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National Comments regarding the Norwegian data for 2004

Rapport 944/2005

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REPORT

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Abstract

This report is part of the Norwegian contribution to the SIME 2006 meeting administrated by OSPAR. JAMP 2004 included the monitoring of contaminants in sediment (17 stations), blue mussel (58), dogwhelk (20), cod (9) and flatfish (11) along the coast of Norway from Oslo to Bergen, Lofoten and Varangerfjord. The results indicated elevated levels of contaminants, i.e., poorer than Class I in SFT's classification system, or over provisional “high background”, in the inner Oslofjord (PCBs, mercury and lead in cod; PCBs in mussels), and Sørfjord and Hardangerfjord (cadmium, lead, mercury and DDT (ppDDE) in mussels, and mercury in cod). The results from the remaining stations showed low or moderate levels of contamination in 2004. Considering the whole monitoring period, significant upward trends were found for mercury in cod from the inner Oslofjord and a downward trend was found for lead in mussels from Sørfjord/Hardangerfjord. The “Pollution" index was between “marked” and “severe,” as it was in 2003, in the SFT system. The “Reference” index was between “slight” and “moderate” in the system, as before. Contamination of organotin in mussels and imposex in dogwhelk were still apparent. No significant improvement was registered in comparison to 1992 investigations. The results from studies using biological effects methods in cod (4 stations) are discussed.

4 keywords, Norwegian	4 keywords, English
1. Miljøgifter	1. Contaminants
2. Organismer	2. Organisms
3. Marin	3. Marine
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WORKING GROUP ON CONCENTRATIONS, TRENDS AND EFFECTS OF SUBSTANCES IN THE MARINE ENVIRONMENT (SIME)

LONDON 21-23 FEBRUARY 2006

O-80106 / O-25106

JOINT ASSESSMENT AND MONITORING PROGRAMME (JAMP)

NATIONAL COMMENTS REGARDING

THE NORWEGIAN DATA FOR 2004

Oslo, 24. December 2005

Submitted by:	NORWAY Norman W. Green Norwegian Institute for Water Research (NIVA) PB 173 Kjelsås N-0411 Oslo
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Foreword

This report presents the Norwegian national comments on the 2004 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 2004 investigations are directed to particular JAMP issues relating to contaminants and implemented by SIME. JAMP replaced Joint Monitoring Programme (JMP) in 1995.

The Norwegian JAMP for 2004 was carried out by the Norwegian Institute for Water Research (NIVA) by contract from the Norwegian Pollution Control Authority (SFT), (NIVA contract O-80106, O-25106).

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).

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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.

***Reader's guide**. The comments are presented in accordance with the agreed standardised format (ASMO 1997, Annex 12). Following the SIME meeting in London, 21-23 February 2006, 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/arbeidsomr/overvaking/rapporter/get.cfm?1=1&kat=8 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, Åse Bakketun, for field work, sample preparations and data entry; Alfhild Kringstad, Merete Grung, 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 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, 24 December 2005.

Norman W. Green
Project co-ordinator

Contents

1. General Details

1.1. Executive Summary / Sammendrag

The Norwegian JAMP 2004 included the monitoring of micropollutants (contaminants) in sediment (17 stations), blue mussel (58), dogwhelks (20), cod (9) and flatfish (11) from the border of Sweden in the south along the coast of Norway to the Bergen area, Lofoten and the Varangerfjord bordering Russia. The mussel sites include supplementary stations for the Norwegian Index programme, The results showed several cases of levels of contaminants, higher than Class I 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 (up to Class III for PCBs and to a lesser extent lead and mercury), where cod liver from the inner Oslofjord was markedly polluted with PCB (Class III), and 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 1984-2004;
- JAMP areas 63 and 62: Sørfjord and Hardangerfjord (for mussels, up to Class IV for lead, Class III for cadmium and DDE, and for cod, Class II for mercury and ppDDE). A significant downward trend was found for lead in mussels at two stations in Hardangerfjord 1987-2004, and an upward trend was found for mercury in fillet in flounder. Surficial sediment is contaminanted with mercury and PAH (Class V), TBT (Class IV) and to a lesser extent cadmium, lead, zinc and copper (Class II or III).

Part of JAMP area 26: Langesundsfjord has been an area of concern partly due to concentrations of HCB in mussels. However, since 2001 concentrations have been low or moderate (Class I and II), and a downward trend was found for the period 1990-2004, and there is less of a reason for concern when considering this contaminant.

Two environmental indices have been applied annually since 1995 to assess the levels of contamination in mussels from “polluted” and “reference” areas. The 2004 Pollution Index result was between the classes "markedly" and “severely” polluted in the Norwegian Pollution Control Authority's (SFT's) classification system, the same class as in 2003. The Reference Index was between the classes “slightly” and "moderately” polluted" (Class II), as in years prior to 2004.

The biological effects methods OH-pyrene (pyrene metabolite; marker for PAH exposure), δ-aminolevulinic acid dehydrase (ALA-D; marker for lead exposure), and the activity of cytochrome P4501A (EROD; marker for planar hydrocarbons, such as certain PCBs/PCNs, PAHs and dioxins) were determined in cod from three to four stations along the coast from the Oslofjord to Hardanger. With respect to OH-pyrene metabolites in 2004, the Oslofjord showed the most elevated levels of OH-pyrene. Furthermore, levels of OH-pyrene were higher at Lista, than in the Sørfjord, as observed prior to 2002. Results for ALA-D indicated exposure of lead to cod from the inner Oslofjord and inner Sørfjord. EROD activity in the inner Oslofjord was higher than in the less contaminated Sotra-Bømlo area, while EROD activity in the inner Sørfjord was lower. Previous years have also shown that EROD in fish from the Oslofjord and the Sørfjord are not consistently higher than at other presumed cleaner stations.

The presence of organotin (as TBT) in Norwegian waters was still a problem in 2004, most evident close to harbours, but also at stations remote from known point-sources. Concentrations of organotin in mussels and dogwhelk were elevated, and biological effects from TBT were found in dogwhelk from all of the investigated areas. However, TBT concentrations in mussels and dogwhelk were mostly lower than in 2003, but no significant trends were found, nor significant difference when compared to 1992 investigations. It is a cause for concern that the restrictions on the use of TBT in antifouling agents on vessels has not lead to a clear improvement in the investigated areas.

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 2004 omfattet JAMP undersøkelse av sediment (på 17 stasjoner), blåskjell (58, inkludert de til SFTs forurensningsindeks og til overvåking av TBT), purpursnegl (20), torsk (9) og flatfisk (11) fra svenskegrensen i syd til Bergen, Lofoten og Varangerfjorden mot den russiske grensen. 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 opp til Kl.III for PCB og i mindre grad bly og kvikksølv, hvor torskelever fra indre Oslofjord var markert forurenset med PCB (Kl.III), og det ble funnet signifikant økende trender for kvikksølv i torskefilet fra både "store" og "små" individer og for kadmium i torskelever fra indre Oslofjord 1984-2004;*
- *Sørfjorden og Hardangerfjorden for blåskjell med opp til Kl.IV for bly, Kl.III for kadmium og DDE og for torsk Kl.II når det gjaldt kvikksølv og kadmium. Det ble funnet en signifikant avtagende trend for bly i blåskjell på to stasjoner i Hardangerfjorden 1987-2004, og en økende trend for kvikksølv i skrubbefilet. Overflatesediment er forurenset med kvikksølv og PAH (Kl.V), TBT (Kl.IV), og i mindre grad kadmium, bly, zinc og kobber (Kl.II eller Kl.IIII.*

Langesundfjorden har vært et område med bl.a. høye konsentrasjoner av HCB i blåskjell. Men konsentrasjonene siden 2001 har vært lav eller moderat (Kl.I eller II), og en avtagende trend ble funnet for perioden 1990-2004, slik at det er mindre grunn til bekymring når det gjelder dette stoffet.

SFTs blåskjell-forurensningsindeks og blåskjell-referanseindeks har blitt brukt årlig siden 1995 på en gruppe "forurensede-" og "referanse-" fjordområder. Forurensningsindeksen for 2004 betegnet sin gruppe mellom "markert" og "sterk" forurenset, den samme klassen som i 2003. 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. Videre var OH-pyren nivåene ved Lista høyere enn i Sørfjorden, slik det har vært observert før 2002. Resultatene for ALA-D indikerte bly-eksponering for torsk fra indre Oslofjord og indre Sørfjord. EROD aktivitet i indre Oslofjord var høyere enn i det mindre forurensede Sotra-Bømlo området, mens EROD aktivitet i indre Sørfjorden var lavere. Tidligere år har også vist at EROD i fisk fra Oslofjorden og Sørfjorden ikke er konsistent høyere enn på andre, antatt mindre forurensede stasjoner.

Effekter av organotin (bl.a. TBT) kunne fortsatt registreres i 2004, 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. Ingen tydelig utvikling i imposex over tid ble registrert, men konsentrasjoner i blåskjell og purpursnegl var lavere enn tidligere år. Noen tidstrend for perioden 1997-2004 kunne imidlertid ikke påvises. Forbud mot bruk av TBT som begroingshindrende middel på båter har ikke ført til klar 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).

Data are submitted to ICES under three categories: for Purpose A (health assessment) on a voluntary basis, Purpose C (spatial distribution) on a voluntary basis and Purpose D (temporal trend assessment) on a mandatory basis. Where practical, data collection was in accordance to agreed procedures (OSPAR 1990, 1997). Data were screened and submitted to ICES in accordance with procedures outlined by ICES (1996).

This report focuses on issues and situations in Norway concerning contaminants and considered of interest to the implementation of JAMP (Table 1). It should be noted that these issues are being revised (cf., MON 2001). The Norwegian programme for JAMP 2003 has been outlined previously (Green 2003).

Table 1. Extract from list of JAMP issues, subjects and descriptions to which the Norwegian investigations for 2003 can be addressed (cf. ASMO 1997, Annex 30).

Issue	Subject	Description
1.2	Hg, Cd, and Pb	What are the concentrations and fluxes in sediments and biota?
1.3	TBT	To what extent do biological effects occur in the vicinity of major shipping routes, offshore installations, marinas and shipyards?
1.7	PCBs	Do high concentrations pose a risk to the marine ecosystem?
1.8	PCBs	Do high concentrations of non-ortho and mono-ortho CBs in seafood pose a risk to human health?
1.10	PAHs	What are the concentrations in the maritime area?
1.11	PAHs	Do PAHs affect fish and shellfish?
1.12	Other synthetic compounds	How widespread are synthetic organic compounds within the maritime area?
1.15	Chlorinated dioxins and dibenzofurans	What concentrations occur and have the policy goals (for the relevant parts of the maritime area) been met?
1.17	Biological effects of pollutants	Where do pollutants cause deleterious biological effects?
5.3	Chemical used [mariculture]	In which areas do pesticides and antibiotics affect marine biota?
6.1	Ecosystem health	How can ecosystem health be assessed in order to determine the extent of human impact?

The chapter structure of this report for the first and second level is according to agreed format (ASMO 1997, Annex 12) which *inter alia* presents results before methodology.

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 2004 investigations are noted in the tables in Appendix E. Data reports have been published recently for sediment 1986-1997 (Green *et al.* 2002a) and biota 1981-2002 (Green *et al.* 2002b-d).

Sediment was samples at 17 stations, blue mussel at 58 stations (including supplementary stations for Index and TBT), dogwhelk at 20, cod at 9 and flatfish at 11 stations from the border to Sweden in the south to the border to Russia in the north. Generally, mussels 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 and Appendix K, depending on the year and concentration basis in question. 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 5 and Table 6 and includes unofficial conversion to other bases. The system does not cover some contaminants for some 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, or slightly (also stated in classifications system as “insignificantly”) polluted. 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

Mussels 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 2620 µg/kg w.w., higher than in 2003. Cod liver from the outer Oslofjord was slightly polluted with regard to ΣPCB-7 (st.36B, Figure 2B).

In 1994, and renewed in 2004, the Norwegian Food Safety Authority (SNT) advised not to consume liver of cod from the inner Oslofjord (north of st.31A, 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 mussels from the inner Oslofjord (30A and 31A Figure 1A, B) for the period 1988 to 2004.

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 10 to 13 years to be detected with 90% significance (Appendix I).

The fillet of "small"[1] (29-44 cm) and “large” cod (45-70 cm) from the inner Oslofjord in 2004 were moderately polluted with mercury (Class II, Figure 3A, B). A significant *upward* trend was detected for the period 1984-2004 for both size groups, even though the concentrations in 2002-2004 were lower than the three previous years. No significant trend was found for period 1998-2004. 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 (10-11 years) than “large” fish (13 years) (cf. Appendix I). Concentrations of mercury were significantly higher in "large" cod compared to "small" cod.

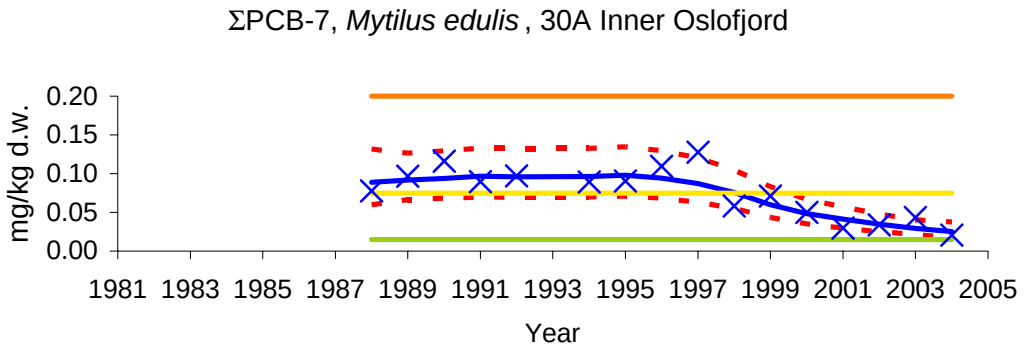
Median concentration of cadmium and lead in cod liver from the inner Oslofjord (30B) 2004 was 0.10 and 0.17 mg/kg w.w., respectively. For lead, this was less than a third of the concentration found in 2002, which was the second highest found during the entire period (1990-2004). “High background” for these metals is 0.1 mg/kg w.w. A significant *upward* trend was found for cadmium in these cod. A significant *upward* trend was also found for cadmium in mussel from one station in the inner Oslofjord (st. 30A). These mussels were moderately polluted with respect to both cadmium and lead in 2004.

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

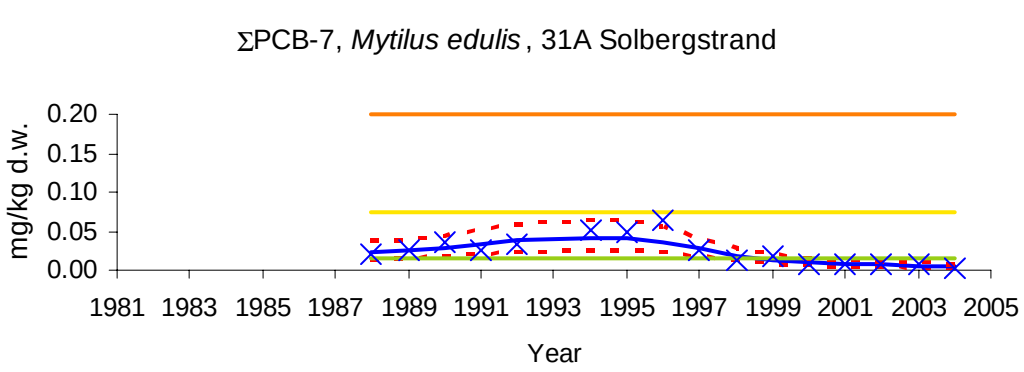
It should be noted that the Index programme indicated severe concentrations of TBT in mussels from a station located in the inner Oslofjord (see chapter 1.3.8).

[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



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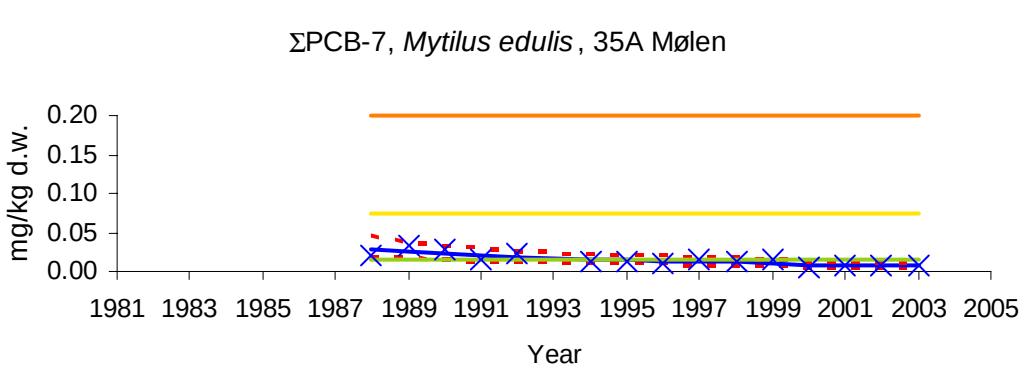


D

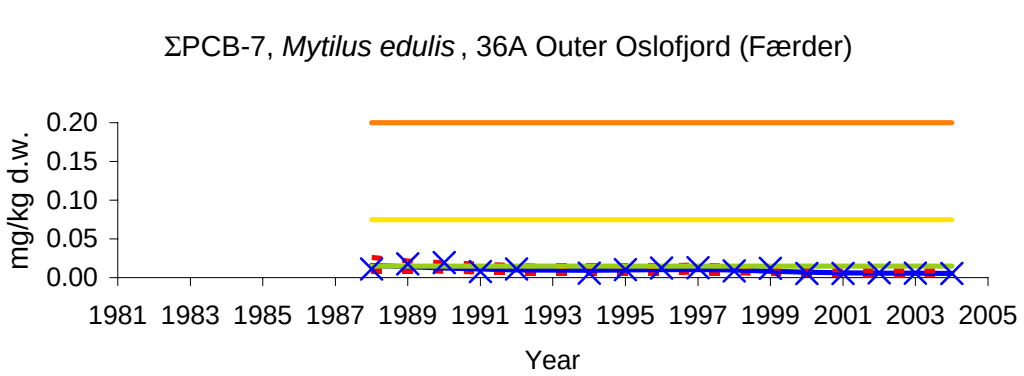
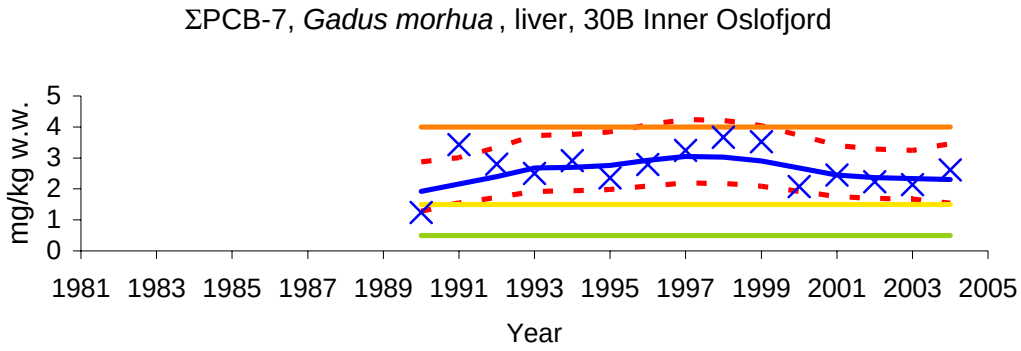


Figure 1. Median ΣPCB-7 (sum of PCB 28, 52, 101, 118, 138, 153 and 180) concentration in blue mussel (*Mytilus edulis*) from inner (st.30A) to outer (st.36A) Oslofjord. (cf. Appendix G and Appendix I, and and key in Figure 21).

A



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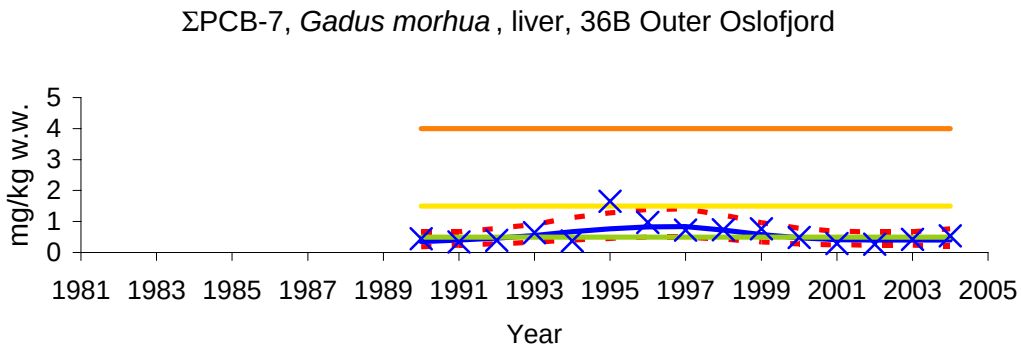

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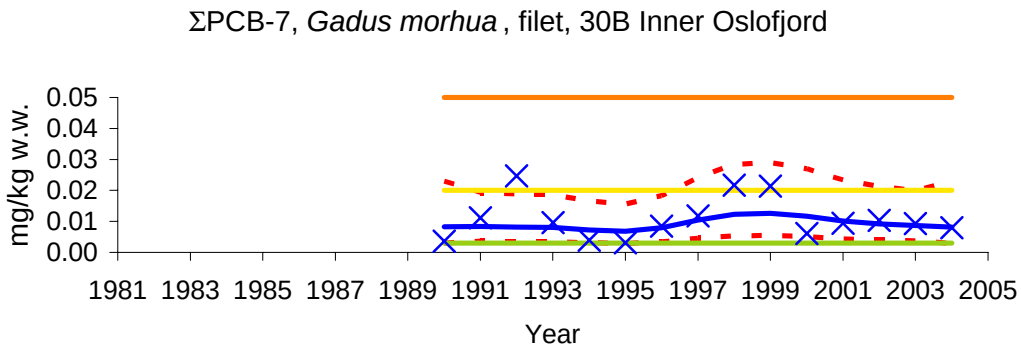

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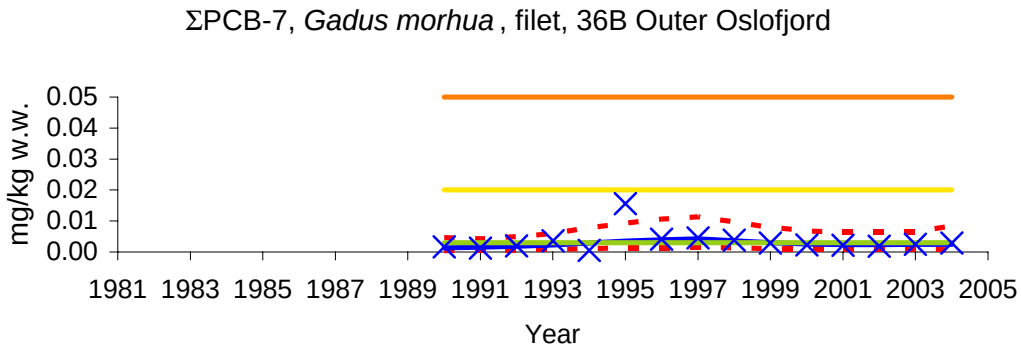


Figure 2. Median ΣPCB-7 (sum of PCB 28, 52, 101, 118, 138, 153 and 180) concentration in liver and fillet of cod (*Gadus morhua*) from the inner (st.30B) to outer (st.36B) Oslofjord. (cf. Appendix G and Appendix I, and key in Figure 21).

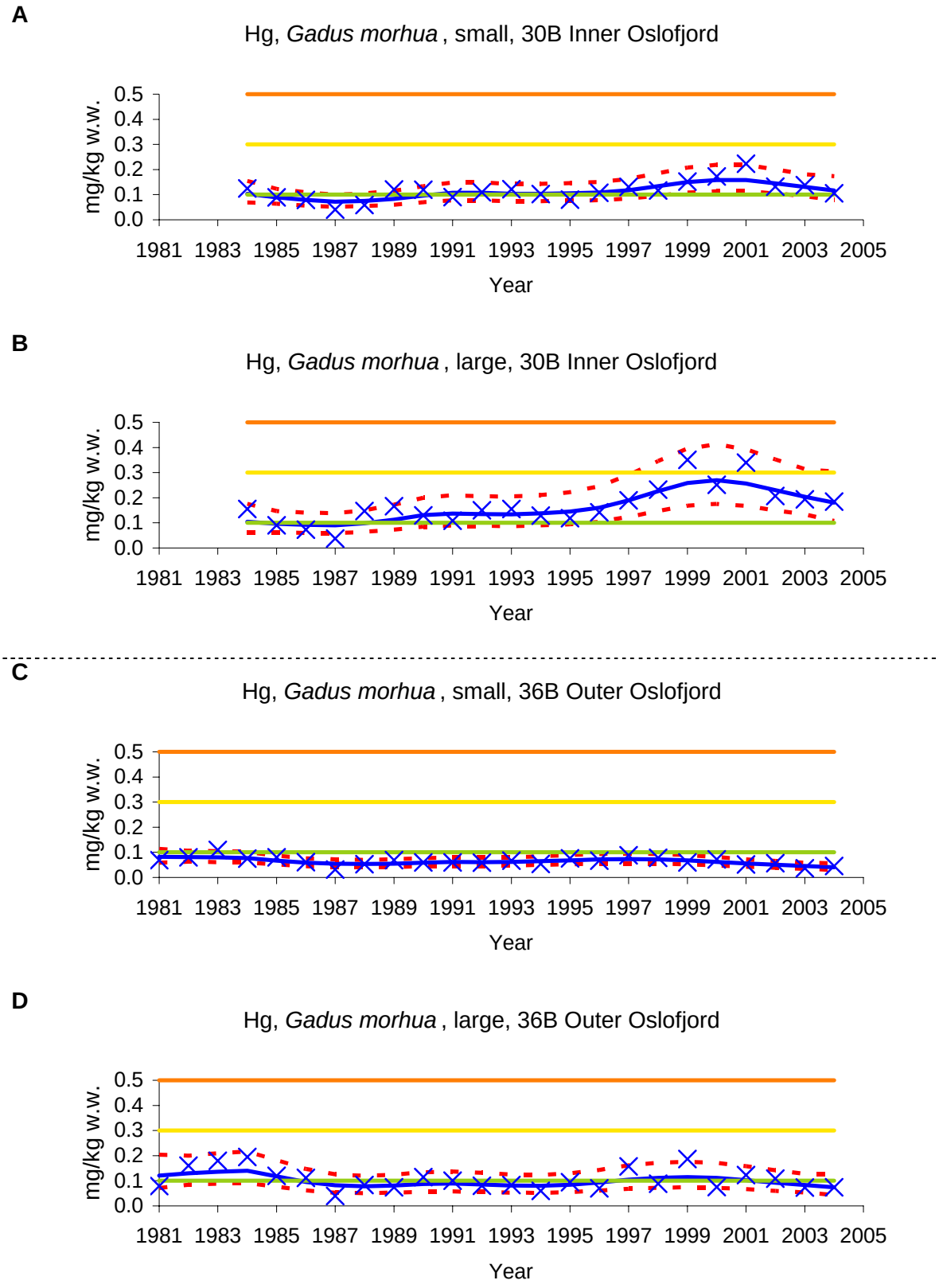


Figure 3. Median mercury (Hg) concentration in fillet of cod (*Gadus morhua*): for the inner Oslofjord (st.30B) "small" (**A**) and "large" (**B**) fish, and for the outer Oslofjord (st.36B) "small" (**C**) and "large" (**D**) fish. (cf. Appendix G and Appendix I, and key in Figure 21).

Mussels from Langesundsfjord (st.71A) in 2004 were slightly polluted with HCB (Class II, Figure 4). The median concentration for 2004 was higher compared to 2003, which was the lowest at this station since 1983. Concentrations have varied greatly since 1983 but median value 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 15 years for the period 1990-2004 and more than 25 years for the entire period (cf. Appendix I). The 1983-2004 data series and the 1990-2004 data series both had significant *downward* trends.

Extremely high lindane concentrations (Class V) were found in blue mussel from st. 71A in 2002 (cf. Green *et al.* 2004a), but the concentrations were low (Class I) in both 2003 and 2004. The reason for high values in 2002 has not been determined.

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) in mussels from 71A were marked (SFT Class III) and severe values were found at a nearby Index station (I712) (Figure 34).

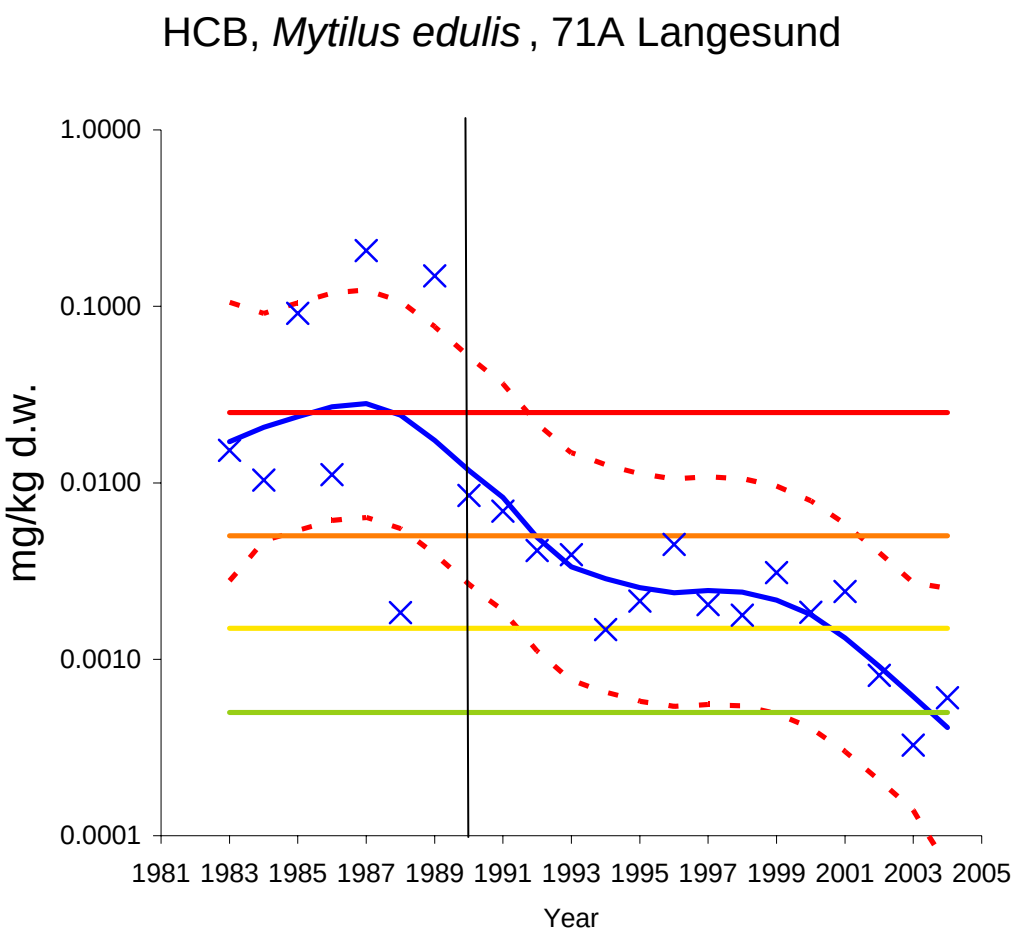


Figure 4. Median HCB concentration in blue mussel (*Mytilus edulis*) from Langesundsfjord (west of Oslofjord). (cf. Appendix G and Appendix I, and key in Figure 21). Vertical line indicates when a magnesium factory reduced it's discharge by 99%. **NB: log-scale.**

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 2004 are coupled to other studies in this area (cf. Knutzen & Green 2001a, Ruus & Green 2002, 2003, 2004, 2005) and confirm that the Sørfjord, and in some cases also Hardangerfjord, continue to be contaminated especially with cadmium (Figure 5 and Figure 6), lead (Figure 7 and Figure 13), mercury (Figure 8, Figure 9 and Figure 13), ppDDE (Figure 10, Figure 11 and Figure 12). PAH (represented by benzo[*a*]pyrene (Figure 13)) and to a lesser extent PCB (Figure 12).

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

Results for mussels 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). Mussels as far as Krossanes at the mouth of Sørfjord (st.57A) and about 35 km from Odda, were moderately polluted with cadmium (Figure 5). In 2003 this limit was as far as Lille Telløy in Hardangerfjorden (100 km from Odda). 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 one station nearest Odda (st.51A) was severe (Class IV), whereas the other three stations in the Sørfjord were moderately or markedly polluted with lead. A *downward* trend was found for lead at st. 63A and 65A, 1990-2004. Three stations in Sørfjord were moderately polluted with respect to mercury.

Cod fillet from “small” (33-39 cm) and "large" individuals (40-47 cm) from the inner Sørfjord (st.53B) were moderately polluted with mercury (Class II). Overconcentrations for mercury were found in fillet in flounder (4-5 times "background") and an *upward* trend was also found. Overconcentrations were found for cadmium in cod liver and flounder liver from inner Sørfjord (3-5 times). Overcentrations of lead in flounder liver were also observed (2 times).

The power of the sampling strategies for mussels was relatively poor for samples collected from Odda; the innermost part of Sørfjord (st.51A or 52A). For example for lead in mussels, it is estimated that it would take 19-23 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, ca.50 km from Odda) it was only 13 years.

Mussels at one station (st.56A) near the outer Sørfjord were markedly polluted with ppDDE (Class III); with a median concentration of 49.3 µg/kg d.w. The lower limit to Class IV, severely polluted, is 50 µg/kg d.w. Mussels elsewhere in the Sørfjord were moderately polluted (Class II) (Figure 10 and Figure 11). Cod fillet and liver from the Sørfjord were only moderately polluted with ppDDE (Figure 12A, Appendix I).

The liver of cod from Hardangerfjord for 2004 were only slightly 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 mussels and cod. A *downward* trend was found for these substances in flounder fillet from inner Sørfjord.

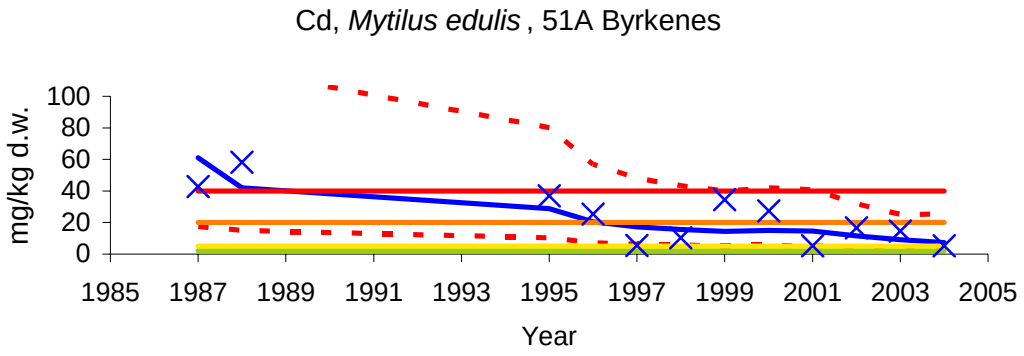
Sediment has been sampled from seven stations from the Sørfjord-Hardangerfjord region in 2004, and also previously in 1990 and 1997 (Appendix F and Appendix K). The position for sampling near Strandebarm (st.67S) was moved in 2004 about 250 m to avoid submerged power lines. The water depth was 680 m, about 30 m deeper than previous sampling. The sampling near Krossanes at the mouth of Sørfjorden was mistakenly taken 600 m east of previous sampling. The water depth was 170 m and 135 m shallower than previously. Comparisons between stations were based on concentrations in surficial sediment; usually 0-1 cm, but 0-2 cm for analyses of organic contaminants prior to 2004.

Surficial sediment from the inner Sørfjorden (st.52S) was extremely polluted with mercury and PAH (Class V), severely polluted with cadmium and lead (Class IV), markedly polluted with zinc and TBT (Class III) and moderately polluted with copper (Class II). Concentrations of these contaminants generally decreased with distance from Odda, but still above Class I well into Hardangerfjorden (Figure 13).

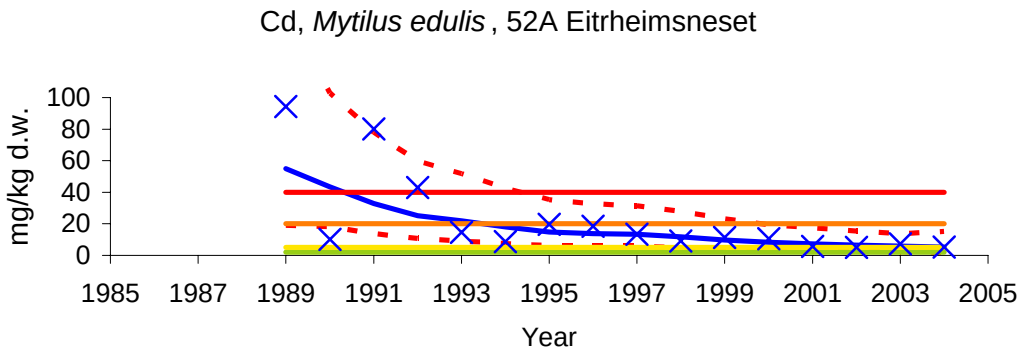
Concentrations of PCBs and organic pesticides were low (Class I).

Sedimentation rate is about 1 mm per year (Green *et al.* 2002a), and there has not been sufficient time nor sampling to do an adequate temporal trend assessment for the period of investigation (1990-2004). Furthermore, the problem of such an assessment is compounded for the organic contaminants because of the above mentioned change in surface sample depth (0-1 vs. 0-2 cm). Taking these aspects into consideration, there is some evidence that concentrations of PAH have decreased from 1990 to 2004 (e.g. PAH compound benzo[*a*]pyrene in Figure 13). It should also be noted that where surficial sediment was markedly polluted with DDE before (Class III), it was only slightly polluted in 2004 (Class I).

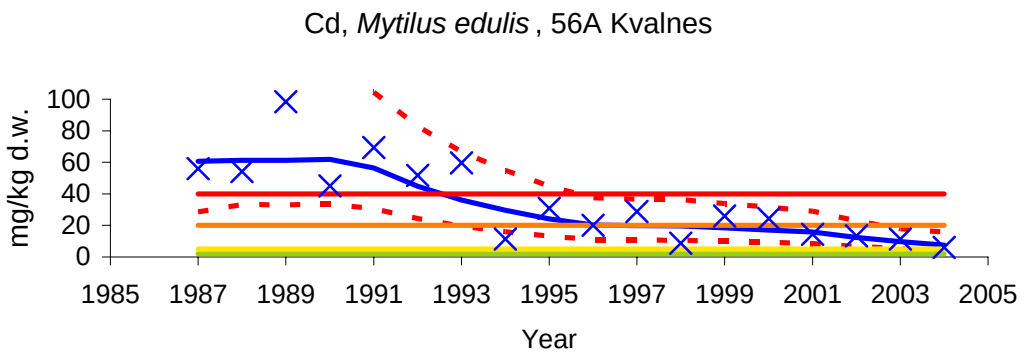
A



B



C



D

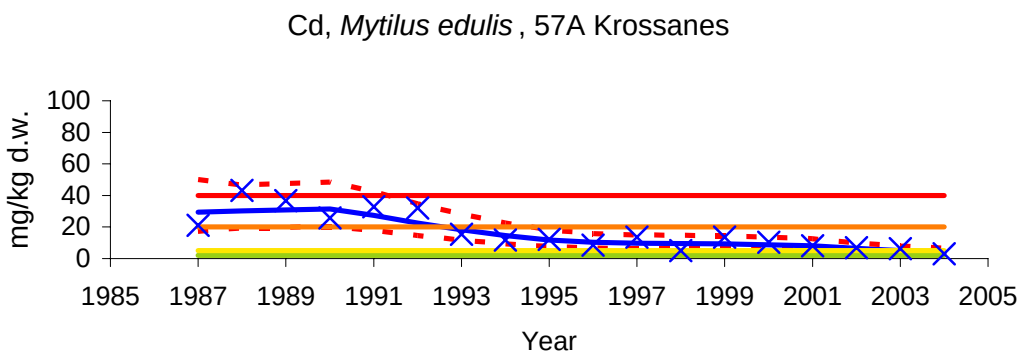
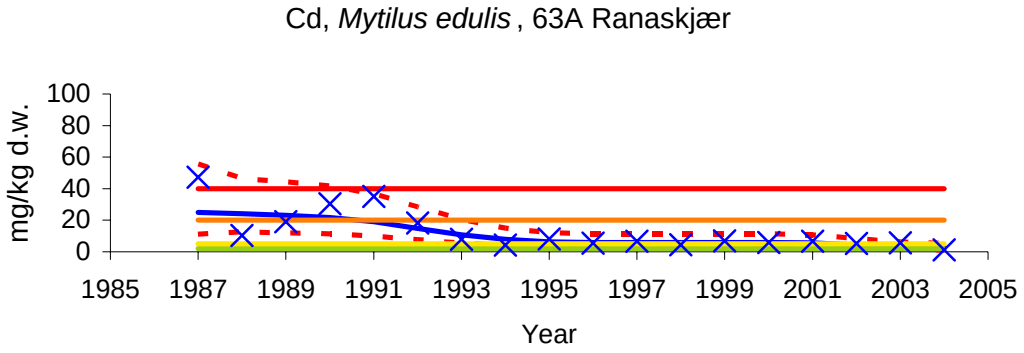


Figure 5. Median cadmium (Cd) concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. NB: (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in figures A-C. Note: horizontal lines for Classes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

A



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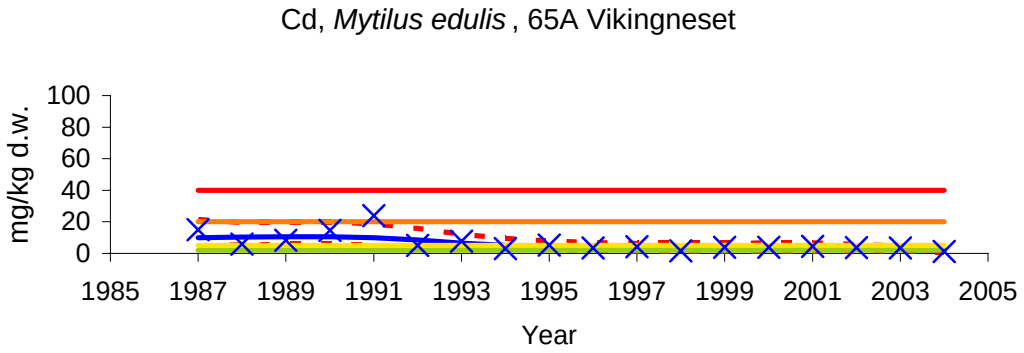


C

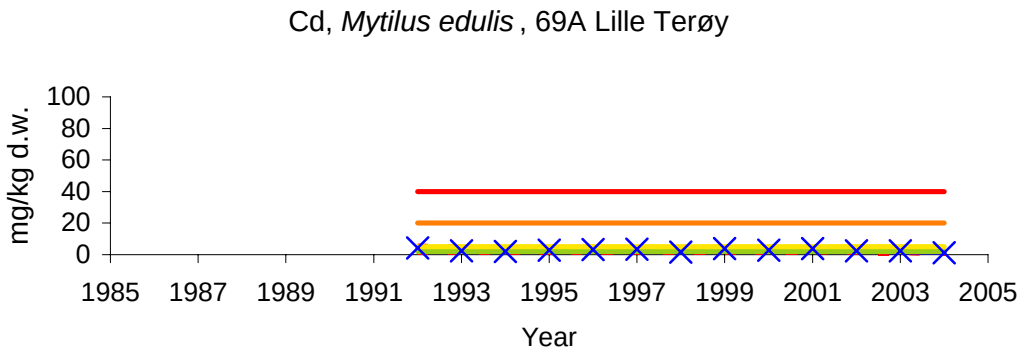
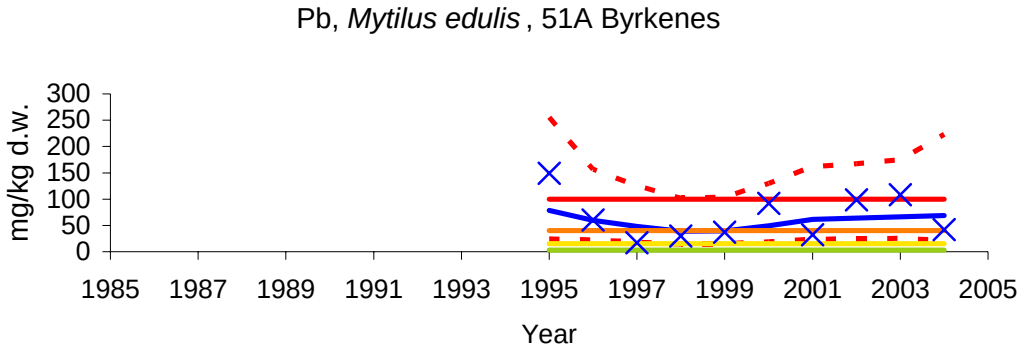
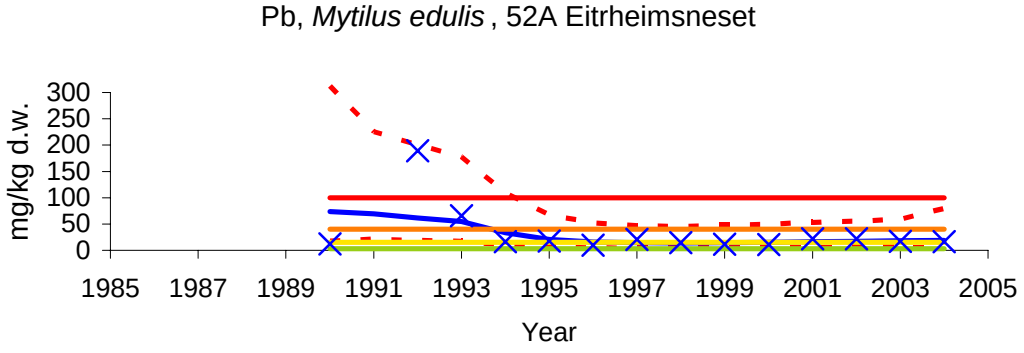


Figure 6. Median cadmium (Cd) concentration in blue mussel (*Mytilus edulis*) from Hardangerfjord (st. 63A, 65A and 69A). (cf. Appendix G and Appendix I, and key in Figure 21). **Note: horizontal lines for Classes I and II are near x-axis.**

A



B



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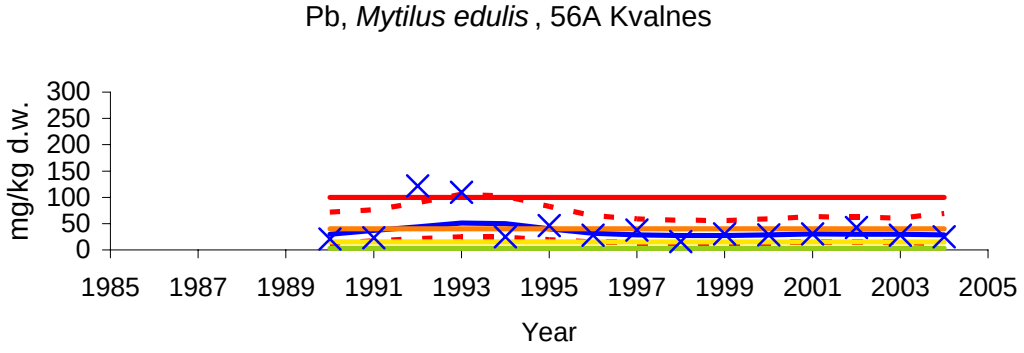


D

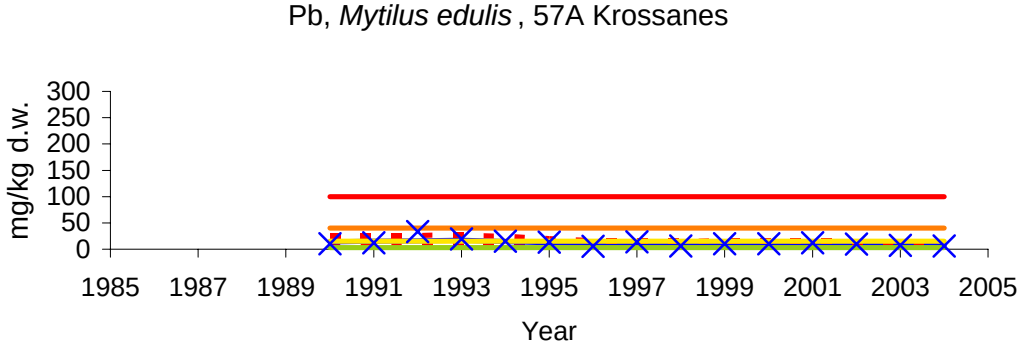
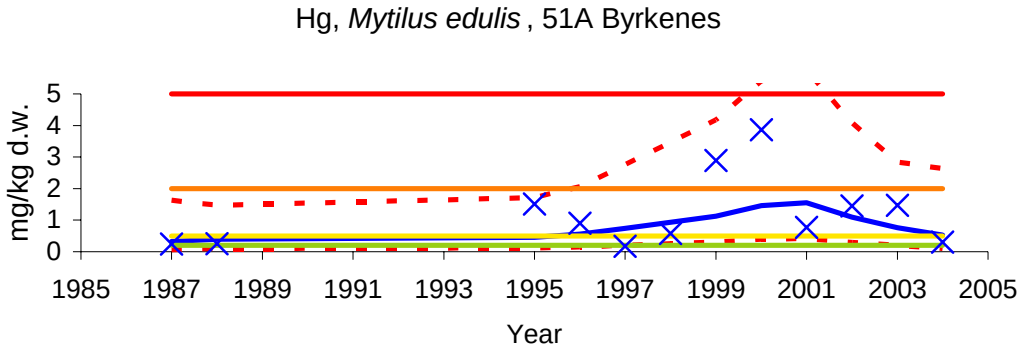


Figure 7. Median lead (Pb) concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. (cf. Appendix G and Appendix I, and key in Figure 21). **Note: horizontal lines for Classes I and II are near x-axis.**

A



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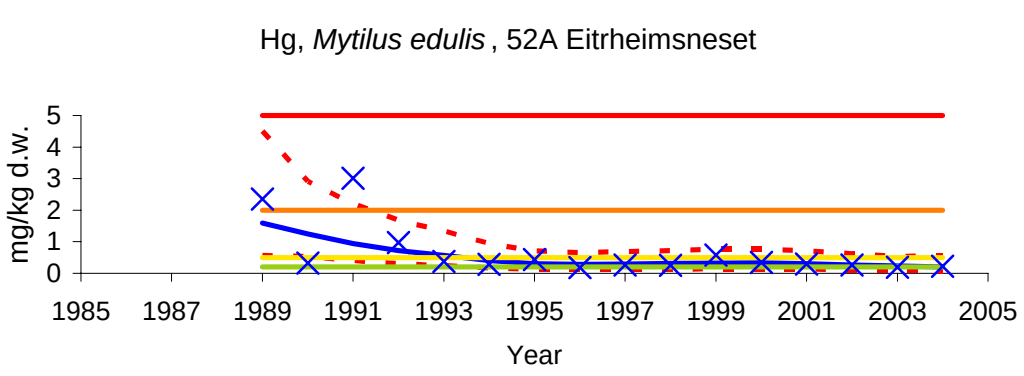
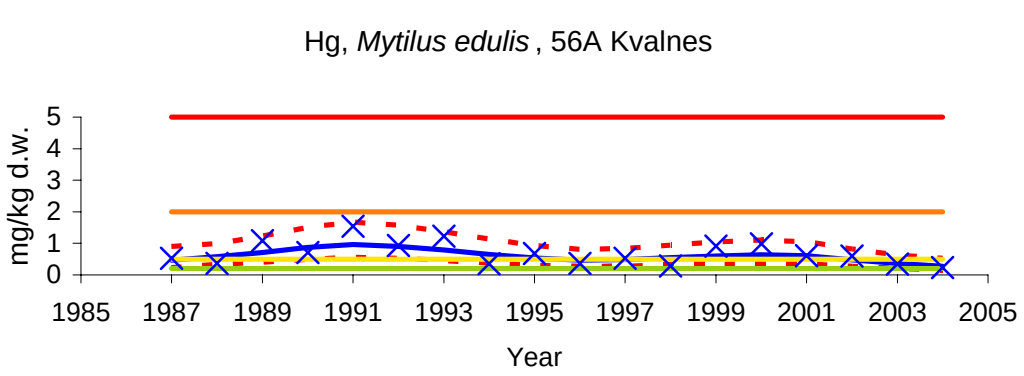


C



D

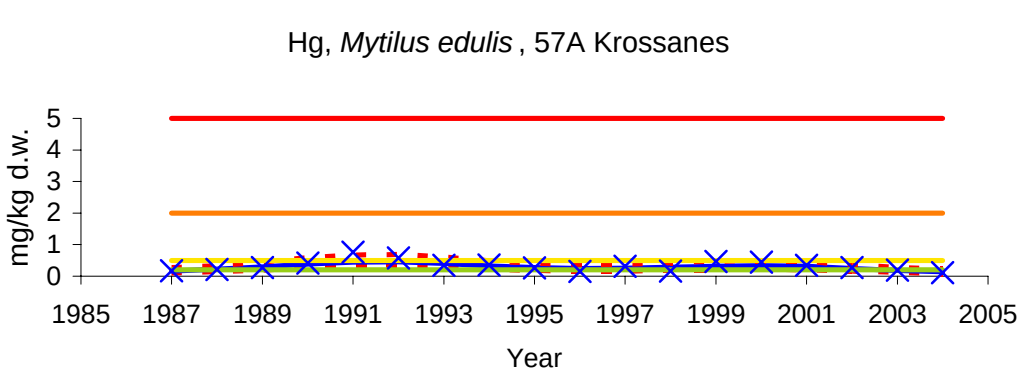
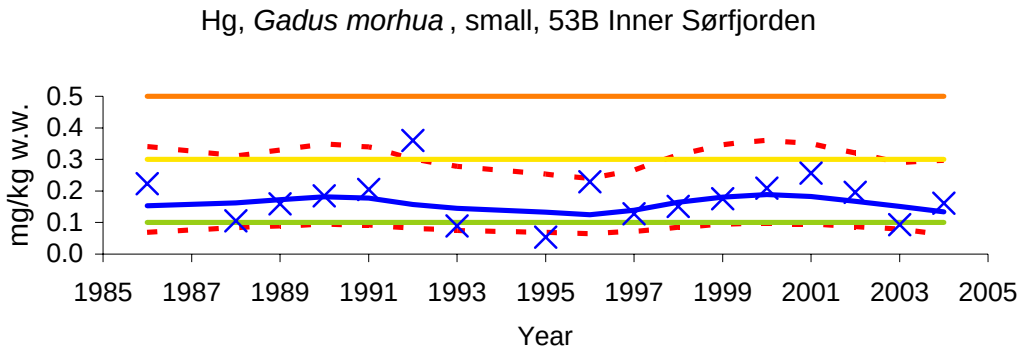


Figure 8. Median mercury (Hg) concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in figure A. Note: horizontal lines for Classes I and II are near x-axis.**

A



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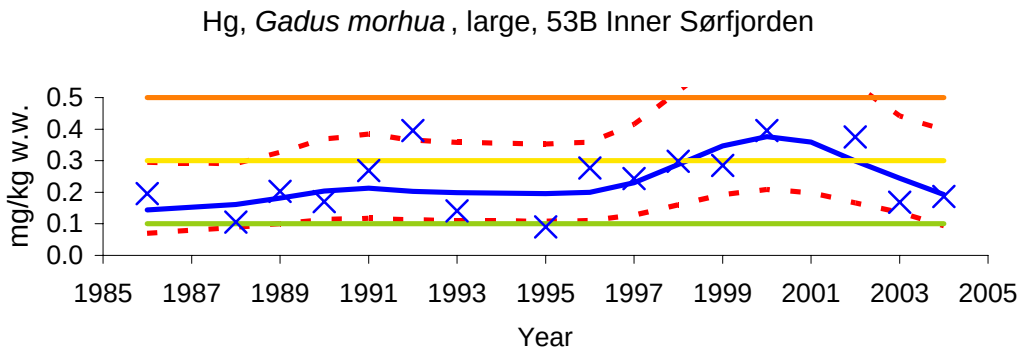
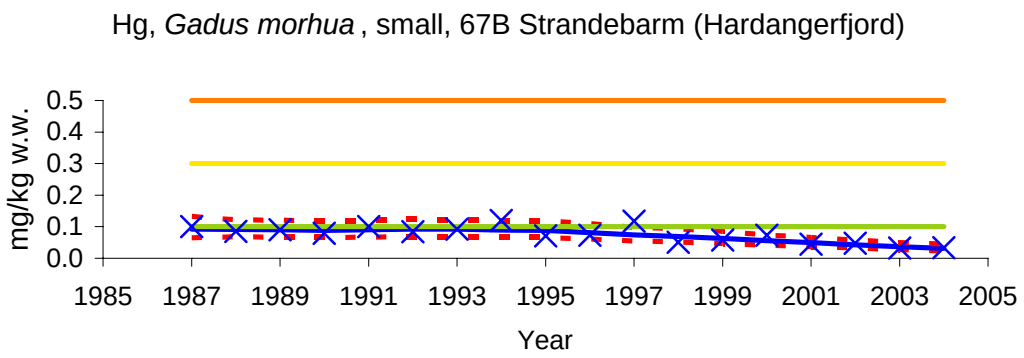


C



D

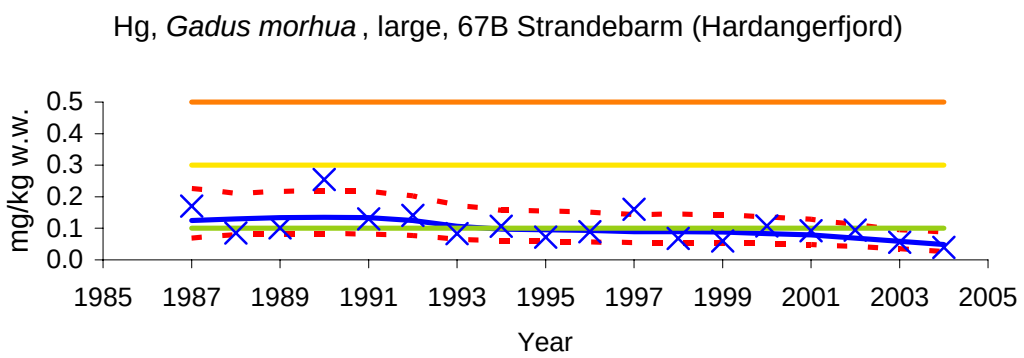
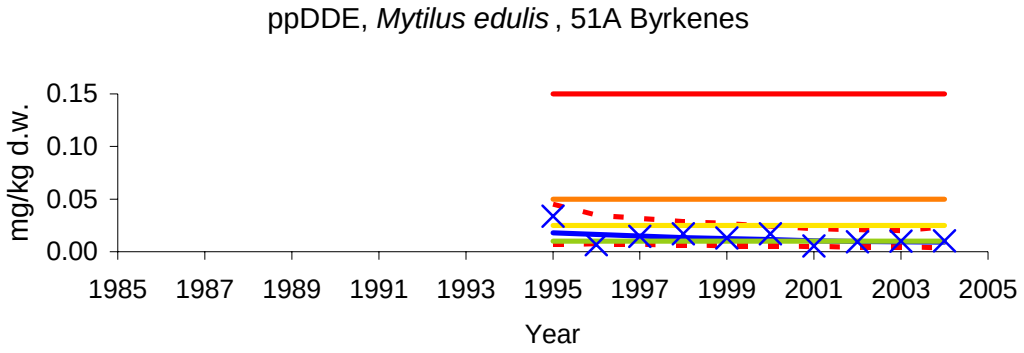


Figure 9. Median mercury (Hg) concentration in fillet of cod (*Gadus morhua*): from Sørfjord (st.53B) for "small" (**A**) and "large" (**B**) fish and Hardangerfjord (st.67B) for "small" (**C**) and "large" (**D**) fish (cf. Appendix G and Appendix I, and key in Figure 21). **Note: for some years the upper confidence interval line is off-scale in Figure B.**

A



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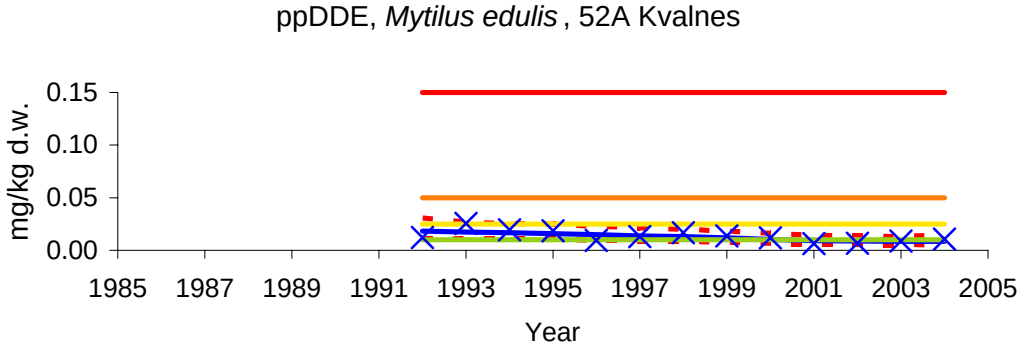

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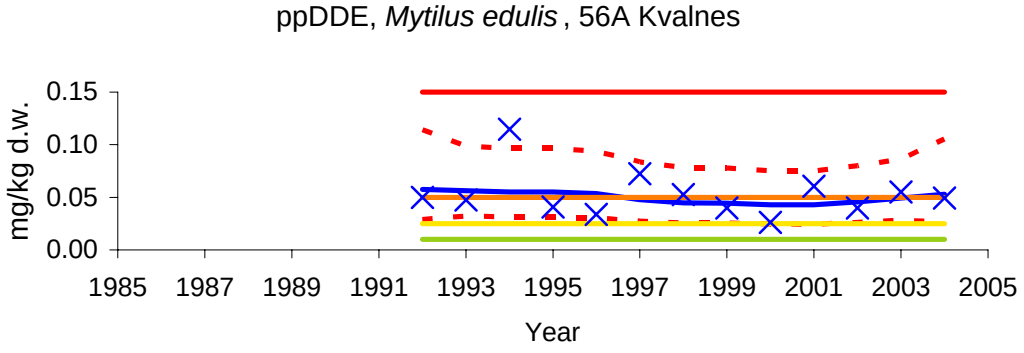


D

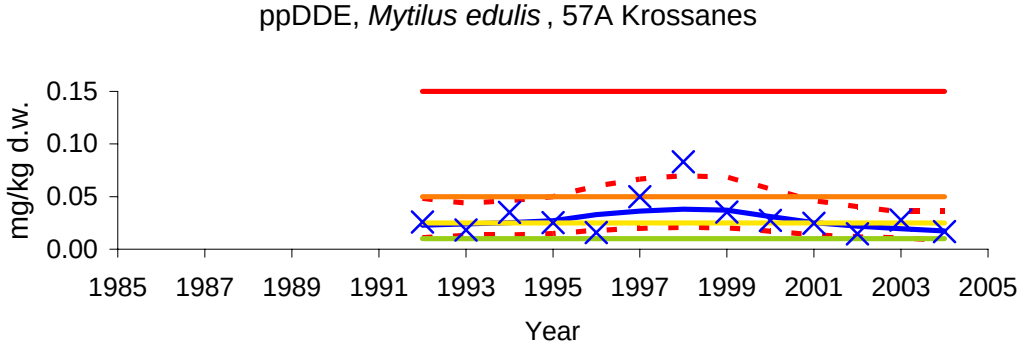
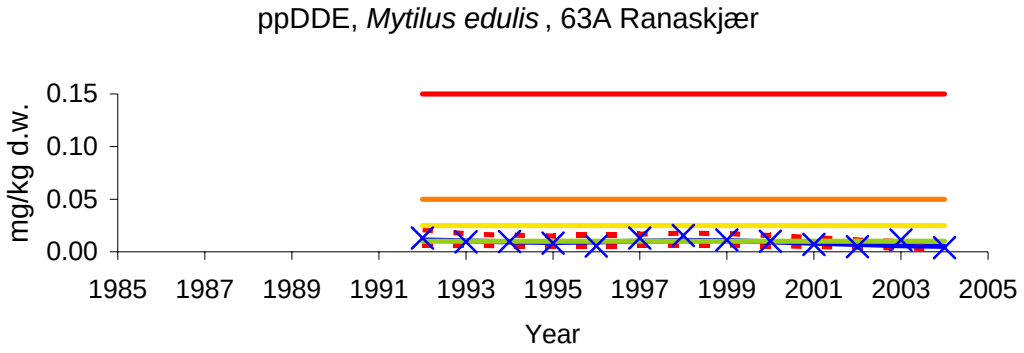


Figure 10. Median ppDDE concentration in blue mussel (*Mytilus edulis*) from inner (st.51A) to outer (st.57A) Sørfjord. (cf. Appendix G and Appendix I, and key in Figure 21). **Note: horizontal line for Class I is near x-axis.**

A



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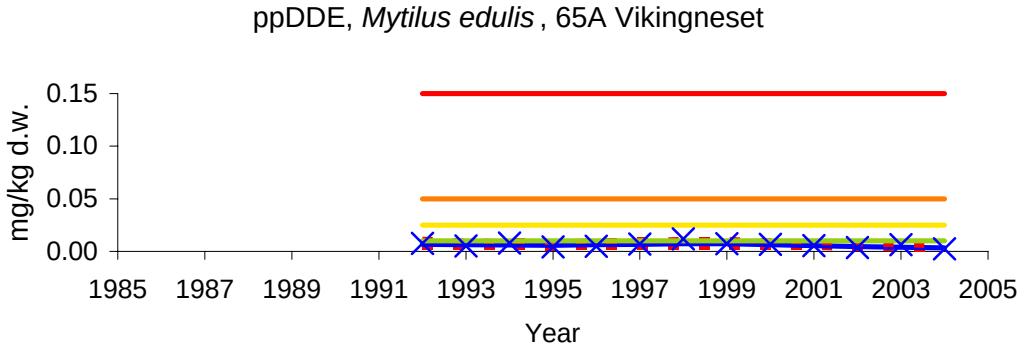


C

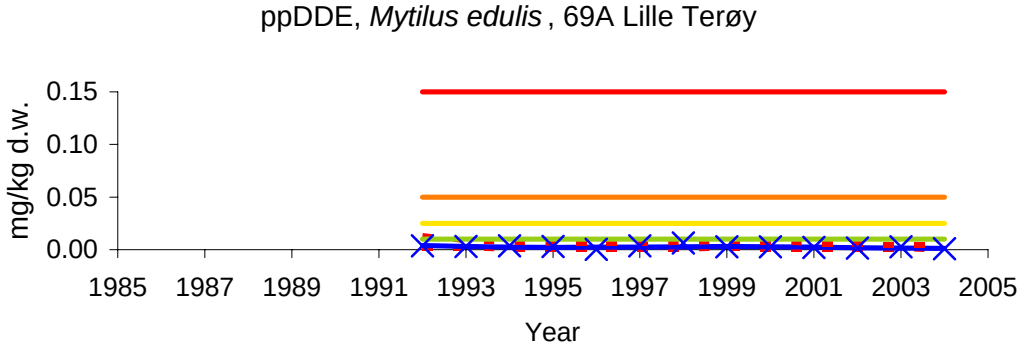
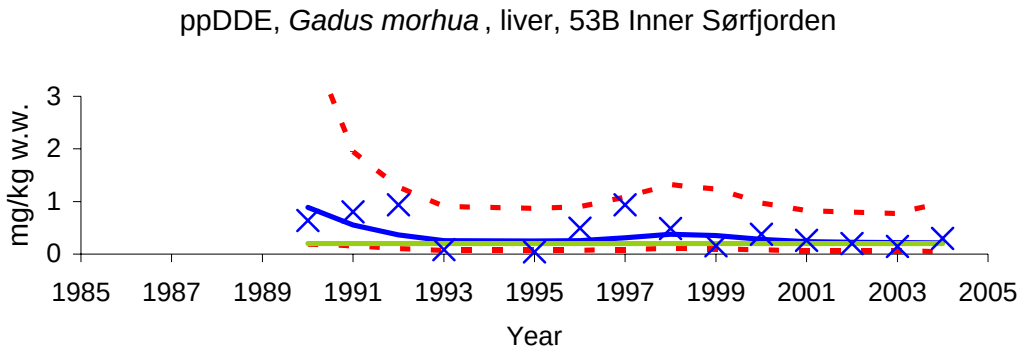


Figure 11. Median ppDDE concentrations in blue mussel (*Mytilus edulis*) from Hardangerfjord (st. 63A, 65A and 69A). (cf. Appendix G and Appendix I, and key in Figure 21). **Note: horizontal line for Class I is near x-axis.**

A



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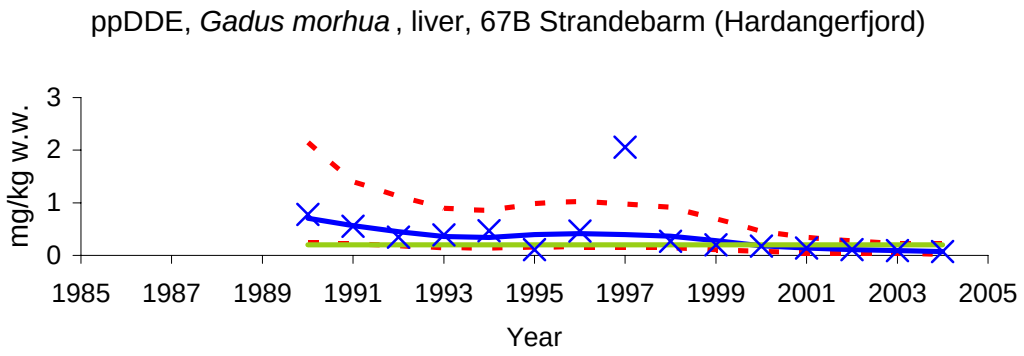
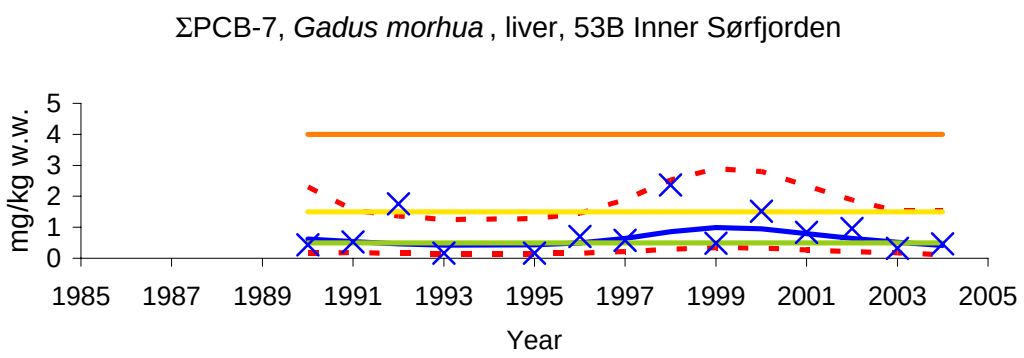


C



D

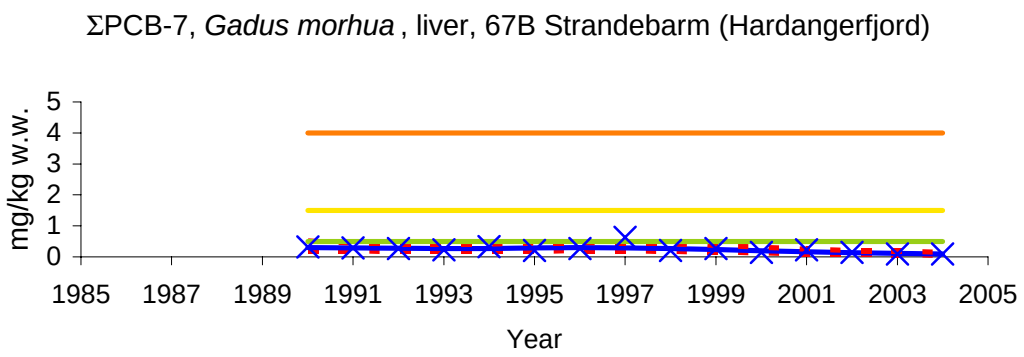


Figure 12. Median ppDDE and ΣPCB-7 concentrations in liver of cod (*Gadus morhua*) from Sørfjord (st.53B) and Hardangerfjord (st.67B) (cf. Appendix G and Appendix I, and key in Figure 21). **Note that for 1989 the upper confidence interval line is off-scale in Figure A.**

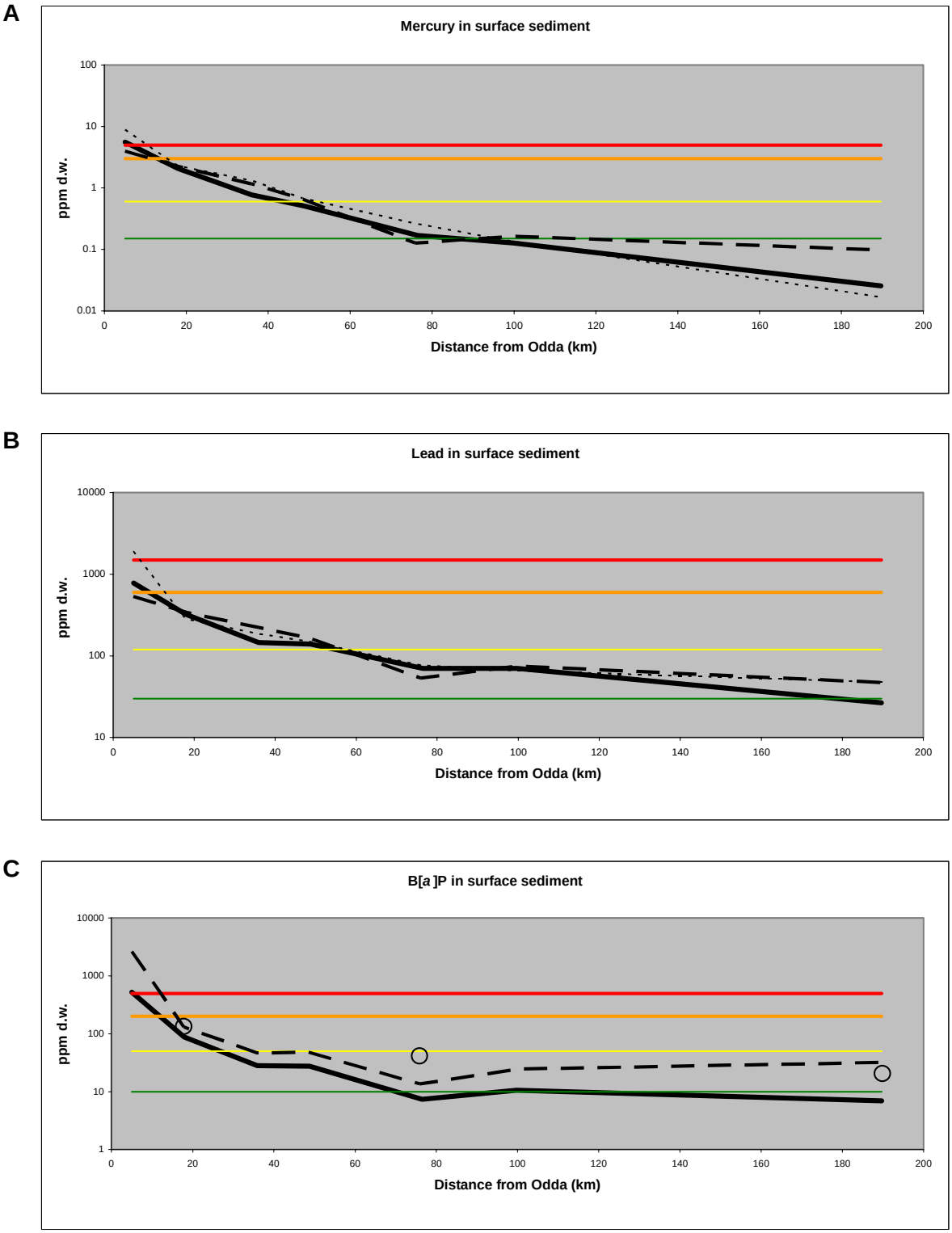


Figure 13. Median concentration of mercury (**A**), lead (**B**) and benzo[*a*]pyrene (**C**) in surficial sediment (0-1 cm (alt. 0-2 cm)) ordered by distance from near Odda (st.52S) to Bømlo area (22S), almost 200 km seaward. The Station order is 52S, 56S, 57S, 63A, 65A and 22S and the results are from 1990 (dotted line or open circles), 1997 (dashed line) and 2004 (solid line). (cf. Appendix K, and key in Figure 21). **Note: log scale.**

1.3.3. Lista area

Median concentrations of contaminants in mussels, cod and dab were slight, with one exception (moderate (Class II) for mercury in ”large” dab) and 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 st.22F Borøyfjorden. Thus, a new station in Åkrafjorden, 21F Kyrping, was initiated in 2000. This station is located about 82km south-east of 22F, but like 22F, 21F is located in a reference area.

Mussels, cod and flounder from this area (22A, 23B, 21F) generally were only slightly polluted (Class I) or showed no overcentrations with respect to metals or organochlorines (Appendix I and Appendix J). One exception was the unexpectedly the high concentration of ppDDE in the single bulk sample of flounder liver from Kyrping. This was the highest found in not only flounder but also plaice and cod in this area (both for lever and fillet) since 1990 The concentrations was three times background and higher than any found in the Sørfjord or Hardangerfjord for this species-tissue. The median concentration in flounder fillet from Kyrping was also above background (1.2 times).

1.3.5. Orkdalsfjord area

Mussels from this area were monitored for the period 1984-1996, and then not again until 2004 when bulk samples from four stations were investigated (Trossavika – st.84A, Flakk – 82A or Ingdalsbukt – 87A). Median concentrations found in 2004 can be classified as “slight” in SFT’s system (Class I). , as found before.

Sediment was sampled from four stations from the Orkdalsfjord region in 2004, and also previously in 1987 and 1992 (Appendix F and Appendix K). Surficial sediment from the inner Orkdalsfjorden (st.89S) was markedly polluted with cadmium and copper (Class III) and moderately polluted with lead and zinc (Class II) (Appendix K, Figure 14). The concentrations of ΣPCB-7, PAH and TBT were low (Class I). No temporal trends were evident for the period 1987-2004.

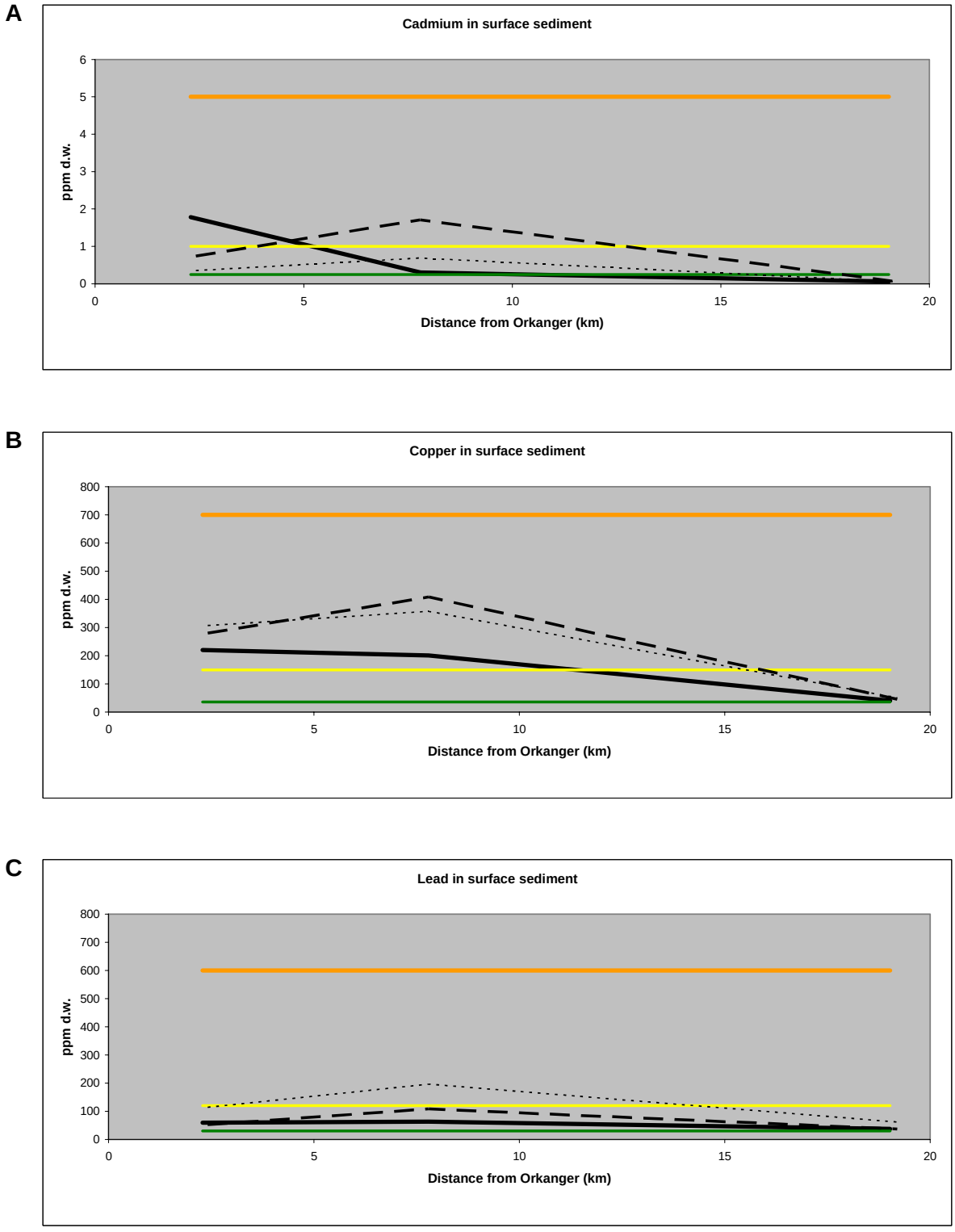


Figure 14. Median concentration of cadmium (**A**), copper (**B**) and lead (**C**) in surficial sediment (0-1 cm (alt. 0-2 cm)) ordered by distance from near Orkanger(st.89S) to Trondheimsfjorden (90S), about 20 km seaward. The Station order is 89S, 84S, and 90S and the results are from 1987 (dotted line), 1992 (dashed line) and 2004 (solid line). (cf. Appendix K, and key in Figure 21).

1.3.6. Open coast areas from Bergen to Lofoten

This stretch of coastline covers 7° of latitude to 68°N (Appendix G). Fourteen mussel stations were investigated in 2004, thirteen of these not since the period 1990-1993. The longest times series was obtained from mussels collected at the island of Skrova (st. 98A). Samples were collected in 1992-1993, however, during the period 1994-1996 mussels were not found at this station, but nearby in the Skrova harbour (98X). Since 1997 a "new" 98A location 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.

In 2004, the mussels were only slightly contaminated (SFT's Class I), which was generally the case for the period 1997-2003. “Large” cod were moderately contaminated with mercury (Class II) (Appendix I and Appendix J).

The median concentrations in mussels from Sætervik (st.93A) 2004 were moderate (Class II) for ΣPCB-7. PCB and pesticides were not measured at this station previously.

Sediment was sampled from Sotra (st.24S) to Lofoten (st.98S) in 2004; a total of six stations (24S, 27S, 93S, 95S, 99S and 98S). Most of these stations were also investigated previously in 1990-1992 (Appendix F and Appendix K). Surficial sediment was markedly polluted with TBT at Sotra (st.24S), east of Statlandet (27S) and northeast of Raudøya (st.93S) (Class III) and moderately polluted with lead, HCB, benzo[*a*]pyrene east of Statlandet (Class II) (Appendix K). No temporal trends were evident for the period 1990-2004.

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). In 2004 only two mussel stations, one cod station and one plaice station were investigated in the Varangerfjord (at approximately 70°N).

Slight overconcentrations (less than 2 times “high background”) of cadmium were found in liver of plaice (st.10F) (Appendix I and Appendix J).

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, when all areas or fjords are slightly polluted (Class I in SFT's environmental quality classification system (Molvær *et al.* 1997)), to 5, in which at least one sample from each area or fjord could be classified as 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 (TBT and dioxin) into consideration the Index was 3.4 for 2004 compared to 3.6 for 2003 (cf. Appendix L). A value between 3 and 4 would be between "Markedly" and "Severely" polluted in the SFT classification system. Indices calculated with and without supplementary stations and analyses has been presented earlier (cf. Green *et al.* 2004a, b).

Six areas were included in Reference Index for 2004 compared to five for 1998-2003, and seven-eight fjords used in previous years. With the new calculation where supplementary analyses of TBT are included, the Reference Index was 1.3 for 2004, compared to 1.8 for 2003. 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 classified between "Slight" and "Moderate" in SFT's system. Five of the six 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 (1995-2004) has been calculated and show both significant upward and downward trends in mussels (cf. Appendix I). Some cases are worth noting:

- I024 Kirkø in the Hvaler area (Map 1, Appendix G), where a *downward* trend for ΣPCB-7 was found, and where moderate concentrations (Class II) were found previously,
- 30A Gressholmen and I307 Ramtonholmen in the inner Oslofjord (Map 1, Appendix G), where *upward* trends in cadmium were found and where the 2004 median at 30A was in Class II,
- 30A Gressholmen, where a *downward* trend in ΣPCB-7 was found and where the 2004 median was in Class II,
- I306 Håøya and I307 Ramtonholmen in the inner Oslofjord, where *upward* trends in benzo[*a*]pyrene were found and where the 2004 median at I307 was in Class II,
- 71A Bjørkøya in the Langesund area (Map 3, Appendix G), where a *downward* trend in HCB was found and where the 2004 median was still in Class II,
- I713 Strømtangen also in the Langesund area (Map 3, Appendix G), where an *upward* trend in ppDDE was found but where the 2004 median was still in Class I,
- I133 Odderø in the Kristiansand harbour (Map 4, Appendix G), where a *downward* trend for ΣPCB-7 was found, and where moderate concentrations (Class II) were found previously,
- 52A Eitrheimsneset in the inner Sørfjord (Map 6, Appendix G) where the 2004 median for cadmium was in Class III and a *downward* trend detected.

1.4. Biological effects methods for cod

The JAMP-programme for 2004 included five biological effects methods (BEM): OH-pyrene, ALA-D, EROD, CYP1A and TBT (Table 2). The first four are discussed in this chapter (Figure 15 to Figure 17) 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 published earlier (Ruus *et al.* 2003). For the 2004 investigations OH-pyrene, ALA-D, EROD and CYP1A were measured in Atlantic cod in 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-2004.

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	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
TBT	Imposex/Intersex	snail soft tissue	organotin

The reason 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 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.

Under controlled conditions the measures derived from OH-pyrene, EROD 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. 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.

In 2004 the median concentration of OH-pyrene metabolites in cod from the inner Oslofjord (30B), was over twice that of cod from Lista (15B), and more than a factor of 10 higher than that of cod from Inner Sørfjorden (53B) and the "reference" station on the west coast (23B) (Figure 15, Appendix I).

For 1998, 1999, 2001 the median concentrations of OH-pyrene in cod from Lista (15B) were higher than at stations 30B, 53B and 23B (no samples from 15B in 2000). In 2003 concentrations were below those at st. 30B but above st. 23B and st. 53B. The variability at Lista was relatively high in 2003, indicated by the standard deviation:median ratio of >3, suggesting large differences among the 25 cod sampled. In 2004 the ratios varied from 1.4 at 53B to 2.3 at 30B, and OH-pyrene levels at Lista (15B) were again higher than in Inner Sørfjorden (although still lower than in the inner Oslofjord, 30B). There was a slight increase in the median OH-pyrene-level at Lista from 2002-2003 to 2004 (Figure 15). 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. No significant temporal trends were found at these three stations.

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 sampling.

In 2004, as in 2000 and 2002-2003, the median concentration of OH-pyrene in cod from st. 30B (inner Oslofjord) was higher than the other three stations. When considering the whole period (1998-2004), the yearly median concentration at 30B was the highest or next highest compared to the other 2-3 stations Appendix I). Furthermore concentrations at 53B Sørfjorden were usually higher than 23B. This presumably reflect the general contamination of the two areas (inner Sørfjord and inner Oslofjord).

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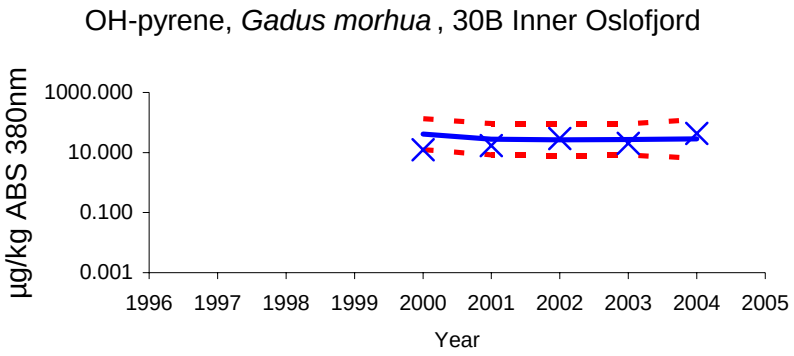

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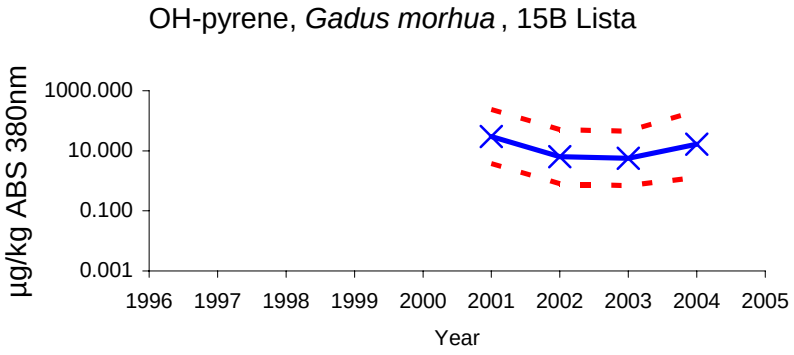

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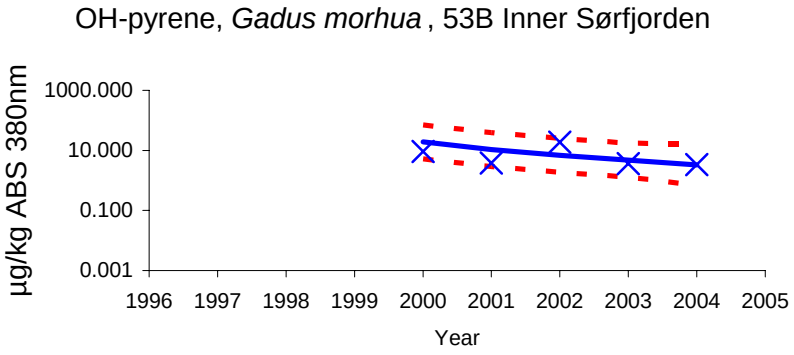

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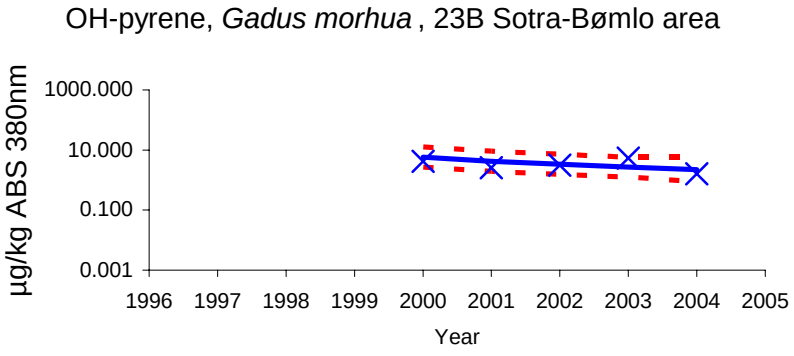

Figure 15. Concentration of OH-pyrene (µg/kg ABS 380nm) in bile from Atlantic cod collected at the indicated stations 2004. There was insufficient data to present a time series from st. 15B. (cf. Appendix G and Appendix I, and key in Figure 21). **NB: log-scale.**

1.4.2. ALA-D in blood cells

Most years the activity of ALA-D in cod was generally inhibited (indicating the influence of lead contamination) in the inner Oslofjord (30B) and inner Sørfjord (53B), compared to reference stations, i.e. outer Oslofjord (36B), Sotra-Bømlo area (23B), and Varangerfjord (10B). This was the case for 1997, 1998, and 2000-2004 (cf. Appendix I, results for stations 30B, 53B, and 23B in Figure 16). For all years 1997-2004 the activity of the enzyme at st.53B in Sørfjord was generally lower than st. 23B on the open coast, about 130 km away.

Since 2002, ALA-D was measured only in cod at stations 23B, 30B and 53B. As in previous years, the inibition was largest in the Sørfjord (53B) and the inner Oslofjord (30B) in 2003. (Figure 16, Appendix I). This indicates pollution of metals at 53B and 30B. The median ALA-D activity 1997-2002 and 2004 was lowest at st. 53B (Appendix I, cf. Green *et al.*2004a, b). A slight increase in median ALA-D activity could be seen from 2002 to 2003-2004 indicating less exposure. This was supported by measurements of lead concentrations in cod liver, where the median decreased about a third from 2002 to 2003 (Appendix I). Furthermore, the total discharge of lead into the inner Sørfjorden in 2004 was about 3.2 tonnes, a 37% increase from 2003, but 80% of the 2002 discharge (Ruus & Green 2004, 2005). No significant temporal trends in ALA-D activity were found at any of the three stations.

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.

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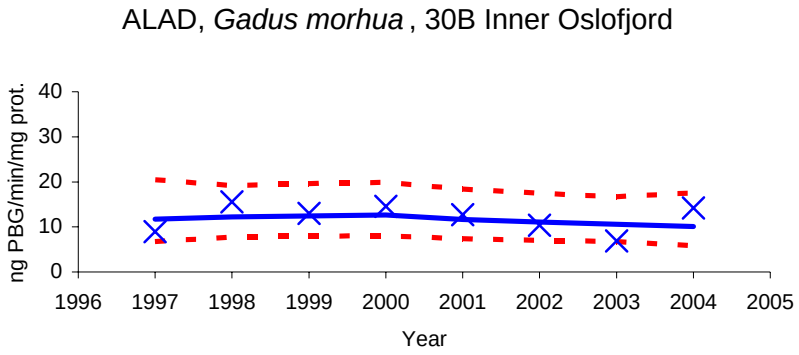

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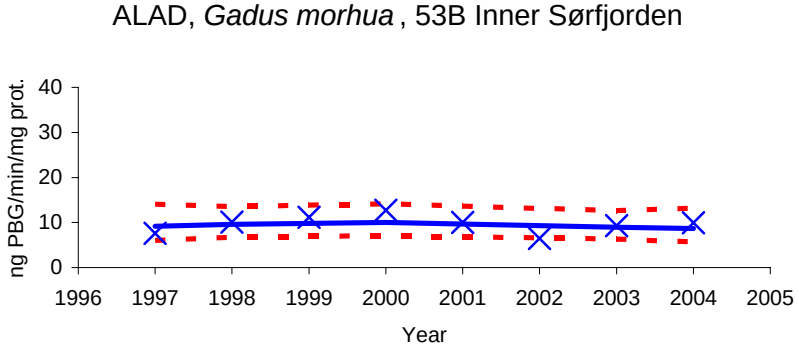

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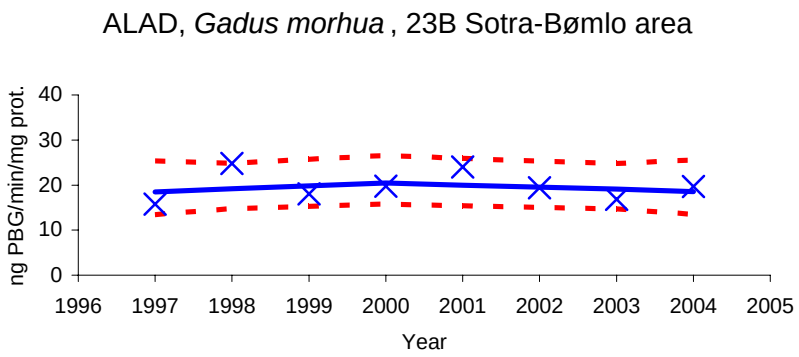

Figure 16. Activity of δ-aminolevulinic acid dehydrase (ALA-D, ng PBG/min/mg protein) in red blood cells from Atlantic cod collected at the indicated stations 2004. (cf. Appendix G and Appendix I, and key in Figure 21).

1.4.3. EROD activity in liver

EROD activity

High activity of hepatic cytochrome P4501A activity (EROD) 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 perturbated by planar PCBs, PCNs, PAHs or dioxins, which were st.30B (inner Oslofjord) and 53B/F (inner Sørfjord). However, median EROD activity at 53B was lower than at reference station 23B (Figure 17, Appendix I). Previous years have also shown that EROD in fish at stations 30B and 53B are not consistently higher than at other stations. No significant temporal trends were found at these three stations.

Extreme concentrations of PCBs were found in four individuals of cod from the inner Sørfjord in 2002 (Green *et al.* 2004a), which should induce a subfamily of cytochrome P450A1 proteins (CYP 1A) and thus increase EROD activity in these individuals. Two of these fish were those with the highest EROD-activities (although not much higher than some individuals with moderate PCB-concentrations). However, the other two extreme-PCB-concentration-fish had moderate hepatic EROD activities. It was concluded from the finding that undetermined confounding factors, which affects EROD activity, were likely present, and that moderate EROD activities do not disprove an environmental problem, at least with respect to the PCB congeners in question (Green *et al.* 2004a). There were no individuals with correspondingly high PCB-concentrations in 2004 (unpublished data).

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 has been found 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 response.

In 2003, a correlation was shown between the EROD activity and the amount of CYP1A protein measured (Green *et al.* 2004b).

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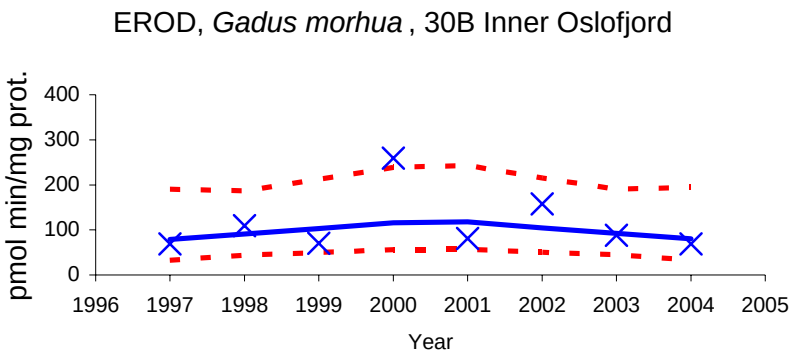

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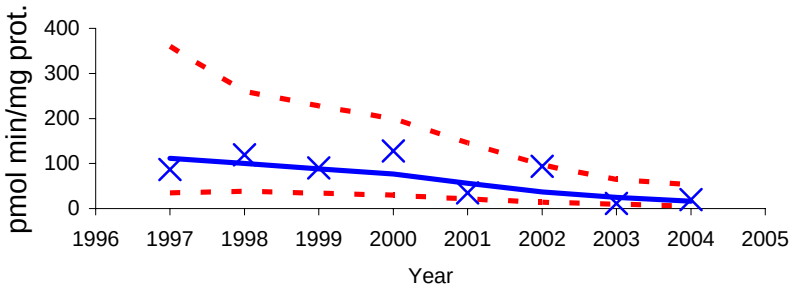

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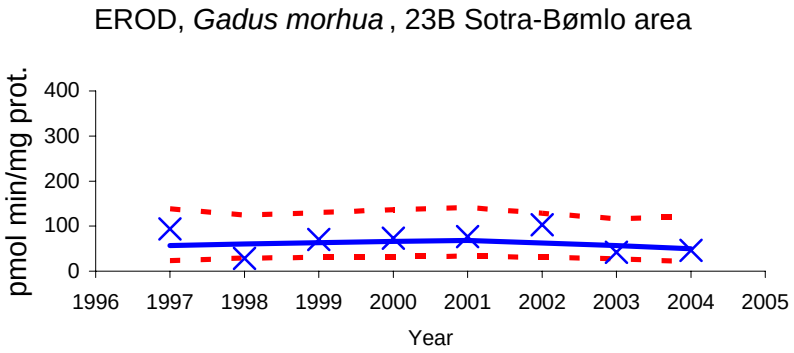

Figure 17. Activity of cytochrome P4501A (EROD, pmol/min/mg protein) in liver from Atlantic cod collected at the indicated stations 2004. (cf. Appendix G and Appendix I, and key in Figure 21).

1.4.4. Concluding remarks

The application of BEM methods within JAMP through the years 1997-2001 has indicated that the location Lista, st. 15B, previously regarded as only diffusely polluted, has an input of PAH which is sufficient to markedly affect fish in the area. For 2002-2003, however, the median concentrations of OH-pyrene in cod at 15B were below those at the inner Oslofjord, st. 30B, and inner Sørfjord, st. 53B. In 2004 the levels at Lista (15B) were again higher than in inner Sørfjorden (53B), but still lower than in the inner Oslofjord (30B). The median concentration of OH-pyrene in cod was lowest at the reference station in the Bømlo-Sotra area, st. 23B. Chronic exposure to PAHs may lead to liver lesions and reproductive disorders in fish, as shown through National Ocean and Atmospheric Administration's (NOAA (USA)) studies in Puget Sound. The highest levels of PAH metabolites observed in the bile of cod from st. 15B, and recently from the inner Oslofjord, are high compared to other studies, but it is not at present possible to infer population effects on cod in the area. It would be relevant to include DNA adduct analyses at some stage to clarify whether the cellular repair system of cod is sufficient to protect against damage from PAH radicals.

Results for the period 1997-2004 clearly 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 (30B) and cod from the inner Sørfjord (53B).

Median EROD activity at st. 53B was lower than at the less contaminated 23B station. Previous years have also shown that EROD in fish at stations 30B and 53B are not consistently higher than at other, presumed cleaner stations.

1.5. Effects and concentrations of organotin

Effects from organotin in dogwhelk (*Nucella lapillus*) were investigated at twenty stations. Organotin concentrations in dogwhelk and blue mussel (*Mytilus edulis*) were quantified at twenty and twenty-eight stations respectively. The stations are located along the coast of Norway and samples were collected September-October 2004 (Appendix E and maps in Appendix G).

TBT-induced development of male sex-characters in females, known as imposex (VDSI and RPSI), 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

Twenty stations were investigated in 2004; most of these were on the west coast. Effects from organotin were observed at all stations. VDSI varied from 0.29 to 4.47. The three lowest VDSI (<2) were found at Brashavn (st. 11G), in the Varangerfjord, northern Norway, Landfast (st.94G) on the east side of the island of Vega and at Klakholm (st.97G) northwest of Bodø (Appendix J). The VDSI at the remaining stations were above 3.2; the highest at Grinden (st.27G) between Stadt and Ulsteinvik. A significant *upward* trend was found at the station in Lofoten (st. 98G) (Appendix I, Figure 18).

Concentrations of organotin from the nineteen stations measured were relatively low (<0.040 mg/kg w.w., <0.26 mg/kg d.w.). As in 2003 the highest organotin levels were found at Haugesund (Appendix I, Appendix J, Figure 19). Concentrations decreased compared to 2003, however, no statistically significant temporal trends for the period 1997-2004 were found.

The results for 1997-2004 indicates elevated concentrations and imposex-indexes not only near harbours (e.g., Haugesund), but also in presumably less polluted areas (e.g. Grinden) (Figure 19, Appendix I).

A comparison of imposex was made with samples from nine stations collected both in 1992 and 2004. The stations included four from the Stadtland area (st. 25G, 26G, 27G, 28G), two from Orkdalsfjord area (82G, 87G) and three along the coast from the island of Vega and north to Lofoten (94G, 95G, 97G). The 1992 samples were kept frozen until their VDSI was assessed together with the 2004 samples. The effect of freezing should not effect the index (Minchin & Davies 1999). A paired-t-test revealed no difference between the two years ($p>0.475$).

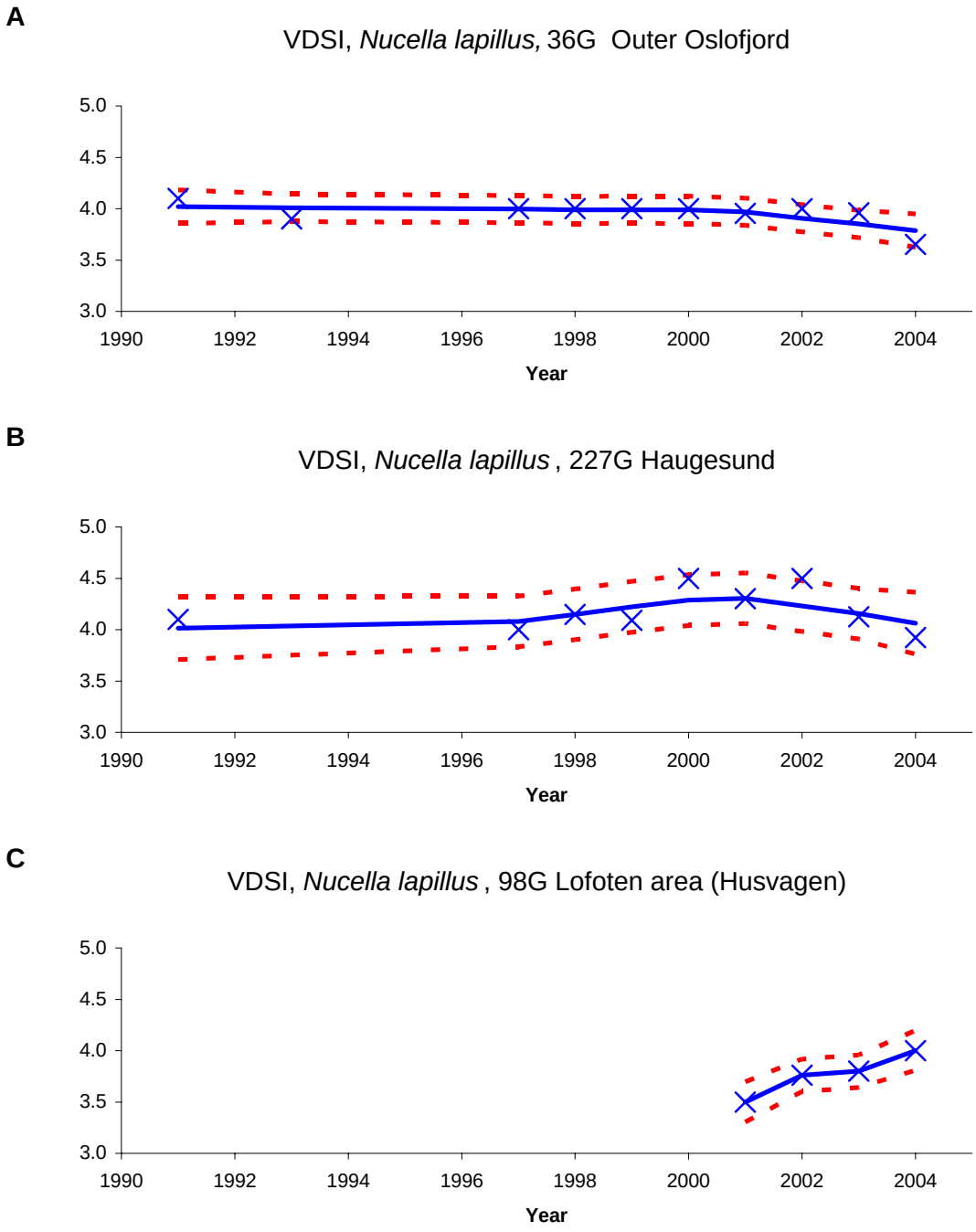

Figure 18. Imposex (VDSI) in dogwhelk (*Nucella lapillus*) at 2 stations in southern Norway; Færder (36G) and Haugesund (227G) and one at Lofoten (98G). Data from 1991 (Harding *et al*. 1992) and 1993 (Walday *et al*. 1997). (cf. Appendix G and Appendix I, and key in Figure 21).

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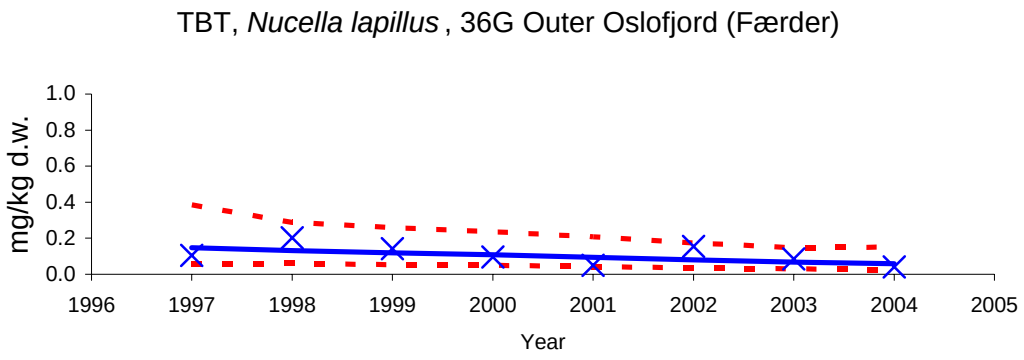

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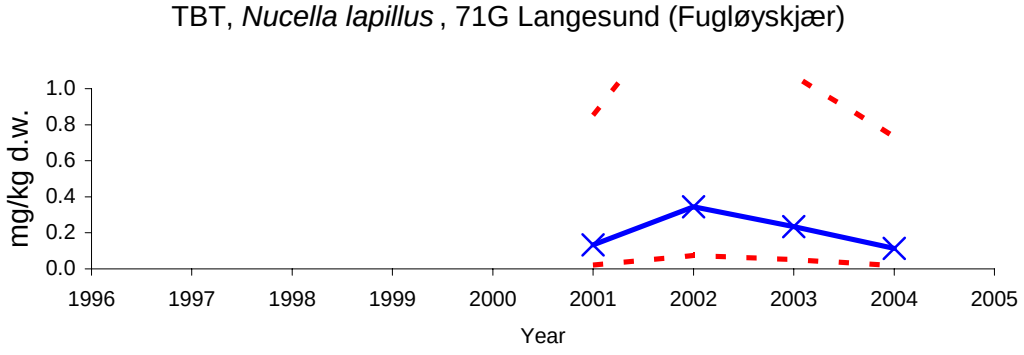

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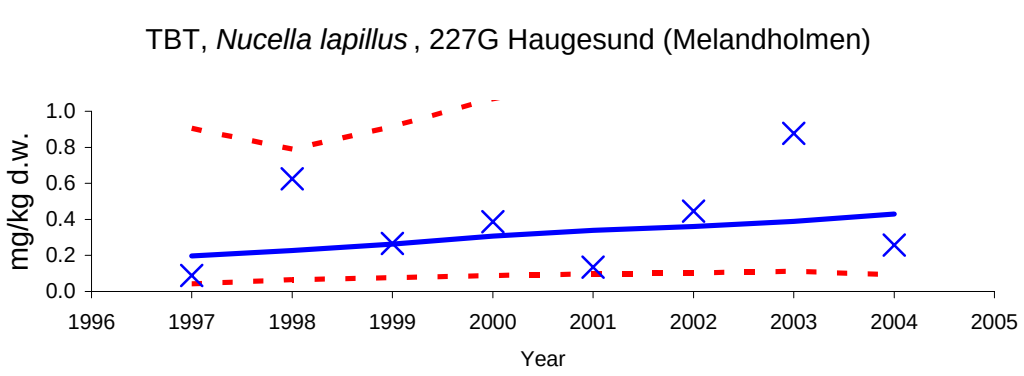

Figure 19. Median concentration of TBT (on a formulation basis) in dogwhelks (*Nucella lapillus*) from outer Oslofjord (st.36G), Langesundsfjord (west of Oslofjord) (st.71G) and Haugesund (St.227G), mg/kg (mg TBT/kg) dry weight. NB: (cf. Appendix G and Appendix I, and key in Figure 21). Note: for some years the upper confidence interval line is off-scale in Figures B and C.

1.5.2. Mussels

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), and another station nearby was markedly contaminanted (Cl.III, Figure 20). Moderately (Cl.II) or markedly polluted (Cl.III) mussels were not only found in other harbour areas (e.g. the Frierfjord (712, 713) and Haugesund (227A)) but also in areas in western Norway that are presumably remote from point sources (e.g. 22A, 27A, 93A). Low concentrations were found at the northern stations (11X) and at Farsund (15A) as well as some stations in western Norway. Levels (median) ranged between 0.006 and 2.8 mg/kg d.w.. Compared to 2003, most concentrations were lower in 2004, however, significant temporal trends were not detected at any station for the 1997-2004 period investigated.

1.5.3. Concluding remark

The presence of organotin (as TBT) in Norwegian waters still exceeded acceptable levels in 2004, not only in harbour areas but also some stations presumably remote from known point sources. Concentrations of organotin in mussels and dogwhelk were elevated, and biological effects from TBT were found in dogwhelk from all of the investigated areas. No significant trends were found. Furthermore, there was no significant difference between the VDSI in 1992 compared to 2004 at nine stations on the westcoast. It is a cause for concern that the ban on the use of TBT in antifouling on boats <25 m of length, in effect since 1.January 2003, has not lead to a clear improvement in the investigated areas.

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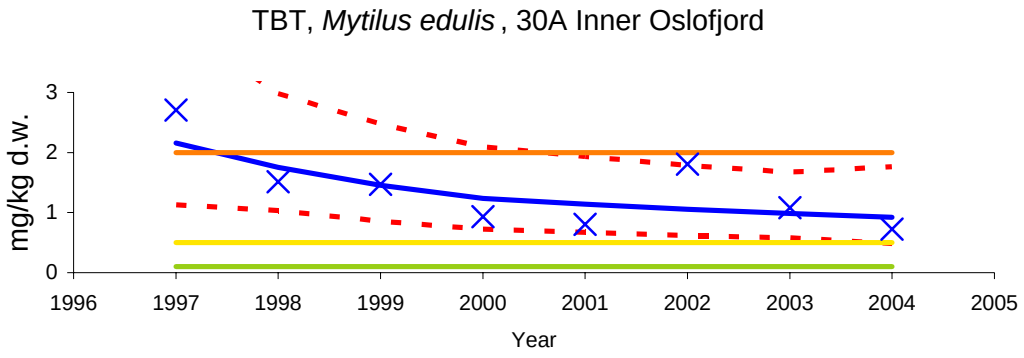

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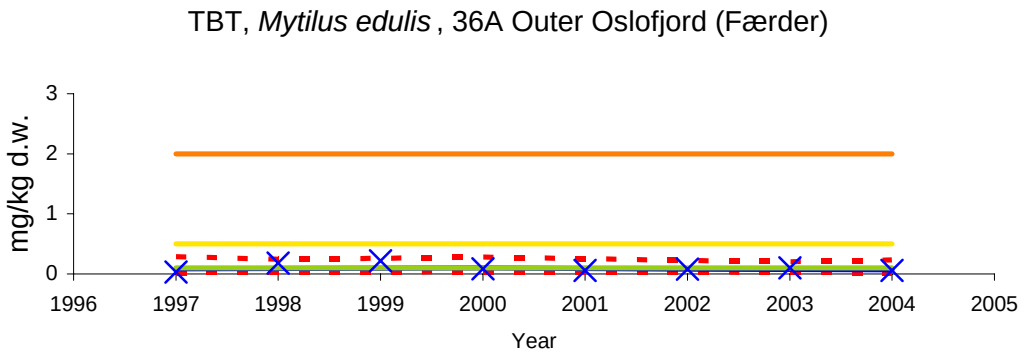

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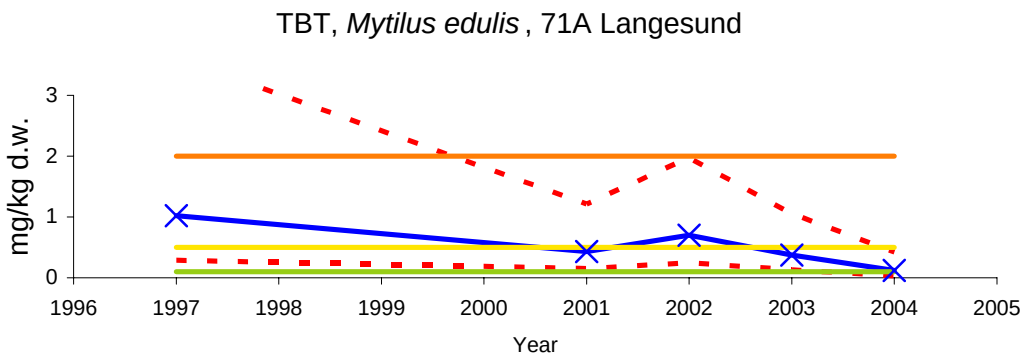

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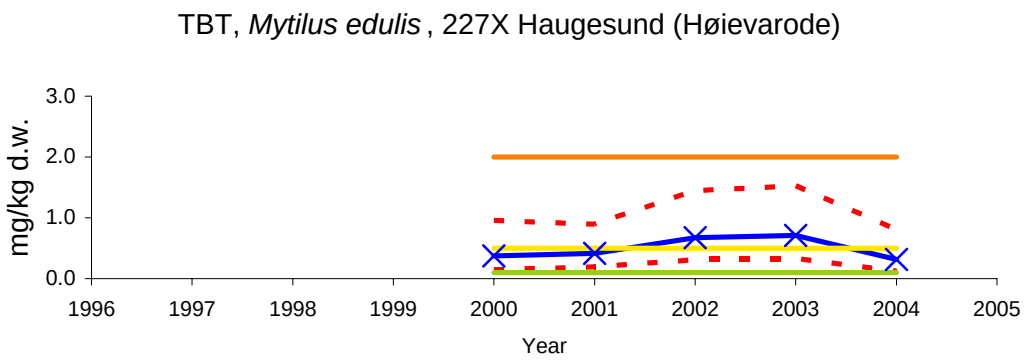

Figure 20. Median concentration of TBT (on a formulation basis) in blue mussel (*Mytilus edulis*) from inner (st.30A) and outer (st.36A) Oslofjord, Langesundsfjord (west of Oslofjord) (st.71A) and Haugesund (St.227X), mg/kg (mg TBT/kg) dry weight. (cf. Appendix G and Appendix I, and key in Figure 21). 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. Overall conclusions

In regards to JMP/JAMP Purpose A (health assessment), 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 Norwegian fjord areas (Table 3). Furthermore, *Mattilsynet* has issued general advice to avoid consumption of seafood taken in or in close proximity to harbours (cf. Økland, 2005).

In regards to JMP/JAMP Purpose C (spatial distribution assessment), the concentrations found in 2004 are indicated in the bar graphs shown in Appendix J and Appendix K. 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 JMP/JAMP Purpose D (temporal trend assessment), and considering where statistically significant linear trends have been found, the following cases should be noted:

- ΣPCB-7 in mussels from the inner Oslofjord has decreased since 1988;
- Mercury in cod fillet from the inner Oslofjord has increased since 1984;
- Cadmium in cod liver and mussels (1 st.) from the inner Oslofjord has increased since 1984;
- HCB in mussel from Langesundsfjorden has decreased since 1983;
- Mercury in flounder fillet from the inner Sørfjorden has increased since 1988;
- Cadmium in mussels (3 st.) in the Hardangerfjord/Sørfjorden has decreased since 1987;
- Lead in mussels (2 st.) in the Hardangerfjorden has decreased since 1990 (1987);

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 2004 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).

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 (based on 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/ evaluation	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	2002	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	2000	fish, shellfish	Consumption and sale
Farsund area (42.0)	PCB PAH	2000	fish liver, mussels	Consumption and sale
Fedafjord (11.2)	PAH	1995	mussels	Consumption and sale
Flekkefjord (4.2)	PCB	2000	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 (??)	PCB, PAH	2005	fish liver [3], shellfish	Consumption and sale
Saudafjord (24.1)	PAH	1992	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
Årdalsfjord (30.4)	PAH	2002	mussels	Consumption and sale
Ålesund, Åsefjorden (16.7)	HBCDD [4]	2005	fish, shellfish	Consumption
Sunndalsfjord (100.1)	PAH	2005	fish liver, mussels	Consumption and sale
Hommelvik (2.6)	PAH	1985	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	2000	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

The JAMP issues to which these investigations are relevant are shown in Table 4.

Table 4. JAMP issues relating to the Norwegian JAMP (cf., SIME 2002).

Subject	JAMP issue	Question	Recent Norwegian contribution
Hg, Cd and Pb	JAMP issue 1.2.	What are the concentrations and fluxes in sediments and biota?	1996-1997: Levels in sediment (cf., Green *et al.* 2000) 2003: Levels and trends in biota (annual investigations since 1981, Chapter 1.3) 2003: INDEX for blue mussel from selected stations (annual investigations since 1995, cf. Chapter 1.3.8)
TBT	JAMP issue 1.3.	To what extent do biological effects occur in the vicinity of major shipping routes offshore installations, marinas and shipyards	2003: Levels and trends in mussels and snails (annual investigations since 1997, cf. Chapter 1.5)
PCBs	JAMP issue 1.7.	Do high concentrations pose a risk to the marine ecosystem	[as for JAMP issue 1.2]
PCBs	JAMP issue 1.8.	Do high concentrations of non-ortho and mono-ortho CBs in seafood pose a risk to human health?	1995: INDEX for blue mussel from selected stations (cf. Green 1997) 1996: Levels in cod (cf. Green *et al.* 2000)
PAHs	JAMP issue 1.10.	What are the concentrations in the maritime [1)] area?	1992: Levels in shellfish (Green *et al.* 1995) 1992-1993: Levels in fish and mussels for selected stations (Knutzen & Green 1995) 1996-1997: Levels in sediment (cf., Green *et al.* 2000) 2003: INDEX for blue mussel from selected stations (annual investigations since 1995, Chapter 1.3.8)
PAHs	JAMP issue 1.11.	Do PAHs affect fish and shellfish?	1998: Biological effects methods in cod (cf. Chapter 1.4)
Other synthetic organic compounds	JAMP issue 1.12.	How widespread are synthetic organic compounds within the maritime [1)] area?	2003: Levels and trends in biota (annual investigations since 1983 of selected organochlorines, cf. Chapter 1.3) 1996: Introductory investigation of organochlorines in cod livers (cf. Green *et al.* 2000)
Chlorinated dioxins and dibenzofurans	JAMP issue 1.15. [2)]	What concentrations occur and have the policy goals (for the relevant parts of the maritime [1)] area) been met?	2003: INDEX for blue mussel from selected stations (cf. Appendix L) 1996: Introductory investigation of organochlorines in cod livers (cf. Green *et al.* 2000)
Biological effects of pollutants	JAMP issue 1.17.	Where do pollutants cause deleterious biological effects?	2003: Southern Coast, planar PCBs, metals, PAHs in cod (annual investigations since 1997, cf. Chapter 1.4)
Chemicals used	JAMP issue 5.3.	In which areas do pesticides and antibiotics affect marine biota?	2003: Levels and trends in biota (cf. Chapter 1.3)
Ecosystem health	JAMP issue 6.1.[2)]	How can ecosystem health be assessed in order to determine the extent of human impact?	Results for the other issues are also relevant here

[1]) Not defined in original text
[2]) See SIME 1997

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) 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

This report focuses 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, “slightly 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 mussels (in the same order 0.2; 2; 3; 200 and 10 mg/kg d.w.). However, for chromium and nickel in mussels 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 mussels 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 mussels, 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. Extracts of the Norwegian Pollution Control Authority revised environmental classification system of contaminants in blue mussel and fish (from Molvær *et al.* 1997 and revised (shaded) Class I concentrations as suggested in this report).

Contaminant			**Classification (upper limit for Classes I-IV)** *Degree of pollution*				
			I ***Slight***	**II** ***Moderate***	**III** ***Marked***	**IV** ***Severe***	**V** ***Extreme***
BLUE MUSSEL							
Lead	mg/kg	d.w.	3	15	40	100	>100
Cadmium	mg/kg	d.w.	2	5	20	40	>40
Copper	mg/kg	d.w.	10	30	100	200	>200
Mercury	mg/kg	d.w.	0.2	0.5	1.5	4	>4
Zinc	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
$TE_{PCDF/D}$ [2)]	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 6. Extracts of the Norwegian Pollution Control Authority revised environmental classification system of contaminants in sediment (from Molvær *et al.* 1997).

Contaminant			Classification (upper limit for Classes I-IV)				
			Degree of pollution				
			I	II	III	IV	V
			Slight	*Moderate*	*Marked*	*Severe*	*Extreme*
SEDIMENT							
Lead	mg/kg	d.w.	30	120	600	1500	>1500
Cadmium	mg/kg	d.w.	0.25	1	5	10	>10
Copper	mg/kg	d.w.	35	150	700	1500	>1500
Mercury	mg/kg	d.w.	0.15	0.6	3	5	>5
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	w.w.	0.5	2.5	10	50	>50
HCB	µg/kg	w.w.	0.5	2.5	10	50	>50
∑PAH	µg/kg	w.w.	300	2000	6000	20000	>20000
B[*a*]P	µg/kg	w.w.	10	50	200	500	>500
$TE_{PCDF/D}$ [2)]	µg/t [3)]	w.w.	0.01	0.03	0.1	0.5	>0.5

[1]) Tributyltin on a formula basis

[2]) TCDDN (Appendix B)

[3]) 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). The respective "high background" limits are from Knutzen & Skei (1990) with mostly minor adjustments (Knutzen & Green 1995; 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)]	0.1		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 mussels 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.

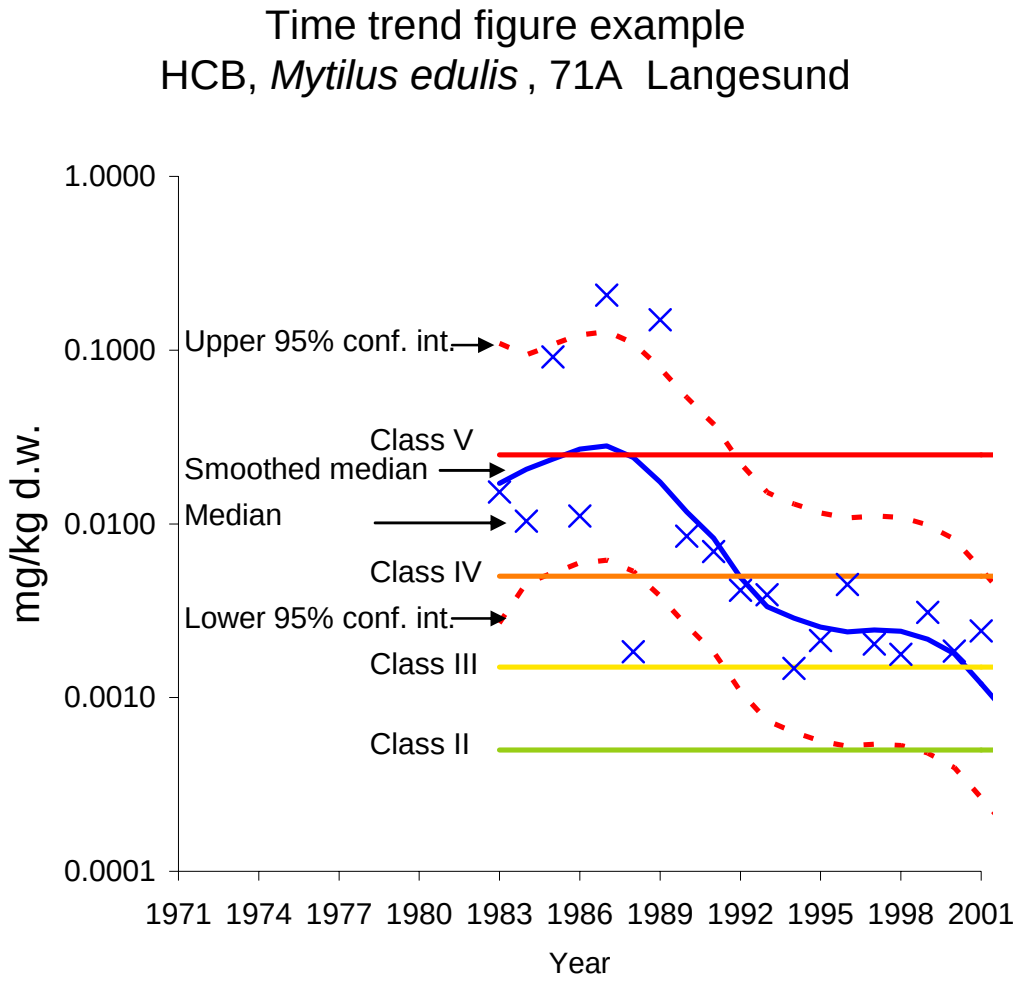

Figure 21. Example presentation and variation in contaminant concentration with time, indicating median concentrations, running mean of median values (Loess smoother), 95% confidence intervals. The horizontal lines indicate the lower boundaries to SFT classes of pollution: Class II (moderate=upper boundary to Class I (slight)), 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, 53, 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.

2.1.4. The effect of depuration and freezing on mussels

Based on samples collected in the Sørfjord and Hardangerfjord, the JAMP-method of pre-treatment of mussels (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 mussels 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 mussels. 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 42. These exercises have included nearly all the contaminants analysed for JAMP. Quality assurance programme for NIVA is similar to the 2003 programme (cf. Green *et al.* 2005). In addition, NIVA was accredited in 1993 and are now 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.

2.3. Description of the Programme

The sampling for 2004 involved blue mussel at 58 stations, dogwhelk at 20, 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 mussels, 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 2004 except witch from st.67F (10 individuals), flounder st.21F (5 individuals). Plaice st.98F (25 individuals) and 10F (20 individuals).

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

Analytical methods have been described previously (Green *et al*. (2001b). An overview of the samples collected from 1981 to 2003 is given in Appendix E. An overview of analyses applied from 1981 to 2003 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

Station positions 1981-2004
(cf. Appendix H and Appendix L)

Appendix G (cont.) Map of stations

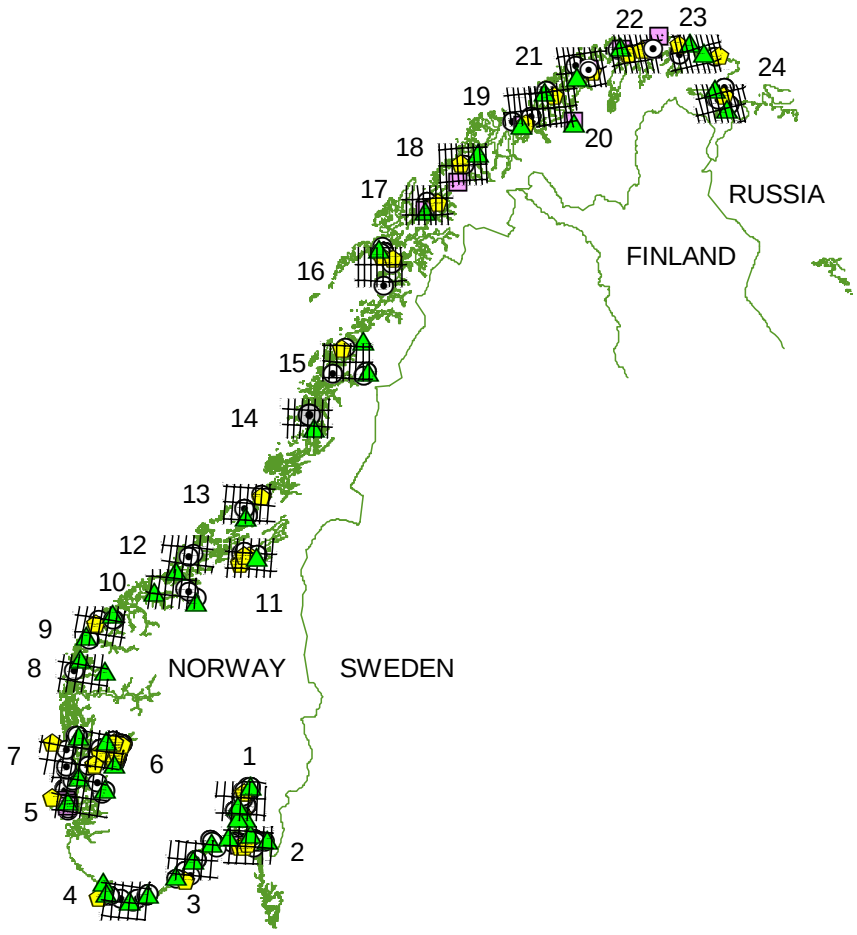
NOTES

For a few stations the geolocation has varied somewhat in order to collect sufficient material (e.g., st. 36B and 98A) or investigate local geographical variations (e.g., in the inner Oslofjord and Sørfjord). Hence, the same station name may appear more than once on a map.

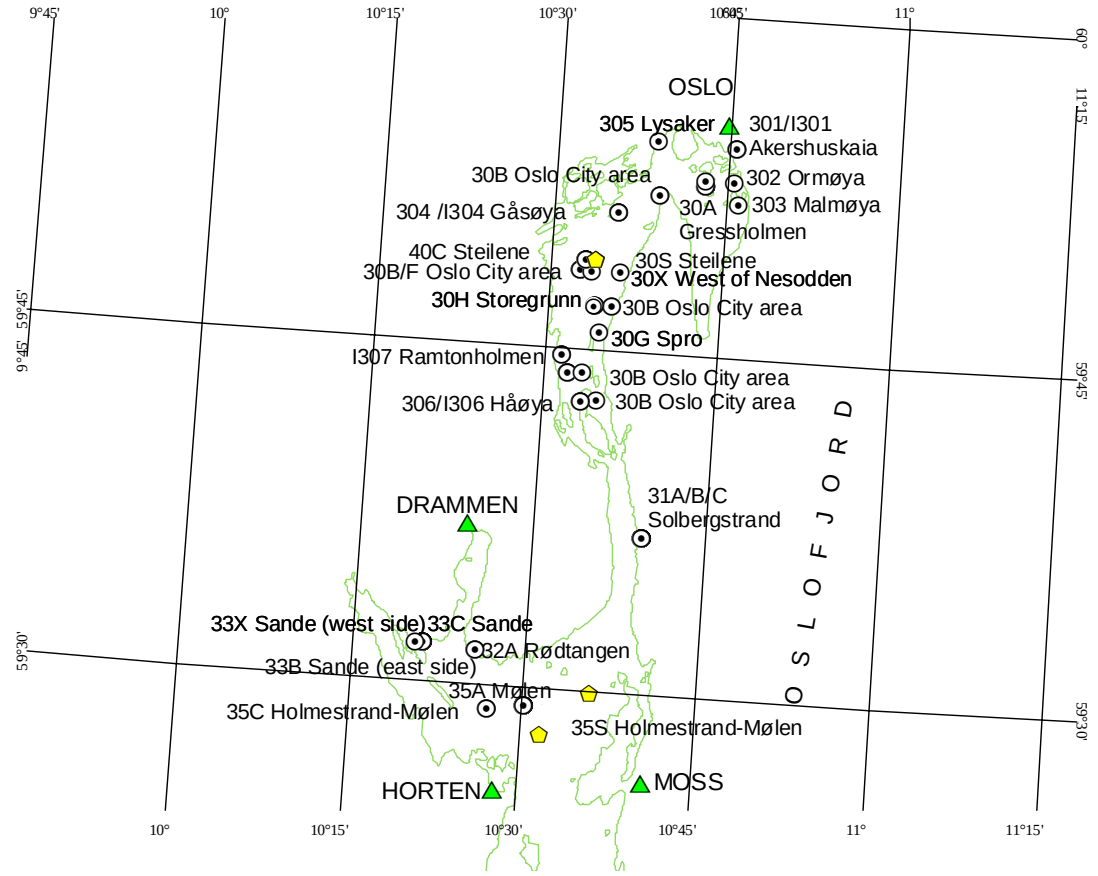
The letter A following the station identification number indicates that blue mussel was sampled. The letter B indicates sampling for cod and the letter F indicates sampling for flatfish. This system for fish is not consistent for some older stations (30, 33, 52 and 67) where only the letter B is used indicating that either cod or flatfish or both were sampled. An encircled dot indicates a mussel, shrimp or fish station. The letter G indicates sampling for dogwhelks and S indicates sampling for sediment. An encircled dot indicates the position for sampling mussels, shrimp or fish. A square and pentagon symbol indicates the position for sampling dogwhelks or sediment, respectively. A triangle indicates the position of a town or city.

The letter "I" preceding the station identification number indicates an INDEX station for determining a "pollution" index. The letter R indicates a station for evaluating a "reference" index. Only blue mussel is used for these indices. The indices are based on a selection of JAMP and INDEX stations (cf. Green *et al.* 2001).

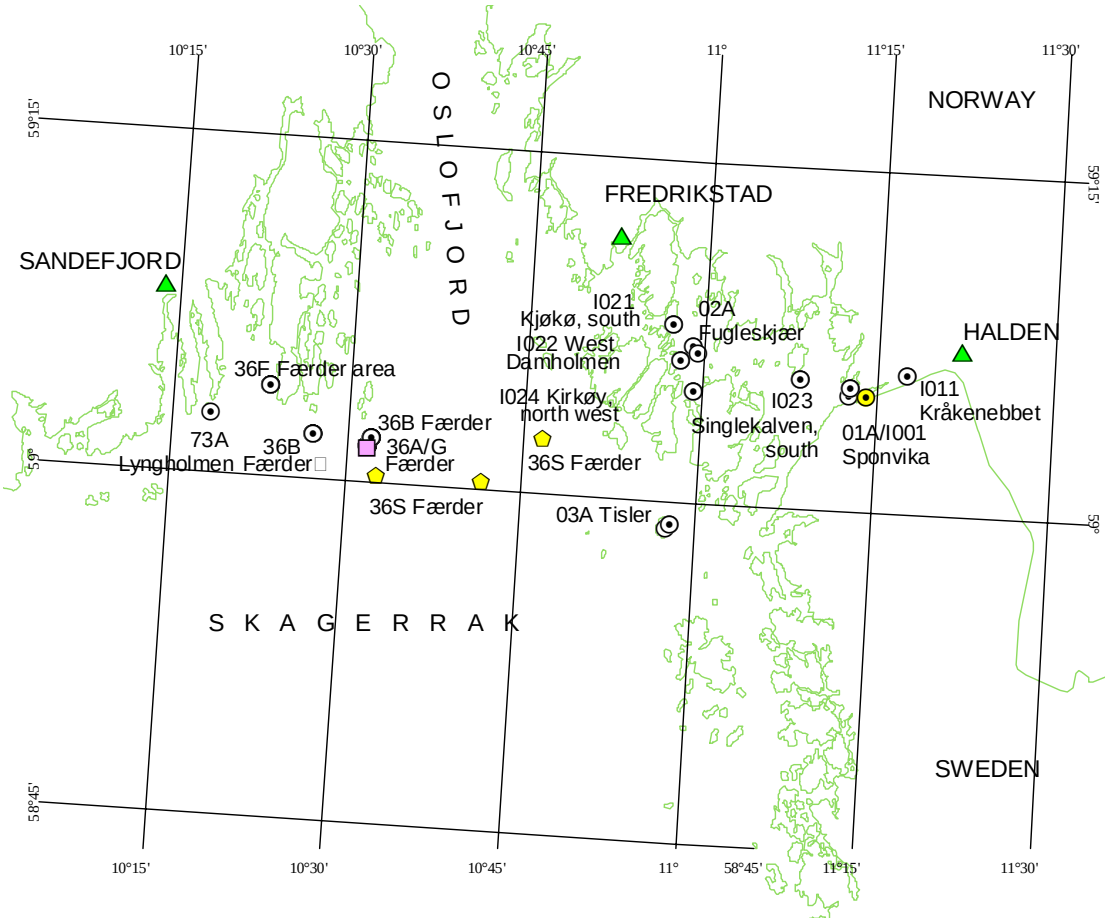
The maps are generated using ArcView GIS version 3.3.



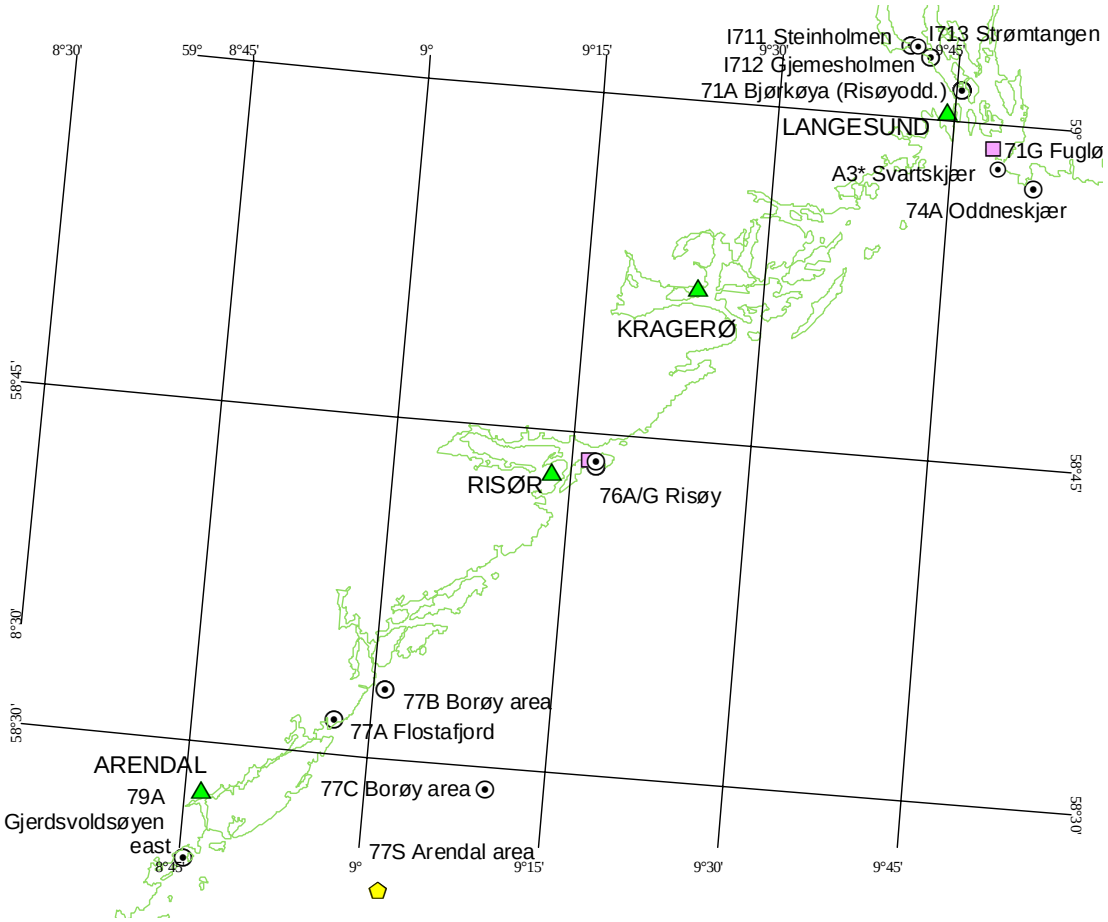
JAMP stations Norway. Numbers indicate map reference


OSLO
305 Lysaker
301/I301
Akershuskaia
30B Oslo City area
302 Ormøya
304 /I304 Gåsøya
30A
303 Malmøya
Gressholmen
40C Steilene
30S Steilene
30B/F Oslo City area
30X West of Nesodden
30H Storegrunn
30B Oslo City area
30G Spro
I307 Ramtonholmen
30B Oslo City area
306/I306 Håøya
30B Oslo City area
OSLOFJORD
DRAMMEN
31A/B/C
Solbergstrand
33X Sande (west side)
33C Sande
32A Rødtangen
33B Sande (east side)
35A Mølen
35C Holmestrand-Mølen
35S Holmestrand-Mølen
HORTEN
MOSS
9°45'
10°
10°15'
10°30'
10°45'
11°
11°15'
60°
59°45'
59°30'

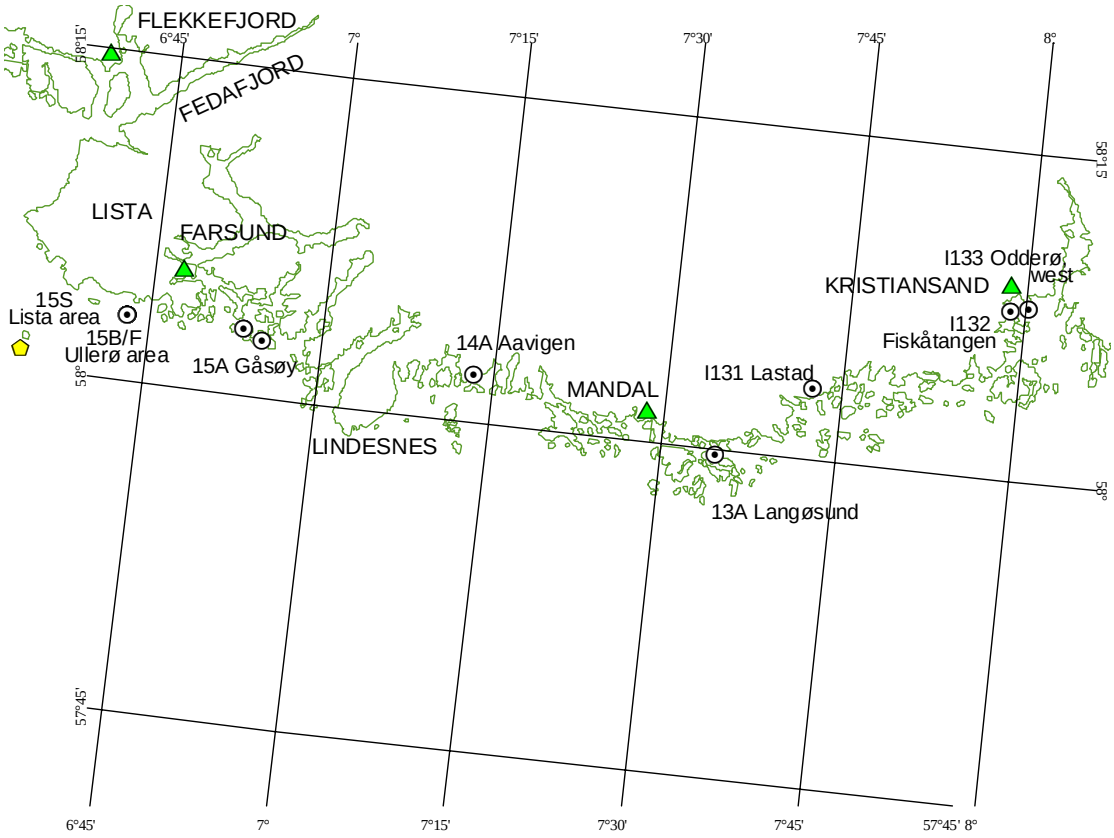
MAP 1


NORWAY
OSLOFJORD
FREDRIKSTAD
SANDEFJORD
I021
Kjøkø, south
02A
Fugleskjær
I022 West
Damholmen
HALDEN
36F Færder area
I024 Kirkøy,
north west
I023
Singlekalven,
south
I011
Kråkenebbet
01A/I001
Sponvika
73A
36B
Lyngholmen Færder
36B Færder
36A/G
Færder
36S Færder
36S Færder
03A Tisler
SKAGERRAK
SWEDEN
10°15'
10°30'
10°45'
11°
11°15'
11°30'
59°15'
59°
58°45'

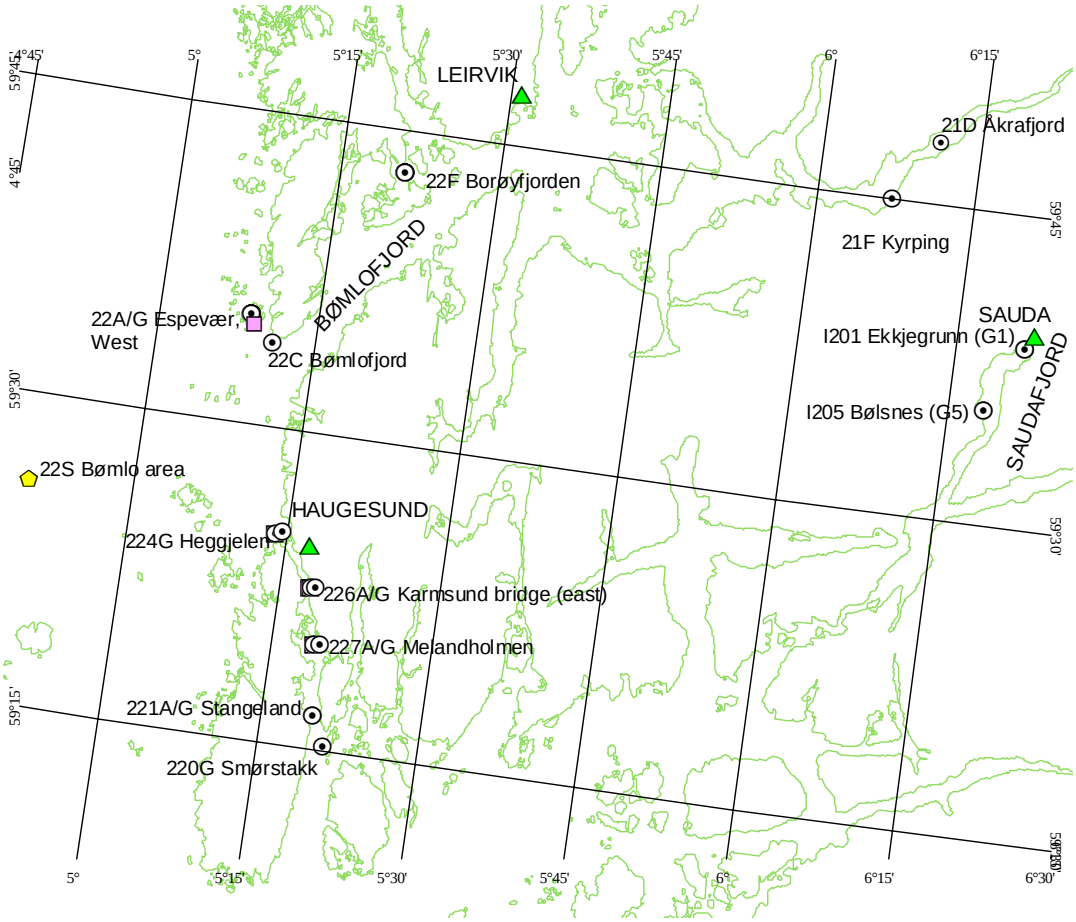
MAP 2


I711 Steinholmen
I713 Strømtangen
I712 Gjemesholmen
71A Bjørkøya (Risøyodd.)
LANGESUND
71G Fuglø
A3* Svartskjær
74A Oddneskjær
KRAGERØ
RISØR
76A/G Risøy
77B Borøy area
77A Flostafjord
ARENDAL
79A
Gjerdsvoldsøyen
east
77C Borøy area
77S Arendal area
8°30'
59°
8°45'
9°
9°15'
9°30'
9°45'
58°45'
58°30'

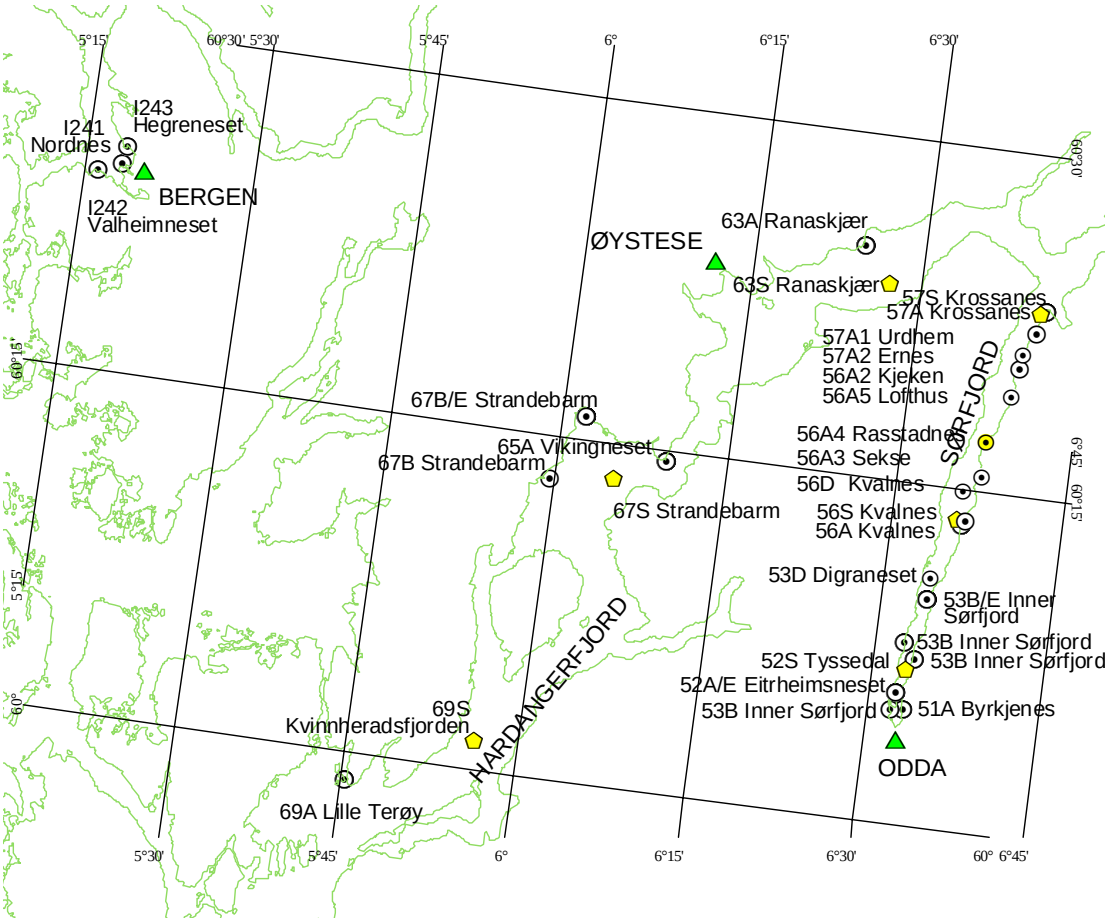
MAP 3


FLEKKEFJORD
FEDAFJORD
LISTA
FARSUND
15S
Lista area
15B/F
Ullerø area
15A Gåsøy
14A Aavigen
LINDESNES
MANDAL
I131 Lastad
13A Langøsund
I133 Odderø, west
KRISTIANSAND
I132
Fiskåtangen
6°45'
7°
7°15'
7°30'
7°45'
8°
58°15'
58°
57°45'

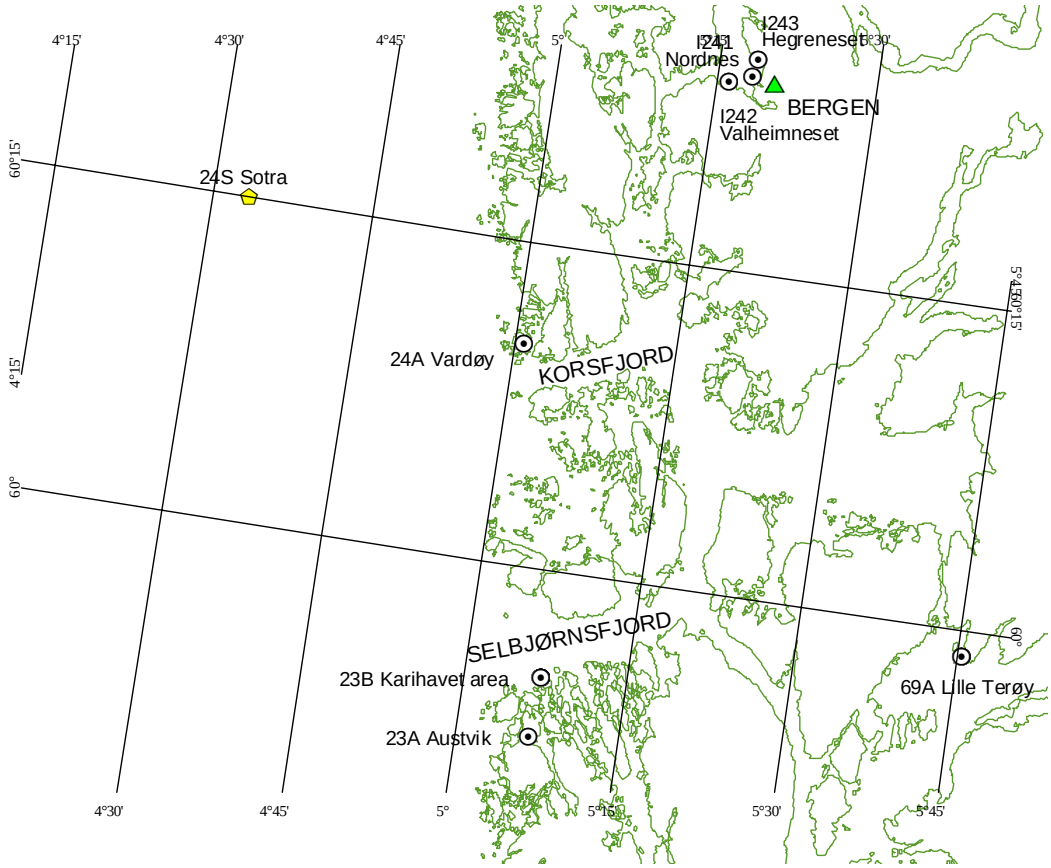
MAP 4


LEIRVIK
21D Åkrafjord
22F Borøyfjorden
21F Kyrping
BØMLOFJORD
22A/G Espevær, West
22C Bømlofjord
SAUDA
I201 Ekkjegrunn (G1)
SAUDAFJORD
I205 Bølsnes (G5)
22S Bømlo area
HAUGESUND
224G Heggjelen
226A/G Karmsund bridge (east)
227A/G Melandholmen
221A/G Stangeland
220G Smørstakk
5°
5°15'
5°30'
5°45'
6°
6°15'
6°30'
59°45'
59°30'
59°15'

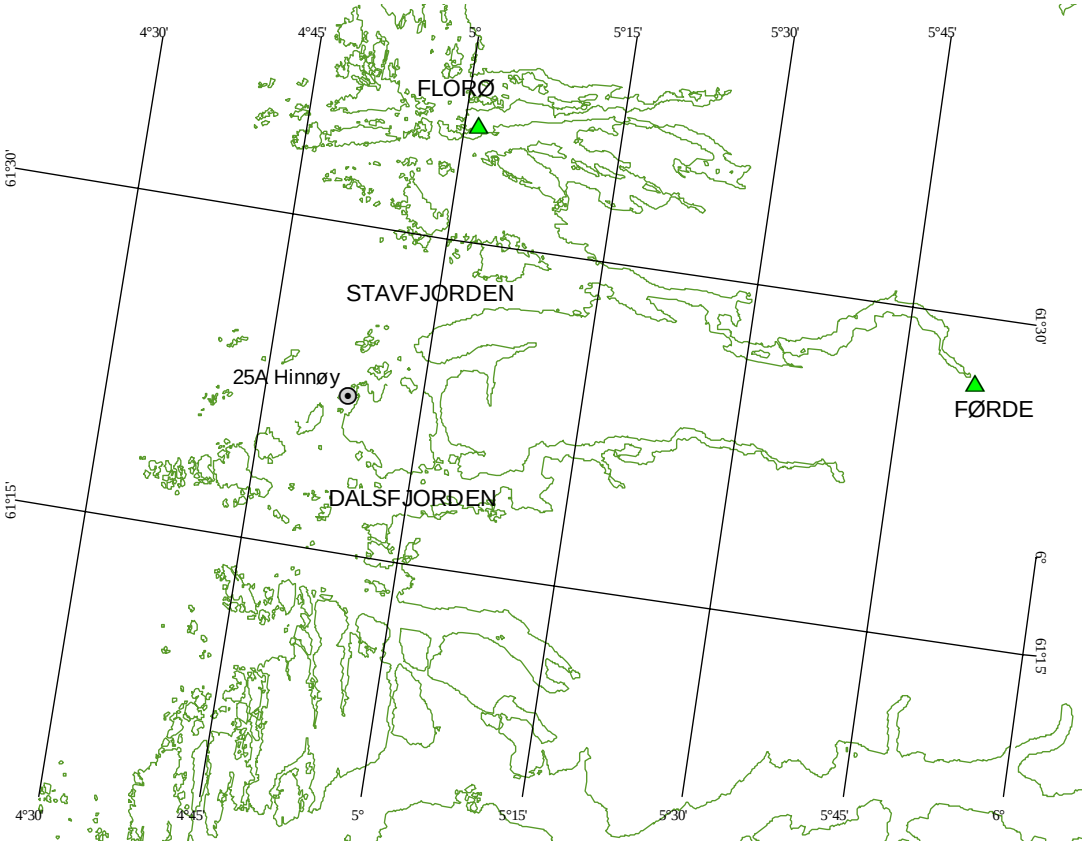
MAP 5


I243 Hegreneset
I241 Nordnes
BERGEN
I242 Valheimneset
ØYSTESE
63A Ranaskjær
63S Ranaskjær
57S Krossanes
57A Krossanes
57A1 Urdheim
57A2 Ernes
56A2 Kjeken
56A5 Lofthus
SØRFJORD
67B/E Strandebarm
56A4 Rasstadneset
56A3 Sekse
65A Vikingneset
67B Strandebarm
56D Kvalnes
67S Strandebarm
56S Kvalnes
56A Kvalnes
53D Digraneset
53B/E Inner Sørfjord
53B Inner Sørfjord
52S Tyssedal
53B Inner Sørfjord
52A/E Eitrheimsneset
53B Inner Sørfjord
51A Byrkjenes
HARDANGERFJORD
69S Kvinnheradsfjorden
ODDA
69A Lille Terøy
5°15'
5°30'
5°45'
6°
6°15'
6°30'
6°45'
60°30'
60°15'
60°

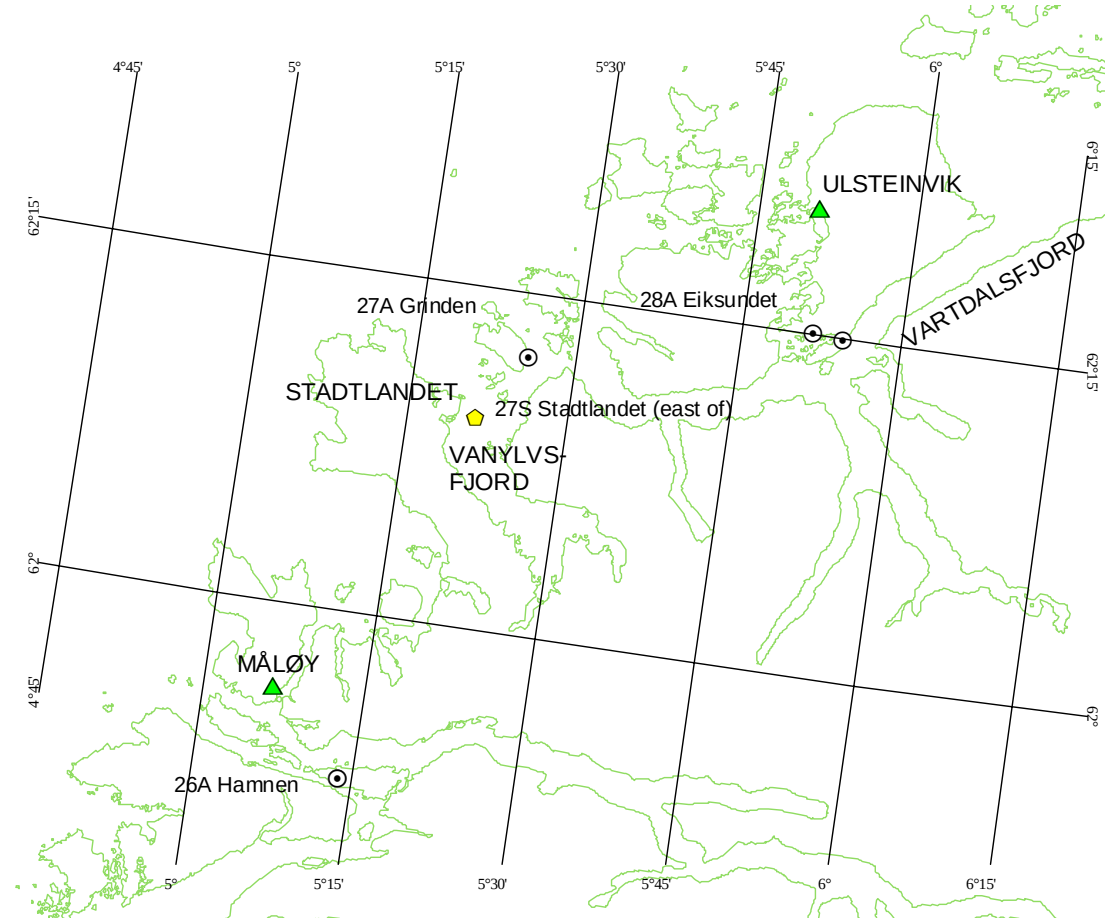
MAP 6


4°15'
4°30'
4°45'
5°
5°30'
I243
Hegreneset
I241
Nordnes
BERGEN
I242
Valheimneset
60°15'
24S Sotra
24A Vardøy
KORSFJORD
60°
SELBJØRNSFJORD
23B Karihavet area
23A Austvik
69A Lille Terøy
4°30'
4°45'
5°
5°15'
5°30'
5°45'

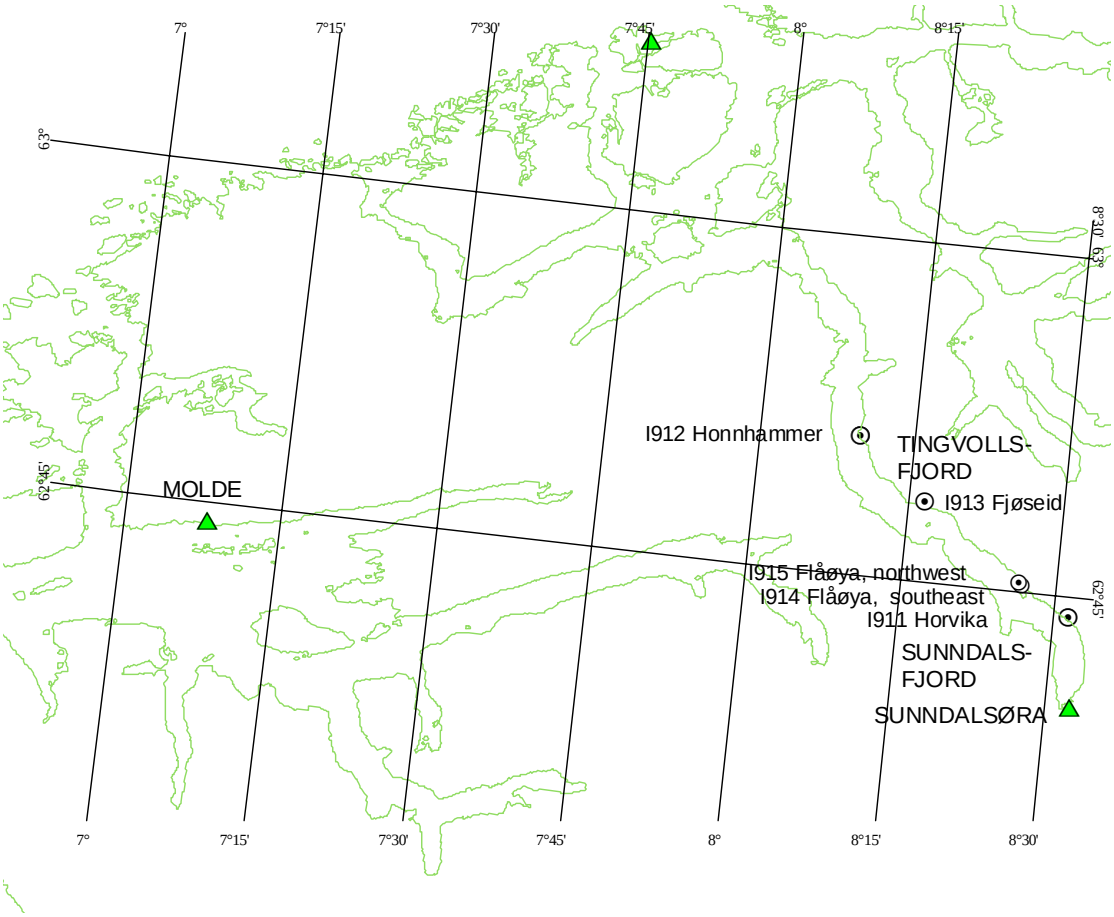
MAP 7


4°30'
4°45'
5°
5°15'
5°30'
5°45'
FLORØ
61°30'
STAVFJORDEN
25A Hinnøy
FØRDE
61°15'
DALSFJORDEN
6°
4°30'
4°45'
5°
5°15'
5°30'
5°45'
6°

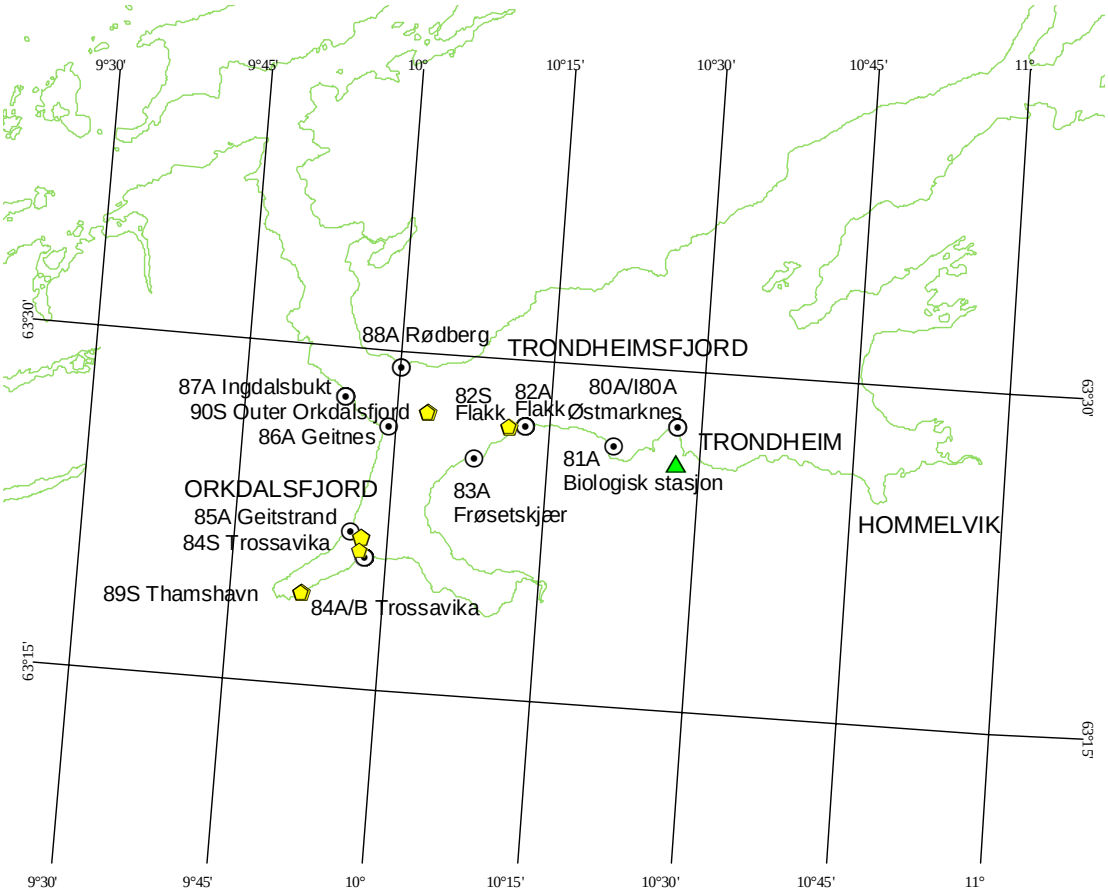
MAP 8


4°45'
5°
5°15'
5°30'
5°45'
6°
6°15'
62°15'
62°
ULSTEINVIK
VARTDALSFJORD
28A Eiksundet
27A Grinden
STADTLANDET
27S Stadtlandet (east of)
VANYLVS-
FJORD
MÅLØY
26A Hamnen

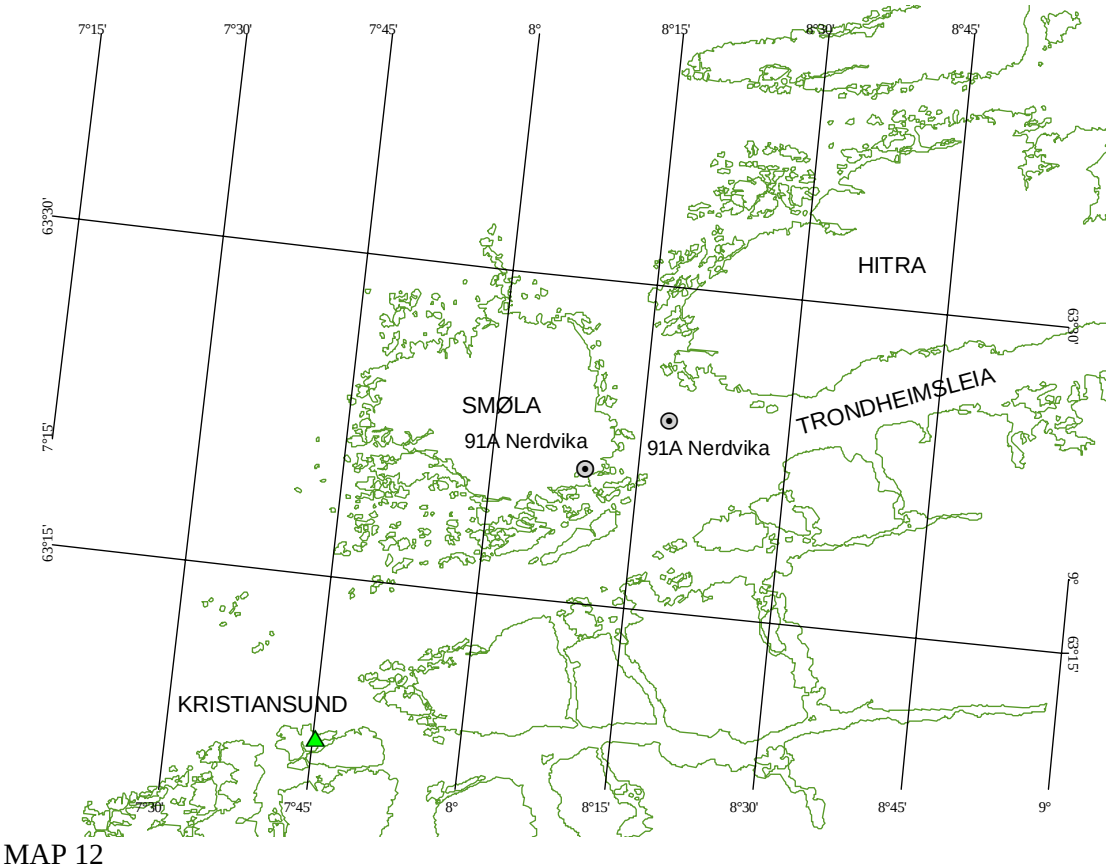
MAP 9


7°
7°15'
7°30'
7°45'
8°
8°15'
8°30'
63°
62°45'
62°30'
I912 Honnhammer
TINGVOLLS-
FJORD
I913 Fjøseid
MOLDE
I915 Flåøya, northwest
I914 Flåøya, southeast
I911 Horvika
SUNNDALS-
FJORD
SUNNDALSØRA

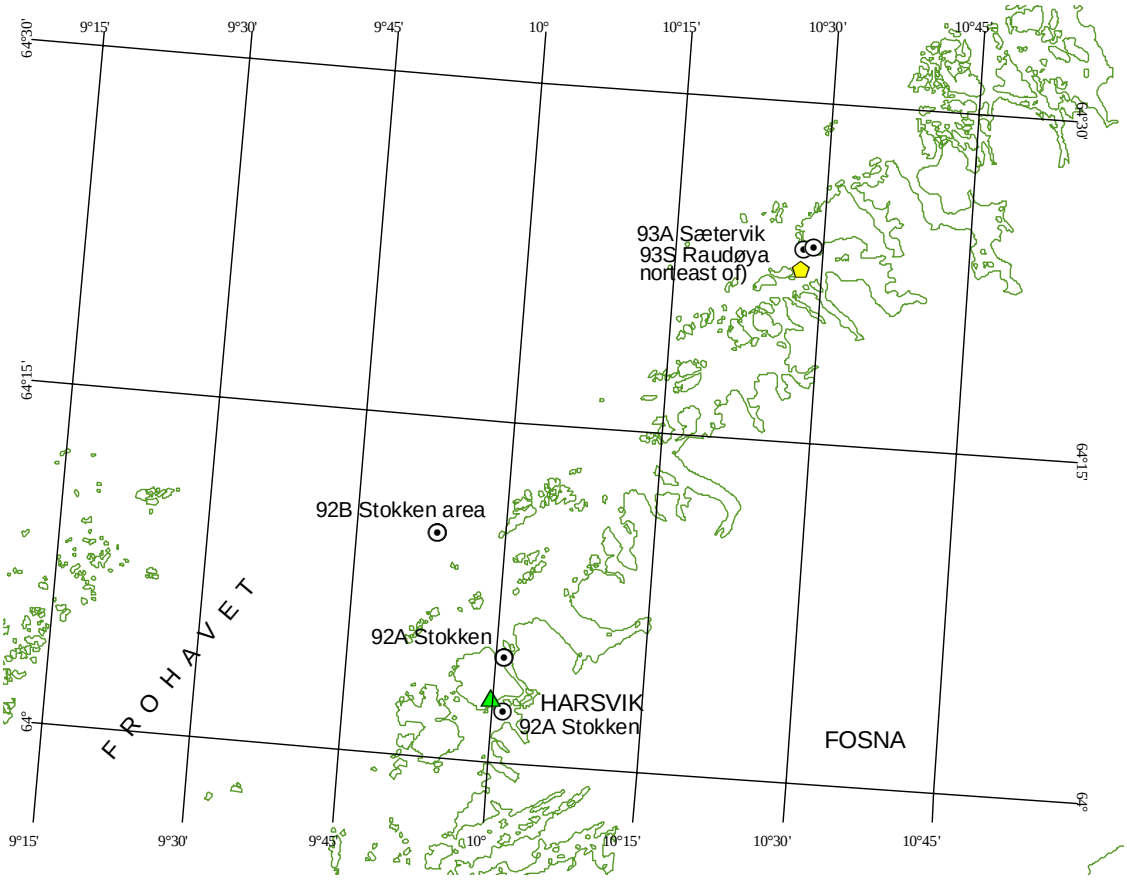
MAP 10


9°30'
9°45'
10°
10°15'
10°30'
10°45'
11°
63°30'
63°15'
88A Rødberg
TRONDHEIMSFJORD
87A Ingdalsbukt
90S Outer Orkdalsfjord
82S Flakk
82A Flakk
80A/I80A Østmarknes
86A Geitnes
TRONDHEIM
81A
Biologisk stasjon
ORKDALSFJORD
83A
Frøsetskjær
85A Geitstrand
84S Trossavika
HOMMELVIK
89S Thamshavn
84A/B Trossavika

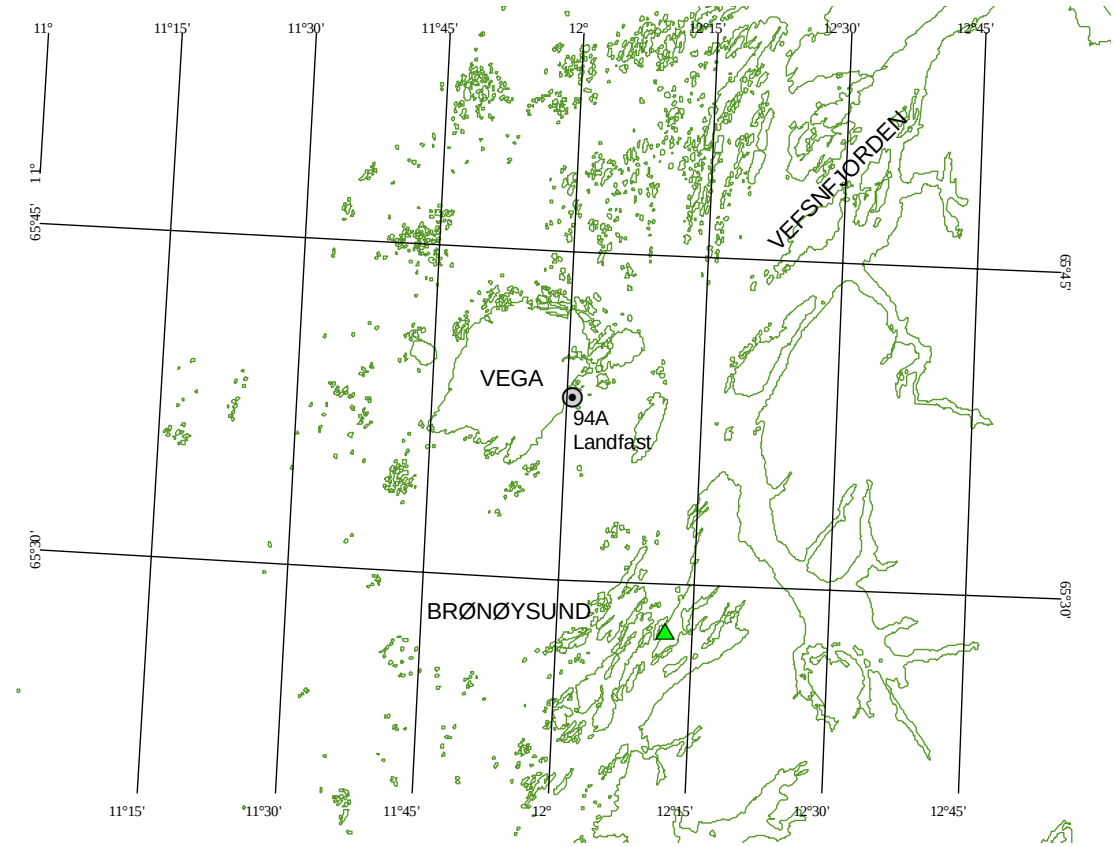
MAP 11


7°15'
7°30'
7°45'
8°
8°15'
8°30'
8°45'
9°
63°30'
63°15'
HITRA
SMØLA
91A Nerdvika
91A Nerdvika
TRONDHEIMSLEIA
KRISTIANSUND

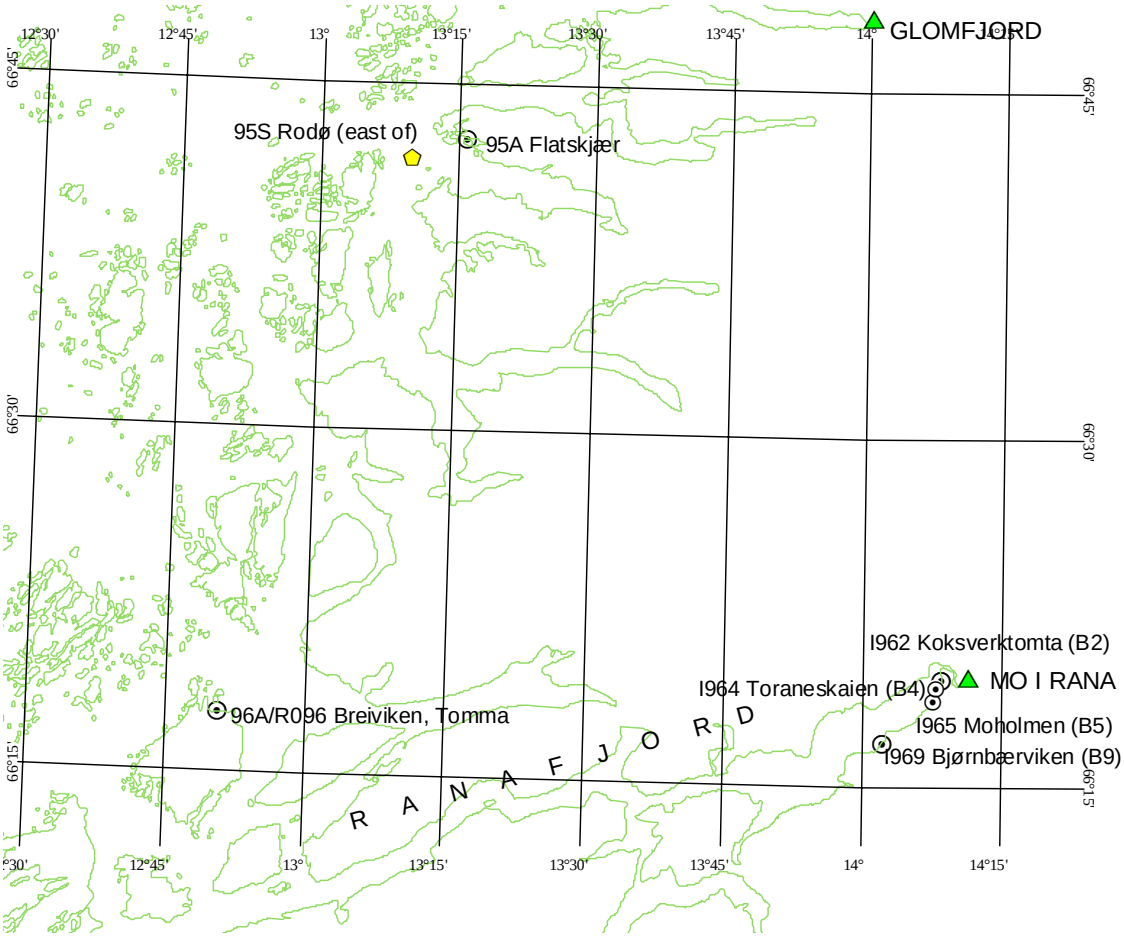
MAP 12


9°15'
9°30'
9°45'
10°
10°15'
10°30'
10°45'
64°30'
64°15'
64°
93A Sætervik
93S Raudøya
northeast of)
92B Stokken area
92A Stokken
HARSVIK
92A Stokken
FOSNA
F R O H A V E T

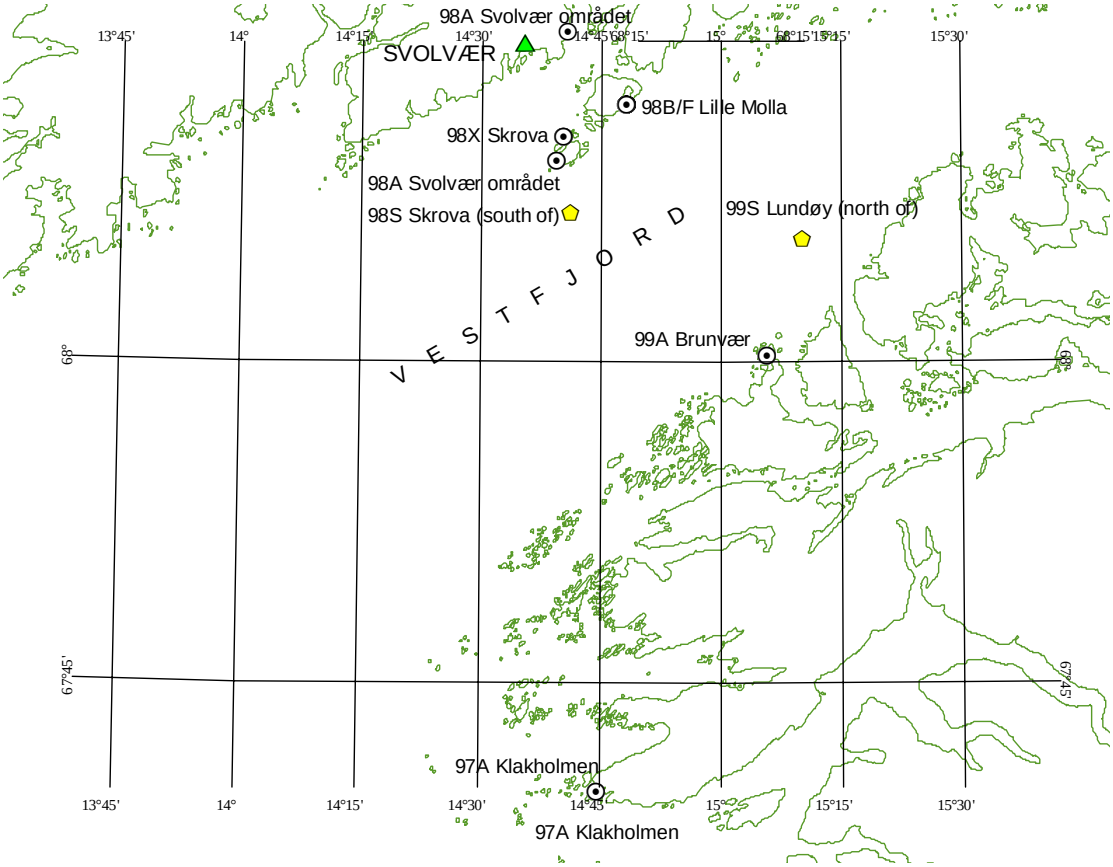
MAP 13


11°
11°15'
11°30'
11°45'
12°
12°15'
12°30'
12°45'
65°45'
65°30'
VEFSNFJORDEN
VEGA
94A
Landfast
BRØNØYSUND

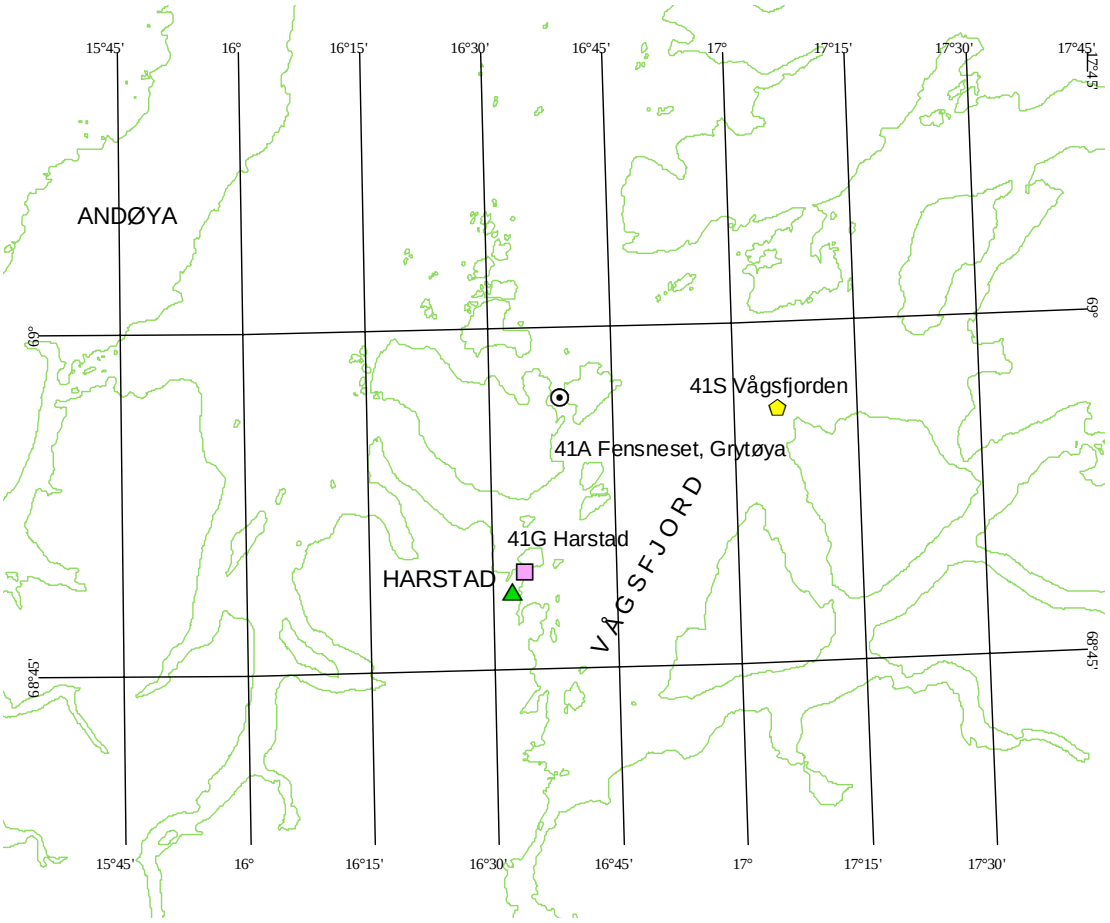
MAP 14


GLOMFJORD
95S Rodø (east of)
95A Flatskjær
I962 Koksverktomta (B2)
I964 Toraneskaien (B4)
MO I RANA
I965 Moholmen (B5)
I969 Bjørnbærviken (B9)
96A/R096 Breiviken, Tomma
RANAFJORD
12°30'
12°45'
13°
13°15'
13°30'
13°45'
14°
14°15'
66°45'
66°30'
66°15'

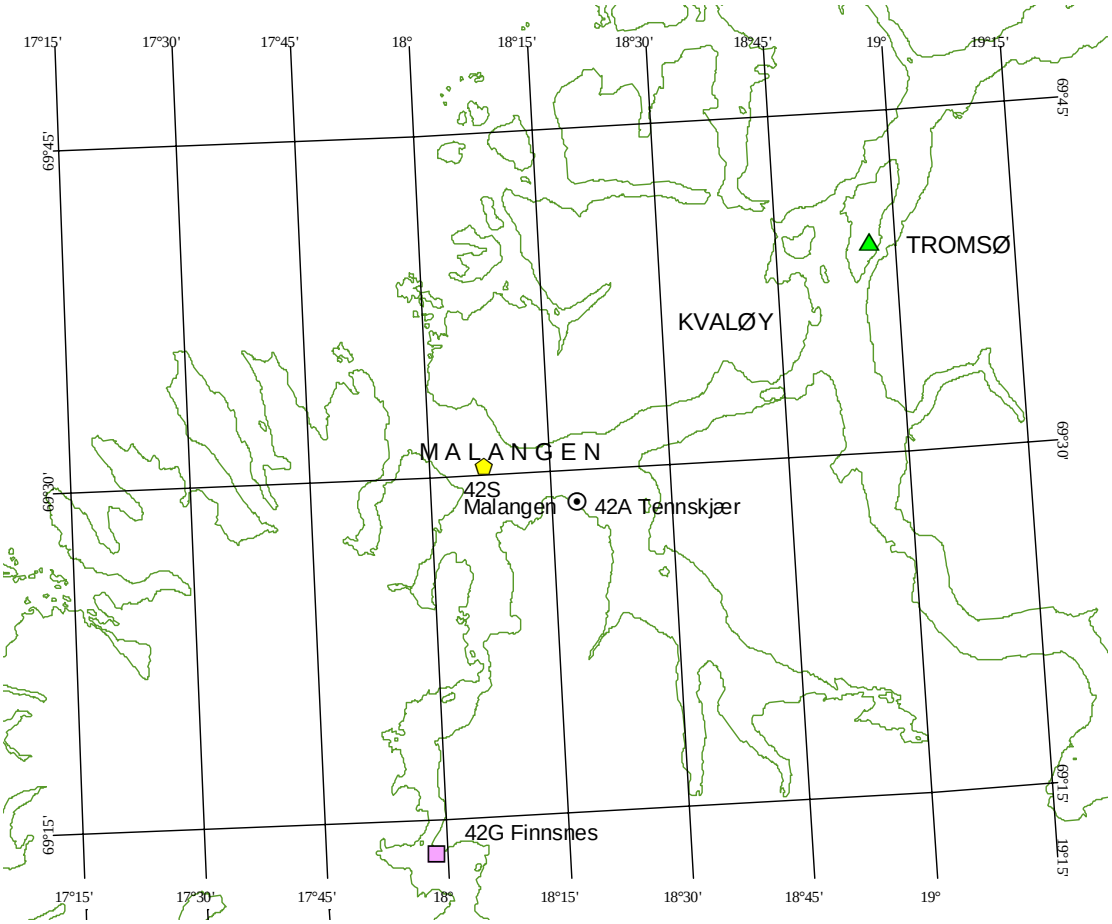
MAP 15


98A Svolvær området
SVOLVÆR
98B/F Lille Molla
98X Skrova
98A Svolvær området
98S Skrova (south of)
99S Lundøy (north of)
VESTFJORD
99A Brunvær
97A Klakholmen
97A Klakholmen
13°45'
14°
14°15'
14°30'
14°45'
15°
15°15'
15°30'
68°
67°45'

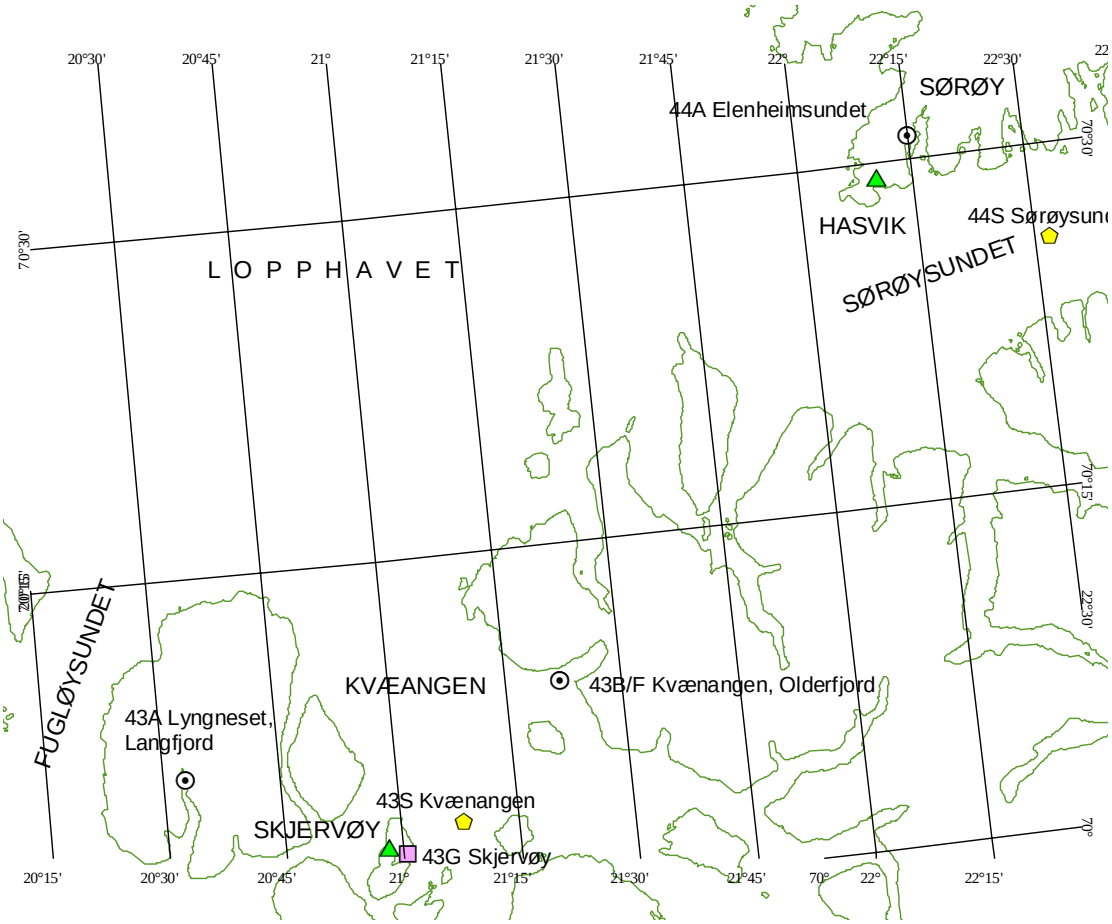
MAP 16


15°45'
16°
16°15'
16°30'
16°45'
17°
17°15'
17°30'
17°45'
69°
68°45'
ANDØYA
41S Vågsfjorden
41A Fensneset, Grytøya
41G Harstad
HARSTAD
VÅGSFJORD

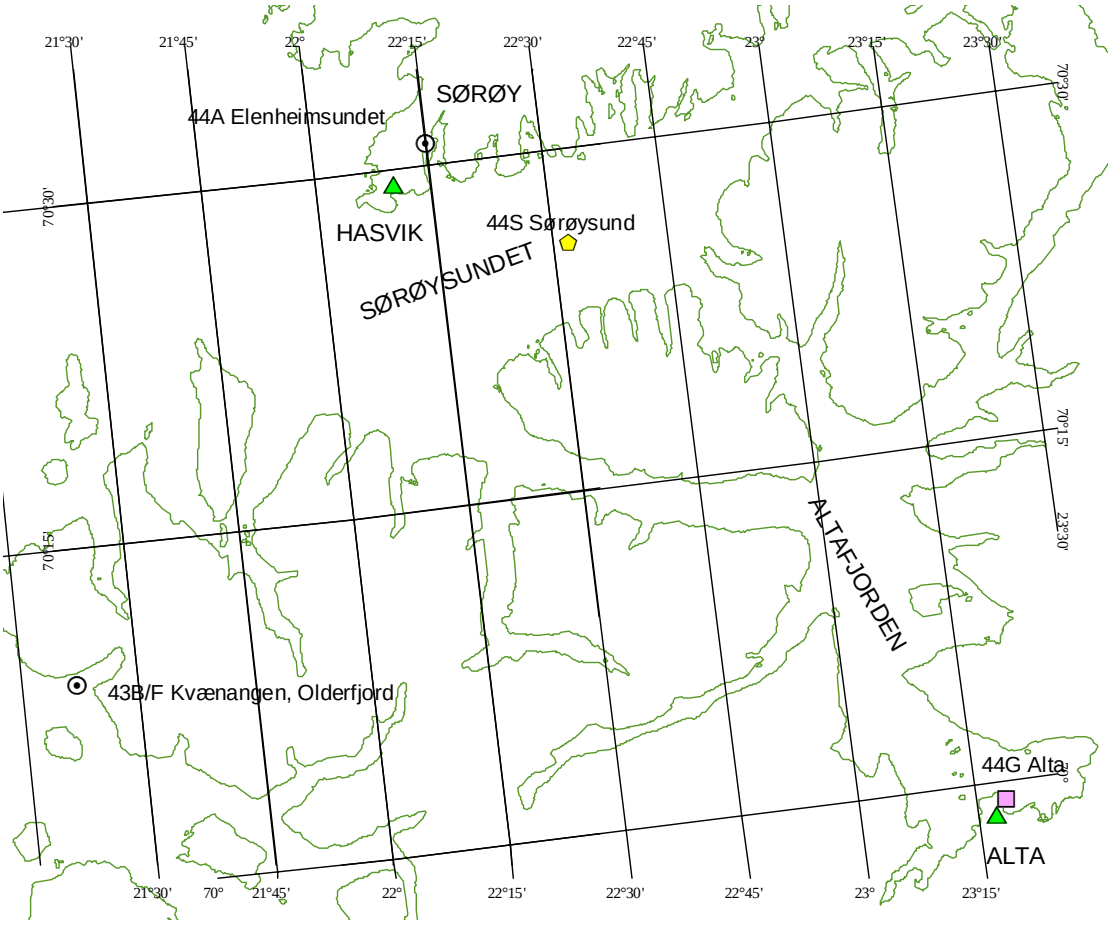
MAP 17


17°15'
17°30'
17°45'
18°
18°15'
18°30'
18°45'
19°
19°15'
69°45'
69°30'
69°15'
TROMSØ
KVALØY
MALANGEN
42S
Malangen
42A Tennskjær
42G Finnsnes

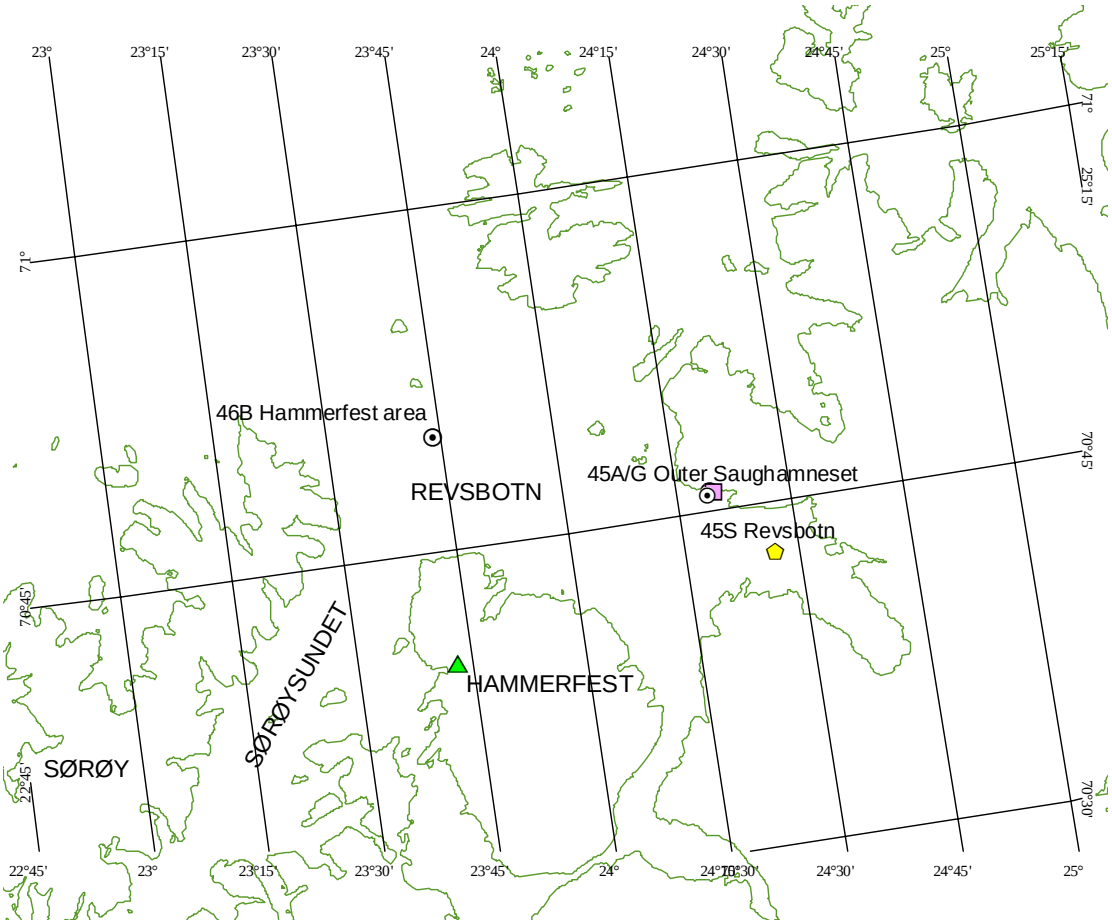
MAP 18


SØRØY
44A Elenheimsundet
HASVIK
44S Sørøysund
SØRØYSUNDET
L O P P H A V E T
FUGLØYSUNDET
KVÆANGEN
43B/F Kvænangen, Olderfjord
43A Lyngneset, Langfjord
43S Kvænangen
SKJERVØY
43G Skjervøy

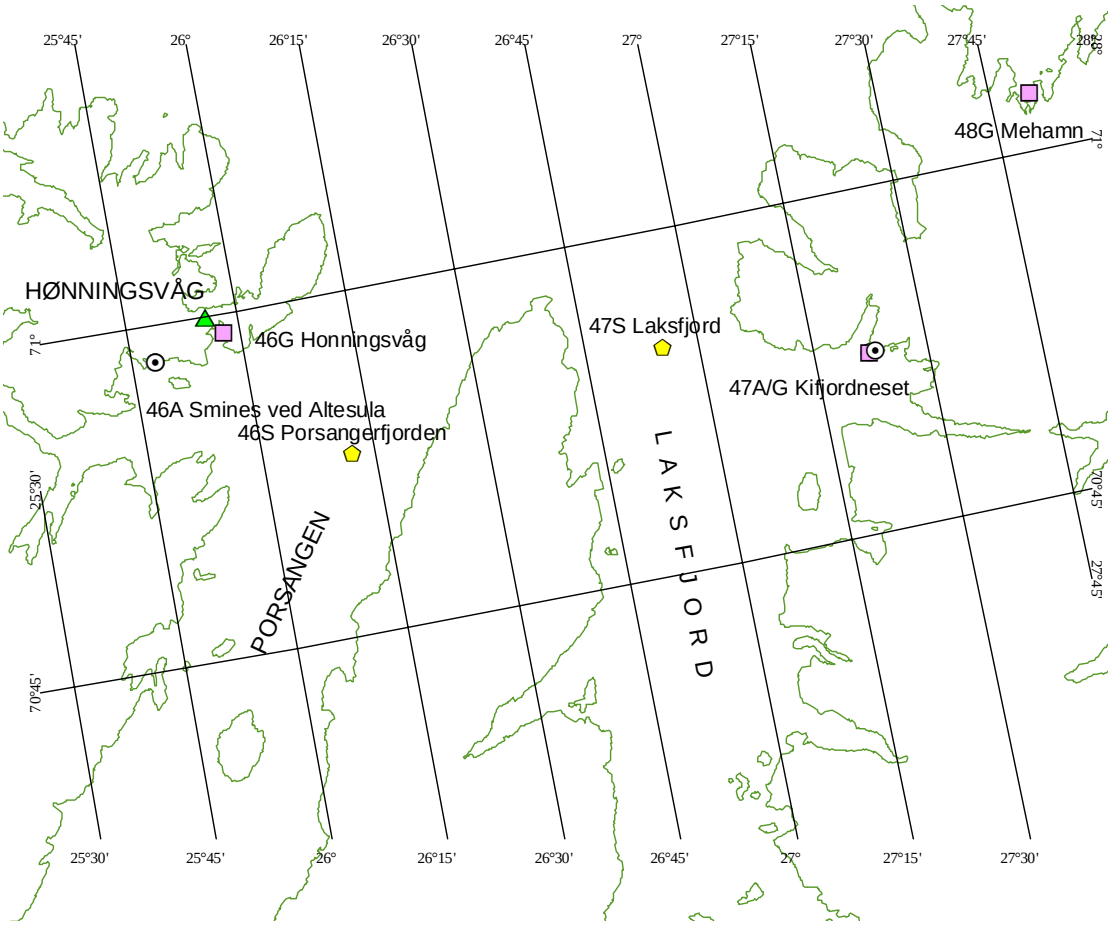
MAP 19


SØRØY
44A Elenheimsundet
HASVIK
44S Sørøysund
SØRØYSUNDET
ALTAFJORDEN
43B/F Kvænangen, Olderfjord
44G Alta
ALTA

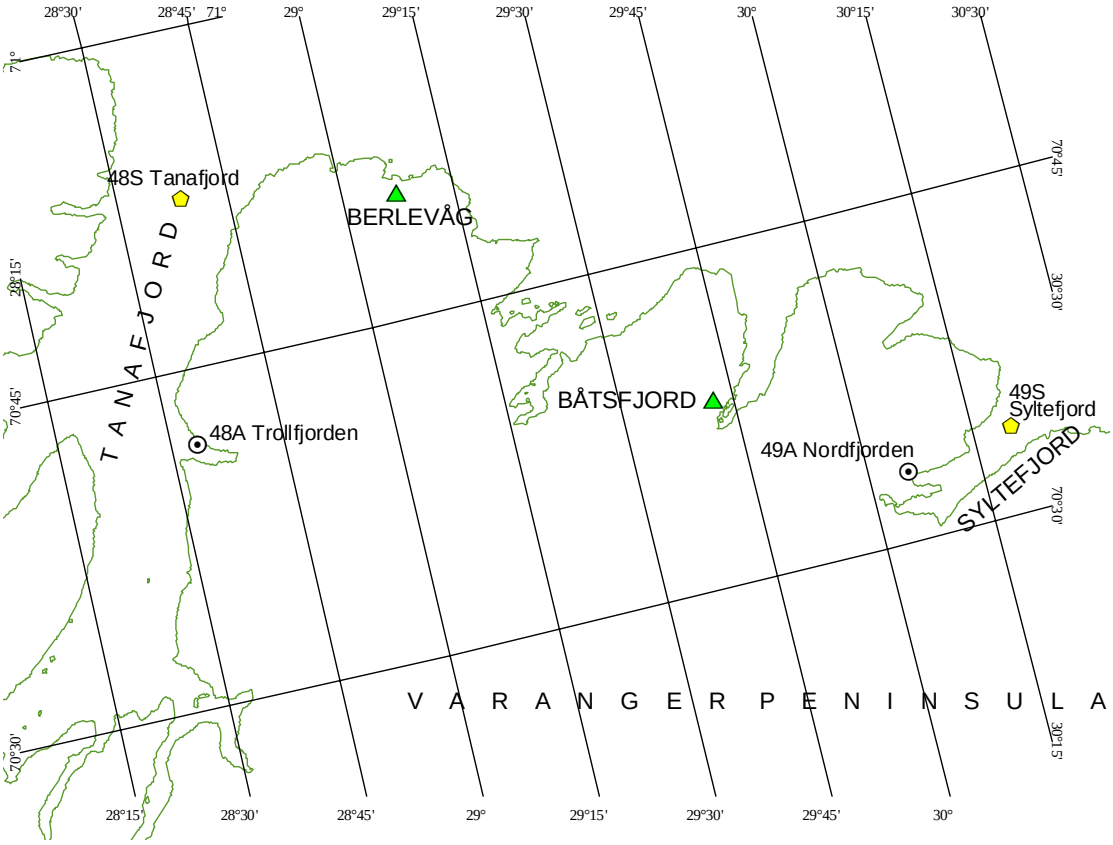
MAP 20


46B Hammerfest area
REVSBOTN
45A/G Outer Saughamneset
45S Revsbotn
HAMMERFEST
SØRØYSUNDET
SØRØY

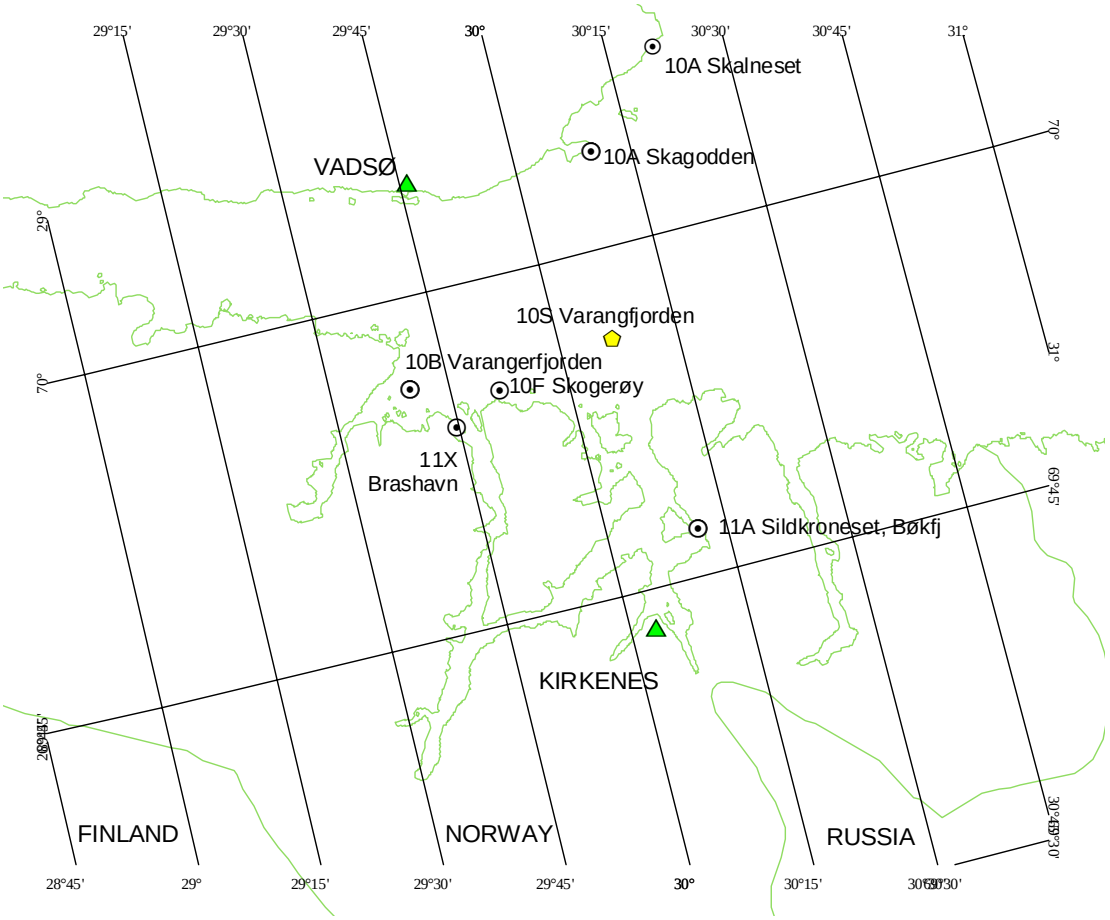
MAP 21


48G Mehamn
HØNNINGSVÅG
46G Honningsvåg
47S Laksfjord
47A/G Kjfjordneset
46A Smines ved Altesula
46S Porsangerfjorden
PORSANGEN
LAKSFJORD

MAP 22


48S Tanafjord
BERLEVÅG
TANAFJORD
BÅTSFJORD
49S
Syltefjord
48A Trollfjorden
49A Nordfjorden
SYLTEFJORD
VARANGERPENINSULA

MAP 23


10A Skalneset
VADSØ
10A Skagodden
10S Varangfjorden
10B Varangerfjorden
10F Skogerøy
11X
Brashavn
11A Sildkroneset, Bøkfj
KIRKENES
FINLAND
NORWAY
RUSSIA

MAP 24