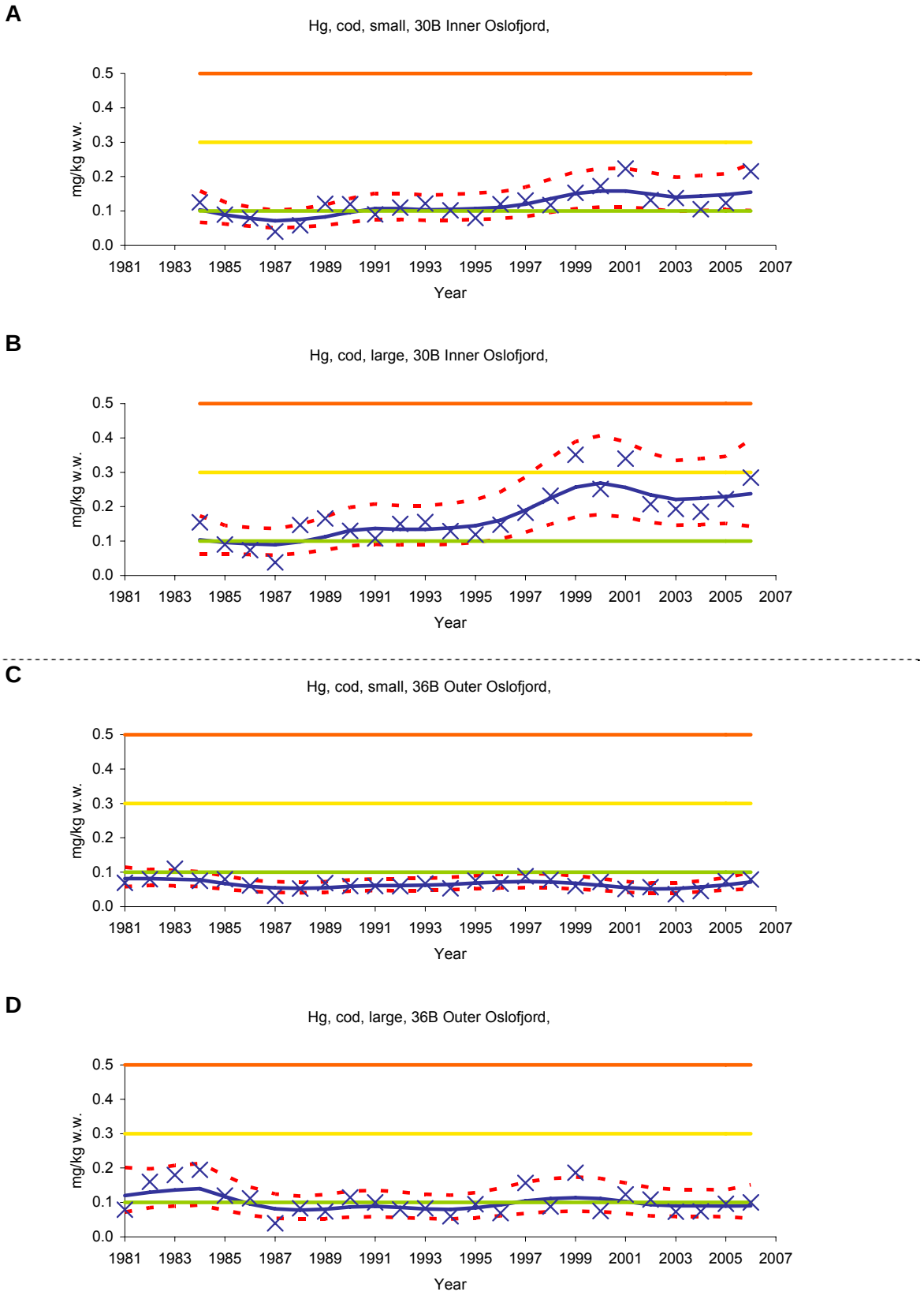


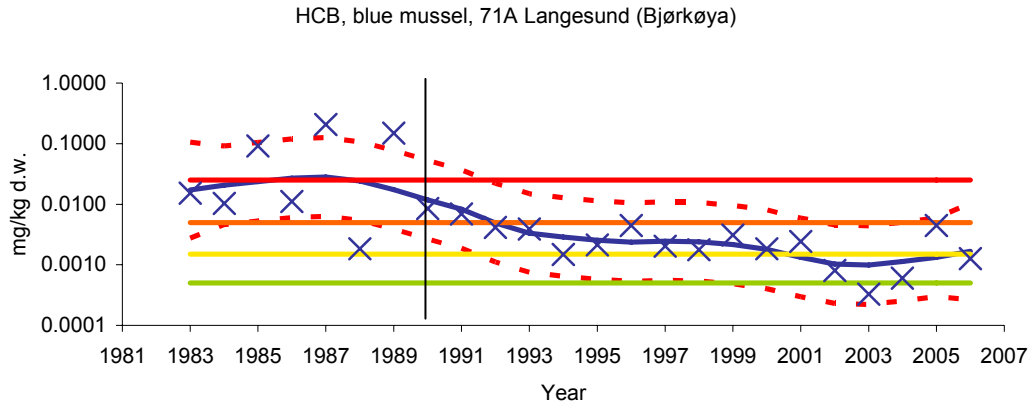
Figure 3. Median mercury (Hg) concentration in fillet of cod (*Gadus morhua*): for the inner Oslofjord (st.30B) "small" (**A**) and "large" (**B**) fish, and for the outer Oslofjord (st.36B) "small" (**C**) and "large" (**D**) fish. (cf. Appendix G and Appendix I, and key in Figure 21).

Blue mussel from Langesundsfjord (st.71A) in 2006 were moderately polluted with HCB (Class II, Figure 4A). The median concentration for 2006 was 1.27 mg/kg dry weight, about a third of the relatively high median found in 2005 which was the highest since 1991. Median values found at two nearby Index stations (I712 and I713) were markedly polluted (Class III), but also lower i 2006 compared to 2005 (Figure 4B and C). Concentrations have varied greatly since 1983 but median values have decreased distinctly since 1989 (Figure 4) due to about 99% reduction in discharge of HCB and other organochlorines from a magnesium factory (cf. Knutzen *et al.* 2001).

The power of the monitoring programme was 19 years for the period 1990-2006 and more than 25 years for the entire period (cf. Appendix I). The 1983-2006 data series had a significant *downward* trends and also a significant *downward* trend was found for the recent period (1990-2006).

It should be noted that dioxin is one of the contaminants monitored to establish the Pollution Index (see section 1.3.8). Dioxin toxicity equivalents based on the Nordic model (TCDDN) showed that the blue mussel was severely polluted (SFT Class IV) at Langesund (st. 71A) and extremely polluted at one nearby Index station (I712), whereas the other Index station, and closest to Frierfjord, (I713) was markedly polluted (Figure 35).

A



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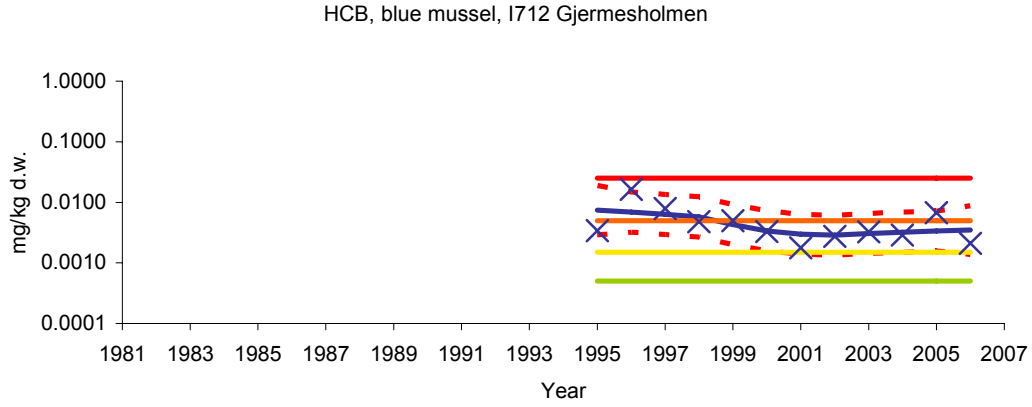


C

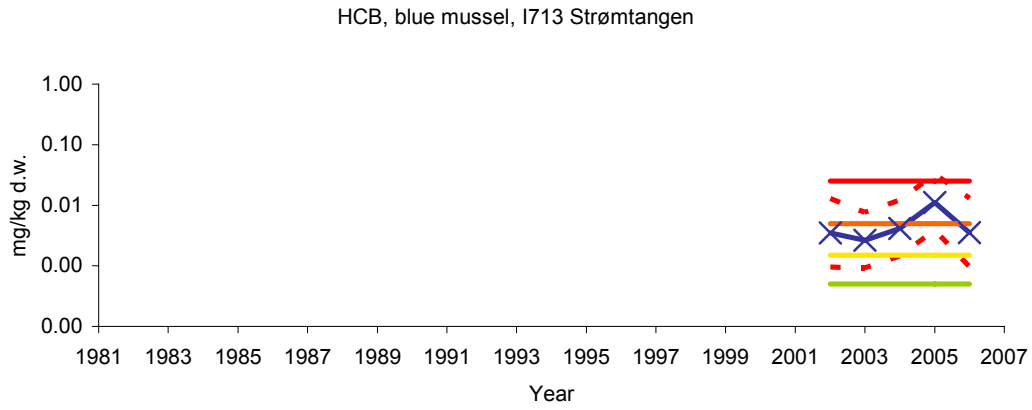


Figure 4. Median HCB concentration in blue mussel (*Mytilus edulis*) from Langesundsfjord (west of Oslofjord **A**) and two "Index" stations in the vicinity; Gjemesholmen (**B**) and Strømtangen (**C**) (cf. Appendix G and Appendix I, and key in Figure 21). Vertical line indicates when a magnesium factory reduced it's discharge by 99%. **NB: log-scale.**

1.3.2. Sørfjord and Hardangerfjord

The development of the contaminant conditions in these connected fjords and the main remedial actions that have been taken, have been outlined in the JAMP National comments for 1989 (Green 1991) and in recent reports concerning Sørfjord in particular (Skei 2000, 2001, Skei & Knutzen 2000, Skei *et al.* 1998). The results from JAMP 2006 are coupled to other studies in this area (cf. Knutzen & Green 2001a, Ruus & Green 2002, 2003, 2004, 2005, 2006, 2007) and confirm that the Sørfjord, and in some cases also Hardangerfjord, continue to be contaminated especially with cadmium (Figure 5), lead (Figure 6), mercury (Figure 7 and Figure 8), ppDDE (Figure 9, Figure 10 and Figure 11), and to a lesser extent PCB (Figure 11).

In 2002 the Norwegian Food Safety Authority (*Mattilsynet*, earlier referred to as SNT) extended their advice against the consumption of blue mussel to include all seafood in the Sørfjord including deep-water fish due to concerns about metal and PCB contamination (Table 3).

Results for blue mussel collected from the Sørfjord indicated that these were moderately (Class II) or markedly polluted (Class III) with cadmium in respect to SFT's classification system (Figure 5, Appendix I). Blue mussel as far as Vikingneset (st.65A. ca.84 km from Odda at the head of the Sørfjord) were moderately polluted with cadmium (Figure 5). A significant *downward* trend was found for cadmium at three stations in Sørfjord (st.52A, 56A and 57A) and two in Hardangerfjord (st.63A and 65A) (Appendix I). Also, the median lead concentration at the station nearest Odda (st.51A) and at Kvalnes (st.56A), about 15 km distant, were markedly polluted (Class III), whereas the other two stations in the Sørfjord (st.52A and 57A) and the two nearest stations in the Hardangerfjord (st.63A and 65A) were moderately polluted. A *downward* trend was found for lead at Ranaskjær (st.63A), 1990-2006. Three stations in Sørfjord were moderately polluted with respect to mercury.

Cod fillet from “small” (35-41 cm) and "large" individuals (42-55 cm) from the inner Sørfjord (st.53B) were moderately polluted with mercury (Class II). Overconcentrations were found for cadmium in cod liver from inner Sørfjord (2 times). It was not feasible to collect flounder from the inner Sørfjord, however, flounder caught in the adjacent Hardangerfjord had no overconcentrations.

The power of the sampling strategies for blue mussel was relatively poor for samples collected from Odda; the innermost part of Sørfjord (st.51A or 52A). For example for lead in blue mussel from these stations, it is estimated that it would take 19-22 years to detect a hypothetical trend of 10% per year with 90% significance (Appendix I). This reflects the large variability found in the data series from this area. The variability is mostly due to the irregular/accidental input of contaminated discharges. The power improved with distance from Odda, and at Ranaskjær (st.63A) and Vikingneset (st.65A) it was only 13 years.

Blue mussel at Kvalnes (st.56A) in the mid Sørfjord region were extremely polluted with ppDDE (Class V); with a median concentration of 186 µg/kg d.w.. The lower limit to Class V is 150 µg/kg d.w.. Blue mussel at the mouth of the Sørfjord, Krossanes (st.57A) about 20 km to the north, was moderately polluted (Class II, Figure 9 and Figure 10). Cod liver from the Sørfjord was moderately polluted with ppDDE (Figure 11A, Appendix I).

The liver of cod from Hardangerfjord for 2006 were insignificantly polluted (Class I) with respect to ΣPCB-7. Since JAMP monitoring started in the Sørfjord and Hardangerfjord the median values have varied between 100 and 2400 µg/kg w.w. (Appendix I). This indicated that cod is subject to a variable exposure from PCB, but the cause of this variation is not clear.

No trends were evident for ppDDE and ΣPCB-7 in blue mussel and cod.from inner Sørfjord where 2006 median were in Class II or higher.

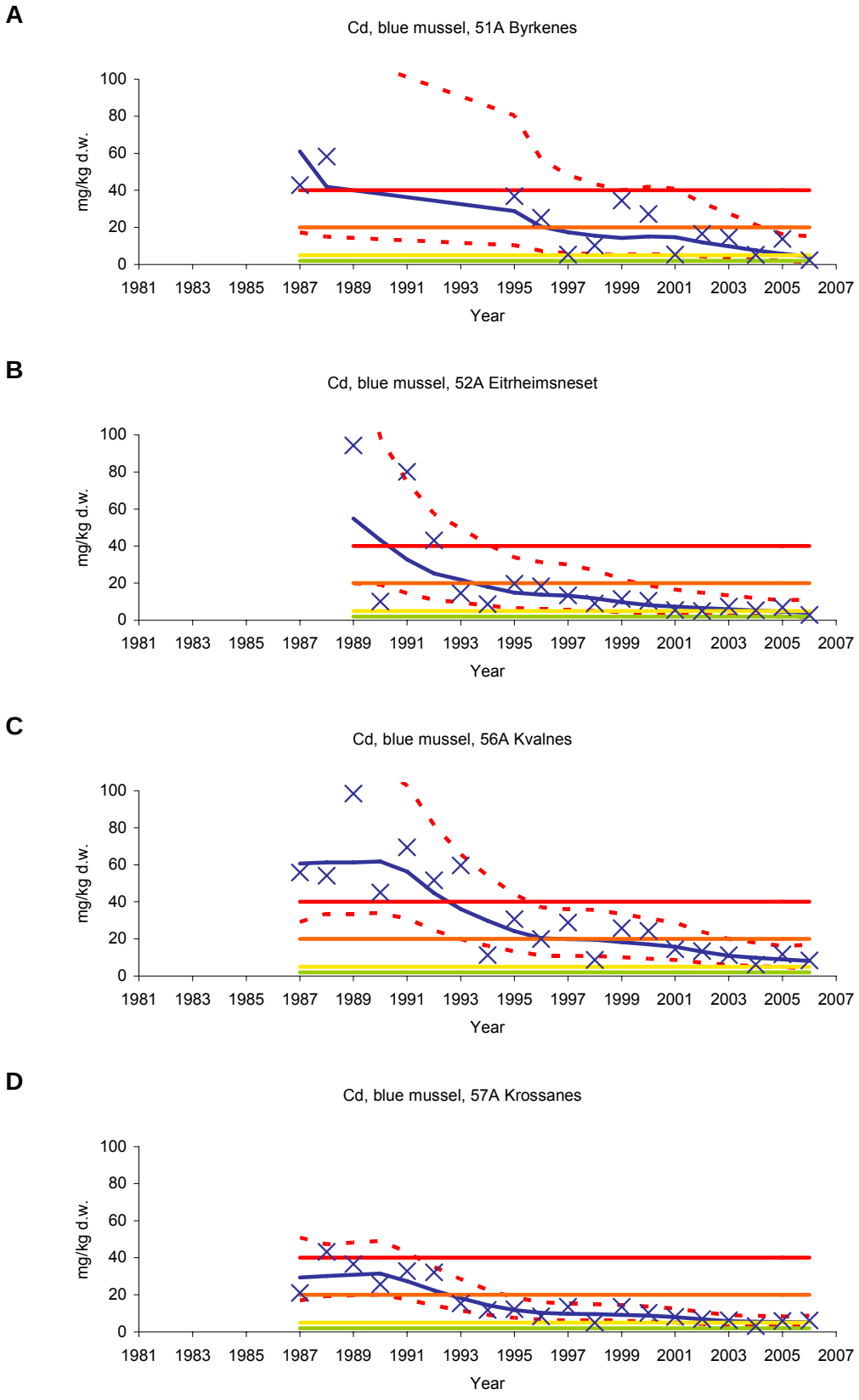
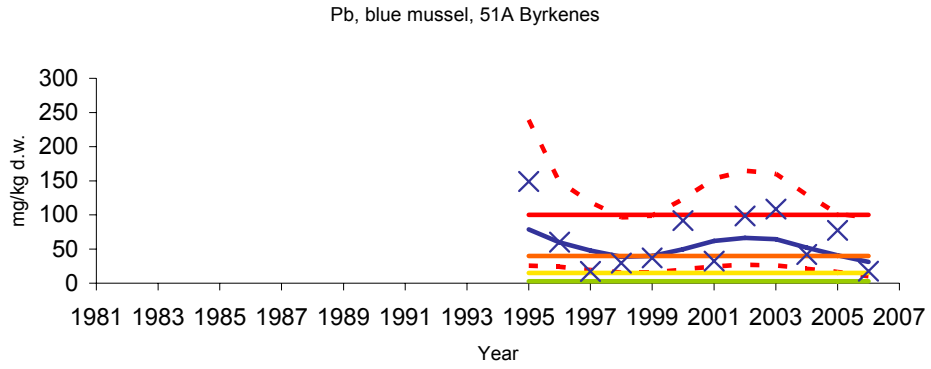
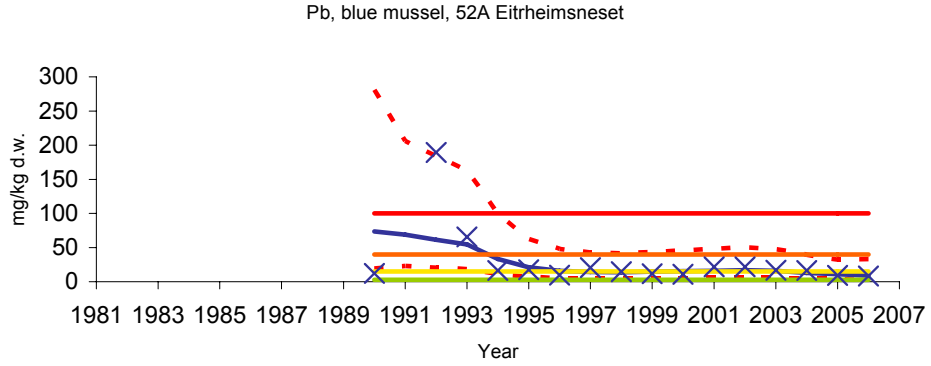


Figure 5. Median cadmium (Cd) concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. NB: (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in figures A-C. Note: horizontal lines for Classes I and II are near x-axis.**

A



B



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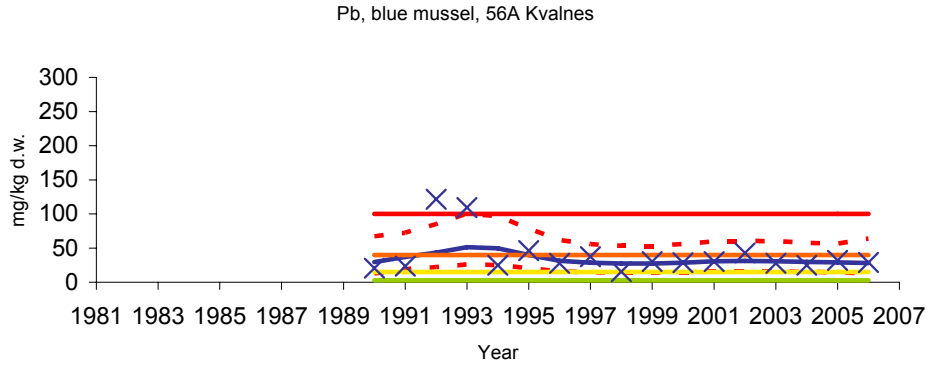


D

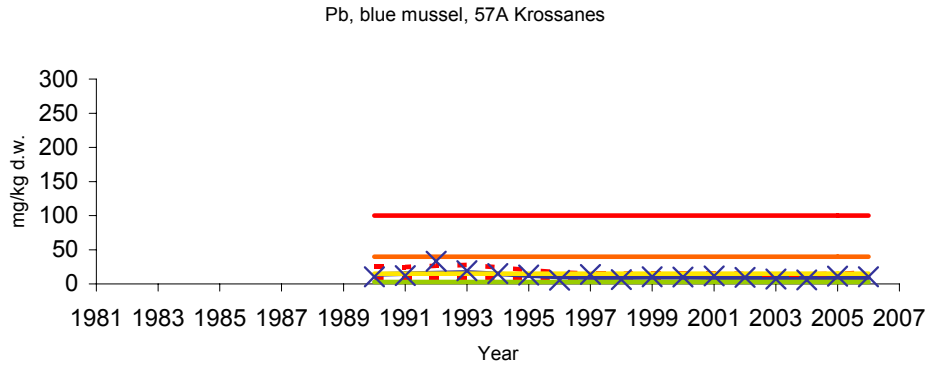
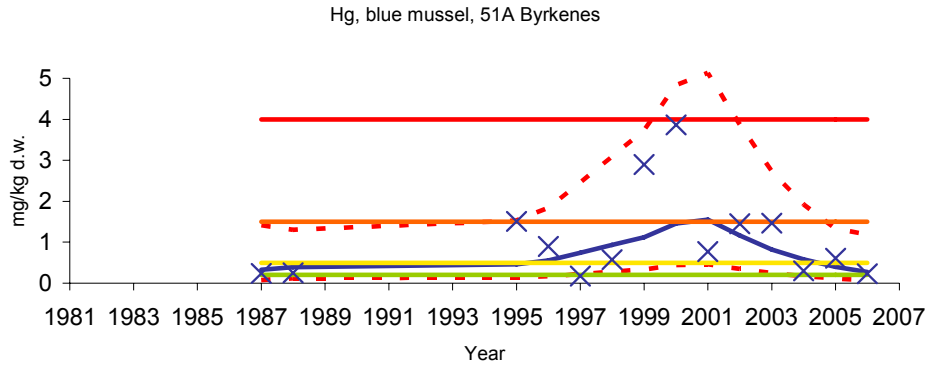
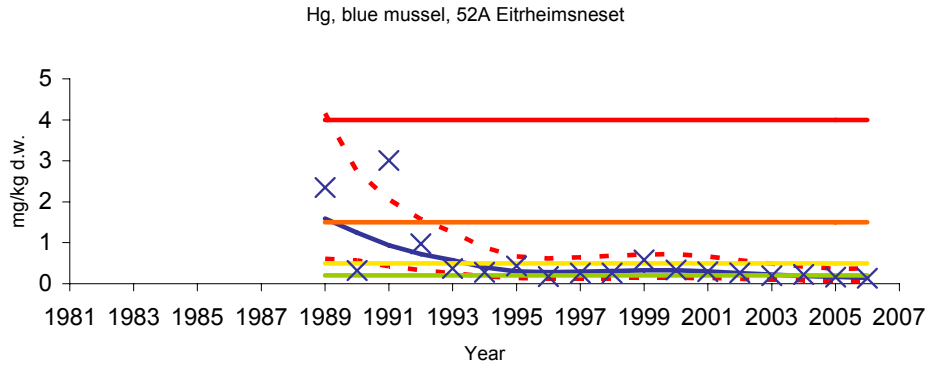


Figure 6. Median lead (Pb) concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. (cf. Appendix G and Appendix I, and key in Figure 21). **Note: horizontal lines for Classes I and II are near x-axis.**

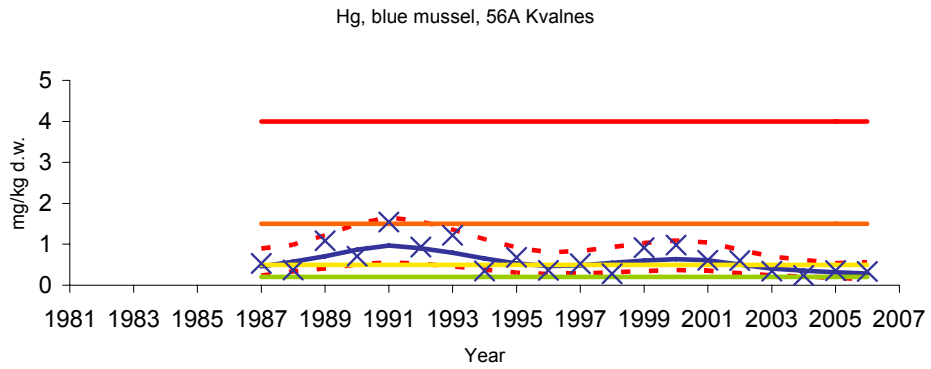
A



B



C



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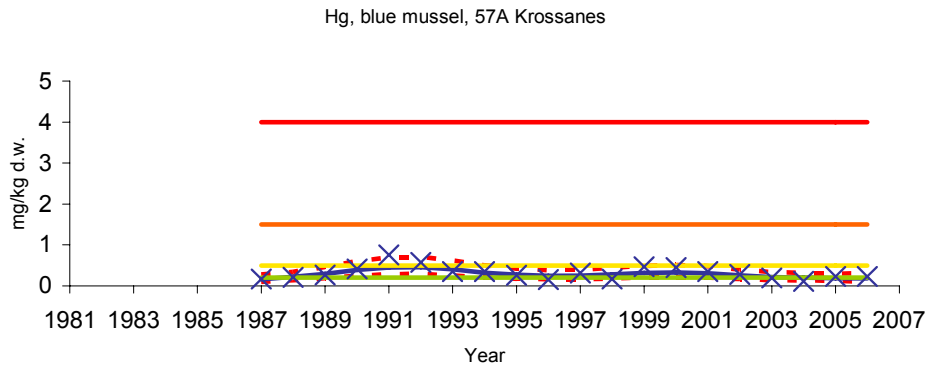


Figure 7. Median mercury (Hg) concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in figure A. Note: horizontal lines for Classes I and II are near x-axis.**

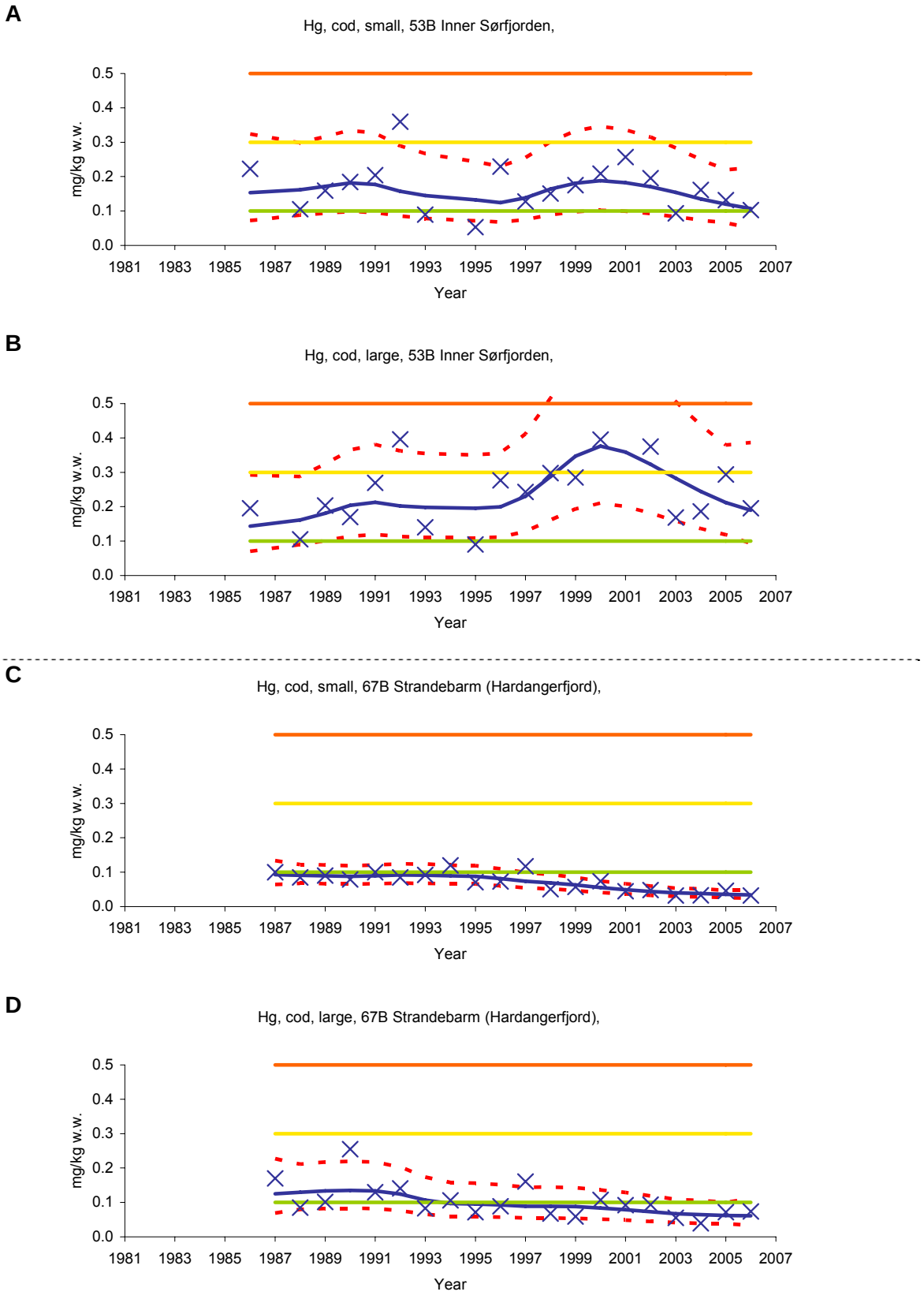
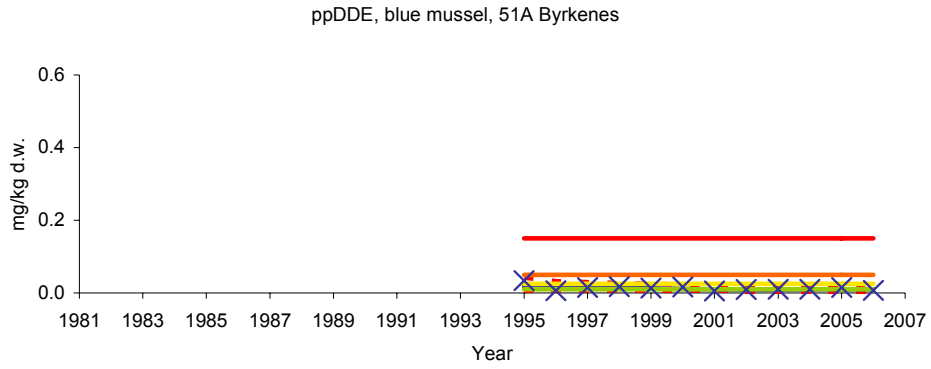


Figure 8. Median mercury (Hg) concentration in fillet of cod (*Gadus morhua*): from Sørfjord (st.53B) for "small" (**A**) and "large" (**B**) fish and Hardangerfjord (st.67B) for "small" (**C**) and "large" (**D**) fish (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in Figure B.**

A



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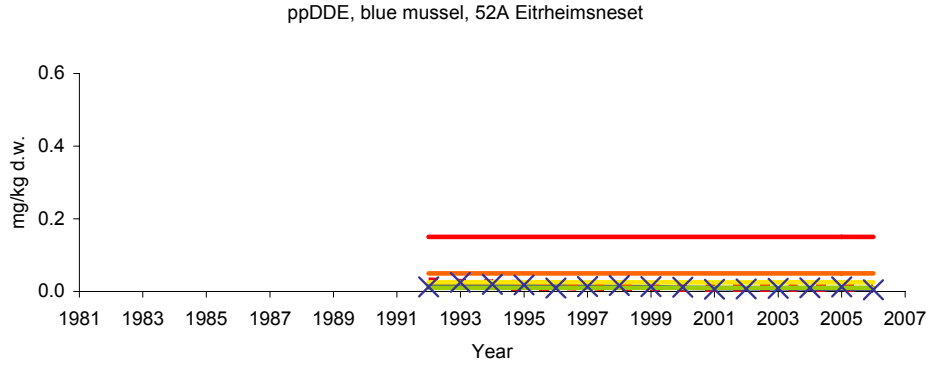

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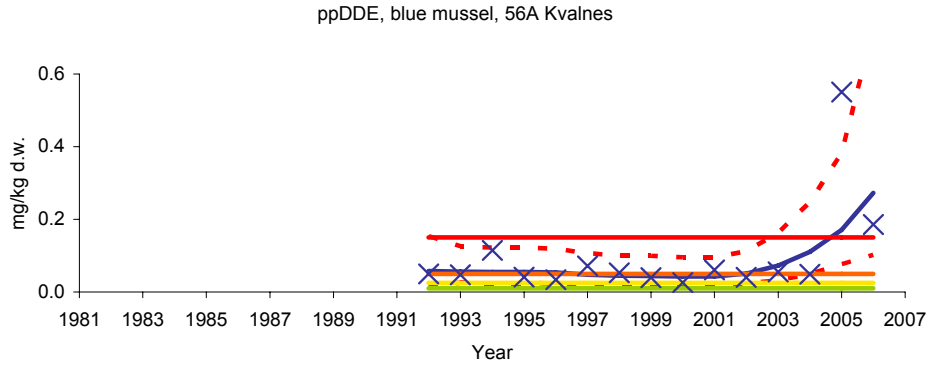


D

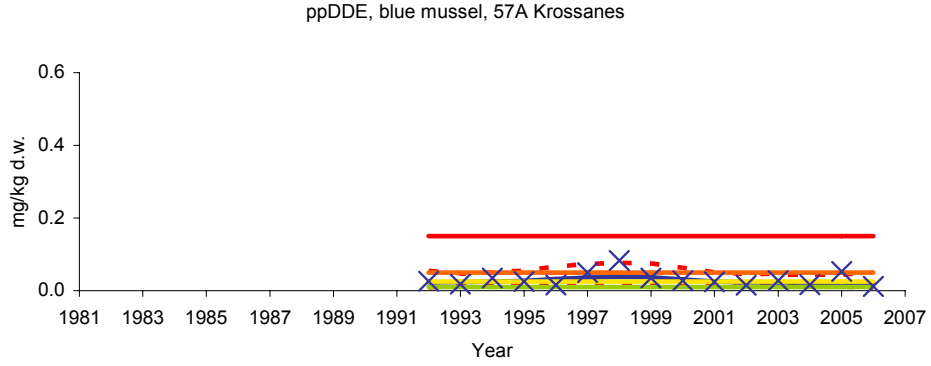


Figure 9. Median ppDDE concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. (cf. Appendix G and Appendix I, and key in Figure 21). **Note: Class limits for ΣDDT used. Horizontal line for Class I is near x-axis.**

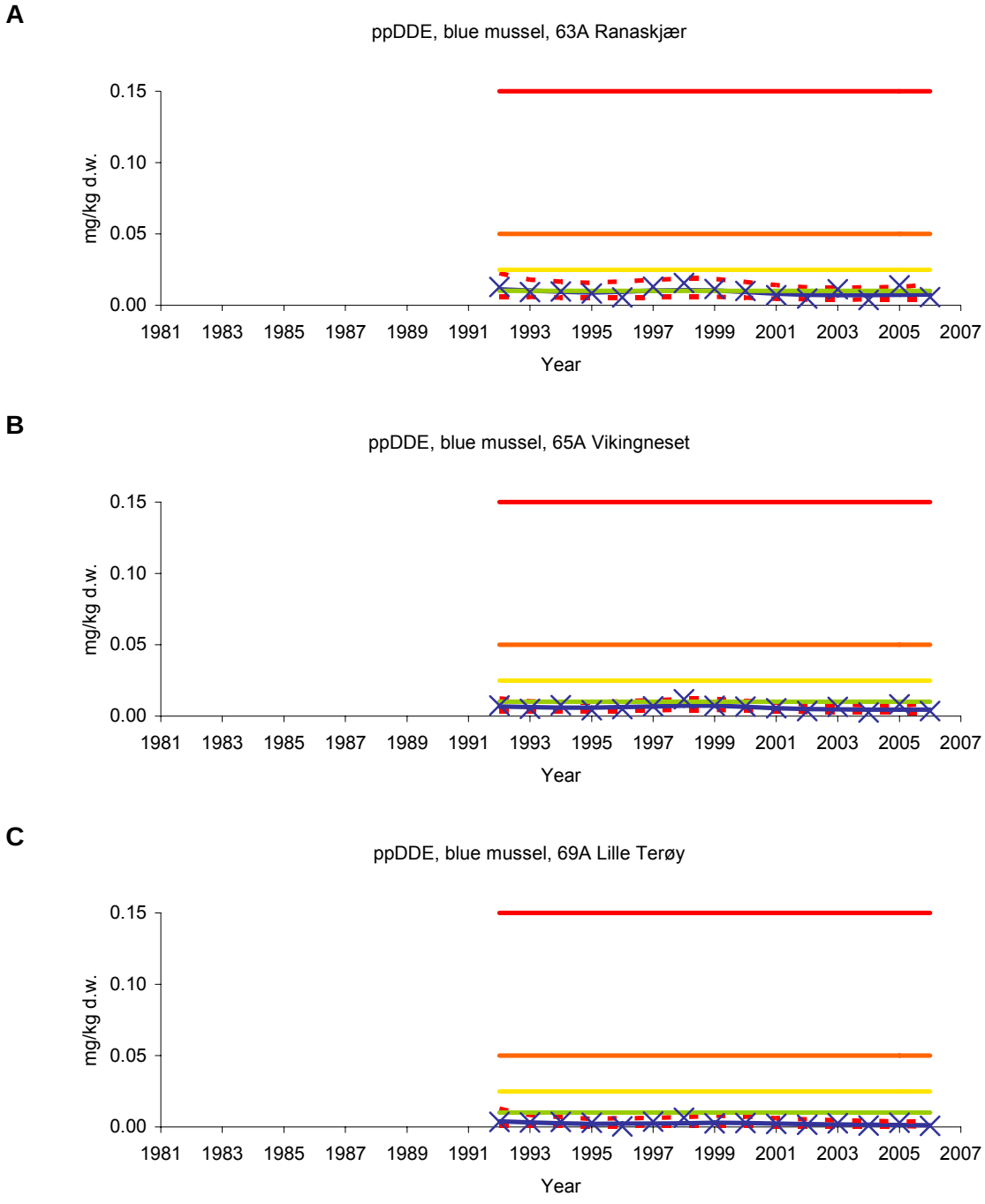


Figure 10. Median ppDDE concentrations in blue mussel (*Mytilus edulis*) from Hardangerfjord (st. 63A, 65A and 69A). (cf. Appendix G and Appendix I, and key in Figure 21). **Note: Class limits for ΣDDT used. Horizontal line for Class I is near x-axis.**

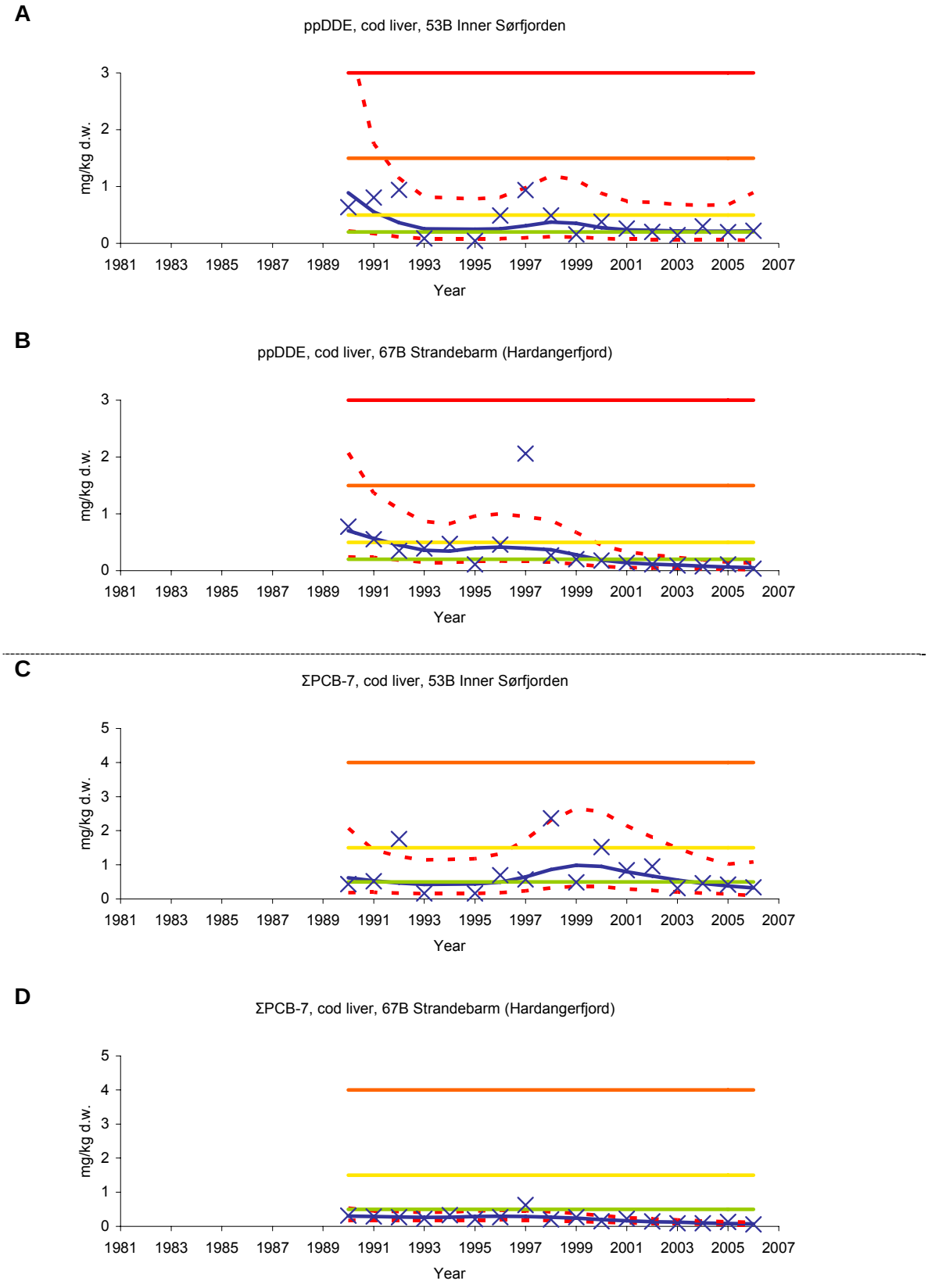


Figure 11. Median ppDDE and ΣPCB-7 concentrations in liver of cod (*Gadus morhua*) from Sørfjord (st.53B) and Hardangerfjord (st.67B) (cf. Appendix G and Appendix I, and key in Figure 21). **Note: Class limits for ΣDDT used for ppDDE. Note also that for 1989 the upper confidence interval line is off-scale in Figure A.**

1.3.3. Lista area

Blue mussel, cod and dab were insignificantly polluted (Class I or below provisional high background), with the exceptions of cadmium in dab liver and mercury in "large" dab which were moderately polluted in 2006. No upward trends were found (st.15, Appendix I and Appendix J).

1.3.4. Bømlo-Sotra area

It was impractical to continue sampling for flatfish at Borøyfjorden (st.22F). Thus, a new station in Åkrafjorden, Kyrping (st.21F), was initiated in 2000. This station is located about 82km south-east of Borøyfjorden, but like this fjord, Kypring is located in a reference area.

Blue mussel, cod and flounder from this area (22A, 23B, 21F) generally were only insignificantly polluted (Class I) or showed no overcentrations with respect to metals or organochlorines with the exception of cod fillet which was moderately polluted with mercury (Class II, Appendix I and Appendix J).

1.3.5. Orkdalsfjord area

Blue mussel from this area were monitored for the period 1984-1996, and then not again until 2004-2005 when bulk samples from four stations were investigated (Trossavika – st.84A, Flakk – 82A or Ingdalsbukt – 87A).

1.3.6. Open coast areas from Bergen to Lofoten

This stretch of coastline covers 7° of latitude to 68°N (Appendix G). Sixteen mussel stations were investigated in 2005, of which fourteen also in 2004. These fourteen were investigated prior to 2004-2005 in 1990-1993. The longest times series, from 1997 to 2006, is with blue mussel from the Husvågen area in Lofoten (st. 98A2). Blue mussel have been collected from two sites in the Lofoten area. In 1992-1993 samples were collected from Litj Skarvsundet (98A1) in the Skrova area of Lofoten, however, during the period 1994-1996 blue mussel were not found here, but nearby in the Skrova harbour (98X). In 1997 st.98A2 was established at Husvågen, roughly 18 km north of Skrova, in a small fjord remote from any apparent point source of contamination, and hence considered comparable. However, the statistical trend-analyse is based only on the Husvågen data.

In 2006, the blue mussel were only insignificantly contaminated (SFT's Class I), which has been generally the case since 1997 (Appendix I and Appendix J). Plaice from Husholmen (98F2) in the Lofoten area had overconcentrations of cadmium, 3 times “background”.

1.3.7. Exposed area of Varangerfjord near the Russian border

The remaining and northern area of JAMP in Norway stretches north of 68°N and east from a longitude of 17 to 29°E (Appendix G). Twelve mussel stations were investigated in 2006, ten of which were also investigated during the period 1994-1995. Only two mussel stations, one cod station and one plaice station were investigated in the Varangerfjord (at approximately 70°N).

In 2006, the mussels were only insignificantly contaminated (Class I) except for the moderate concentrations (Class II) found at six stations remote from point sources (stations 41A, 43A, 46A, 47A and 49A). This could indicate a natural regional difference (Appendix I and Appendix J).

Sediment was sampled at 10 stations in remote from point sources from Vågsfjorden (st.41S, near Harstad) to Varangerfjorden (10S). All were investigated previously in 1994. Surficial sediment was moderately polluted with TBT at all stations, nickel at all but Syltefjord (st.49S), and chromium at all but Tanafjord (st.48S) and Syltefjorden; benzo[*a*]pyrene at Tanafjord and Syltefjord (Appendix K).

1.3.8. Norwegian Pollution and Reference Indices (The Index Programme)

The Norwegian Pollution Control Authority (SFT) has requested a specific and small group of indices to assess the quality of the environment with respect to contaminants - The Index Programme. One index is based on the levels and trends of contaminant concentrations in blue mussel collected annually from a selection of the more contaminated fjords in Norway (Appendix L). SFT has also requested the testing of this index against "reference" stations from selected areas and fjords.

The Index scale varies from 1 to 5. Index 1 means that all areas or fjords are insignificantly polluted (Class I in SFT's environmental quality classification system (Molvær *et al.* 1997)), Index 5 means that at least one sample from each area or fjord is extremely polluted or Class V in SFT's system.

Nine fjord areas were used to calculate the Pollution Index. Taking the supplementary stations (Strømtangen, Flåøya, Moholmen and Toraneskaien) and analyses of TBT and dioxins into consideration, the Index was 2.9 for 2006 compared to 3.1 for 2005 (cf. Appendix L). A value between 3 and 4 would be between "Marked" and "Severe" Classes in the SFT system. A value bewteen 2 and 3 would be between the "Moderate" and "Marked" Classes. Indices calculated with and without supplementary stations and analyses have been presented earlier (cf. Green *et al.* 2004a, b).

Five areas were included in the Reference Index for 2006 compared to the same five for 1998-2005, and seven or eight fjords used in previous years. With the new calculation where supplementary analyses of TBT are included, the Reference Index was 1.4 for 2006, unchanged from 2005. Comparison between the old and new calculations has been done for 2002 and 2003 (cf. Green *et al.* 2004a, b). A value between 1 and 2 would be between "Slight" and "Moderate" Classes. Four of the five fjords/areas included TBT analyses.

The use of the indices to assess the general level of pollution in contaminated or reference areas of coastal water for the period 1995 to 1999 has been reviewed (Green & Knutzen, 2001). The conclusions were mainly that the sample and analytical strategies lacked adequate coverage of the relevant contaminants and geographical areas. Furthermore, the report suggested supplementing the assessment of this type with relevant analyses of sediment. In 2002 the programme was improved by including more stations and parameters relevant to the blue mussel Pollution Index.

It is not the intent of the application of the indices to give a station by station account. However, time trend analyses for the entire period (1995-2006) have been calculated and show both significant upward and downward trends in blue mussel (cf. Appendix I). Some cases are worth noting (2006 median Class / trend):

- Inner Oslofjord, Gressholmen (st.30A, Map 1, Appendix G) – TBT, ΣPCB-7, Class II / *downward*,
- Inner Oslofjord, Gressholmen (st.30A, Map 1, Appendix G) – benzo[*a*]pyrene, Class II / *upward*,
- Frierfjord area, Bjørkøya (Risøyodden) (st.71A, Map 3, Appendix G) - HCB, Class III / *downward*,
- Frierfjord area, Gjemesholmen (st.I712) and Strømtangen (st.I713) (Map 3, Appendix G) - TBT, Class II / *downward*,
- Sørfjord, Eitrheimsneset (st.52A, Map 6, Appendix G) – Cd, Class II / *downward*,
- Byfjorden (Bergen), Nordnes (st.I241) in Bergen harbour (Map 7, Appendix G) – HCB, Class III / *upward,*
- Byfjorden (Bergen), Gravdalsneset (st.I242) in Bergen harbour (Map 7, Appendix G) – HCB, Class II / *downward*.

1.4. Biological effects methods for cod

The rationale to use biological effects methods within monitoring programmes is to evaluate whether marine organisms are affected by contaminant inputs. Such knowledge can not be derived from tissue levels of contaminants only. In addition to enable conclusions on the health of marine organisms, some biomarkers assist in the interpretation of contaminant exposure and bioaccumulation. The biological effects component of the Norwegian JAMP is possibly the most extensive of its type in Europe and includes imposex in gastropods as well as biomarkers in fish. The four chosen methods for fish were selected for specificity, for robustness and because they are among a limited set of methods proposed by international organisations, including OSPAR and ICES.

The JAMP-programme for 2006 included five biological effects methods (BEM): OH-pyrene, ALA-D, EROD-activity, CYP1A and TBT (Table 2). The first four are discussed in this chapter (Figure 12 to Figure 14) and TBT is discussed separately (cf., section 1.5). Results for OH-pyrene, ALA-D, EROD and metallothionein (MT) in cod and flatfish, 1997-2001, have been reported earlier (Ruus *et al.* 2003). For the 2006 investigations OH-pyrene, ALA-D, EROD-activity and CYP1A were measured in Atlantic cod from the inner Oslofjord (30B), Sørfjord (st.53B), and Sotra-Bømlo area (23B). OH-pyrene was also measured in cod outside Lista (15B). It has become clear that cod caught in the open coastal area outside Lista are more strongly affected by PAHs than cod at the other stations, despite the large water exchange in that area (Ruus *et al.* 2003). Furthermore, stations from the inner Oslofjord and Sørfjord are considered to be more contaminated with metals and organochlorines than the other stations.

Table 2. Summary of biological methods employed by the JAMP-2006.

Code	Name	tissue sampled	Specificity
OH-pyrene	Pyrene metabolite	fish bile	PAH
ALA-D	δ-aminolevulinic acid dehydrase inhibition	fish red blood cells	Pb
EROD-activity	Cytochrome P4501A-activity (CYP1A/P4501A1, EROD)	fish liver	planar PCB/PCNs, PAHs, dioxins
CYP1A	Relative amount of cytochrome P450 1A-protein	fish liver	Supporting parameter for EROD-activity
TBT	Imposex/Intersex	snail soft tissue	organotin

Under controlled conditions the measures derived from 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 higher exposure.

As in most previous years, 25 individual cod were sampled for biological effects measurements at each station. However, since 2002 only three stations (four for OH-pyrene) were sampled, instead of eight stations as in previous years. Furthermore, no samples for BEM were taken from flatfish. All fish were collected by local fishermen and kept alive until sampling by NIVA staff within 5 days. There is a continuous process to train and inform the fishermen that collect fish for JAMP to ensure the quality of the material.

1.4.1. OH-pyrene metabolites in bile

Detection methods for OH-pyrene have been changed (improved) two times since the initiation of these analyses in the JAMP programme. In 1998 the support/normalisation parameter biliverdin was changed to measurement of light absorbance at 380 nm. Furthermore, in 2000, the use of single-wavelength fluorescence for quantification of OH-pyrene was discontinued and the use of HPLC separation with fluorescence detection was implemented. All data shown in Figure 12 were obtained by the latter method. Although there is a good correlation between results from the two methods they can not be compared directly. The single wavelength fluorescence method is naturally more unspecific and will include fluorescence from more components than the HPLC method, which has extremely high specificity towards individual metabolites. The interpretation of OH-pyrene data is therefore primarily focused on the differences between the stations within each year.

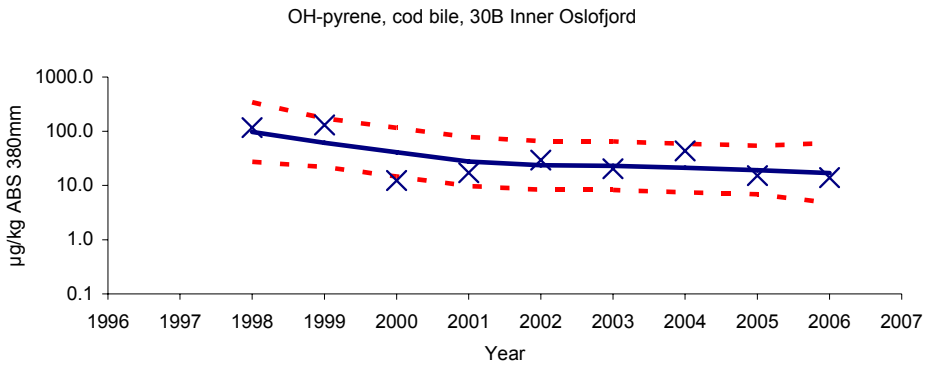
As in 2005, the median concentrations of OH-pyrene metabolites in bile from cod ranged between stations in the following order in 2006: Oslofjord (st. 30B) > Sørfjord (st. 53B) > Sotra-Bømlo area (reference; st. 23 B) > Lista (st. 25B). However, variability was high, and the highest at Lista (st. 15) as previous years. More specifically, in 2006 the median concentration of OH-pyrene metabolites in cod from the inner Oslofjord (st.30B), was a factor >6 higher than that of cod from Lista (st.15B). (Figure 12, Appendix I). This result differ from previous years (before 2000, and in 2001).

For 1998, 1999, 2001 the median concentrations of OH-pyrene in cod from Lista (st.15B) were higher than at stations 30B, 53B and 23B (no samples from st.15B in 2000). In 2002, the OH-pyrene levels at Lista were above those at the reference locality, Karihavet (23B), but lower than in the inner Oslofjord (st.30B) and in the inner Sørfjord (st.53B). In 2003 and 2004 concentrations were below those from the inner Oslofjord (st. 30B) but above the reference (st.23B) and those found in the inner Sørfjord (st.53B). It is worth mentioning again that the variability in the OH-pyrene bile concentrations in cod from Lista (st.15B) are relatively large (compared to at the other stations), all years (Figure 12). A significant *downward* trend in OH-pyrene in bile from cod at Lista is visible for the period 1998-2006 Figure 12, Appendix I). Lista is located in an area with a large discharge of PAH to water from an aluminium-smelter. The fish were collected on the open coast and the discharge from the smelter occurred in a small bay about 2-3 km away.

In 2006, as in most years, concentrations of OH-pyrene in cod from Sørfjorden (53B) were higher than the concentrations in cod from Sotra Bømlo (23B) This also confirm the generally assumed contamination of this area.

Bile metabolites of PAH can be detected within a short period (hours) following exposure, and holding conditions prior to sampling may affect results. However, measures were taken in 1998 and 1999 to minimise or remove the problem. Given the precautions taken, it is unlikely that the observed levels have been caused by storage of fish prior to tissue sampling.

A



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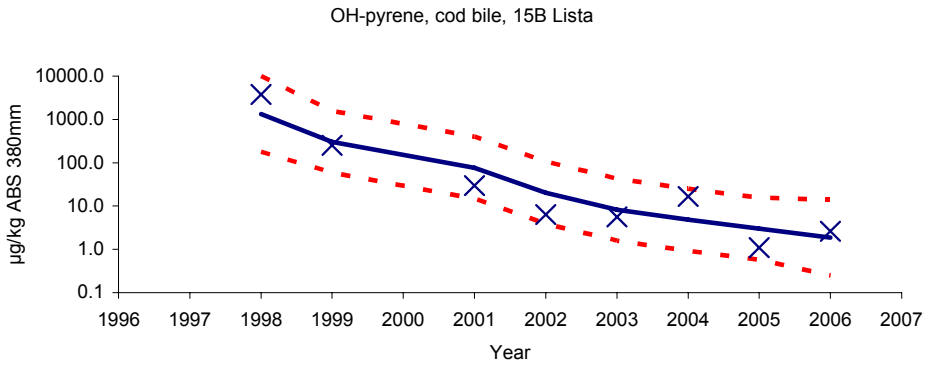

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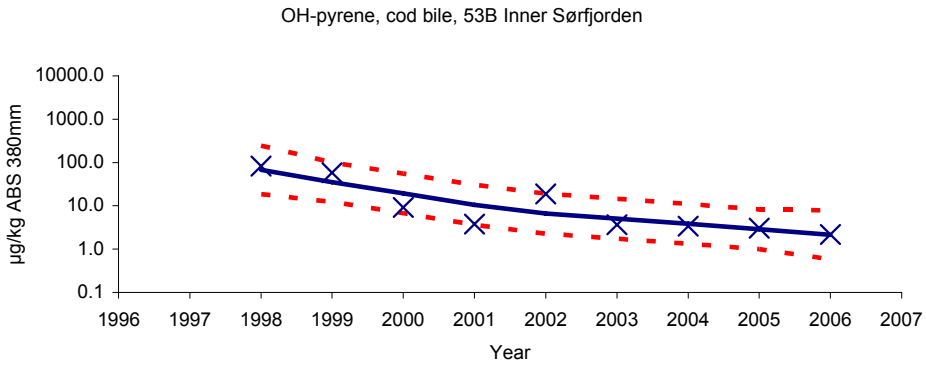

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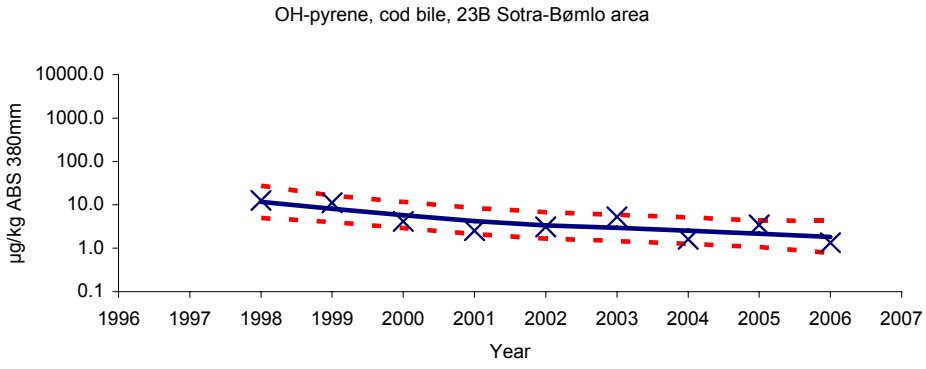


Figure 12. Concentration of OH-pyrene (µg/kg ABS 380nm) in bile from Atlantic cod collected at the inner Olsofjord (st.30B), Lista (st.15B), inner Sørfjorden (st.53B) and Sotra-Bømlo (st.23B). (cf. Appendix G and Appendix I, and key in Figure 21). **NB: log-scale.**

1.4.2. 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. Previous studies indicate that only zinc may ameliorate the effect of lead to some extent, but the effect is variable and weak. Other studies have also shown ALA-D to be a remarkably robust biomarker and factors such as sex, age or season do not appear to affect the response.

Most years the activity of ALA-D in cod was generally inhibited in the inner Oslofjord (st.30B) and inner Sørfjord (st.53B), compared to reference stations, i.e. outer Oslofjord (st.36B), Karihavet in the Sotra-Bømlo area (st.23B), and Varangerfjord (st.10B). This was the case for 1997, 1998, and 2000-2006 (Figure 13 and Appendix I,). For all years 1997-2006 the median activity of the enzyme in cod from inner Sørfjord (st.53B) was generally lower than on the open coast (Karihavet - st. 23B), about 130 km to the west.

Since 2002, ALA-D has been measured only in cod from Karihavet (st. 23B), inner Oslofjord (st.30B) and inner Sørfjord (st.53B). In 2006 as in previous years, the inibition was largest in the inner Sørfjord and the inner Oslofjord, although the trend was less evident than in 2005 (Figure 13, Appendix I). This indicates pollution of lead (and possibly other metals) in these two fjords. An increase in median ALA-D activity could be seen over the years from 2002 to 2006 indicating less exposure. In the Oslofjord (st. 30B), this is consistent with a decrease in hepatic lead concentrations since 2002 (Appendix I). .

No significant temporal trends in ALA-D activity were found neither in Sotra-Bømlo (23B), Oslofjord (st.30B) or Sørfjord(st.53B).

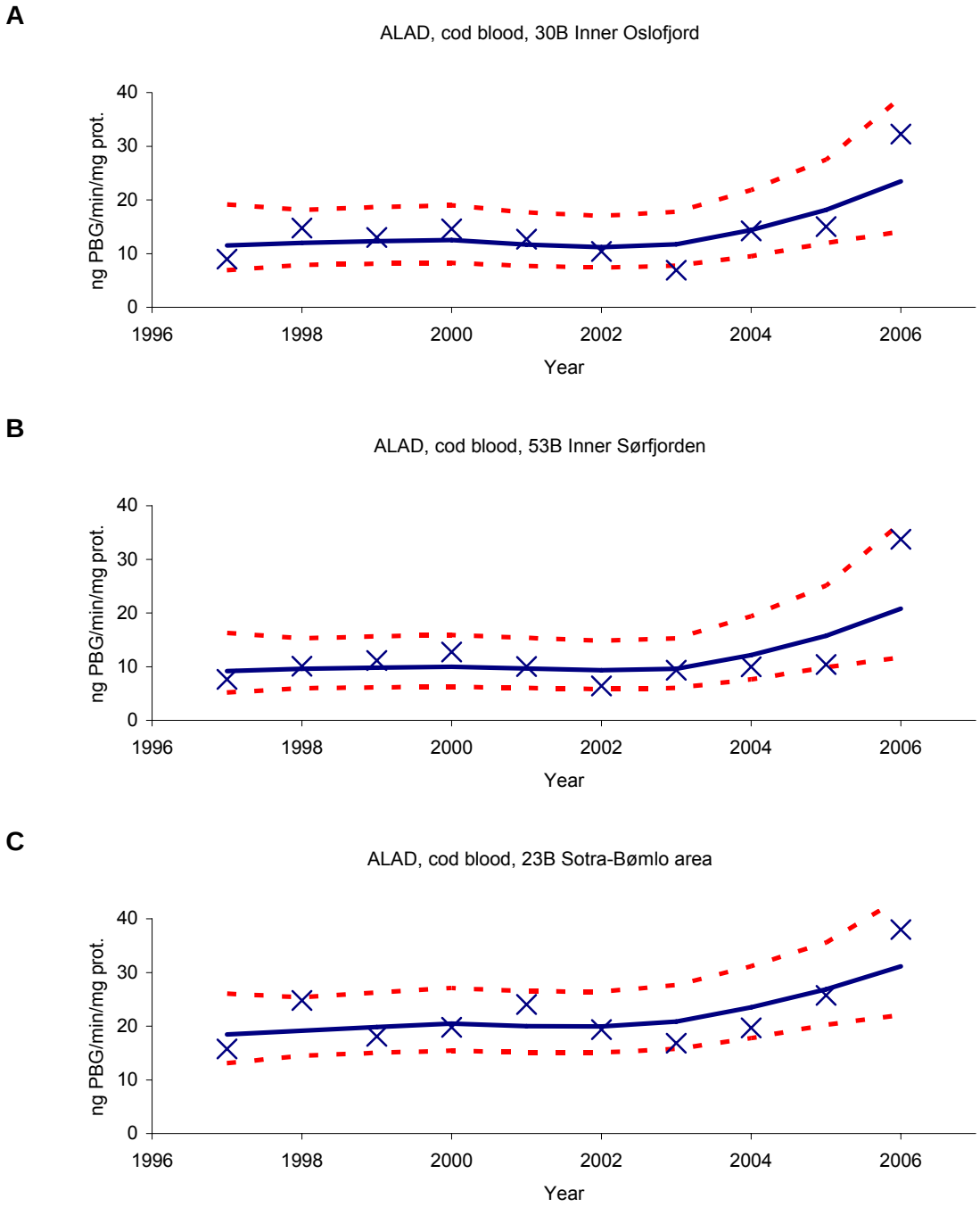


Figure 13. Activity of δ-aminolevulinic acid dehydrase (ALA-D, ng PBG/min/mg protein) in red blood cells from Atlantic cod collected at the inner Olsofjord (st.30B), inner Sørfjorden (st.53B) and Sotra-Bømlo (st.23B). (cf. Appendix G and Appendix I, and key in Figure 21). OBS: lower activity means higher exposure and vice versa.

1.4.3. EROD-activity and amount of CYP1A protein in liver

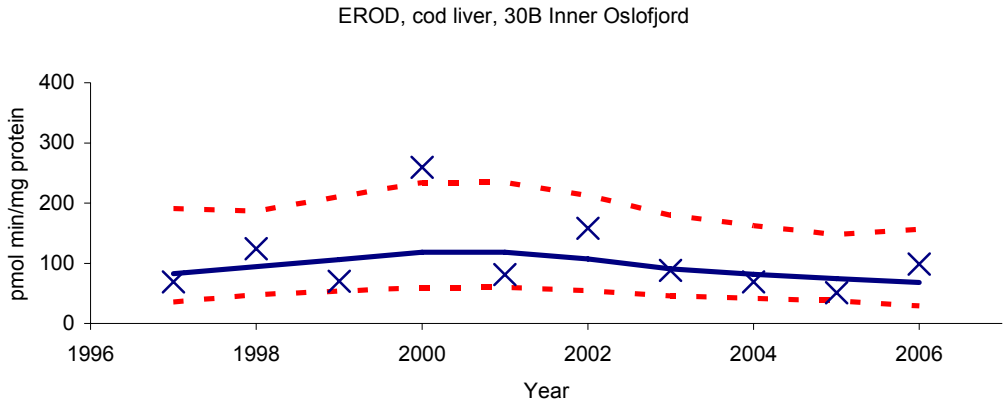
EROD-activity

High activity of hepatic cytochrome P4501A activity (EROD-activity) normally occurs as a response to the contaminants indicated in Table 2. 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, i.e. inner Oslofjord (st.30B) and inner Sørfjord (st.53B/F). In 2005, no such differences were evident. In 2006 median EROD-activity was highest in the Oslofjord (st. 30B), allthough variability was high, There were no differences between the cod from the inner Sørfjord and Karihavet in 2005 (Figure 14, Appendix I). Previous years have also shown that EROD-activity in both fish from the inner Oslofjord and from the inner Sørfjord are not consistently higher than at the reference station on the west coast (st.23B). No significant temporal trends were found at these three 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 I), 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.

In 2006, there was a significant correlation between the EROD-activity and the amount of CYP1A protein measured, corresponding to earlier results (Green *et al.* 2004b). The goodness of fit for the linear model was, however, poor (R^2=0.32). Furthermore, more evidently than the EROD-activity, CYP1A was in 2006 consistently higher in the inner Oslofjord (st.30B) than in the inner Sørfjord (st.53B) and at the reference station on the west coast (st.23B) (Figure 15, Appendix I).

A



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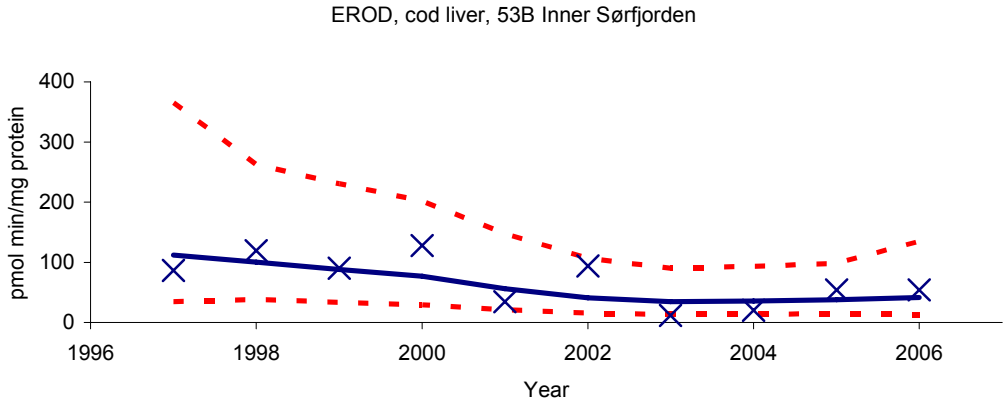

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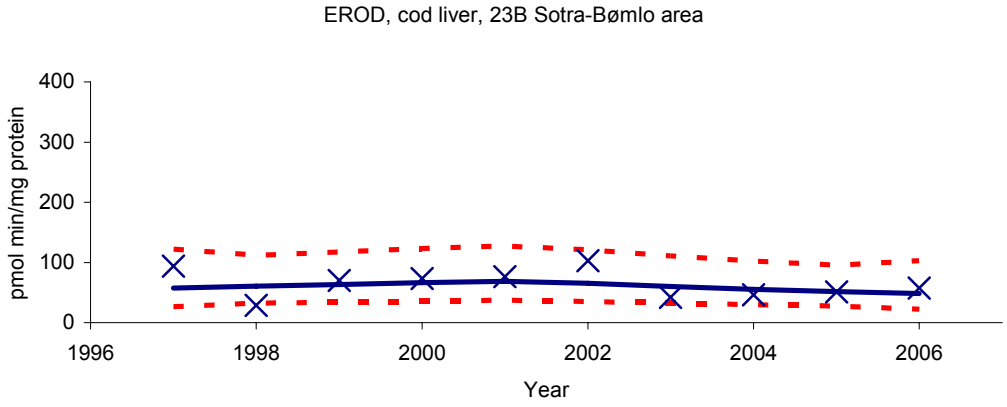

Figure 14. Activity of cytochrome P4501A (EROD-activity, pmol/min/mg protein) in liver from Atlantic cod collected at the inner Olsofjord (st.30B), inner Sørfjorden (st.53B) and Sotra-Bømlo (st.23B). (cf. Appendix G and Appendix I, and key in Figure 21).

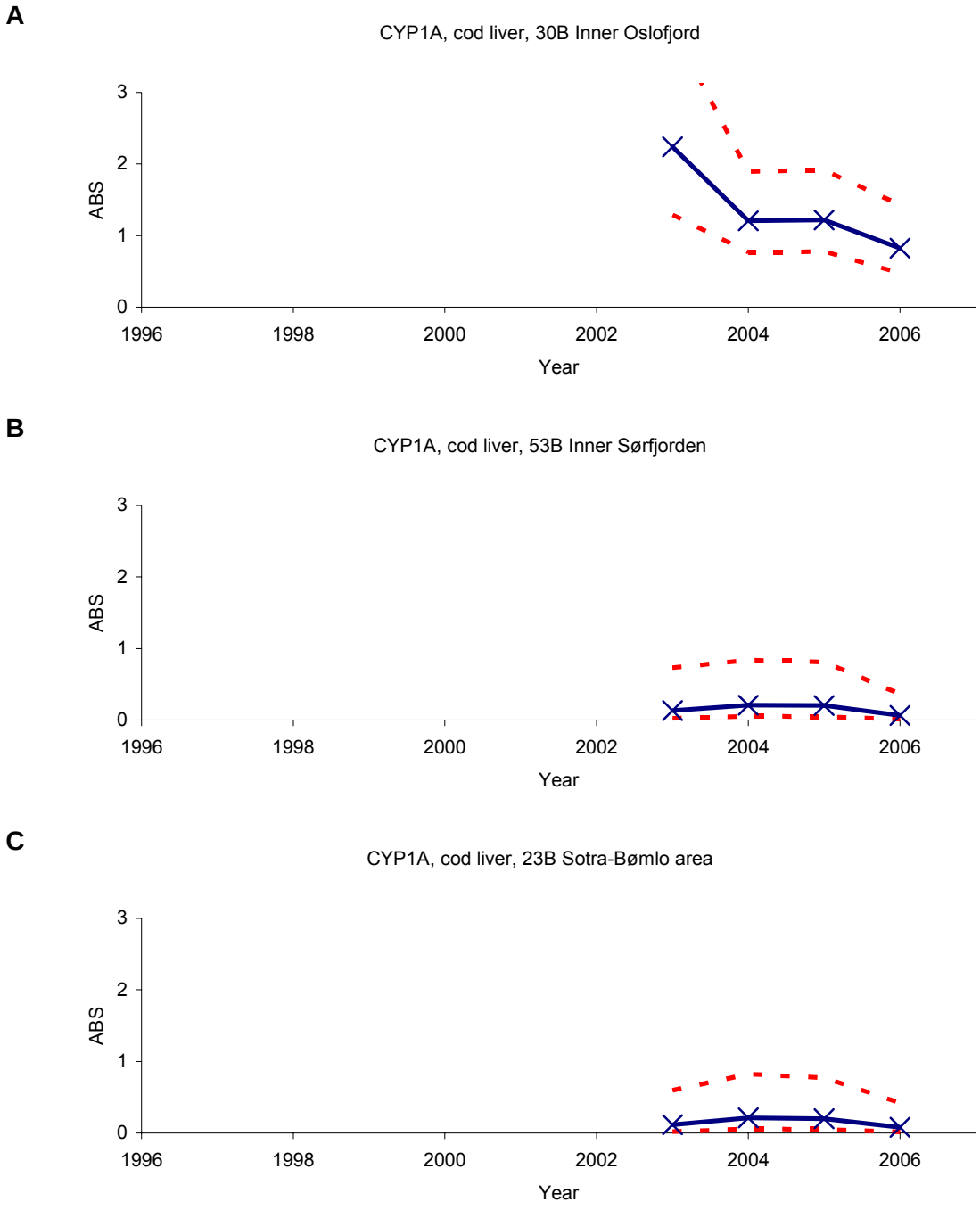

Figure 15. Activity of cytochrome CYP1A (relative amount of Cytochrome P4501A-protein) in liver from Atlantic cod collected at the inner Olsofjord (st.30B), inner Sørfjorden (st.53B) and Sotra-Bømlo (st.23B). (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in Figure A.**

1.4.4. Concluding remarks

The application of BEM methods within JAMP through the years 1997-2001 (and 2004) indicated that the location Lista (st. 15B), which was previously regarded as only diffusely polluted, had an input of PAH which was sufficient to clearly affect fish in the area. However, in 2002 and 2003 the median concentrations of OH-pyrene in cod from Lista were lower than those from the inner Oslofjord (st.30B) and inner Sørfjord (st.53B) and in 2005, OH-pyrene concentrations in cod from Lista were the lowest ever recorded within JAMP. In 2006, the lowest median OH-pyrene concentration was found at Lista, as in 2005. As in some previous years, relatively large variability was observed between individuals from Lista.

Results for the period 1997-2005 indicated that there are lead effects, shown by decreased activity of the enzyme ALA-D in the two most strongly polluted areas, i.e. cod from the inner Oslofjord (st.30B) and cod from the inner Sørfjord (st.53B). This indication was less evident in 2006.

The highest median EROD-activity was found in the inner Oslofjord (st.30B). Median EROD-activity in the inner Sørfjord was no higher than in the less contaminated Sotra-Bømlo area. Previous years have also shown that EROD-activity in fish from the inner Oslofjord and Sørfjord stations are not consistently higher than at other, presumed cleaner stations. The amount of CYP1A protein was higher in the Osloford (st.30B) than in the Sørfjord (st.53B), and the Sotra-Bømlo area (st.23B).

1.5. Effects and concentrations of organotin

Effects from organotin in dogwhelk (*Nucella lapillus*) were investigated at 8 JAMP and Index stations in 2005. Concentrations of organotin in dogwhelk and blue mussel (*Mytilus edulis*) were quantified at 8 and 12 stations, respectively, and including both the JAMP and Index stations. The stations are located along the coast of Norway and samples were collected August-November 2005 (Appendix E and maps in Appendix G).

TBT-induced development of male sex-characters in females, known as imposex (Vas Deferens Sequence Index - VDSI), was analysed according to OSPAR-JAMP guidelines. Detailed information about the chemical analyses of the animals is given in Følsvik *et al*. (1999).

1.5.1. Dogwhelk

The effects from organotin were generally low. Espevær (st. 22G) on the West coast had a VDSI of 4, (Appendix J). The remaining 7 stations had low VDSI (<2). No effects were found at Brashavn (st. 11G). A significant *downward* trend was found at Færder (st. 36G) (Appendix I, Figure 16).

Concentrations of organotin from the eight stations measured were relatively low (<0.24 mg/kg d.w.). As in 2003 and 2004 the highest organotin levels were found at Haugesund (st. 227G2, Appendix I, Appendix J, Figure 17). Concentrations had decreased compared to 2003 and 2004, however, no statistically significant temporal trends for the period 1997-2005 were found.

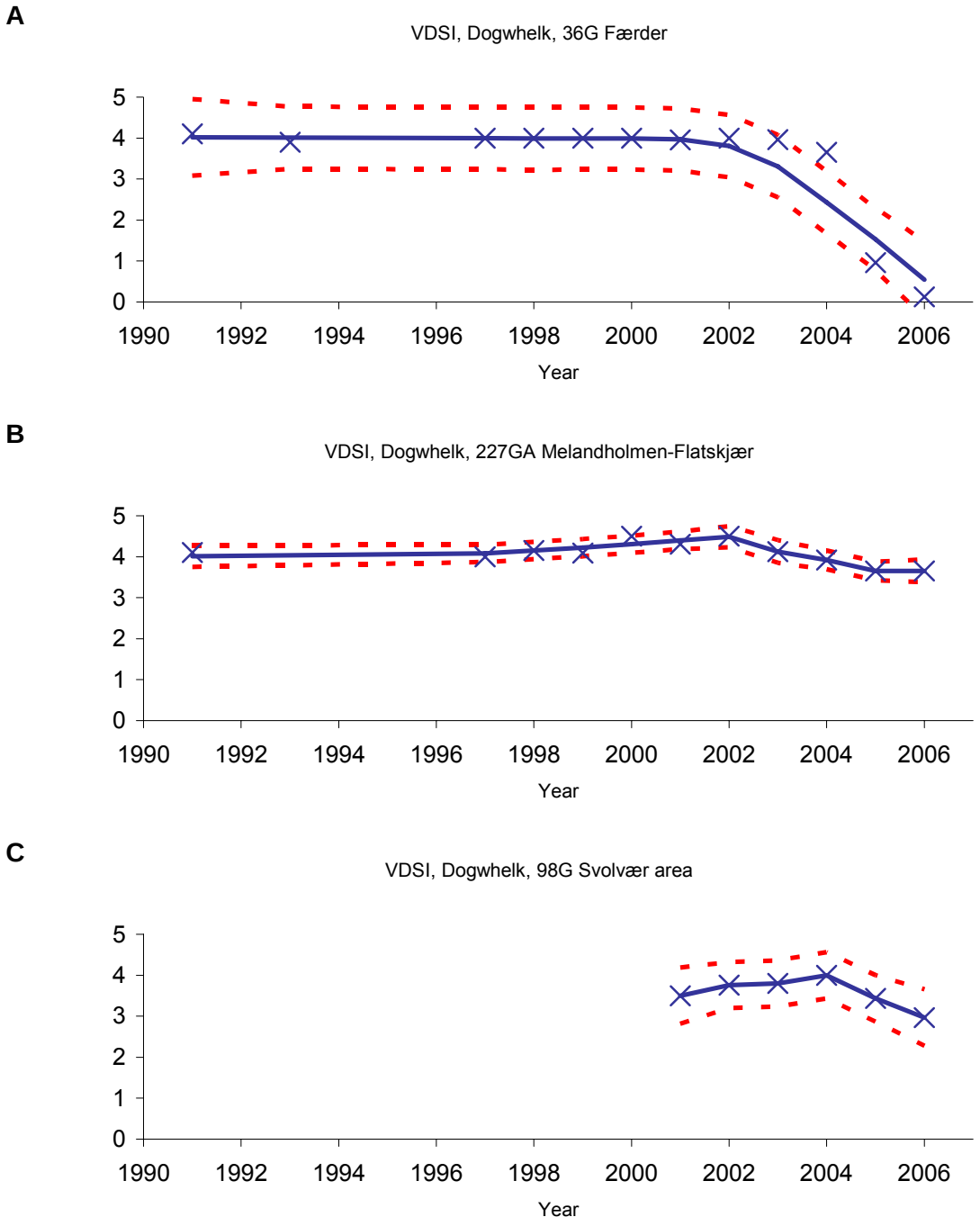

Figure 16. Imposex (VDSI) in dogwhelk (*Nucella lapillus*) at 2 stations in southern Norway; Færder (36G) and Melandholmen-Flatskjær of the Haugesund area(227G1 and 227G2) and one at Lofoten (98G). Data from 1991 (Harding *et al*. 1992) and 1993 (Walday *et al*. 1997). (cf. Appendix G and Appendix I, and key in Figure 21).

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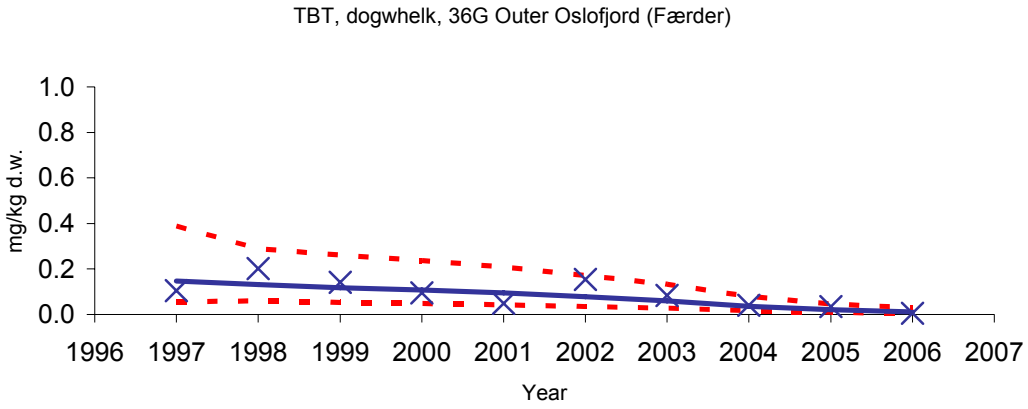

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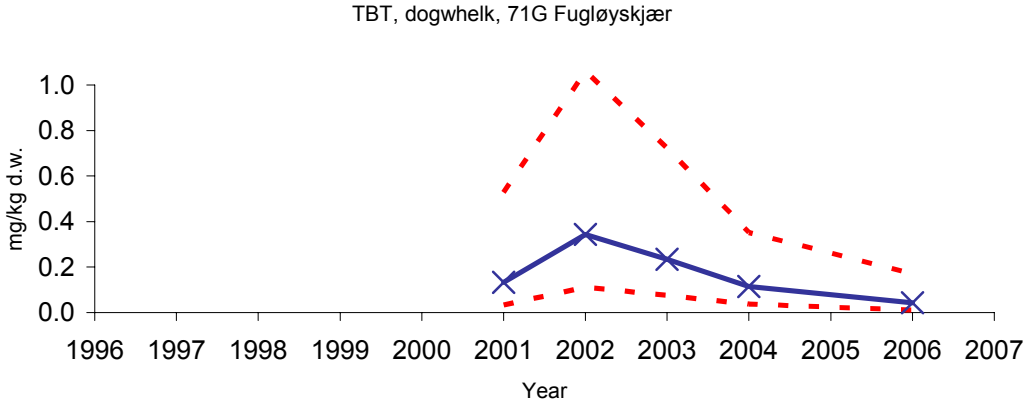

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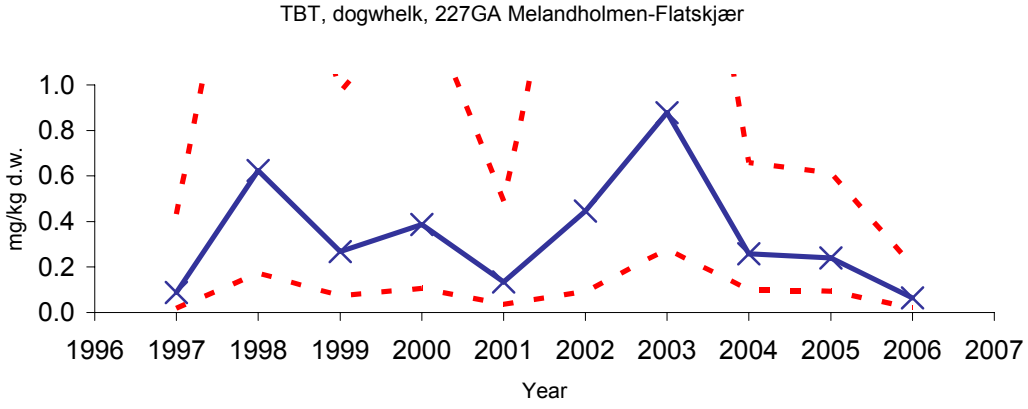

Figure 17. Median concentration of TBT (on a formulation basis) in dogwhelks (*Nucella lapillus*) from outer Oslofjord (36G), Langesundsfjord (west of Oslofjord) (st.71G) and Melandholmen-Flatskjær of the Haugesund area (227G1 and 227G2), mg/kg (mg TBT/kg) dry weight. NB: (cf. Appendix G and Appendix I, and key in Figure 21). Note: for some years the upper confidence interval line is off-scale in Figures B and C.

1.5.2. Blue mussel

Blue mussel was severely contaminated with organotin at one station in the inner Oslofjord (Index st. 301); Class IV in SFTs environmental classification system (Appendix J, Figure 18). Moderately (Class II) or markedly (Class III) polluted blue mussel were not only found in other harbour areas (e.g. the Frierfjord (st.712, and 713) and Haugesund (st.227A)) but also in an area in Espevær (st. 22A) on the West coast presumably remote from point sources. Low median concentrations (Class I) were found at the northern stations (st.11X) and at Farsund (st.15A) as well as some stations in western Norway. Significant *downward* trends were found in the inner Oslofjord (st.30A) and the Langesund area (st. 71A).

1.5.3. Concluding remarks

The presence of organotin (as TBT) in Norwegian waters exceeded acceptable levels at 7 of the 13 blue mussel stations monitored in 2006, not only in harbour areas but also one station presumably remote from known point sources. Concentrations of organotin in blue mussel and dogwhelk were elevated, and biological effects from TBT were found in dogwhelk from all but one of the fourteen stations investigated. eight of the twelve timeseries for TBT in blue mussel showed significant *downward* trends. This may be an indication that the ban on the use of TBT in antifouling on boats <25 m of length, in effect since 1.January 2003, has had an effect.

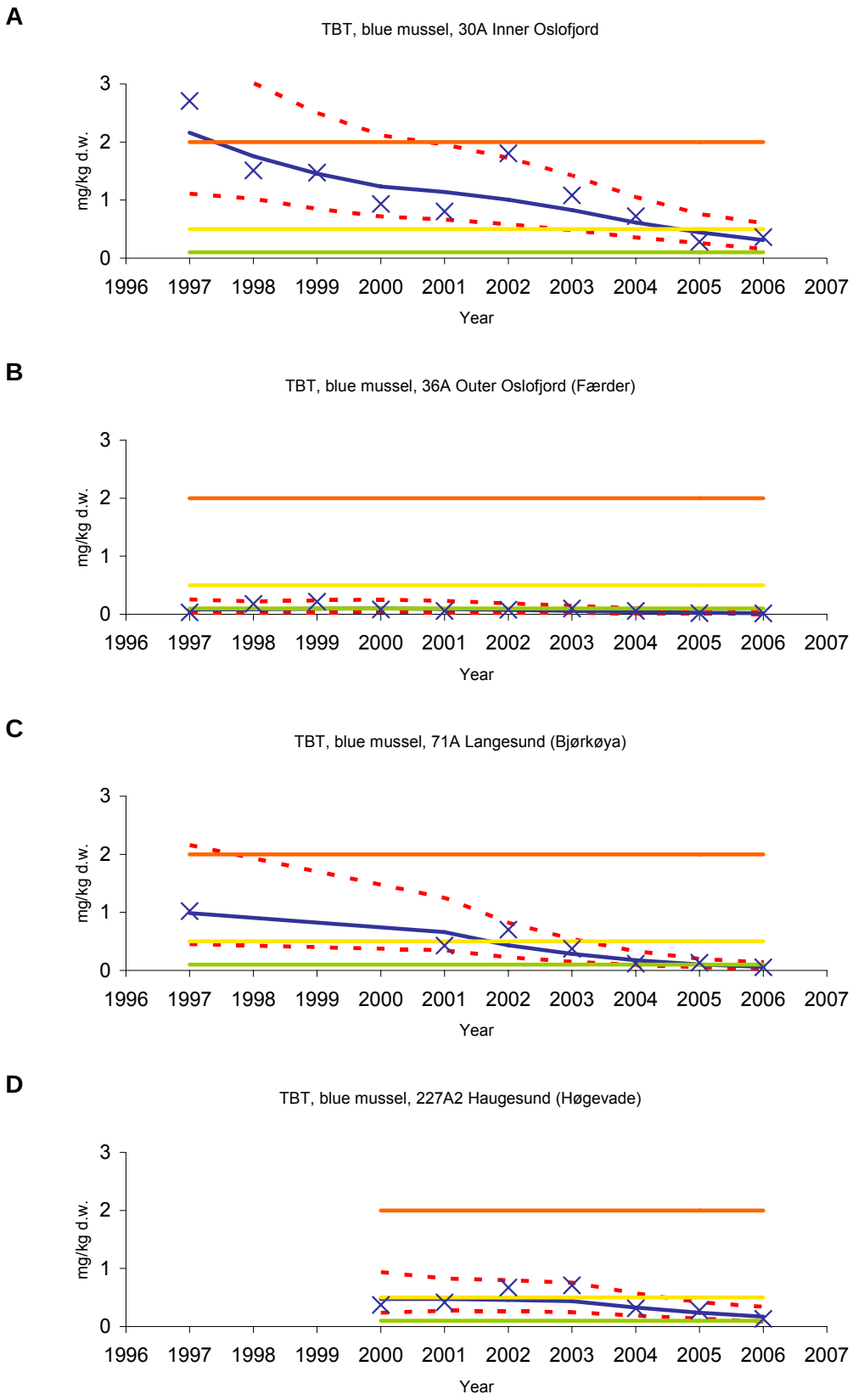

Figure 18. Median concentration of TBT (on a formulation basis) in blue mussel (*Mytilus edulis*) from inner (st.30A) and outer (st.36A) Oslofjord, Langesundsfjord (west of Oslofjord) (st.71A) and Haugesund (St.227X), mg/kg (mg TBT/kg) dry weight. (cf. Appendix G and Appendix I, and key in Figure 21). Note: for 1997 in Figure A the upper confidence interval line is off-scale. Note: horizontal line for Class I is near x-axis

1.6. Polybrominated diphenyl ethers

For the second year, polybrominated diphenyl ethers (PBDs) were investigated. Three cod stations were selected: inner Oslofjord (st.30B), inner Sørfjord (st.53B) and Karihavet (st.23B) (Figure 19). The median concentration of sum BDE was highest in the inner Oslofjord and lowest at the reference area in Karihavet. Median concentrations found at presumed reference stations of Svolvær, Færder, Utsira and Bømlo-Sotra indicated that a high background in these diffusely contaminated areas might be 30 µg/kg w.w. (Fjeld *et al.* 2005) which was higher than the median found in inner Sørfjord and Karihavet. The median found in the inner Osloford was 60 µg/kg w.w. and in the interval of 37-112 µg/kg w.w. found in other contaminated areas (Fjeld *et al.* 2005; Berge *et al.* 2006).

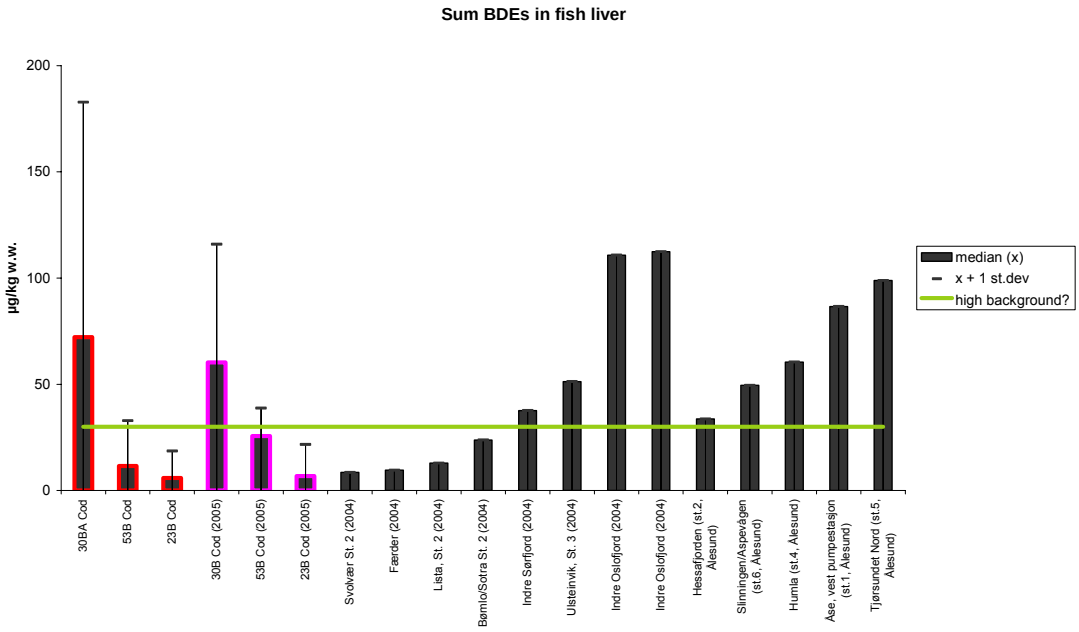

Figure 19. Polybrominated diphenyl ethers (PBDE) in liver of cod (*Gadus morhua*) at 3 JAMP-stations in southern Norway (inner Oslofjord - 30B, inner Søfjord - 53B, and Karihavet - 23B) bar shown with red (2006) and purple (2005) borders, and results from two other investigations (Fjeld *et al.* 2005 – marked as 2004, Berge *et al.* 2006), see text.

1.7. PFOS

For the first time under JAMP, perfluroalkyl compounds (PFAS) were investigated. Three cod stations were selected: inner Oslofjord (st.30B), inner Sørfjord (st.53B) and Karihavet (st.23B) and monitored in 2005 and 2006 (Figure 19). The median concentration of the indicator PFAS compound perfluoroktylsulfonate (PFOS) was highest in the inner Oslofjord. Median concentrations found at presumed reference stations of Svolvær, Frakfjord, Varangerfjord indicated that a high background in these diffusely contaminated areas might be 30 µg/kg w.w. (Bakke *et al.* 2007a) which was higher than the median found in inner Sørfjord and Karihavet. The median found in the inner Osloford was 60 µg/kg w.w. and in the interval of 37-112 µg/kg w.w. found in other contaminated areas (Fjeld *et al.* 2005), Berge *et al.* 2006).

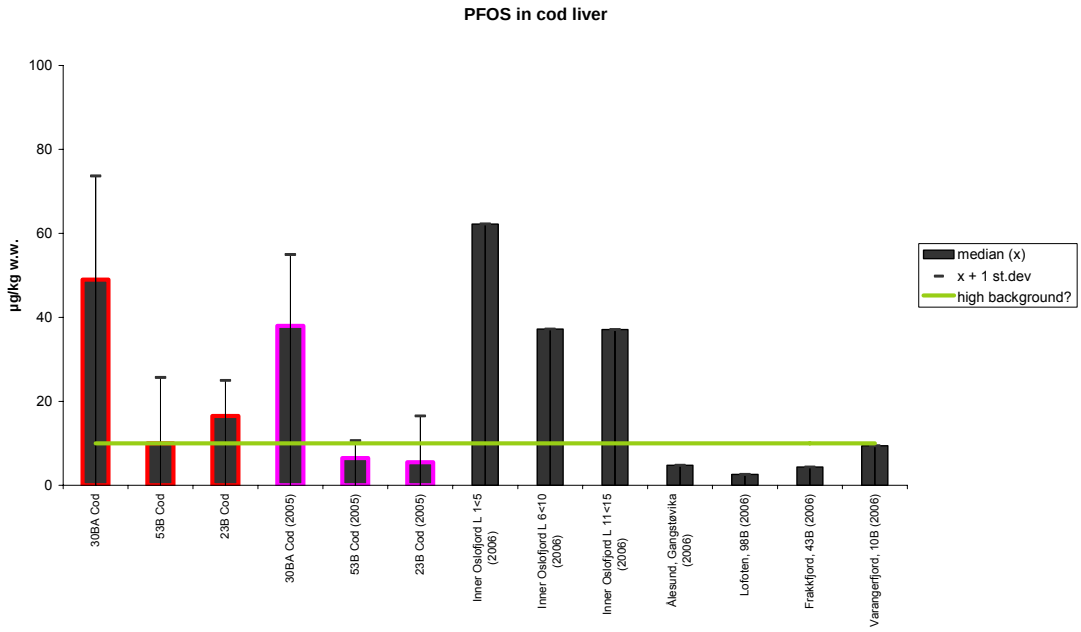

Figure 20. Perfluoroktylsulfonate (PFOS) in liver of cod (*Gadus morhua*) at 3 JAMP-stations in southern Norway (inner Oslofjord - 30B, inner Søfjord - 53B, and Karihavet - 23B) bar shown with red (2006) and purple (2005) borders , and results from one other investigation (Bakke *et al.* 2007a – marked as 2006), see tex

1.8. Comment on dioxins

Recent assessment of dioxin data from the regional Grenland monitoring in cod liver (Bakke *et al.* 2007b) has indicated that an apparent downward trend in wet-weight concentrations over the last 16 years in the most polluted fjord area may be a spurious effect of a major long-term reduction in fat content; the concentrations on fat basis are constant over the years, apart from a few deviations in some years. The decrease in fat content may be due e.g. to (unknown) changes in general life conditions in the fjord. Cod liver samples from the other fjord areas do not show a similar long-term decrease in fat content, and therre is not a clear connection between lipid content and wet weight based dioxin levels for these fjords. This emphasizes the need to investigate the relations between contaminant levels and biological characteristics to interpret observed time series of contaminant levels in biota as signs of changes in the external environment.

1.9. Overall conclusions

In regards to *temporal trend* assessment, 807 timeseries were analysed (Appendix I). There were 137 significant trends detected, of which 116 were downward and 21 upward.The following cases should be noted:

- ΣPCB-7 in blue mussel from the inner Oslofjord has *decreased* since 1988;
- Mercury in cod fillet from the inner Oslofjord has *increased* since 1984;
- Cadmium in blue mussel from the inner Oslofjord (1 st.) has *increased* since 1984;
- HCB in mussel from Langesundsfjorden has *decreased* since 1983;
- Cadmium in blue mussel in the Hardangerfjord/Sørfjorden (3 st.) has *decreased* since 1987;
- Mercury in flounder fillet from the inner Sørfjorden has *increased* since 1988;
- ΣPCB-7 and ppDDE in flounder fillet from the inner Sørfjorden has *decreased* since 1990;
- Lead in blue mussel in the Hardangerfjorden (2 st.) has *decreased* since 1990;
- TBT has *decreased* in blue mussel at 7 of the 12 stations monitored (Gressholmen - st.30A, Bjørkøy in the Langesund area – st.71A, Strømtangen at the mouth of the Frierfjord – st.I713, Risøy – st.76A, Ullerø area – st.15A, Husvågen, Lofoten – st.98A2, Varangerfjord area– st. 11X);
- ΣPCB-7 in blue mussel from Gjemesholmen also in the Langesund area has *decreased* since 1995
- ΣPAH has *decreased* in blue mussel from Odderø in the Kristiansand harbour (st. I133) since 1995.

Study of the power of temporal trend monitoring was useful in assessing existing sampling strategies, however, modifications might be needed to account for local conditions (see Appendix O in Green *et al.* 2000).

The 2006 investigation also includes results on Norwegian Pollution Control Authority Pollution Indices (Appendix L), and discussion of the results of biological effects methods including imposex and intersex (chapters 1.4 and 1.5).The pollution index dropped from “Marked”-“Severe” to “Moderate”-“Marked”. The Reference index remained unchanged from 2005. The results from the biological effects methods indicate the effects of contamination. The a large number of significant downward trends were found in TBT indicate that regulatory action has lead to improvement in the investigated areas.

In regards to *spatial distribution* assessment, the concentrations found in 2006 are indicated in the bar graphs shown in Appendix J. Provisional “high background" levels were used to identify elevated concentrations. This assessment revealed no new areas of concern that are not currently under surveillance.

In regards to *effects of hazardous substances*, 40 timeseries were analysed (Appendix I). There were 7 significant trends detected, all of which were downward. Levels found in 2006 are indicated in the bar graphs shown in Appendix J. No criteria for classification have been proposed.

In regards to *risk to human health*, attention should be called to the list from Norwegian Food Safety Authority (*Mattilsynet*) which names the restrictions and recommendations concerning the sale and consumption in Norway for seafood taken from 32 Norwegian fjord areas (Table 3). Furthermore, *Mattilsynet* has issued general advice to avoid consumption of seafood taken in or in close proximity to harbours (see www.miljostatus.no > *vannforurensning* > *miljøgifter, vann* > *miljøgifter, marint* > *kostholdsråd* and review by Økland 2005).

Table 3. Summary of action taken by the Norwegian Food Safety Authority (*Mattilsynet*) concerning the consumption and sale of fish products along the Norwegian Coast (see www.miljostatus.no > *vannforurensning* > *miljøgifter*, *vann* > *miljøgifter*, *marint* > *kostholdsråd* and review by Økland 2005). Restrictions on sale vary and may concern the whole or part of fish product.

Area of concern (km^2)	Main parameters of concern	Last year of issue/ adjustment	Main fish/shellfish product of concerned	Recommendations or restrictions of concern:
Mid [1] and Inner Oslofjord (498.9) (includes Drammensfj.)	PCB	2002	fish liver, eel	Consumption and sale
Tønsberg area (23.7) (includes (Vrengen)	PCB	2003	fish liver, eel, mussels	Consumption
Inner Sandefjordfjord (1.5)	PCB	1999	fish liver	Consumption and sale
Grenlandsfjords, Langesundsfjord (90.3)	Chl.org [2]/ Dioxins	2004	fish, shellfish	Consumption and sale
Kragerø (3.2)	PAH Dioxins	2002	eel, mussels	Consumption
Tvedestrand (2.3)	PCB	2002	fish liver	Consumption and sale
Arendal (8.0)	PCB	2002	fish liver	Consumption and sale
Inner Kristiansandsfjord (33.3)	Chl.org [2]/ Dioxins/PCB	2002	fish, shellfish	Consumption and sale
Farsund area (42.0)	PCB PAH	2002	fish liver, mussels	Consumption and sale
Fedafjord (11.2)	PAH	2002	mussels	Consumption and sale
Flekkefjord (4.2)	PCB	2002	fish liver	Consumption and sale
Stavanger (4.0)	PCB PAH	2001	fish liver, mussels	Consumption
Sandnes (1.7)	PAH	2001	Mussels	Consumption
Karmsund-Eidsbotn, Vedavågen (24.1 [6])	PCB, PAH	2005	fish liver [3], shellfish	Consumption and sale
Saudafjord ()	PAH	2007	fish liver, mussels	Consumption and sale
Sørfjord (62.2)	Cd Pb Hg PCB	2005	fish, shellfish	Consumption and sale
Bergen area (169.9)	PCB	2002	fish, shellfish	Consumption and sale
Høyangerfjorden ()	Cd Pb	2007	fish, shellfish	Consumption
Årdalsfjord (30.4)	PAH	2002	mussels	Consumption and sale
Ålesund, Åsefjorden ()	HBCDD [4]	2007	fish, shellfish	Consumption
Sunndalsfjord (100.1)	PAH	2005	fish liver, mussels	Consumption and sale
Hommelvik (2.6)	PAH	2002	mussels	Consumption and sale
Inner Trondheimfjorden (1.2)	PAH PCB	2002	fish liver, mussels	Consumption
Brønnøysund (7.0)	PAH	2003	mussels	Consumption
Vefsnfjord (76.4) [5]				
Sandnessjøen (0.4)	PAH	2005	mussels	Consumption
Inner Ranfjord (16.6)	PAH	2005	mussels	Consumption and sale
Ramsund (5.4)	PCB	2002	fish, shellfish	Consumption and sale
Harstad (2.9)	PCB Pb Cd	2003	fish liver, mussels	Consumption and sale
Narvik (11.6)	PCB PAH	2005	fish, mussels	Consumption
Tromsø (17.7)	PAH	2003	mussels	Consumption and sale
Hammerfest (4.1)	PAH	2003	mussels	Consumption and sale
Honningsvåg (3.3)	PAH	2002	mussels	Consumption and sale

[1] Includes, Hvitsten, Moss, Horten og Holmenstrand
[2] Organochlorine compounds
[3] Concerns only Eidsbotn
[4] A brominated flame retardant
[5] Grounds for concern were cleared in 2005
[6] Exclusive Vedavågen

Until 2004 JAMP issues posed questions to which monitoring should provide answers, but since 2004 JAMP has been geared towards OSPAR strategy themes with specific products to be addressed (cf SIME 2004a). The relevant products and related parts of Norwegian JAMP relevant to some of these products are shown in Table 4. viz (from SIME 2004b):

Table 4. Component of the CEMP, JAMP products and related Norwegian JAMP work (cf., OSPAR 2007, SIME 2004b).

Subject	JAMP products [6]	Recent Norwegian contribution
Mandatory		
Hg, Cd and Pb	AA-2, HA-5, HA-6	2006: Levels in sediment (cf., Green *et al.* 2000) 2006: Levels and trends in biota (annual investigations since 1981, Chapter 1.3) 2006: INDEX for blue mussel from selected stations (annual investigations since 1995, cf. Chapter 1.3.8)
PCBs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8) 2006: Levels in sediment and biota (Chapter 1.3)
PAHs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8) 2006: Levels in sediment and biota (Chapter 1.3)
TBT	AA-2, HA-5, HA-6	2006: Levels and trends in blue mussel and snails (annual investigations since 1997, cf. Chapter 1.5) 2006: Levels in sediment (Chapter 1.3)
TBT effects	AA-2, HA-4, HM-3	2006: IMPOSEX in snails (annual investigations since 1997, cf. Chapter 1.5)
Voluntary		
BFR [1]	AA-2, HA-5, HA-6	2006: in cod (annual investigations since 2005, cf. Chapter 1.6)
Planar PCBs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 2002, Chapter 1.8)
Alkylated PAHs	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8) 2006: Levels in sediment and biota (Chapter 1.3)
PFOS [2]	AA-2, HA-5, HA-6	2006: in cod (annual investigations since 2005, cf. Chapter 1.7)
Dioxins [3]	AA-2, HA-5, HA-6	2006: INDEX for blue mussel from selected stations (annual investigations since 2002, Chapter 1.8)
Specific BEM [4]	AA-2, HA-4, HM-3	2006: OH-pyrene, ALA-D in cod (annual investigations since 1997, cf. Chapter 1.4) 2006: IMPOSEX in snails (annual investigations since 1997, cf. Chapter 1.5)
General BEM [5]	AA-2, HA-4, HM-3	2006: EROD-activity in cod (annual investigations since 1997, cf. Chapter 1.4)

[1]) Certain Brominated Flame Retardents
[2]) Perfluoroktylsulfonate
[3]) Polychlorinated dibenzodioxins and furans
[4]) PAH- and Metal-Specific Biological Effects
[5]) General Biological Effects
[6]) From SIME 2004b:

AA-2 An assessment in 2010 of the quality status of the OSPAR maritime area and of its sub-regions.

HA-4 A more elaborated assessment by 2009 of biological effects of hazardous substances in the maritime area;

HA-5 An assessment by 2009 of temporal trends and (where relevant/feasible) spatial distribution for the hazardous substances where periodic sampling and analysis is undertaken, in particular under CAMP, CEMP and RID;

HA-6 A general assessment by 2009 of the development in the quality status of the maritime area in relation to hazardous substances that should take into account the results of the assessments under HA-1 and HA-5, HA-2 and HA-4 and HA-3, and the results of any screening of levels of substances in the marine environment covered by HM-3;

HM-3 When appropriate, identification of the likely impacts on the marine environment of substances recorded, inter alia, in source inventories, or identified by screening methods.

2. Technical Details

2.1. Compliance with guidelines/procedures

2.1.1. JAMP programme

Samples were collected and analysed, where practical, according to OSPAR guidelines (OSPAR 1990, 1997, see also www.ospar.org/eng/ > *measures* > *list of other agreements*) and screened and submitted to ICES by agreed procedures (ICES 1996). The most important point of concern are those stations where insufficient number of fish were collected (cf. Appendix H).

2.1.2. Overconcentrations and classification of environmental quality

Classification used in this report is primarily based on the Norwegian Pollution Control Authority environmental classification system (Molvær *et al.* 1997). Focus is on the principle cases where *median* concentrations exceeded the upper limit to Class I in the Norwegian Pollution Control Authority's (SFT's) environmental quality classification system (cf. Molvær *et al.* 1997). The relevant extract from the system is shown in Table 5 and Table 6, and show five classes from Class I, "insignificantly polluted", to Class V, "extremely polluted". However, the system does not cover all the contaminants in indicator species-tissues used in JAMP. To assess concentrations not included in the system provisional "high background" values were used (Table 7). The factor by which concentrations exceeded "high background" is termed **overconcentration**. It should be noted that there is in general a need for periodic review and supplement of this list of limits 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 overconcentrations for years prior to 1997 made in this report may not correspond to figures and assessments made in previous national comments. The median concentration can be found in the tables in Appendix I or figures in Appendix J.

A review by Knutzen and Green (2001b) of provisional "high background" concentrations based on recent JAMP-data generally confirmed that the reference concentrations (i.e., upper limit for Class I) in SFT's classification system, but recommended the following revisions (concentrations in µg/kg wet weight):

Cod liver - ΣDDT: Either increase limit from 200 to 300 or preferably replace ΣDDT with p,p-DDE and keep the limit at 200,
Cod liver - ΣHCH: Decrease limit from 50 to 30,
Cod liver - TEPCDD/PCDF: Decrease limit from 0.015 to 0.0,
Cod fillet - ΣPCB7: Decrease limit from 5 to 3,
Cod fillet - ΣHCH: Decrease limit from 0.5 to 0.3,
Blue mussel - ΣPCB7: Decrease limit from 4 to 3.

Furthermore, the review, supplemented by other studies (cf. Green & Knutzen 2003), also suggested the following decreases for Class I in fillet of flounder (µg/kg w.w.):

ΣPCB7: from 5 to 3,
ΣDDT: from 2 to 1 for p,p-DDE only.

The review did not recommend changes in the Class I limits for mercury in fish fillet (1 mg/kg w.w.) or mercury, cadmium, lead, zinc and copper in blue mussel (in the same order 0.2; 2; 3; 200 and 10 mg/kg d.w.). However, for chromium and nickel in blue mussel limits should be decreased from 3 to 2 and from 5 to 3 mg/kg d.w., respectively. Further, reference values for organochlorines were indicated for fillet and liver of fish species that are not included in the classification system (dab, plaice, lemon sole) and for lead and cadmium in liver of cod.

These recommendations for changes have been taken into account in this report. However, corresponding adjustment of Classes II-V has not been done, but should be considered once the above mentioned Class I revisions have been accepted by SFT. SFT is considering these recommendations in a current review of their classification system.

No attempt has been made to compensate for differences in size groups or number of individuals of blue mussel or fish. 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 I). 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).

With respect to Purpose A (health risk assessment), the Norwegian Food Safety Authority (SNT) is responsible for official commentary as to possible health risk due to consumption of seafood. Hence, the results of the JAMP pertaining to this purpose are presented only as a partial basis for evaluation.

Table 5. Norwegian Pollution Control Authority environmental classification system of contaminants in sediment (Molvær *et al.* 1997) used in this report.

Contaminant			**Classification (upper limit for Classes I-IV)**				
			Degree of pollution				
			I	**II**	**III**	**IV**	**V**
			Insignificant	***Moderate***	***Marked***	***Severe***	***Extreme***
SEDIMENT							
Arsenic	mg/kg	d.w.	20	80	400	1000	>1000
Lead	mg/kg	d.w.	30	120	600	1500	>1500
Cadmium	mg/kg	d.w.	0.25	1	5	10	>10
Chromium	mg/kg	d.w.	70	300	1500	5000	>5000
Copper	mg/kg	d.w.	35	150	700	1500	>1500
Mercury	mg/kg	d.w.	0.15	0.6	3	5	>5
Nickel	mg/kg	d.w.	30	130	600	1500	>1500
Zinc	mg/kg	d.w.	150	700	3000	10000	>10000
TBT [1)]	µg/kg	d.w.	1	5	20	100	>100
∑PCB-7	µg/kg	d.w.	5	25	100	300	>300
∑DDT	µg/kg	d.w.	0.5	2.5	10	50	>50
HCB	µg/kg	d.w.	0.5	2.5	10	50	>50
∑PAH	µg/kg	d.w.	300	2000	6000	20000	>20000
B[*a*]P	µg/kg	d.w.	10	50	200	500	>500
$TE_{PCDF/D}$ [2)]	µg/kg [3)]	d.w.	0.01	0.03	0.1	0.5	>0.5

[1]) Tributyltin on a formula basis

[2]) TCDDN (Appendix B)

[3]) Units as noted in cf. Knutzen, 1995.

Table 6. Norwegian Pollution Control Authority environmental 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	II	III	IV	V
			Insignificant	*Moderate*	*Marked*	*Severe*	*Extreme*
BLUE MUSSEL							
Lead	mg/kg	w.w. [2]	*0.6*	*3*	*8*	*20*	*>20*
	mg/kg	d.w.	3	15	40	100	>100
Cadmium	mg/kg	w.w. [2]	*0.4*	*1*	*4*	*8*	*>8*
	mg/kg	d.w.	2	5	20	40	>40
Copper	mg/kg	w.w. [2]	*2*	*6*	*20*	*40*	*>40*
	mg/kg	d.w.	10	30	100	200	>200
Mercury	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
Zinc	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	15	40	100	>100
		d.w. [2]	*15*	*75*	*200*	*500*	*>500*
∑DDT	µg/kg	w.w.	2	5	10	30	>30
		d.w. [2]	*10*	*25*	*50*	*150*	*>150*
∑HCH	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	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	mg/kg	w.w.	0.1	0.3	0.5	1	>1
∑PCB-7	µg/kg	w.w.	3	20	50	150	>150
∑DDT	µg/kg	w.w.	1	3	10	25	>25
∑HCH	µg/kg	w.w.	0.3	2	5	15	>15
HCB	µg/kg	w.w.	0.2	0.5	2	5	>5
COD, liver							
∑PCB-7	µg/kg	w.w.	500	1500	4000	10000	>10000
∑DDT	µg/kg	w.w.	200	500	1500	3000	>3000
∑HCH	µg/kg	w.w.	30	200	500	1000	>1000
HCB	µg/kg	w.w.	20	50	200	400	>400
$TE_{PCDF/D}$ [3]	µg/t [4]	w.w.	10	40	100	300	>300

[1]) Tributyltin on a formula basis

[2]) Conversion assuming 20% dry weight

[3]) TCDDN (Appendix B)

[4]) µg/1000 kg (Appendix B)

Table 7. 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), except for dab where the suggested limit is based on JAMP-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 Pollution Control Authority Environmental 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]) With respect to revisions suggested by Knutzen & Green (2001b) and Green & Knutzen (2003), see text.

2.1.3. Comparison with previous data

A simple 3-model approach has been developed to study time trends for contaminants in biota based on *median* concentrations (ASMO 1994). A variation of this method was applied to mercury in fish fillet to distinguish trends in "small" and "large" individuals, the size of which may vary from year to year, station to station, depending on the catch. To determine the "small" fish, the sample is sorted by length and split into two groups of one or even numbers. The fish with median length in the smaller group is the "small" fish, and the median length in the larger group is the "large" fish. The concentration in these two size groups (one per group) determine the concentrations in the two groups. The method was first used on a large-scale basis by the Ad Hoc Working Group on Monitoring that met in Copenhagen 8-12. November 1993 (MON 1993). At this meeting it was agreed to apply the method on contaminants in fish muscle and liver on a wet weight basis and contaminants in soft tissue of blue mussel on a dry weight basis. The results for this assessment are presented earlier (cf. ASMO 1994). The method has been applied to Norwegian data and results are shown in Appendix H. The results can be presented as in Figure 21.

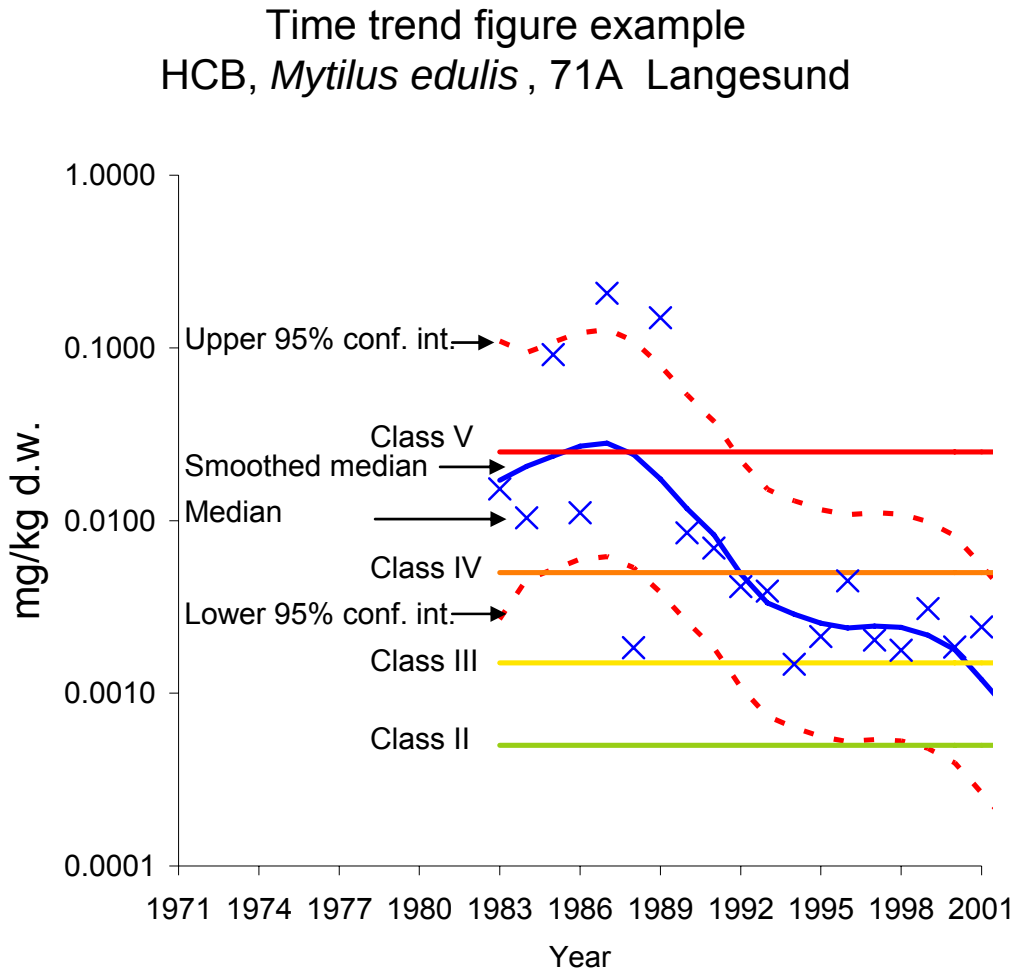

Figure 21. Example presentation and variation in contaminant concentration with time, indicating median concentrations, running mean of median values (Loess smoother), 95% confidence intervals. The horizontal lines indicate the lower boundaries to SFT classes of pollution: Class II (moderate=upper boundary to Class I (insignificant)), III (marked), IV (severe) and V (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. (see text and refer to Table 7).

The method of calculating the smoother is in accordance to the methods employed at Ad Hoc Working Group on Monitoring that met in Copenhagen 23-27. February 1998 (MON 1998). A Loess smoother is based on a running seven-year interval, a non-parametric curve fitted to median log-concentrations (Nicholson *et al.*1997). For statistical tests based on a 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 lognormally distributed (cf. Nicholson *et al.* 1998). No transformation was applied to the imposex (VSDI) data.

The National Comments since 1994 have included two additional analyses. The first is that the smoothed median for the last three sampling years is linearly projected for the next three years. This deviates from previous reports where the upper 95 confidence interval was used to assess the likelihood of overconcentrations (Nicholson, *et al.* 1994). The projected estimate is based on the results for the temporal trend analyses of at least 6 years of data.

The second is 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 3 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 Langesundsfjord (Figure 4).

The statistical analysis was carried out on temporal trend data series for cadmium, mercury, lead, ΣPCB-7 (sum of congeners: 28, 52, 101, 118, 138, 153, 180), ppDDE (ICES code DDEPP), HCB, non-dicyclic PAHs, sum carcinogenic PAHs, B[*a*]P, TBT, and the biological effects parameters imposex (VSDI), PYR10, ALA-D and EROD-activity.

2.1.4. The effect of depuration and freezing on blue mussel

Based on samples collected in the Sørfjord and Hardangerfjord, the JAMP-method of pre-treatment of blue mussel (i.e., depuration and then cleaning) contrasted significantly to the Index-method (freezing then cleaning) (Green *et al.* 2001a). Using the JAMP-method, cadmium concentrations were significantly higher (24%), whereas significant lower concentrations were found for lead (45%), zinc (14%), PCBs (CB101, -118, -138, -153 27-52%) and DDTs (50-64%). Lower concentrations indicated that these contaminants are lost by depuration and gut emptying.

The results from a previous study from this region indicated no significant difference between the methods for mercury, cadmium, copper, lead and zinc (Green 1989). A study on blue mussel from the mouth of the Glomma River in Southern Norway showed that lead and copper were significantly lower in depurated samples (Green *et al.* 1996); however, no differences were found for PCBs or DDTs (on a lipid basis). The PCB concentrations found in the Glomma study were 3-4 times higher than Sørfjord/Hardangerfjord.

Mercury was the only contaminant common to all three studies that had consistent results; that there is no significant difference between the two methods.

The difference in methods has indicated an effect on the concentration of contaminants in blue mussel. However, with the exception of mercury, the results for Sørfjord/Hardangerfjord 2003 are inconsistent with two other studies in Norway. Revision of JAMP guidelines and assessment of data should take these results into consideration.

2.2. Information on Quality Assurance

NIVA has participated in all the QUASIMEME international intercalibration exercises, including Round 48. These exercises have included nearly all the contaminants analysed for JAMP. Quality assurance programme for NIVA is similar to the 2005 programme (cf. Green *et al.* 2007). In addition, NIVA was accredited in 1993 and since 2001 accredited in accordance with the NS-EN ISO/IEC 17025 standard by the Norwegian Accreditation (reference P009). A summary of the quality assurance programme at NIVA is given in Appendix A.

A recent investigation of measurements of certified references materiale from 1999-2006 for PCB indicated a systematic change in the analytical methods (Bakke *et al.* 2007b, Appendix A). This should be taken into consideration in the trend analyses.

2.3. Description of the Programme

The sampling for 2005 involved blue mussel at 61 stations, dogwhelk at 8, cod at 9 and flatfish at 11 stations (cf. Appendix E). The Norwegian JAMP has been expanded since 1989 to include monitoring in more diffusely polluted areas. Though new stations are initially intended for annual monitoring (temporal trends), there has not always been sufficient funds to do this for every station. Sample/station reduction measures have been taken to reduce costs. Furthermore, 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%), indicated in Appendix E, as either 25 individuals or 5 bulked samples consisting of 5 fish per bulked sample, was met for all stations in 2005.

Concentrations of metals, organochlorines (including pesticides) and polycyclic aromatic hydrocarbons in blue mussel and fish were determined at the Norwegian Institute for Water Research (JAMP code NIVA).

Analytical methods have been described previously (Green *et al*. (2001b, Shi *et al.* 2008). An overview of the samples collected from 1981 to 2005 is given in Appendix E. An overview of analyses applied from 1981 to 2005 for biological material is given in Appendix C. Parameter abbreviations are given in Appendix B.

The data is stored at NIVA in MS ACCESS 1997. The tables are generated using MS ACCESS 97 and MS EXCEL 97.

3. References

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

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Appendix G
Map of stations

Nominel station positions 1981-2006
(cf. Appendix H and Appendix L)

Appendix G (cont.) Map of stations

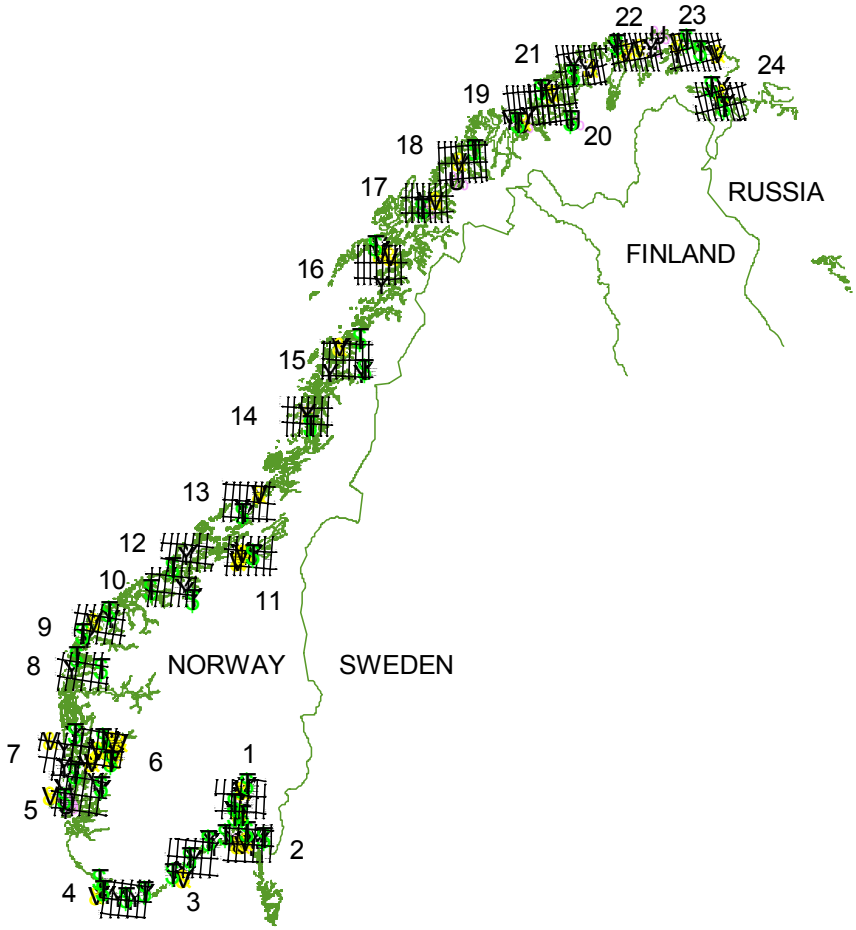
NOTES

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.

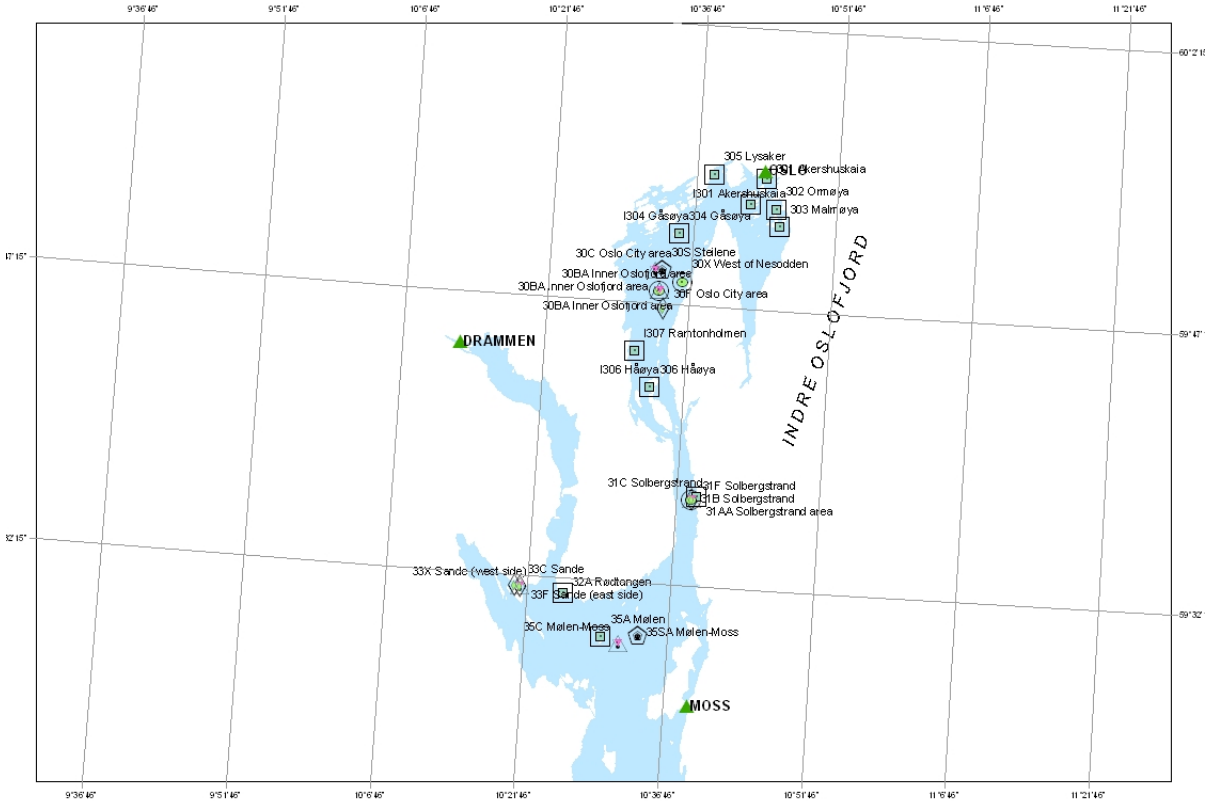
The following symbols and codes apply:

All years	2006	Explanation	Station code
		Sediment	<number>S
		Bluemussel	<number>A
		Bluemussel	I<number/letter> [1]
		Bluemussel	R<number/letter> [1]
		Dogwhelk	<number>F
		Prawn	<number>C
		Atlantic cod	<number>A
		Flatfish	<number>D/E
		Other round fish	
		Town or city	

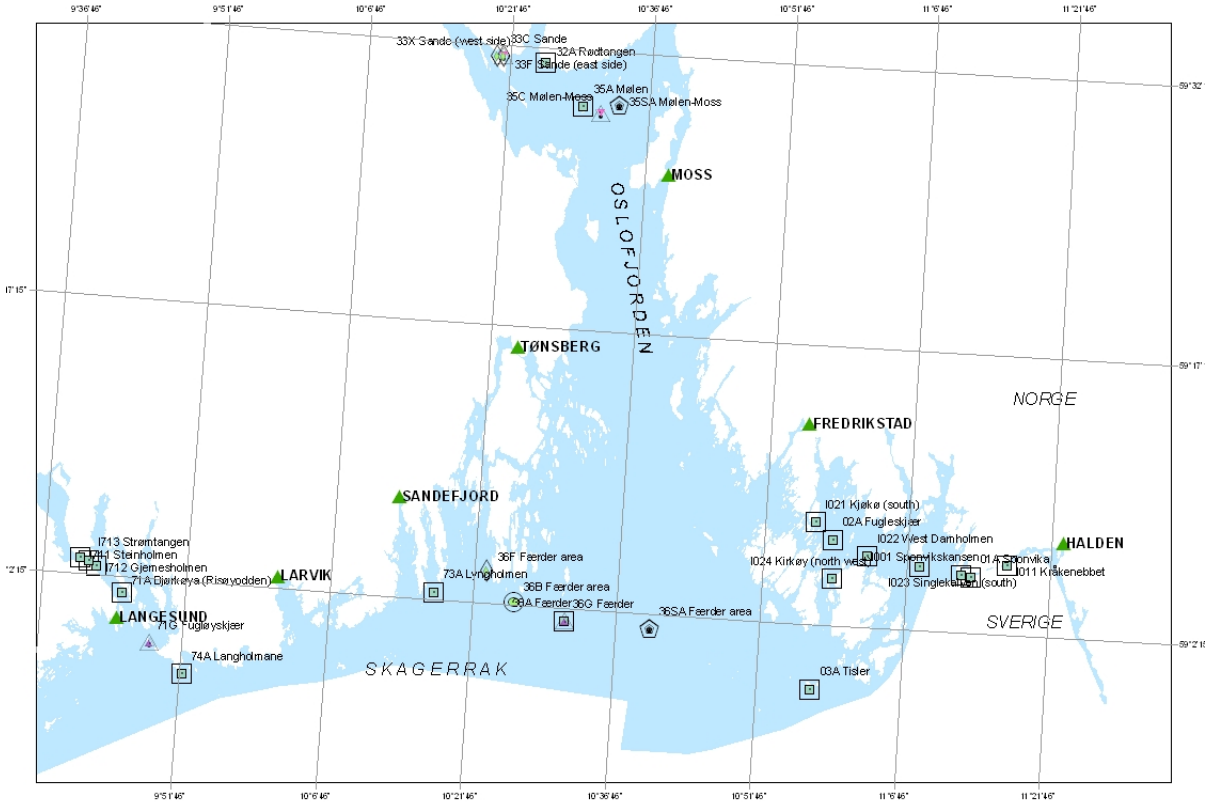
1) Supplementary station used in SFT bluemussel pollution (I) or reference (R) index (cf. Appendix L).



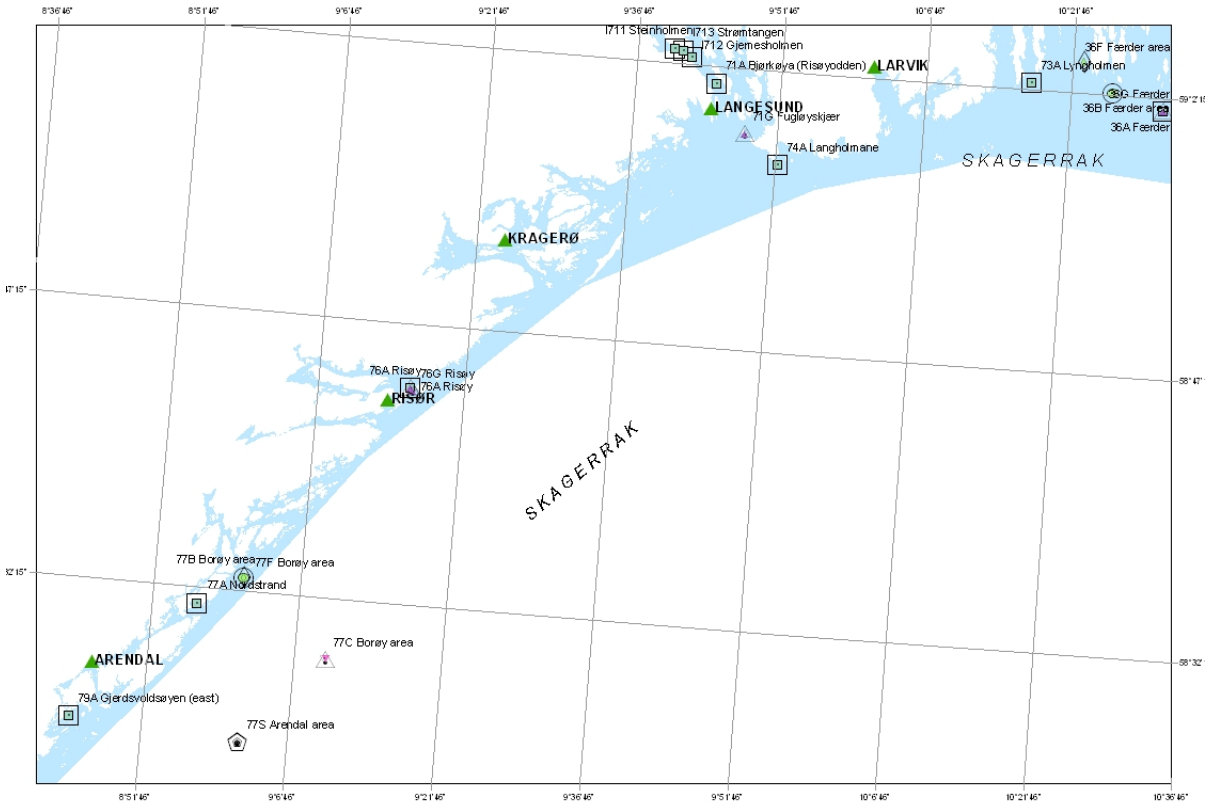
JAMP stations Norway. Numbers indicate map reference that follow.
Note: distance between two lines of latitude is 15 nautical miles (= 27.8 km).


305 Lysaker
SLE
301 Akershuskaia
302 Ormøya
303 Malmøya
304 Gåsøya
30C Oslo City area
30S Stellene
30X West of Nesodden
30BA Inner Oslofjord area
30F Oslo City area
INDRE OSLOFJORD
DRAMMEN
I307 Ramtonholmen
I306 Håøya
31C Solbergstrand
31F Solbergstrand
31B Solbergstrand
31AA Solbergstrand area
33X Sande (west side)
33C Sande
32A Rødtangen
33F Sande (east side)
35A Mølen
35C Mølen-Moss
35SA Mølen-Moss
MOSS

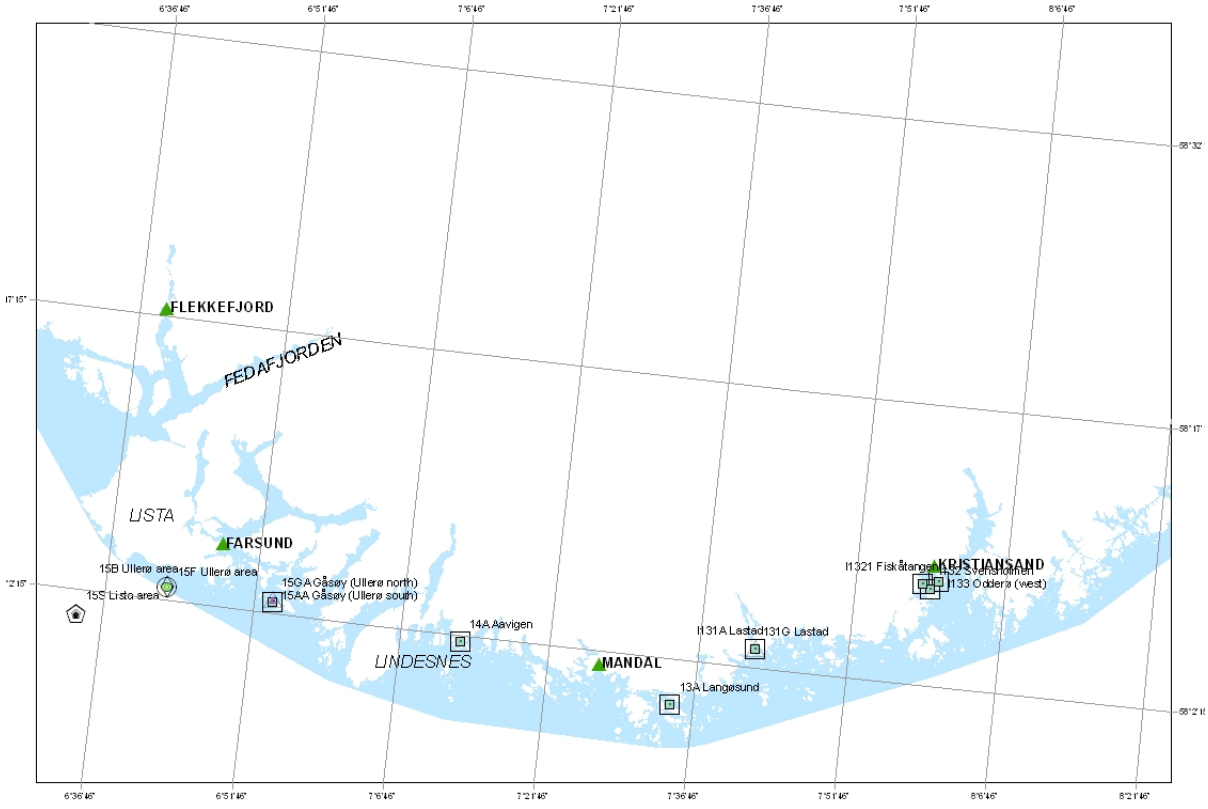
MAP 1


33X Sande (west side)
33C Sande
32A Rødtangen
33F Sande (east side)
35A Mølen
35C Mølen-Moss
35SA Mølen-Moss
MOSS
OSLOFJORDEN
TØNSBERG
NORGE
FREDRIKSTAD
SANDEFJORD
I021 Kjøkø (south)
02A Fugleskjær
I022 Vest Damholmen
HALDEN
I001 Svenskskansen
01A Svinvika
I011 Kråkenebbet
I024 Kirkøy (north west)
I023 Singlekalven (south)
I713 Strømtangen
I711 Steinholmen
I712 Gjemesholmen
71A Djørkøya (Risøyodden)
LARVIK
36F Færder area
73A Lyngholmen
36B Færder area
LANGESUND
71S Fugløyskjær
36A Færder
36G Færder
36SA Færder area
SVERIGE
74A Langholmane
SKAGERRAK
03A Tisler

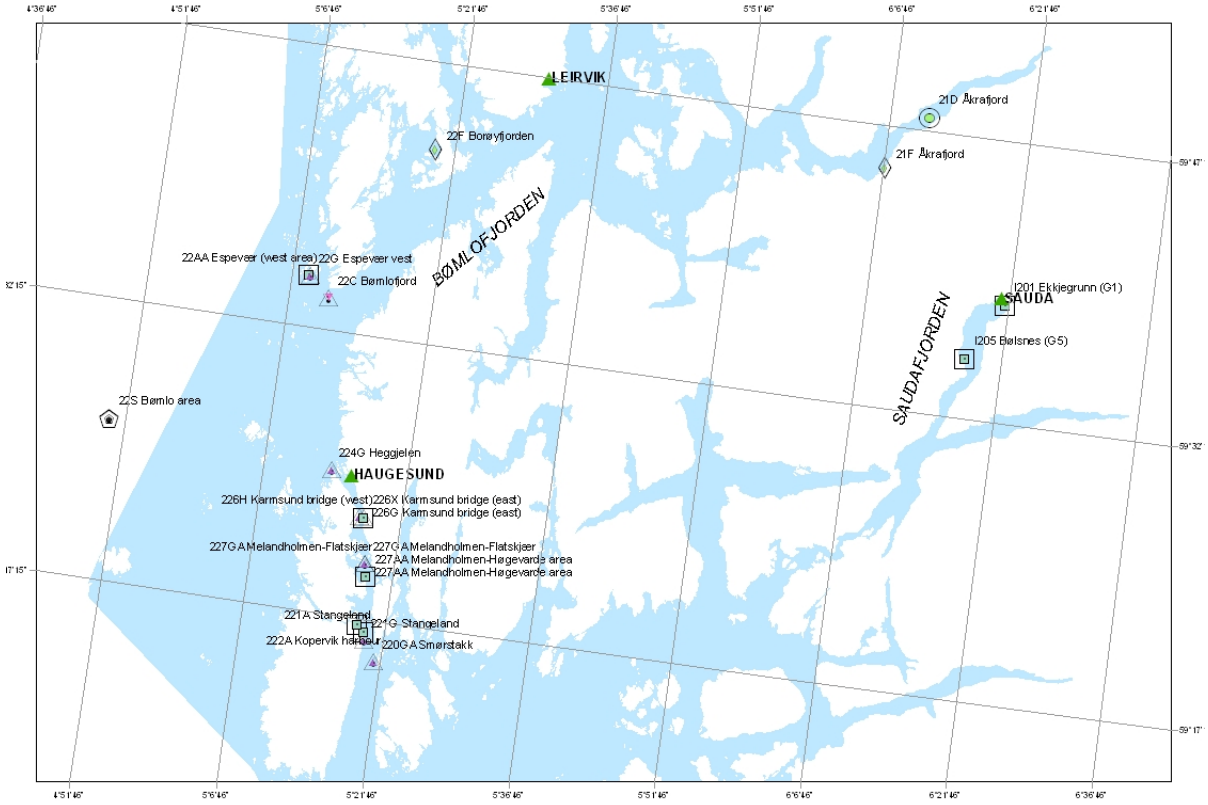
MAP 2


I711 Steinholmen
I713 Strømtangen
I712 Gjemesholmen
71A Bjørkøya (Risøyodden)
LARVIK
73A Lyngholmen
36F Færder area
38G Færder
38B Færder area
36A Færder
LANGESUND
71G Fugløyskjær
74A Langholmane
SKAGERRAK
KRAGERØ
76A Risøy
76G Risøy
76A Risøy
RISØR
SKAGERRAK
77B Borøy area
77F Borøy area
77A Nordstrand
77C Borøy area
ARENDAL
79A Gjerdsvoldsøyen (east)
77S Arendal area

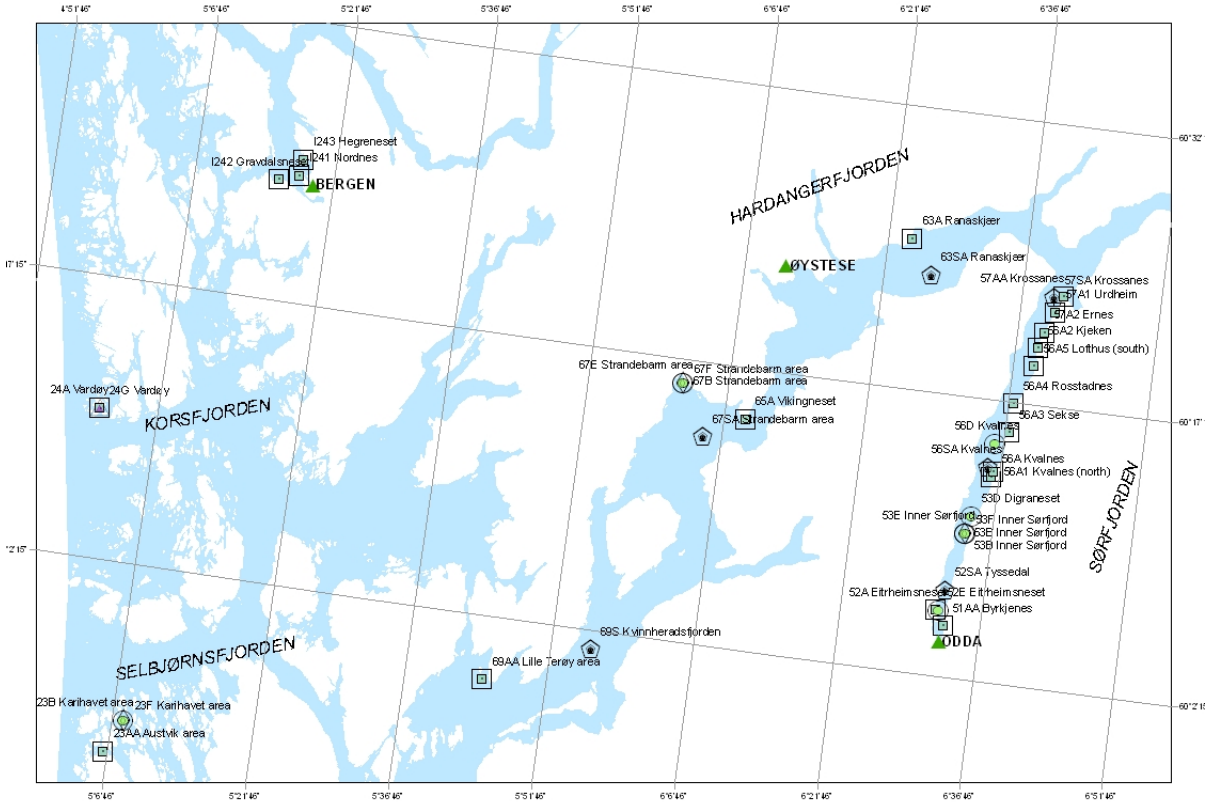
MAP 3


FLEKKEFJORD
FEDAFJORDEN
USTA
FARSUND
15B Ullerø area
15F Ullerø area
15S Lista area
15GA Gåsøy (Ullerø north)
15AA Gåsøy (Ullerø south)
14A Åavigen
UNDESNES
MANDAL
13A Langøsund
I131A Lastad
131G Lastad
I1321 Fiskåtangen
KRISTIANSAND
I1322 Svensholmen
I133 Oddera (west)

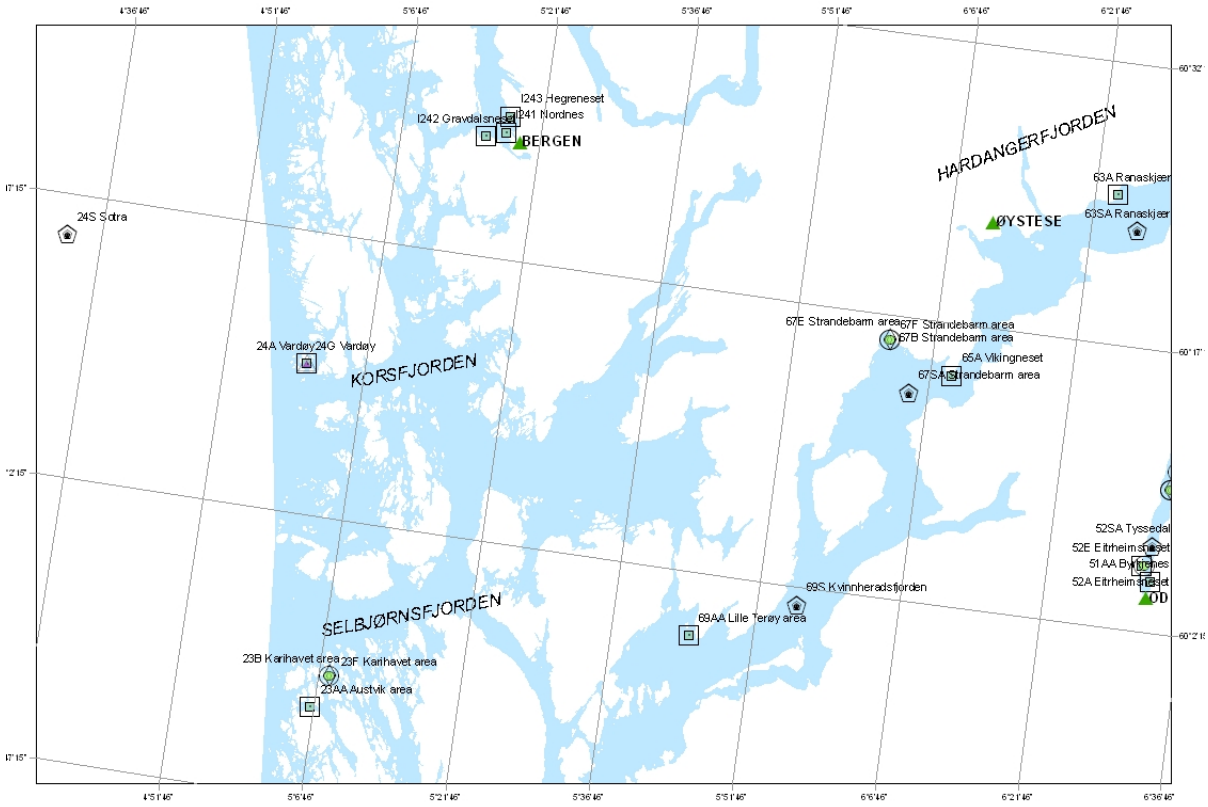
MAP 4


LEIRVIK
21D Akrafjord
22F Borøyfjorden
21F Akrafjord
BØMLOFJORDEN
22AA Espeveer (west area)
22G Espeveer vest
22C Bømlofjord
SAUDA
I201 Ekkjegrunn (G1)
I205 Bølsnes (G5)
SAUDAFJORDEN
22S Bømlo area
224G Heggjelen
HAUGESUND
226H Karmsund bridge (west)
226X Karmsund bridge (east)
226G Karmsund bridge (east)
227GA Melandholmen-Flatskjær
227AA Melandholmen-Høgevarde area
221A Stangeland
221G Stangeland
222A Kopervik harbour
220GA Smørstakk

MAP 5


I243 Hegreneset
I242 Gravdalsneset
I241 Nordnes
BERGEN
HARDANGERFJORDEN
63A Ranaskjær
ØYSTESE
63SA Ranaskjær
57AA Krossanes
57SA Krossanes
57A1 Urdheim
57A2 Ernes
56A2 Kjeken
56A5 Lofthus (south)
67E Strandebarm area
67F Strandebarm area
67B Strandebarm area
24A Vardøy
24G Vardøy
KORSFJORDEN
65A Vikingneset
67SA Strandebarm area
56A4 Rosstadnes
56A3 Sekse
56D Kvalnes
56SA Kvalnes
56A Kvalnes
56A1 Kvalnes (north)
53D Digraneset
53E Inner Sørfjord
53F Inner Sørfjord
53E Inner Sørfjord
53B Inner Sørfjord
SØRFJORDEN
52SA Tyssedal
52A Eitrheimsneset
52E Eitrheimsneset
51AA Byrkjenes
ODDA
69S Kvinneradsfjorden
SELBJØRNSFJORDEN
69AA Lille Terøy area
23B Karihavet area
23F Karihavet area
23AA Austvik area

MAP 6


I243 Hegreneset
I242 Gravdalsneset
I241 Nordnes
BERGEN
HARDANGERFJORDEN
63A Ranaskjær
63SA Ranaskjær
ØYSTESE
24S Sotra
67E Strandebarm area
67F Strandebarm area
67B Strandebarm area
24A Vardøy
24G Vardøy
KORSFJORDEN
65A Vikingneset
67SA Strandebarm area
52SA Tyssedal
52E Eitrheim stasjon
51AA Bykjenes
52A Eitrheim stasjon
OD
69S Kvinnheradsfjorden
SELBJØRNSFJORDEN
69AA Lille Terøy area
23B Karihavet area
23F Karihavet area
23AA Austvik area

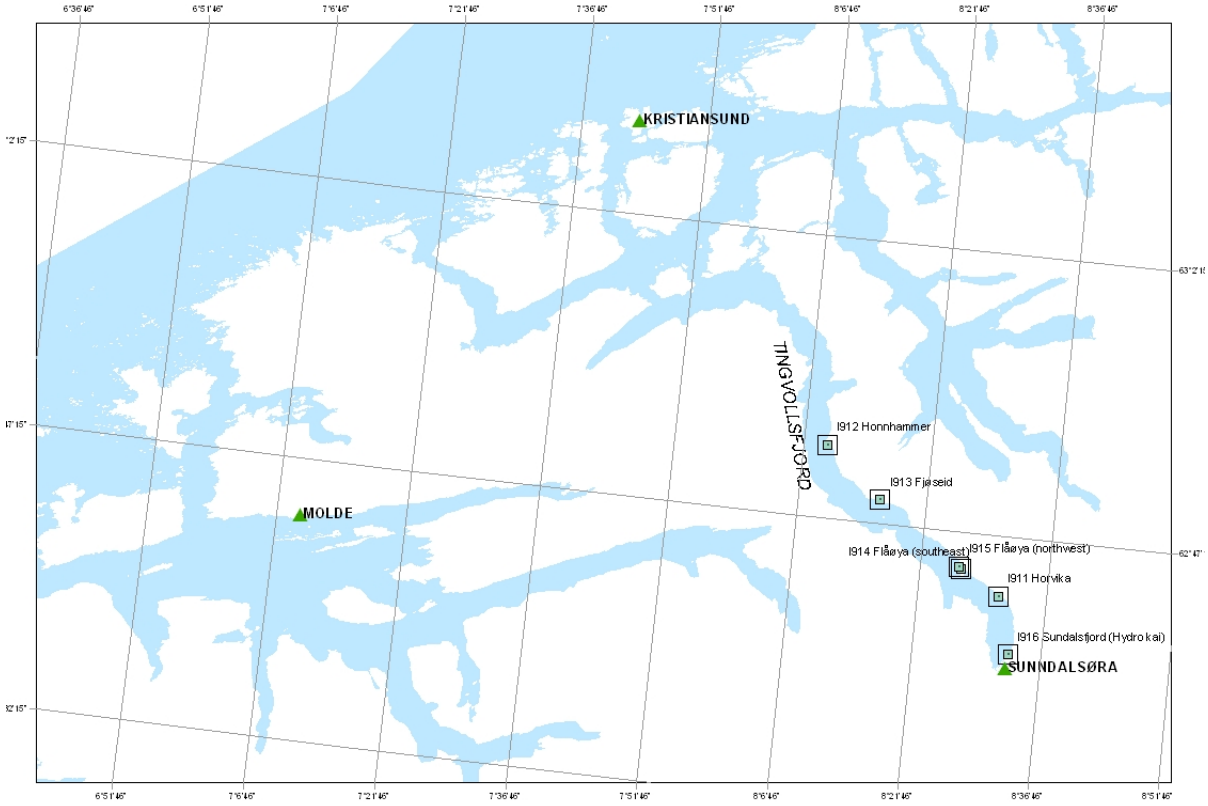
MAP 7


FLORØ
STAVFJORDEN
FØRDE
25AA Hinnøy area
25GA Hinnøy area
VILNESFJORDEN
SOGNEFJORDEN

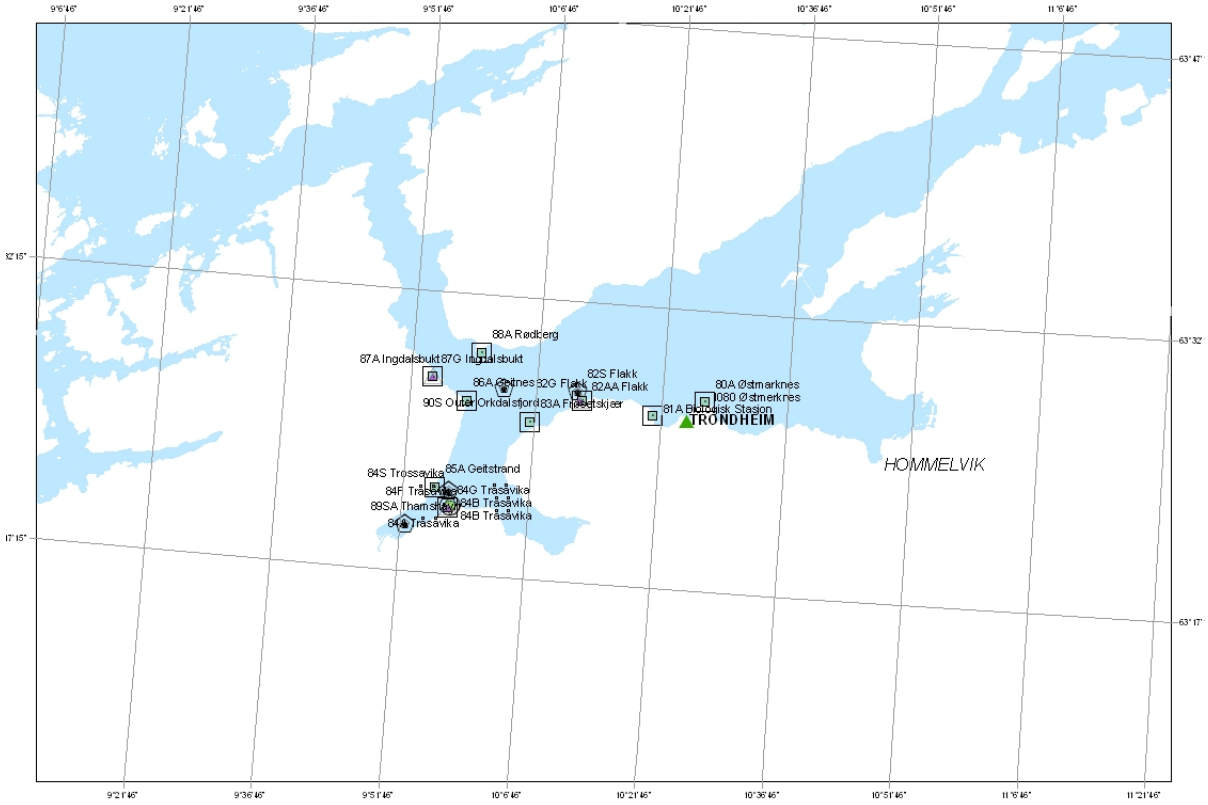
MAP 8


ÅLESUND
ULSTEINVIK
28H Øveråneset (Hareid)
28G Grønevikholmen (Eiksundet)
28AA Eiksundet area
27AA Grinden area
Storholmen
27S Stadtlandet (east)
27GA Røydeskjær area
STADTLANDET
MÅLØY
26AA Hamnen area
26G Hamnen

MAP 9


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

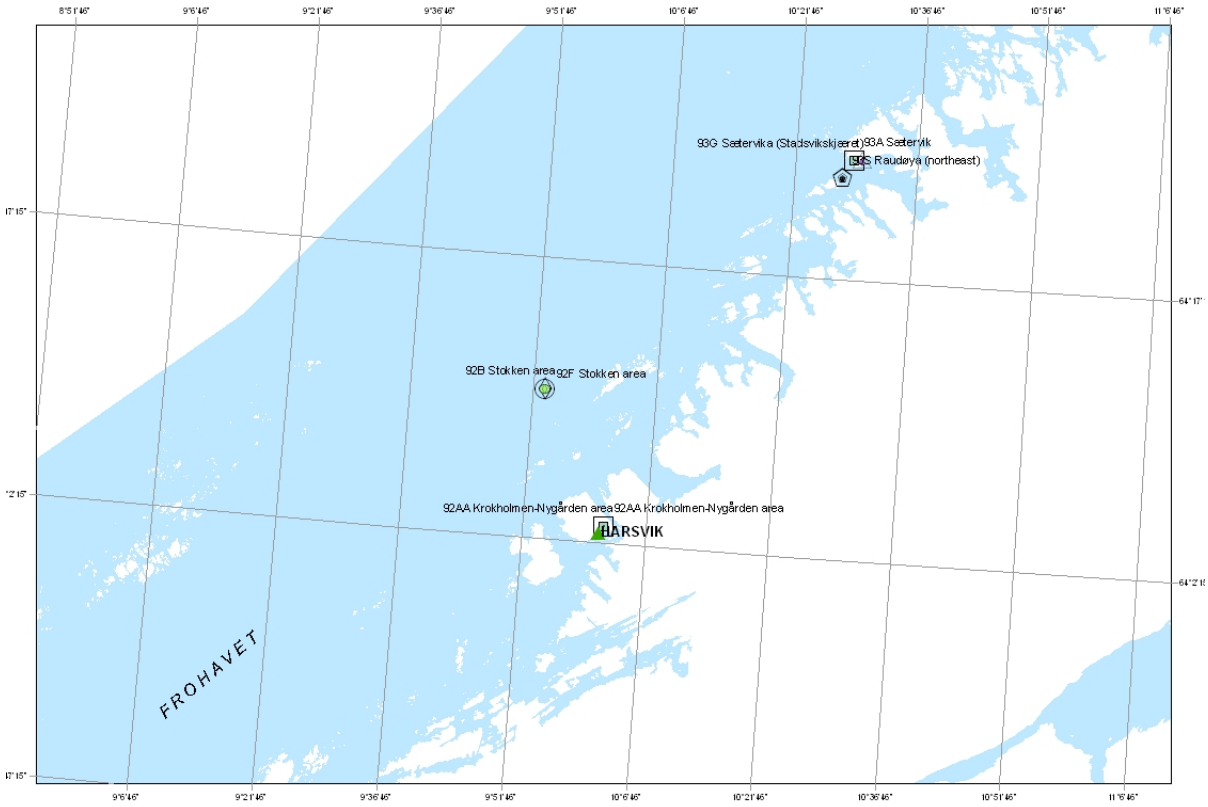
MAP 10


88A Rødberg
87A Ingdalsbukt
87G Ingdalsbukt
82S Flakk
86A Gjetnes
82G Flakk
82AA Flakk
80A Østmarknes
080 Østmarknes
90S Outer Orkdalsfjord
83A Frøyaskjær
81A Biologisk Stasjon
TRONDHEIM
HOMMELVIK
84S Trossavika
85A Geitstrand
84F Tråsavika
84G Tråsavika
89SA Thamshavn
84B Tråsavika
84 Tråsavika
84B Tråsavika

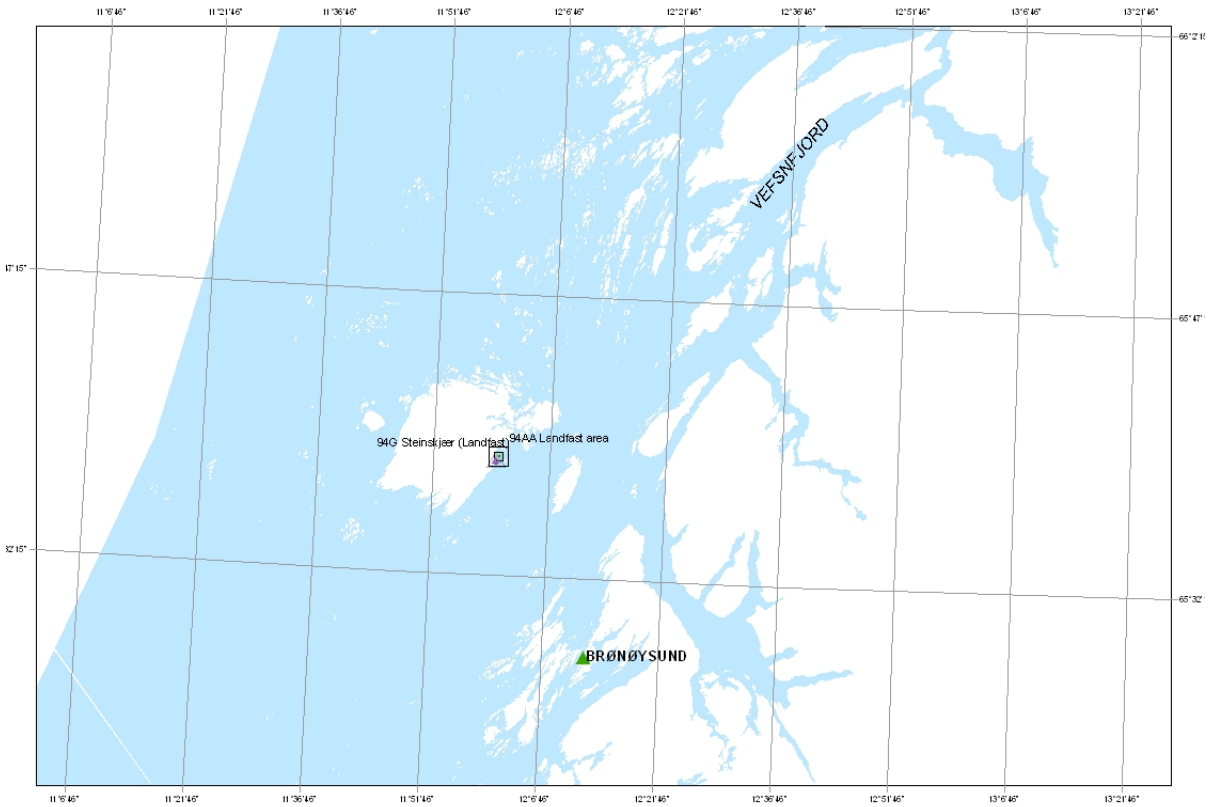
MAP 11


HITRA
TRONDHEIMSLEIA
SMØLA
91A Nerdvika
KRISTIANSUND

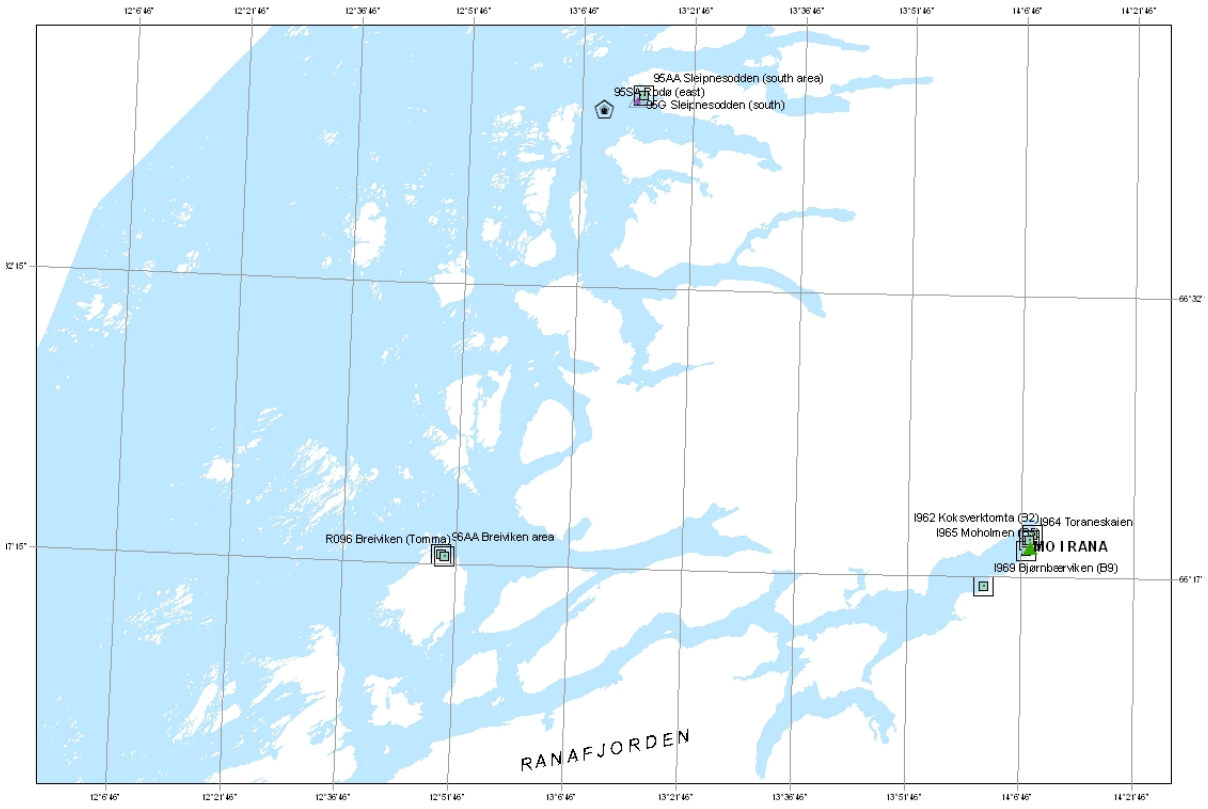
MAP 12


93G Sætervika (Stadsvikskjæret)
93A Sætervik
93S Raudøya (northeast)
92B Stokken area
92F Stokken area
92AA Krokholmen-Nygården area
92AA Krokholmen-Nygården area
HARSVIK
FROHAVET

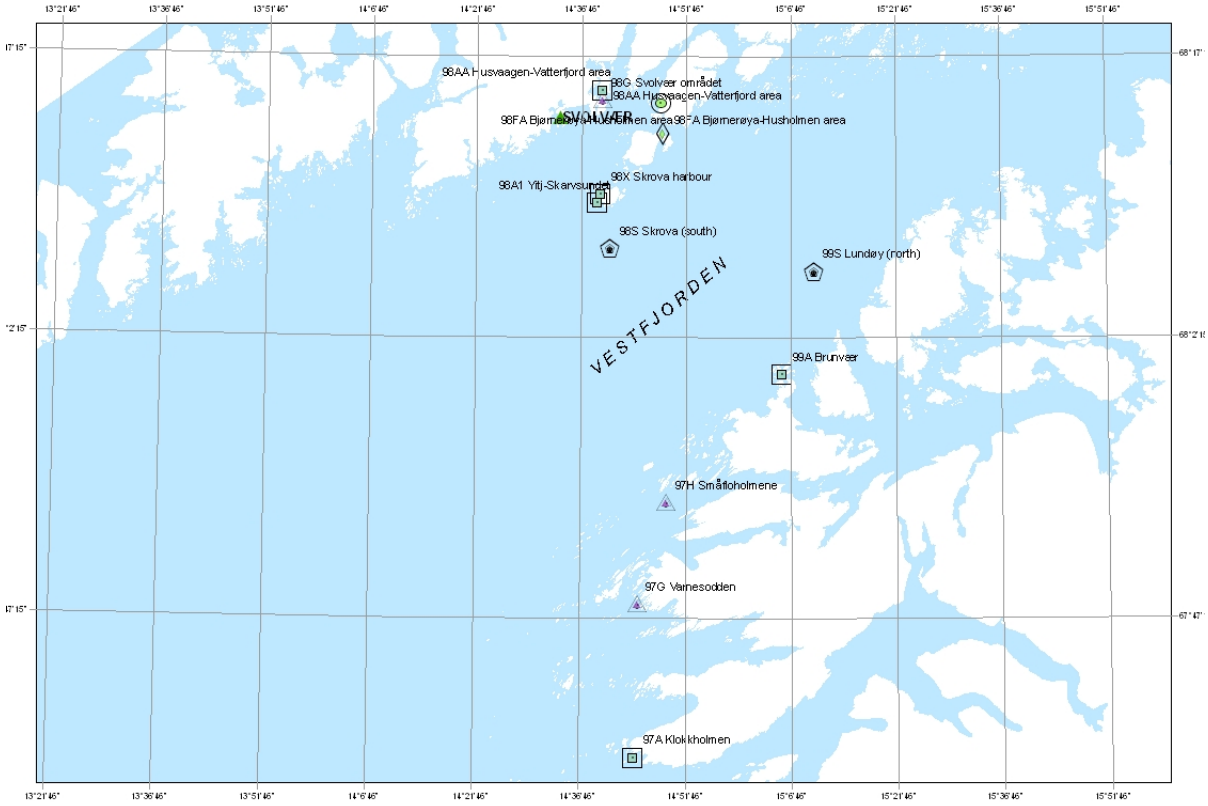
MAP 13


VEFSNFJORD
94G Steinskjær (Landfast)
94AA Landfast area
BRØNØYSUND

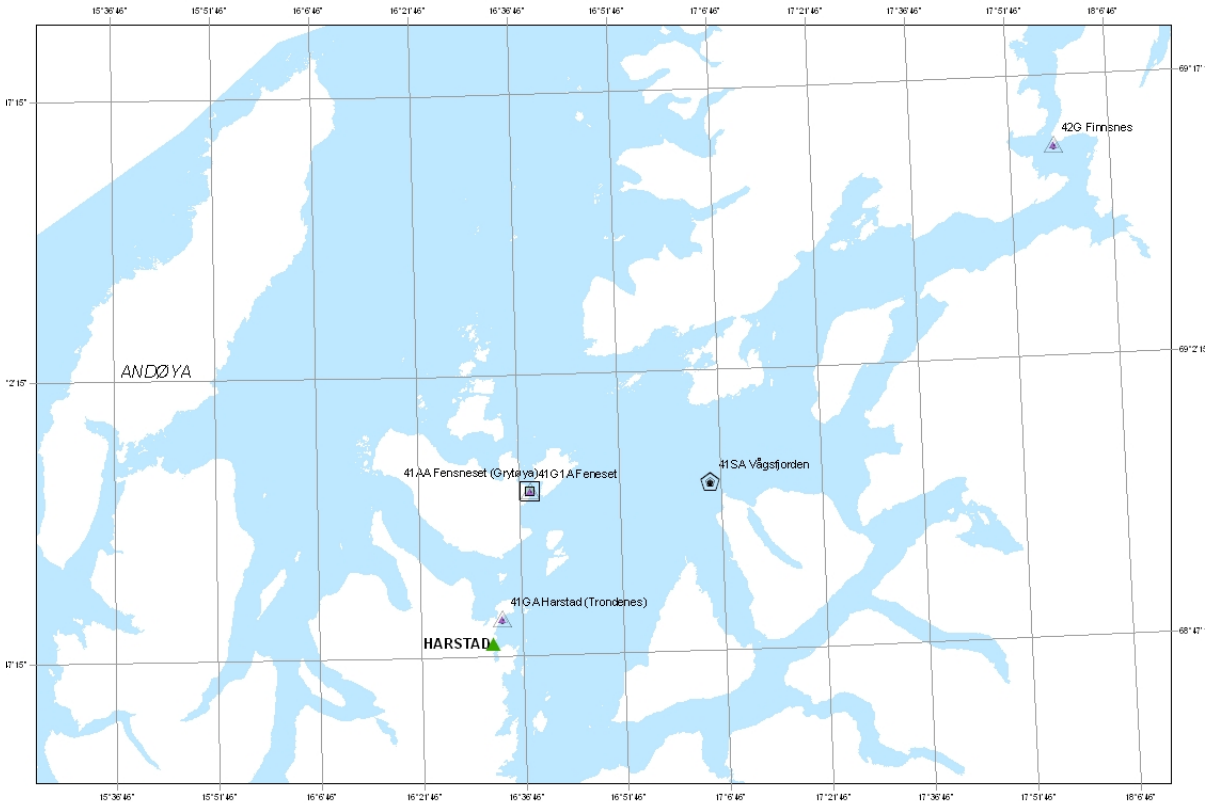
MAP 14


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

MAP 15


98AA Husvaagen-Vatterfjord area
98G Svolvær området
98AA Husvaagen-Vatterfjord area
SVOLVÆR
98FA Bjørnerøya-Husholmen area
98FA Bjørnerøya-Husholmen area
98X Skrova harbour
98A1 Ytti-Skarvsundet
98S Skrova (south)
99S Lundøy (north)
VESTFJORDEN
99A Brunvær
97H Småfiloholmene
97G Vamesodden
97A Klokkholmen

MAP 16


42G Finnsnes
ANDØYA
41AA Fensneset (Grytøya)
41G1A Feneset
41SA Vågsfjorden
41GA Harstad (Trondenes)
HARSTAD

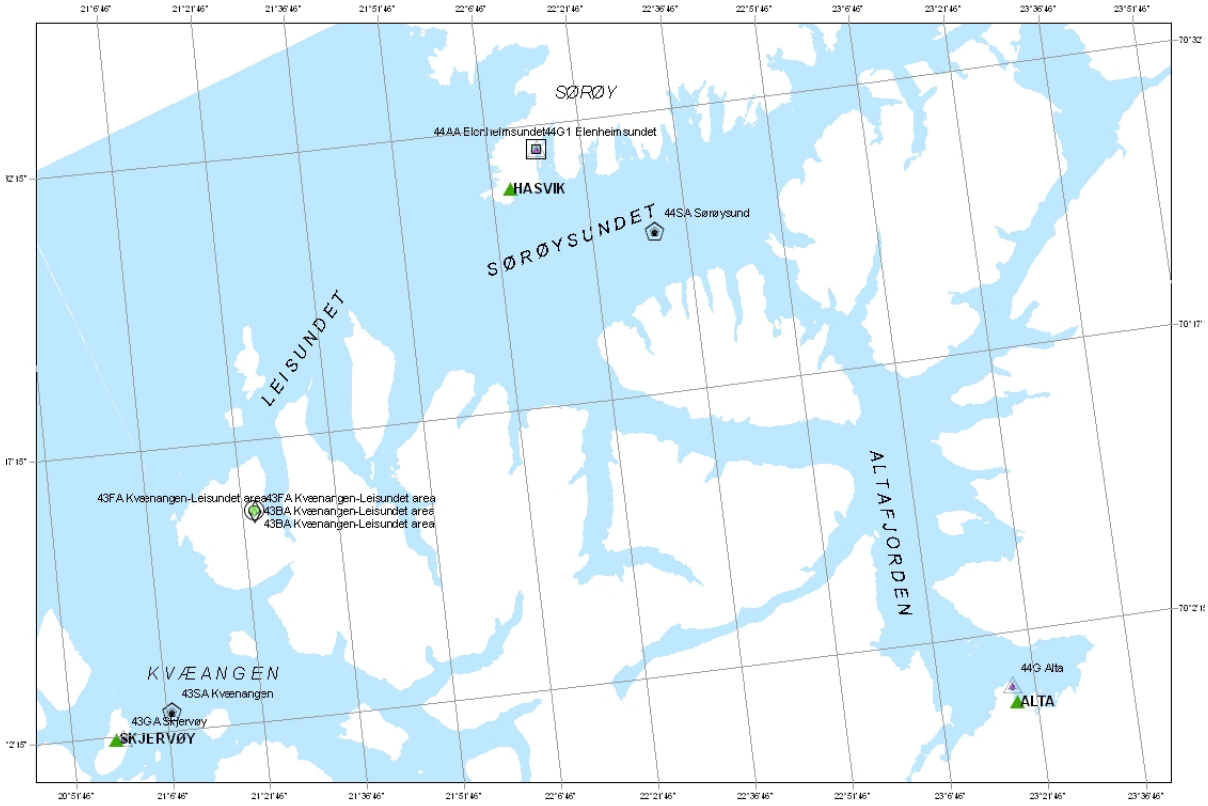
MAP 17


TROMSØ
KVALØY
MALANGEN
42SA Malangen
42AA Tennskjær (Malangen)
42G Finnsnes

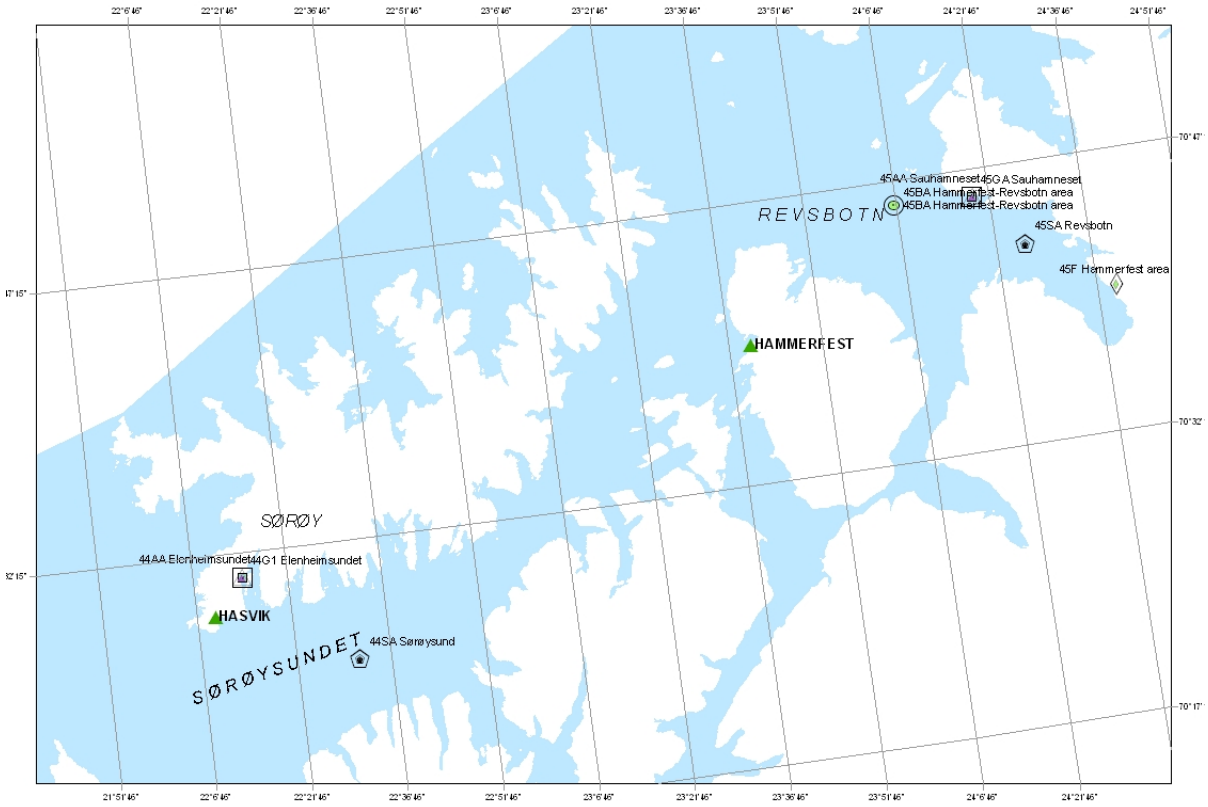
MAP 18


SØRØY
44AA Elenheimsundet44G1 Elenheimsundet
HASVIK
SØRØYSUNDET
44SA Sørøysund
LOPPHAVET
LEISUNDET
43FA Kvænangen-Leisundet area43FA Kvænangen-Leisundet area
43BA Kvænangen-Leisundet area
43BA Kvænangen-Leisundet area
43G1A Lyngneset (Langfjord)43AA Lyngneset (Langfjord)
43SA Kvænangen
43GA Skjervøy
SKJERVØY

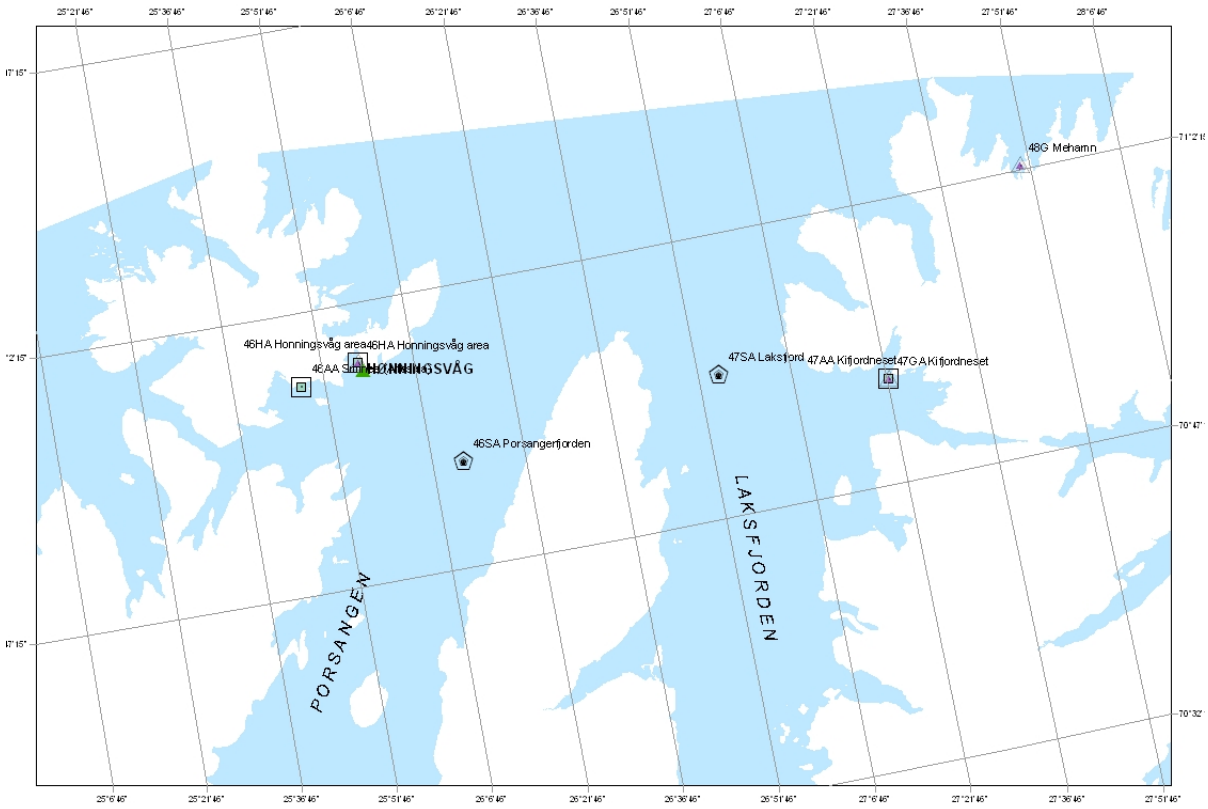
MAP 19


SØRØY
44AA Elenheimsundet44G1 Elenheimsundet
HASVIK
SØRØYSUNDET
44SA Sørøysund
LEISUNDET
ALTAFJORDEN
43FA Kvænangen-Leisundet area43FA Kvænangen-Leisundet area
43BA Kvænangen-Leisundet area
43BA Kvænangen-Leisundet area
KVÆANGEN
43SA Kvænangen
43GA Skjervøy
SKJERVØY
44G Alta
ALTA

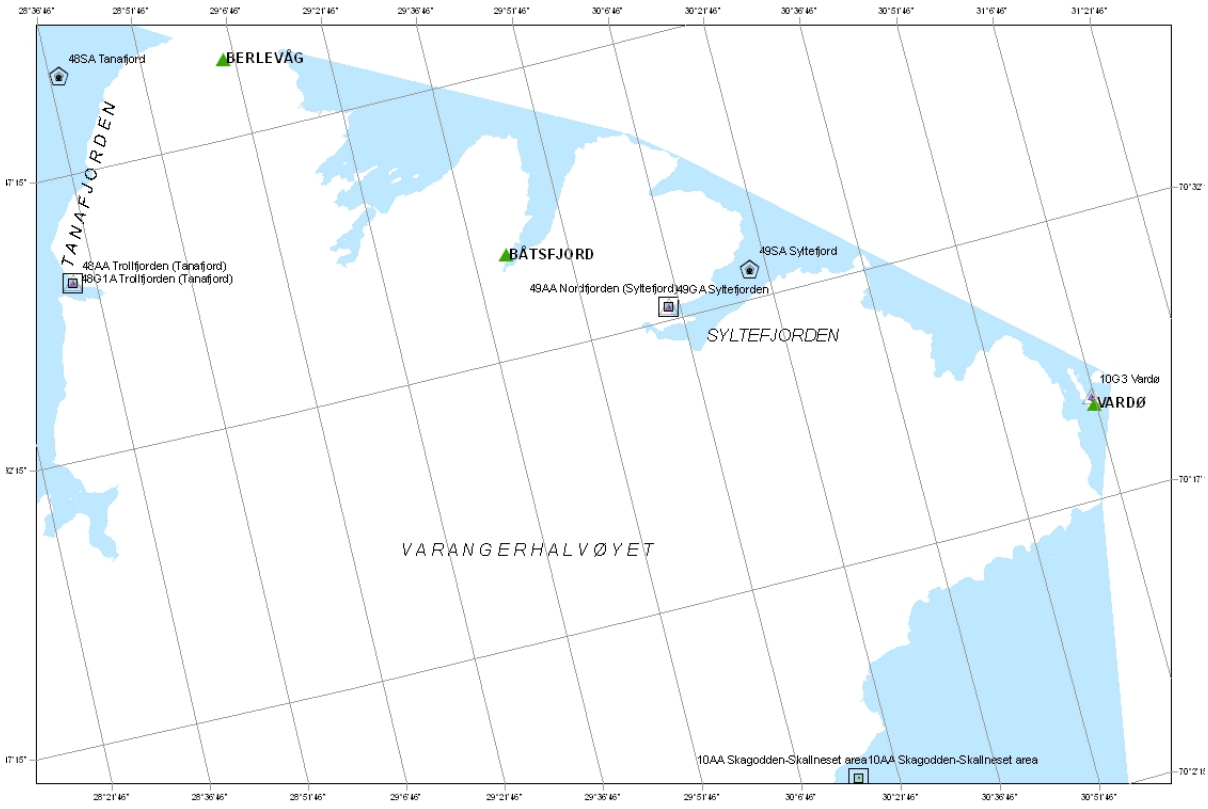
MAP 20


45AA Sauhamneset
45GA Sauhamneset
45BA Hammerfest-Revsbotn area
45BA Hammerfest-Revsbotn area
REVSBOTN
45SA Revsbotn
45F Hammerfest area
HAMMERFEST
SØRØY
44AA Elenheimsundet
44G1 Elenheimsundet
HASVIK
SØRØYSUNDET
44SA Sørøysund

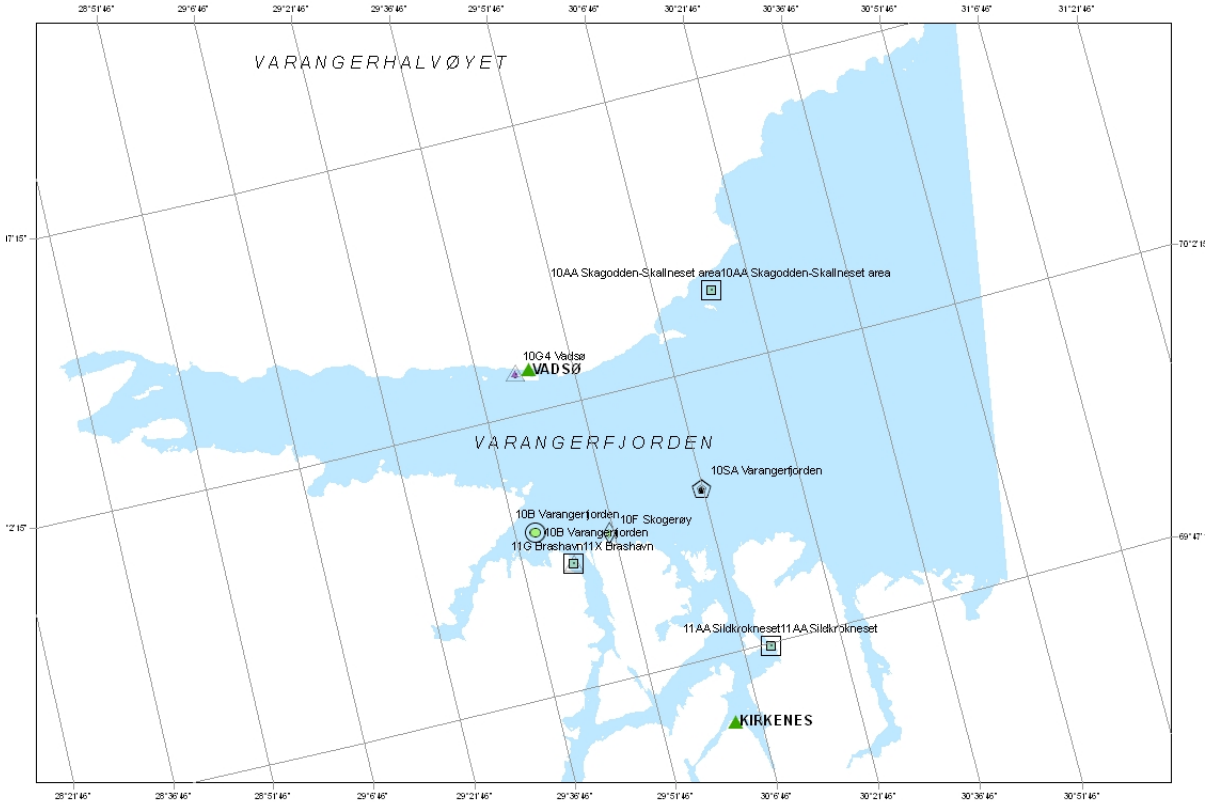
MAP 21


48G Mehamn
46HA Honningsvåg area
46HA Honningsvåg area
HONNINGSVÅG
47SA Laksfjord
47AA Kjfjordneset
47GA Kjfjordneset
46SA Porsangerfjorden
PORSANGEN
LAKSFJORDEN

MAP 22


48SA Tanafjord
BERLEVÅG
TANAFJORDEN
48AA Trollfjorden (Tanafjord)
48G1A Trollfjorden (Tanafjord)
BÅTSFJORD
49SA Syltefjord
49AA Nordfjorden (Syltefjord)
49GA Syltefjorden
SYLTEFJORDEN
10G3 Vardø
VARDØ
VARANGERHALVØYET
10AA Skagodden-Skallneset area
10AA Skagodden-Skallneset area

MAP 23


VARANGERHALVØYET
10AA Skagodden-Skallneset area
10AA Skagodden-Skallneset area
10G4 Vadsø
VADSØ
VARANGERFJORDEN
10SA Varangerfjorden
10B Varangerfjorden
10F Skogerøy
10B Varangerfjorden
11G Brashavn
11X Brashavn
11AA Sildkrokneset
11AA Sildkrokneset
KIRKENES

MAP 24

Statens forurensningstilsyn
Postboks 8100 Dep,
0032 Oslo
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Statlig program for forurensningsovervåking omfatter overvåking av forurensningsforholdene i luft og nedbør, skog, vassdrag, fjorder og havområder. Overvåkningsprogrammet dekker langsiktige undersøkelser av:

- overgjødsling
- forsuring (sur nedbør)
- ozon (ved bakken og i stratosfæren)
- klimagasser
- miljøgifter

Overvåkningsprogrammmet 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. SFT er ansvarlig for gjennomføringen av overvåkningsprogrammet

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