REPORT SNO 4301-2000

Marine investigations in Risavika 2000

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REPORT

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Title	Serial No.	Date
Marine investigations in Risavika 2000	4301-2000	20/11-2000
	Report No. Sub-No. O-20142	Pages 37 Price
Author(s) John Arthur Berge, Arne Fagerhaug (NOTEBY), Brage Rygg	Topic group	Distribution
	Geographical area Rogaland, Norway	Printed NIVA

Client(s)	Client ref.
A/S Norske Shell	

Abstract:
The present investigation was performed in August 2000 in order to provide updated information on the environmental condition of the marine area surrounding Norske Shell's oil refinery at Sola. The refinery ceased normal operation April 1st 2000. The report comprise results from analysis of metals and hydrocarbons (including polycyclic aromatic hydrocarbons, PAH) in sediments, mussels and semipermeable membranes (SPMDs). Analysis of metals in sediments and mussels did not indicate appreciable leakage from the refinery area to the sea. Municipal discharge of sewage may have caused increased concentrations of benzo(a)pyrene and mercury at one station in Risavika. The concentrations of PAH in the sediment were generally low (insignificantly to moderately polluted). Sediments from one station, near the refinery, contained some heavy oil. The transplanted mussels were generally moderately polluted with PAH. The highest concentrations of PAH in mussels were found near a deep water jetty on the refinery area. The concentration of individual PAH components and ΣPAH in SPMDs indicates more water accommodated PAH inside Risavika than on the western side of the refinery. A similar conclusion could also be drawn from the analysis of PAH in mussels. The highest concentrations of PAH in SPMD`s were found at the reference site nearer Tananger harbour and not at the stations near the refinery. The results from the studies of soft bottom macrofauna showed a low species diversity in the Tananger harbour. A considerably higher diversity were found at the two stations in Risavika.

4 keywords, Norwegian	4 keywords, English
1. Raffineri	1. Refinery
2. Driftsnedleggelse	2. Decommissioning
3. Marine miljø	3. Marine environment
4. Forurensning	4. Pollution

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ISBN 82-577-3932-4

Marine investigations in Risavika 2000

Preface

This report was prepared on request from A/S Norske Shell. The scope for the project was outlined in the offer "Revised Investigation program" from NOTEBY AS dated 07.06.00. A/S Norske Shell confirmed the project in requisition (arbeidsrekvisisjon) no. 02211 dated 26/0600.

John Arthur Berge was project leader at NIVA. The project was designed by Ola Bruskeland (NOTEBY AS) and Torgeir Bakke (NIVA) .

Field work was performed by Arne Fagerhaug (NOTEBY AS), Arild Sundfjord (NIVA) and Leif Lien (NIVA).

The chemical analyses were performed by SGAB Analytica.

Oslo, 20/11 2000

John Arthur Berge

Contents

Summary

Norske Shell's oil refinery at Sola, ceased normal operation April 1st 2000. The present investigation was performed in August 2000 in order to provide updated information on the environmental condition of the marine area surrounding the refinery.

Metals and hydrocarbons (including polycyclic aromatic hydrocarbons=PAH) were analysed in sediments, mussels (transplanted from the island Rott) and semipermeable membranes (SPMDs) (metals were not analysed in SPMDs). Mussels and SPMD`s were exposed for 1 month in the sea surrounding the refinery (including Risavika, and the area west of the Refinery). Investigations of soft bottom macrofauna communities were also performed.

The concentrations of metals in the surface sediment had gin general decreased compared to previous years. Increased concentrations were only seen for mercury at one station (station 20). For most metals the concentration level found in the sediments in 2000 were generally low (insignificantly to moderately polluted according to Norwegian environmental quality criteria).

The concentrations of PAH in the sediment were also low (insignificantly to moderately polluted). A higher PAH concentrations was observed in the deeper part of Risavika (station 20A) than in the shallower area west of the refinery. The sediments in Brunnavika and east of Hestholmen (Naut S, Naut V, Naut N) were insignificantly polluted with benzo(a)pyrene. Markedly benzo(a)pyrene-polluted sediment was observed at station 20. Sediments from station 20A, relatively near the refinery, contained some heavy oil.

The increased concentrations of benzo(a)pyrene and mercury in sediments from station 20 may be caused by municipal discharge of sewage.

Metal concentrations in transplanted mussels were low (insignificantly- moderately polluted) after exposure in the Risavika area. The results indicate that mussels are more exposed to metals at the island Rott than in the vicinity of the refinery.

The transplanted mussels were moderately polluted with PAH. The highest concentrations of PAH were found at Risa 1, Risa 3 and at Melingsholmen. The concentration of PAH at Risa 4, Naut S, Naut N did not indicate any increased PAH loading in the Risavika area compared to at the collection site at Rott.

The concentration of individual PAH components and ΣPAH in SPMDs indicates more water accommodated PAH inside Risavika than on the western side of the refinery. A similar conclusion could also be drawn from the analysis of PAH in mussels. The highest concentrations of PAH in SPMD`s were found at the reference site nearer to Tananger harbour and not at the stations near the refinery.

The results from the studies of soft bottom macrofauna show a low species diversity community (H=1.5) in the Tananger harbour, probably caused by a combination of factors like disturbance, pollution and low oxygen level in the bottom water. Considerably higher diversity were found at the two stations (20, 20A) in Risavika (H=3.60, 3,68). This indicates better conditions for macrofauna in the bottom water of Risavika than in Tananger Harbour. The diversity in Brunnarvika (H=2.7) was intermediate to Tananger harbour and Risavika. Since Brunnavika is very shallow the fauna may not be directly comparable with the deeper stations.

1. Background

Norske Shell's oil refinery at Sola closed down normal operation April 1st 2000. The refinery installation will be dismantled and the site redeveloped for future purposes. The present investigation was performed in order to provide updated information on the environmental condition of the marine area surrounding the refinery for comparison with previous results.

Shell has through 1966-1995 conducted several marine chemical and biological studies in Risavika (see chapter 1.2). The present studies are follow-up investigations of previous investigations in Risavika and also includes the area west of the refinery (Brunnavika and around Nautøya), i.e. all areas of concern.

1.1 Site and Location

The Shell Refinery is located in the municipality of Sola, Rogaland, near the town of Stavanger in southwestern Norway. Figures 1 and 2 show the site and the immediate surroundings.

The refinery had a capacity to process 2.6 mill. tonnes of crude oil per year. It has a deep-water jetty, storage facilities for 200.000 tonnes of crude oil in one conventional above ground tank and four underground rock caverns, and tank storage for 220.000 tonnes of products. Product export was either by ship from the refinery jetty or by a 2.7 km long pipeline to an export depot in Risavika. LPG was exported by truck.

The site is a rocky peninsula facing the North Sea to the north and west, and forming the western shore of the bay and harbour Risavika. The ground is bedrock, rock fill and local sand, silt and clay. The total site area is approximately 100 hectares. The adjacent land areas to the south and east have a mixture of commercial and agricultural uses.

Risavika is an open bay with a deep opening. The maximum depth is approximately 40 m, and the bottom slopes gradually towards the shore. In addition to the Shell jetty, there is a supply boat harbour and depot on the north-eastern shore and the harbour of Tananger to east. Tananger harbour is separated from the larger Risavika by an inlet with only 7 m water depth. The maximum depth inside the harbour is approximately 15 m.

Part of the shore surrounding the refinery faces to open sea (to the West) and is exposed to heavy waves and wind conditions. This is reflected on shore and sediment conditions, with rocky beaches and less fine-grained sediments accumulated nearshore.
To the south on this coast lies Brunnavika, a small sheltered bay. Brunnavika was the recipient of cooling water discharge from the refinery. Until 1990, sanitary water from the refinery was also discharged to Brunnavika. Brunnavika will also receive natural drainage water from the farmlands surrounding the bay to the south and southwest.

North of this exposed shoreline lies Hestholmen separated from Nautøyna and the refinery area by a shallow sound. The area between the peninsula and the former island Nautøyna was reclaimed using surplus fill material of blasted rock and sand from the refinery construction period. This site has later been used as a general fill area for surplus excavated material from different construction projects at the refinery/process plant.

In this fill area catalyst, and also some quantities of sulphur and coke, have been deposited over the years. In 1990 the landfill was landscaped. Sulphur, coke and catalyst were found buried at several locations in the fill area. These materials were collected and deposited in an excavated pit covering an area of about 100 m^2. The main constituent of the catalyst were Al_2O_3 and the most leachable elements are Co and Mo. Pb, As and Ni were minor constituents of the catalyst.
Sea movement in the area is believed to be dominated by the Norwegian coastal current, moving northwards along the coast. This general movement will be influenced by local differences due to topography, tide and wind.

1.2 Marine environment – previous investigations

Risavika with Tananger harbour lies north and east of the refinery. Risavika is the recipient of discharged production water from the refinery and from a municipal sewage treatment plant.

Shell conducted chemical and biological baseline studies of Risavika in 1966/67 (Samdal, 1968). Further studies were carried out in 1970-72 (Kristiansen, 1972), from 1974 to 1979. (Bokn, 1975, 1977), in 1982-84 and 1986 (Dahle, 1984, Stokland, 1986), in 1991 (Stokland, 1992) and finally in 1995 (Stokland 1996). Some of these studies were carried out jointly by Shell and IVAR, the local water and sewage Management Company.

A report to the County (Rogalandsforskning, 1996) summarizes the results of several marine environmental investigations in Risavika, except for the last Shell study of 1995.

The above referenced summary report describes the sediments of Risavika to be impacted by heavy metals and PAH, particularly within the Tananger harbour. This was evident from both the chemical analyses of sediment samples and the studies of the benthic fauna. The bacterial water quality was generally good. The report to the County (Rogalandsforskning, 1996) concludes that Risavika is unsuitable as a recipient of further sewage or other discharges. It further states that recreational swimming and fishing should be carried out with care, partly due to the sediment concentrations of PAH and heavy metals at some sampling locations.

The studies carried out in the vicinity of the refinery showed clear signs of benthic fauna impacts and near shore effects in 1971. The refinery discharge outlet was extended in 1978 to 65 m from the shore at 15 m depth, which improved the situation. The subsequent studies seem to indicate some increase in the heavy metals content of the sediments in the vicinity of the new outlet until 1991, and some reduced contents in 1995. The study of 1995 found higher contents of PAH in the sediments near the refinery than in 1991, which was the first year the sediments were tested for these chemicals. Periwinkles (*Littorina litorea*) from the Jetty area has been investigated for PAH since 1986. The 1991 and 1995 results showed considerable improvements relative to 1986, and a PAH content within expected background levels. There was no noticeable change in the soft sediment fauna in general from 1991 to 1995.

The Norwegian system for classification of environmental quality in fjords and coastal waters is given by Norwegian Sate Pollution Control Authority SFT manual 97:03 (Moldvær et al, 1997). Using this system to evaluate the former investigative results, the sediment quality with regards to content of heavy metals is Good to Fair, i.e., Slightly to Moderately polluted. The PAH pollution is also Moderate from a total content evaluation, however, the sediment quality is Poor when considering the benzo(a)pyrene (BaP). Periwinkles were only slightly impacted by PAH and proved to be within quality class Good.

The quality class is also Good with regards to the benthic fauna diversity as determined in 1995.

The latest results and corresponding quality class of sediments from the sampling station near the refinery discharge outlet were as follows:

Table 1. Summary. Marine sediment investigations Risavika station 20 A.
Results in mg/kg dry matter

Year	Hg	Cd	Pb	Cu	Zn	Ni	Cr	PAH	B(a)P
1986			46.4 (II)	17.2 (I)	94.3 (I)				
1991	0.45 (II)	0.6 (II)	62.8 (II)	37.9 (II)	108 (I)	25.6 (I)	25.1 (I)	0.280 (I)	n.d
1995	0.032 (I)	0.60 (II)	79.8 (II)	42.4 (II)	164 (II)	24.1 (I)	20,9 (I)	1.40 (II)	0.10 (III)

Notes: Environmental quality classification: (I) = Good (II) = Fair (III) = Poor

2. Material and methods

2.1 Sediment sampling

Sampling of sediments for sediment chemistry and soft bottom macrofauna was performed with a 0.1 m^2 van Veen grab on the 2nd of August 2000. All grab hauls were examined prior to further handling, and discarded if less than 60% filled, or if other findings suggested that the sampled material was disturbed (overview of sediment stations are given in appendix A).

2.1.1 Sediment chemistry

Sediments are found on the seabed in areas where there over time is a net deposition of particles to the sea floor. Contaminants in the marine environment are in general associated with the surface of the particles in the seawater. This is especially true for the hydrophobic organic contaminants. Large particles have a lower surface/volume ratio than small particles. This implies that higher concentrations of contaminants are usually found in areas with fine sediments than in areas with more coarse sediments.

Samples for chemical investigations were taken from the grab inspection hatches using a 50 mm transparent acrylic tube. The tube was pressed into the sediment to full depth giving an undisturbed core of approx. 10 – 12 cm length. Material for analysis was taken from the top 2 cm of these cores. Six cores could be taken from each grab, giving a sufficient volume of sediments for the chemical analysis to be performed.

Locations of sediment sample stations are shown on figure 2. Co-ordinates and general sediment descriptions are given in appendix A.

The stations 20, 20A and 22 are similar to previously investigated locations. Stations Naut_S, Naut_V and Naut_N are meant to monitor possible influences from the Nautøyna waste deposit, and in Brunnavika stations Brvika Y and Brvika I possible impacts caused by effluent water outlet.

2.1.2 Soft bottom macrofauna

In Risavika five grab samples at each of the stations 20, 20A and 22 were taken (**Figure 2**). In Brunnavika three samples at station Brvika Y just outside the bay and one sample at Brvika I within the bay (**Figure 2**). The depth was 23 m at station 20, 40 m at station 20A, 11 m at station 22, 2 m at station Brvika Y and 1 m at station Brvika I.

The samples were washed through a 1 mm sieve. The material retained on the sieve was preserved with formaldehyde and later transferred to 75% ethanol. The animals were sorted, identified and counted. Abundance, number of species, and diversity were calculated. Based on the results an evaluation of the faunal status and degree of pollution impact was made. Soft bottom macrofauna have previously been investigated at som of the sites (Stokland, 1996).

2.2 Mussels and semipermeable membranes (SPMDs)

The impact of anthropogenic pollutants on the marine ecosystem is related to the concentrations experienced by the biota in the seawater and the resulting concentration in the organism. Results from

monitoring of pollutants in water samples provide snapshots that can be high or low depending on a wide range of variables. To provide more integrated information, mussels and semipermeable membrane devices, SPMDs, have been used to monitor different organic pollutants. In this survey, SPMDs and mussels were used to monitor hydrocarbons in the Risavika area at five stations (Naut N, Naut S, Risa 1, Risa 2, Ref.). SPMDs were exposed to seawater (0.5 m depth) during the period 1-31 August 2000. Due to dislocation of the rig, SPMD were not retrieved at Risa 2. One SPMD were treated as the ones deployed without exposure to seawater in order to assess the effect of air exposure and handling. This SPMD were analysed as the ones exposed to seawater.

Mussels collected at the Island Rott (**Figure 1**) were transplanted to 6 stations (0.5 m depth) in the Risavika area (Naut N, Naut S, Risa 1, Risa 2, Risa 3, Ref.) (**Figure 2**) on 1. August 2000. Melingsholmen was chosen as a local reference site (Ref.) in order to represent an area influenced by the general surface water in Risavika without been directly influenced by possible point source discharges from Tanager harbour and the refinery.

The mussels were placed in cages suspended in the water column. Excess mussels were placed in cages in the intertidal at Risa 3 and west of Risa 2 (Risa 4). The caged mussels were retrieved on the 31. August. The mussels transplanted to Risa 2 were not found. Instead the excess mussels from the intertidal at Risa 3 and Risa 4 were collected. The intertidal mussels have been exposed to the surfacefilm twice a day and are also in nearer contact to the bottom substrate than the mussels in the suspended cages.

Local populations of mussels were not observed in Risavika.

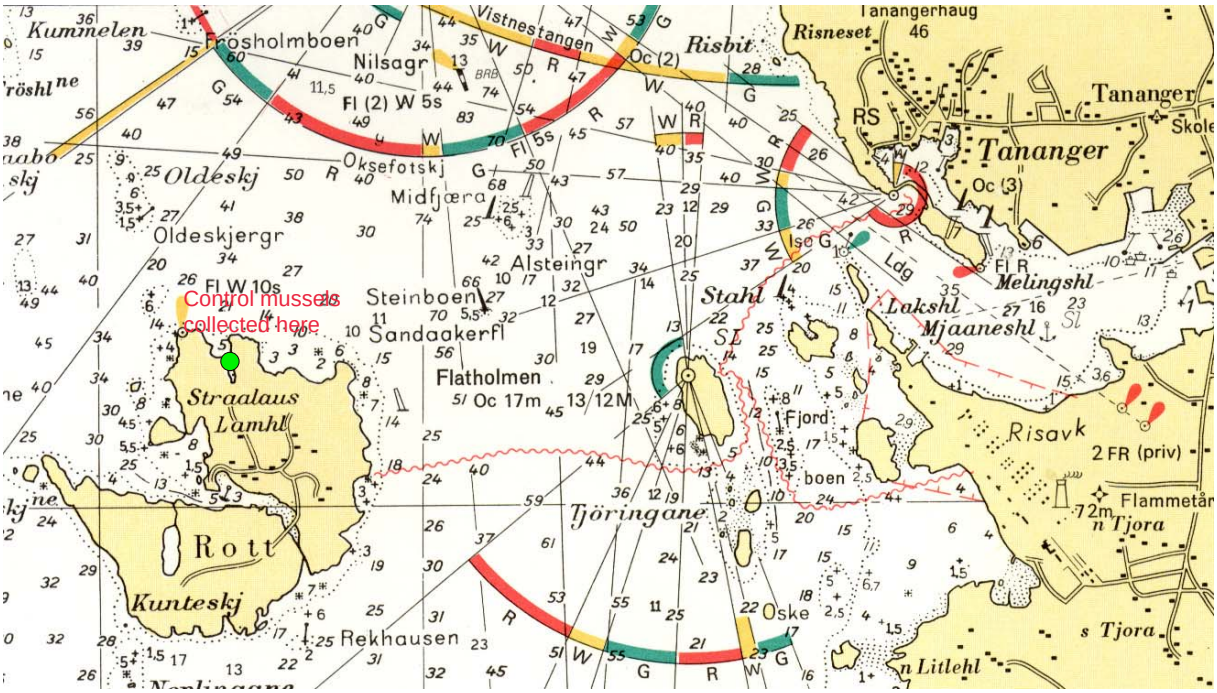

Figure 1. Overview of the investigated area. The location on the island Rott were the transplanted mussels were collected is shown (circular green symbol).

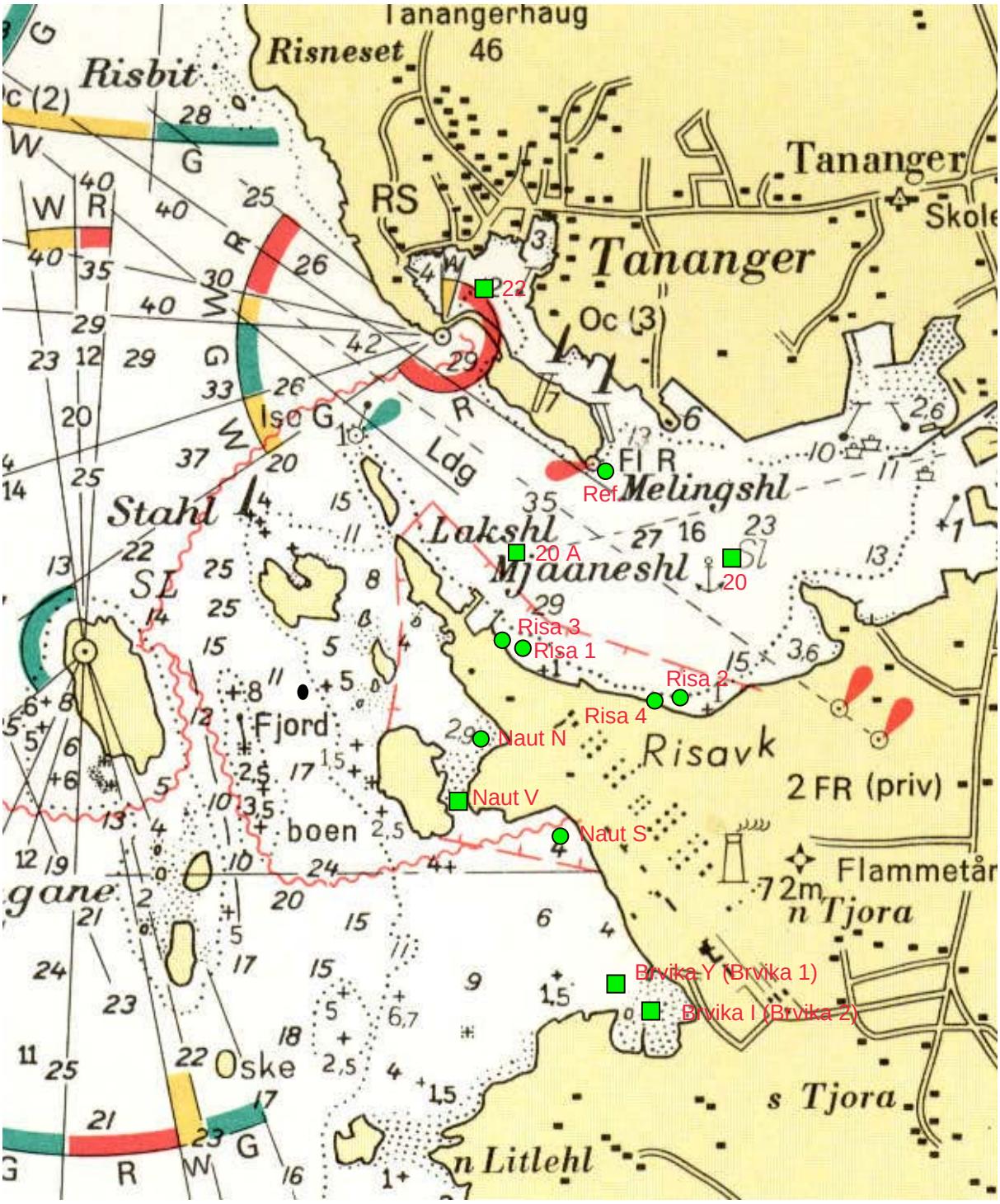

Figure 2. Map showing the Risavik area. Stations for collection of sediments (square green symbols) and deployment of SPMDs and cages for transplanted mussels are shown (circular green symbols). At the stations Risa 3 and Risa 4 only caged mussels placed on the beach in the tidal zone were used for the analysis.

2.3 Chemical analyses

The chemical analyses were performed through SGAB Analytica. An overview of the applied analytic methods can be found in appendix B (in Norwegian).

3. Results

The results are mainly presented as a datareport. Some comments and conclusions based on the results are however also presented.

3.1 Bottom sediments

The dry weight content in the sediments was generally lower in Risavika than in the more shallow stations west of the refinery (**Table 2**). Coarse sediments were found at stations near Hestholmen (Naut, S, V, N). Much finer sediments were found in Riavika (20 A) and Brunnavik (**Table 2**).

Table 2. *Dry weight content (% d.w.) and fraction of the sediment with a particle size less than 63 µm (<63µm).*

Station	% d.w.	<63 µm (%)
20 A	42,9	33,3
20	46,3	n.d.
22	52,6	n.d.
NAUT S	76,2	<0,05
NAUT V	75,0	<0,05
NAUT N	72,5	<0,05
BRVIKA i+y	80,0	0,95

n.d. = no data

3.1.1 Metals

The concentration of metals in surface sediment in the period 1986-2000 is shown in **Table 2**. The concentrations have generally decreased during the investigation period. Increased concentrations were only seen for mercury at station 20. For most metals the concentration level found in the sediments in 2000 were generally low (insignificantly to moderately poluted) according to Norwegian environmental quality criteria (see **Table 3**). Markedly polluted sediment was only observed at station 20 (mercury) and could be caused by the municipal discharge of sewage at 15 m depth east of Melingsholmen.

Table 3. *Concentration of metals in surface sediments in the Risavika area.* Results are classified according to Norwegian environmental quality criteria (Molvær et al. 1997). Cadmium=Cd, Mercury=Hg, Lead=Pb, Copper =Cu, Zink=Zn, Nickel=Ni, Chromium=Cr, Arsenic=As, Cobalt=Co, Manganese=Mn

Colour code used in the table:

I. Insignificantly polluted

II. Moderately polluted

III. Markedly polluted

IV. Severely polluted

V. Extremely polluted

Not in classification system/Can not be classified

		Metal (mg/kg d.w.)					Ref.
Station	**Year**	**As**	**Cd**	**Co**	**Cr**	**Cu**	
20 A	1986					17,2	Stokland, 1986
20 A	1991		0,6		25,1	37,9	Stokland, 1992
20 A	1995		0,60		20,9	42,4	Stokland, 1996
20 A	2000	2,40	0,0216	1,65	5,16	5,04	Present report
20	1986					15,1	Stokland, 1986
20	1991		0,8		25,2	54,5	Stokland, 1992
20	1995		0,47		21,1	34,5	Stokland, 1996
20	2000	5,41	0,218	4,12	18,4	23,3	Present report
22	1986					39,2	Stokland, 1986
22	1991		1,5			98,9	Stokland, 1992
22	1995		1,01			69,1	Stokland, 1996
22	2000	6,13	0,400	3,06	20,7	35,3	Present report
NAUT S	2000	5,98	0,289	3,69	16,4	15,8	Present report
NAUT V	2000	2,70	0,0300	1,34	5,37	5,79	Present report
NAUT N	2000	2,92	0,0354	1,19	5,03	4,33	Present report
BRVIKA i+y	2000	1,30	0,0169	0,864	3,12	2,41	Present report

Table 2 (Continued)

		Metal (mg/kg d.w.)					Ref.
Station	**Year**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**	
20 A	1986				46,4	94,3	Stokland, 1986
20 A	1991	0,45		25,6	62,8	108	Stokland, 1992
20 A	1995	0,026		24,1	79,8	164	Stokland, 1996
20 A	2000	<0,0394	87,4	3,61	7,89	17,7	Present report
20	1986				39,6	106	Stokland, 1986
20	1991	0,2		25,2	134	386	Stokland, 1992
20	1995	0,026		21,1	64,8	128	Stokland, 1996
20	2000	0,793	263	12,2	36,0	101	Present report
22	1986				85,5	169	Stokland, 1986
22	1991	0,33		21	250	354	Stokland, 1992
22	1995	0,032		16,5	116	256	Stokland, 1996
22	2000	0,142	155	8,83	74,9	129	Present report
NAUT S	2000	<0,0398	147	12,8	32,9	70,4	Present report
NAUT V	2000	<0,0394	61,1	3,71	7,25	22,3	Present report
NAUT N	2000	<0,0400	60,7	3,20	3,77	16,8	Present report
BRVIKA i+y	2000	<0,0394	48,7	2,18	1,95	8,97	Present report

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3.1.2 PAH

The concentration of PAH and benzo(a) pyrene in surface sediment in the period 1986-2000 is seen in **Table 4**(Complete data sets are given in appendix C). The concentrations of PAH in the sediment in 2000 were generally low (insignificantly to moderately polluted) according to Norwegian environmental quality criteria (see **Table 4**). Higher PAH concentrations were observed in the deeper part of Risavika (station 20A) than in the shallower area west of the refinery (Naut S, Naut V, Naut N, Brevika I+Y).

The sediments in Brunnavika (Brvika I+Y) and east of Hestholmen (Naut S, Naut V, Naut N) were insignificantely polluted with benzo(a)pyrene. Markedly benzo(a)pyrene polluted sediment was however observed at station 20 in 2000 and could be caused by the municipal discharge of sewage east of Melingsholmen. The chromatogram (C16-C35 faction) (see appendix C) indicate that the sediments from station 20A contained some heavy oil fractions.

Table 4. *Concentration of PAH and benzo(a)pyrene in surface sediments in the Risavika area.* See **Table 3** for colour code used in the table. n.a.= not analysed.

Station	Year	Total PAH (µg/kg d.w.)	Benzo(a)pyrene (µg/kg d.w.)	Reference
20A	1991	280	No data	Stokland, 1992
20A	1995	1353	100	Stokland, 1996
20A	2000	720	57	Present report
22	1991	1860	200	Stokland, 1992
22	1995	1164	110	Stokland, 1996
22	2000	n.a.	n.a.	Present report
Naut S	2000	<210	<10	Present report
Naut V	2000	<210	<10	Present report
Naut N	2000	314	<10	Present report
Brvika I+Y	2000	<210	<10	Present report

3.2 Water masses

3.2.1 Contaminants in mussels

Metals

Metal concentrations in mussels were generally low (**Table 5**). The initial concentration of 7 metals (As, Cr, Cu, Hg, Ni, Pb, Zn) were higher than after exposure for 1 month in the refinery area, and at the local reference station (Melingsholmen) (**Table 5**). This indicates that the mussels are more exposed to metals at the collection site at the island Rott than in the vicinity of the Refinery.

Table 5. *Concentrations of metals in mussels from the Risavika area.*

Results are classified according to Norwegian environmental quality criteria (Molvær et al. 1997). Arsenic=As, Cadmium=Cd, Chromium=Cr, Copper =Cu, Mercury=Hg, Nickel=Ni, Lead=Pb, Zink=Zn, Boron=B, Cobalt=Co, Molybdenum=Mo, Vanadium=V.

Colour code used in the table:

I. Insignificantly polluted

II. Moderately polluted

III. Markedly polluted

IV. Severely polluted

V. Extremely polluted

Not in classification system/Can not be classified

A: *Elements included in Norwegian environmental quality criteria.*

ELEMENT	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
SAMPLE	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.
Rott (start)	36,58	1,47	1,11	12,97	0,39	2,91	2,94	188,29
Naut S	9,34	1,67	0,17	4,86	0,05	0,81	0,40	48,05
Naut N	16,12	4,44	0,37	5,39	0,08	1,56	0,87	96,98
Risa 1	14,04	1,63	0,21	6,93	0,08	1,07	0,54	48,89
Risa 3 (beach)	22,06	2,76	0,55	6,53	0,13	1,81	0,96	82,91
Risa 4 (Beach)	23,48	0,89	0,36	11,87	0,25	0,85	0,60	110,16
Ref. (Melingsholmen)	13,96	2,44	0,32	6,04	0,09	1,84	1,40	105,31

B: *Elements not included in Norwegian classification system.*

ELEMENT	**Dry weight**	**B**	**Co**	**Mo**	**V**
SAMPLE	%	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.	mg/kg d.w.
Rott (start)	11,1		1,11		
Naut S	33,3	16,67	0,56	0,48	1,14
Naut N	23,2	23,45	1,23	1,07	1,09
Risa 1	27		0,89		
Risa 3 (beach)	19,9		1,28		
Risa 4 (beach)	18,7		0,65		
Ref. (Melingsholmen)	20,7	27,25	1,51	0,85	1,80

PAH

The transplanted mussels were after 1 month exposure generally moderately polluted with PAH (**Table 6**) (Complete data sets are given in appendix D). The highest concentrations of PAH were found at Risa 1, Risa 3 and at the local reference site (Melingsholmen). The concentration of PAH at

the remaining stations (Risa 4, Naut S, Naut N) were in the same range as the initial concentration in the mussels used for the transplantation experiment, and thus do not indicate any increased PAH loading in the Risavika area compared to at the collection site at Rott.

Mussels transplanted to Risa 1, Risa 3 and Naut S were, however, markedly polluted with benzo(a)pyrene (**Table 6**).

Table 6. *Polycyclic aromatic hydrocarbons (PAH) in mussels collected at Rott (1/09-00) and transplanted to locations in the vicinity of the Shell refinery in Risavika.* The mussels were left for approximately 1 month before retrieved and analysed.

Colour code used in the table:

I. Insignificantly polluted

II. Moderately polluted

III. Markedly polluted

IV. Severely polluted

V. Extremely polluted

Not in classification system/Can not be classified

ELEMENT	Lipid (%)	PAH µg/kg w.w.	B (a) Pyr. µg/kg w.w.
SAMPLE			
Rott (start)	1,52	55,4	1,6
Naut S	2,93	59,4	3,2
Naut N	1,86	34,7	1,2
Risa 1	2,52	121,	4,4
Risa 3 (beach)	2,50	114,9	5,2
Risa 4 (Beach)	1,99	65	2,2
Ref. (Melingsholmen)	2,79	97,1	2,4

3.2.2 Contaminants in SPMDs

The concentration of PAH and benzo(a) pyrene in SPMD´s is seen in **Table 7** (complete data sets are given in appendix E).

The concentration of PAH was below the detection limit for all analysed components analysed in the SPMD from Naut S (appendix E). Also the concentration in SPMD from Naut S and in the air control were generally below the detection limit (appendix E). The high occurrence of concentrations below the detection limit indicates low concentration of PAH in the seawater at Naut S and Naut N.

The concentration of individual PAH components and ΣPAH were generally somewhat higher at Risa 1 and at the reference site (Ref) than at Naut S and Naut N (appendix E, **Table 7**). This observation indicates that there are somewhat more water accommodated PAH inside Risavika than on the western side of the refinery. A similar trend is also observed in musssels (**Table 6**). The highest concentrations of PAH in SPMDs were found at the reference site nearer Tananger harbour (**Table 7**).

The concentrations of >C11 - C20 hydrocarbons in SPMD`s were higher in the air control than in those exposed to seawater (**Table 7**). This complicates the interpretation of the results.The results do however generally supports the results form the PAH analysis and indicate a somewhat higher exposure inside Risavika than on the western side of the refinery.

Table 7. *Concentration of PAH (ng) and C11-C20 hydrokarbons (µg) in SPMD exposed to seawater in the Risavika area during the period 1-31 August 2000.*

		Station				
Compound	**Unit**	Naut S	Naut N	Risa 1	Ref	Air control
Σ PAH[1]	ng.	0 (0)	348 (4)	1625 (10)	2455 (9)	1153[3] (2)
Σ PAH[2]	ng.	340	738	1715	2560	1363
Hydrocarbons >C11 - C20	µg	<100	47	180	190	490

[1]The sum of components with concentrations above the detection limit. Number of components are indicated in brackets

[2]The sum of 16 components. 0.5 x detection limit are included in the sum for components observed to be below the detection limit.

[3] Dominated by fluoren (1100 ng)

3.3 Soft bottom community structure

The sediments consisted mainly of silt and fragments of shells and algae.

The macrofauna results are shown in **Table 6** and **Table 9**. The raw data are presented in Appendix F.

Table 8. *Fauna parameters at the stations in 1983-2000* . BVY=BRVIKA Y, BVI=BRVIKA I

Station	Year	Area (m^2)	Number of species	Number of individuals	Diversity (H)	Diversity (ES_{100})	Species index (AI)
20	1983	1.0	84	4582			
20	1986	1.0	72	4464	3.60	19.8	
20	1991	0.5	42	1082	3.44	19.2	
20	1995	0.5	67	2103	3.59	21.8	
20	2000	0.5	75	7446	3.60	18.1	6.17
20A	1986	1.0	77	2400	4.10	25.6	
20A	1991	0.5	48	707	3.34	19.4	
20A	1995	0.5	73	1439	4.33	27.1	
20A	2000	0.5	99	4843	3.68	23.0	6.63
22	1983	1.0	39	5590			
22	1986	1.0	37	9045	1.70	8.5	
22	1991	0.5	16	1935	2.03	7.5	
22	1995	0.5	30	1884	2.20	10.0	
22	2000	0.5	58	9954	1.51	7.0	5.08
BVY	2000	0.3	51	3830	2.72	12.6	5.21
BVI	2000	0.1	24	213	3.16	16.7	5.20

Table 9. *Number of individuals of the 10 most abundant species/taxa at the stations in 2000.*
BVY=BRVIKA Y

Station	Group	Species/taxon	Number
20	POLYCHAETA	Paradoneis lyra	1780
20	POLYCHAETA	Tharyx/Caulleriella spp	1969
20	POLYCHAETA	Scoloplos armiger	998
20	POLYCHAETA	Chaetozone setosa	701
20	NEMERTINEA	Nemertinea indet	341
20	POLYCHAETA	Prionospio fallax	296
20	BIVALVIA	Thyasira flexuosa	242
20	OLIGOCHAETA	Tubificoides spp	156
20	POLYCHAETA	Cirratulus cirratus	144
20	OPHIUROIDEA	Amphiura filiformis	135
20A	POLYCHAETA	Paradoneis lyra	1530
20A	POLYCHAETA	Scoloplos armiger	1150
20A	POLYCHAETA	Prionospio fallax	363
20A	BIVALVIA	Thyasira flexuosa/sarsi	190
20A	NEMERTINEA	Nemertinea indet	181
20A	POLYCHAETA	Caulleriella spp	169
20A	OPHIUROIDEA	Amphiura filiformis	161
20A	ECHINOIDEA	Echinocardium spp	123
20A	OLIGOCHAETA	Tubificoides spp	96
20A	POLYCHAETA	Scalibregma inflatum	75
22	OLIGOCHAETA	Tubificoides spp	7000
22	BIVALVIA	Mysella bidentata	1530
22	POLYCHAETA	Capitella capitata	977
22	BIVALVIA	Corbula gibba	49
22	POLYCHAETA	Malacoceros fuliginosus	47
22	POLYCHAETA	Cirriformia tentaculata	36
22	BIVALVIA	Abra alba	36
22	POLYCHAETA	Polydora/Pseudopolydora spp	36
22	ECHINOIDEA	Echinocardium spp	25
22	BIVALVIA	Macoma spp	23
BVY	POLYCHAETA	Capitella capitata	1673
BVY	BIVALVIA	Mytilus edulis	600
BVY	POLYCHAETA	Scoloplos armiger	498
BVY	BIVALVIA	Spisula elliptica	431
BVY	POLYCHAETA	Phyllodoce groenlandica	213
BVY	ECHINOIDEA	Echinocardium spp	104
BVY	BIVALVIA	Montacuta ferruginosa	64
BVY	BIVALVIA	Tellina tenuis	36
BVY	AMPHIPODA	Perioculodes longimanus	28
BVY	AMPHIPODA	Ampelisca brevicornis	24

(table 9 continued)

Station	Group	Species/taxon	Number
BVI	BIVALVIA	Spisula elliptica	57
BVI	POLYCHAETA	Capitella capitata	40
BVI	BIVALVIA	Cerastoderma edule	37
BVI	POLYCHAETA	Scoloplos armiger	29
BVI	BIVALVIA	Mysella bidentata	11
BVI	ECHINOIDEA	Echinocardium spp	7
BVI	BIVALVIA	Mytilus edulis	7
BVI	BIVALVIA	Modiolus spp	4
BVI	BIVALVIA	Cultellus pellucidus	2
BVI	AMPHIPODA	Ampelisca brevicornis	2

Station 20 showed diversity values indicating "Good" conditions (Class II on a scale from I to V, Class I being “Very Good”) (Molvær et al. 1997). The fauna was not dominated by distinctly pollution tolerant species (Rygg 1995). The abundance was very high, indicating a very large supply of nutrition. The faunal conditions were similar to earlier observations at the station.

Station 20A also showed diversity values indicating "Good" conditions (Class II). The fauna was not dominated by distinctly pollution tolerant species. The abundance was high, indicating a large supply of nutrition. The faunal conditions were similar to earlier observations at the station.

Station 22 (in Tananger harbour) showed very low diversity values and the fauna was distinctly dominated by very pollution-tolerant species (the oligochaetes *Tubificoides* spp, the bivalve *Mysella bidentata* and the polychaete *Capitella capitata*). The condition was classified as "Poor" (Class IV). The abundance was very high. The faunal conditions were similar to earlier observations at the station.

Station BRVIKA_Y in Brunnavika showed low diversity values and was dominated by the pollution-indicating species *Capitella capitata*. At station BRVIKA _I in the bay *Capitella* were not that dominating and the diversity values were somewhat higher. Brunnavika is very shallow and the fauna may not be directly comparable with the deeper stations. Using the same criteria for classification, the faunal conditions were classified as "Less Good" (Class III).

4. Conclusions

The concentrations of metals in surface sediment have generally decreased. Increased concentrations were only seen for mercury at station 20. For most metals the concentration level found in the sediments in 2000 were generally low (insignificantly to moderately polluted).

The concentrations of PAH in the sediment were generally low (insignificantly to moderately polluted). There seems to be higher PAH concentrations in the deeper part of Risavika (station 20A) than in the shallower area west of the refinery. The sediments in Brunnavika and east of Hestholmen (Naut S, Naut V, Naut N) were insignificantely polluted with benzo(a)pyrene. Markedly benzo(a)pyrene-polluted sediment was observed at station 20. Sediments from station 20A contained some heavy oil.

The increased concentrations of benzo(a)pyrene and mercury in sediments from station 20 may be caused by municipal discharge of sewage.

Metal concentrations in transplanted mussels were after 1 month of exposure in the refinery area generally low. The results indicate that mussels are more exposed to metals at the island Rott than in the vicinity of the refinery.

Following a 1 month exposure, the transplanted mussels were generally moderately polluted with PAH. The highest concentrations of PAH were found at Risa 1, Risa 3 and at Melingsholmen. The concentration of PAH at Risa 4, Naut S, Naut N did not indicate increased PAH loading in the Risavika area compared to the collection site at Rott.

The concentration of individual PAH components and ΣPAH in SPMDs indicat that there are somewhat more water accommodated PAH inside Risavika than on the western side of the refinery. A similar trend is also observed in mussels. The highest concentrations of PAH in SPMD`s were found at the reference site nearer Tananger harbour and not at the stations near the refinery.

The results from the studies of soft bottom macrofauna show low species diversity (H=1.5) in the Tananger harbour, probably caused by a combination of factors like disturbance, pollution and low oxygen level in the bottom water. A considerably higher diversity was found at the two stations (20, 20A) in Risavika (H=3.60, 3,68) and indicates better conditions in the bottom water for macrofauna than in Tananger Harbour. The diversity in Brunnarvika (H=2.7) was intermediate to Tananger harbour and Risavika. Since Brunnavika is very shallow the fauna may not be directly comparable with the deeper stations.

5. References

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Appendix A. Sediment sampling stations

PROJECT	NO	NAME
	500242	**Sola Refinery De-Construction Project** **Marine Investigations**

INVESTIGATION AREA

RISAVIKA, BRUNNAVIKA AND TANANGER HARBOUR

DATE	OPERATOR	WEATHER	SAMPLING EQUIPMENT
02.08.00	AFa	Nice, calm sea, 12 – 15 °C	0,1 m^2 van Veen grab

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
20			32V					
	LITHOLOGY / SAMPLE DESCRIPTION							
	Clay, silty, sandy. Dark gray to black. Pebbles.							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
20A			32V					
	LITHOLOGY / SAMPLE DESCRIPTION							
	Clay, silty, sandy. Dark gray to black. Pebbles.							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
22			32V					
	LITHOLOGY / SAMPLE DESCRIPTION							
	Clay, silty, sandy. Black spotted to dark gray. Artifacts. Distinct rotten smell (sulfuric).							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
NAUT_N	58 55 12	05 34 38	32V	6536187	302952	2,6	-	-
	LITHOLOGY / SAMPLE DESCRIPTION							
	Sand, medium to fine. Light gray with a thin olive green top layer. Green alga growth on surface. Fresh smell. Mussel station location							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
NAUT_V	058 55 04	05 34 34	32V	6535943	302875	1,5	-	-
	LITHOLOGY / SAMPLE DESCRIPTION							
	Sand, medium to coarse. Light gray with a thin olive green top layer. Green alga growth on surface. Fresh smell.							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
NAUT_S	058 55 02	05 34 47	32V	6535870	303080	4,5	-	-
	LITHOLOGY / SAMPLE DESCRIPTION							
	Sand, medium to fine. Light gray. Fresh smell. Mussel station location							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
BRVIKA_Y	058 54 47	05 35 06	32V	6535591	303360	4,5	-	-
	LITHOLOGY / SAMPLE DESCRIPTION							
	Sand, medium to fine. Light gray. Fresh smell							

STATION	POSITION (EUREF89)					SAMPLE INFORMATION		
	LAT	LONG	ZONE	UTM-N	UTM-E	DEPTH	C.LENGTH	INTERVAL
BRVIKA_I	058 54 46	05 35 09	32V	6535358	303406	1,2	-	-
	LITHOLOGY / SAMPLE DESCRIPTION							
	Sand, medium to fine. Light gray. Fresh smell							

Appendix B. Analytic methods (in Norwegian)

Analyser er foretatt gjennom SGAB Analytica. Torgeir Rødsand hos SGAB Analytica har administrert det analytiske arbeidet.

Nedenfor beskrives analysemetodene stikkordsmessig. For nærmere beskrivelse av metodene kontakt SGAB Analytica.

Metaller i sediment

Analysene er foretatt av SGAB Analytica etter pakke M-2.

Oppslutning er utført i mikrobølgeovn i lukket teflonbeholder med 1:1 ultraren salpetersyre og vann.

Metode for sluttbestemmelse av metallinnholdet og andre støtteparametere ses i tabellen under. Analyseprøvene for bestemmelse av metall er tørket ved 50^{o}C og elementinnholdet er tørrstoff-korrigert.

Parameter	**Metode**
As, Cd, Co, Cr, Cu, Hg, Ni, Pb,	Plasma-massespektrometri (Quadrupol)
Mn, Zn	Plasma-emissjonspektrometri
<63 µm fraksjon	Tørker prøven, Våtsikter så på 0,063, tørker det som ligger på sikten og veier ut.
Tørrstoff (TS)	Tørking ved 105 ^{o}C etter svensk standard (SS028113).

PAH i sediment
Analysene er foretatt av GBA, Gesellschaft für Bioanalytik Hamburg mbH som er akkreditert for analyser av det tyske akkrediteringsorganet DAC (registreringsnummer DAC-P-0040-97-01)

Prøveopparbeiding ble foretatt etter ISO 11464 og tørrvektbestemmelse etter DIN ISO 11465.

Bestemmelse og kvantifisering:

PAH (16 forbindelser eter EPA) på GC-MS.
Alifater (C5-C10) og flyktige aromatiske forbindelser (BTEXN) med headspace GC-MS basert på DIN 38407-F9.
Alifater (C10-C35) basert på ISO/TC190/3/6

For bestemmelse av PAH og alifater (C10-C35) ekstraheres prøven med aceton og heksan (cyclo- og n-) i et tilnærmet Soxhlet oppsett.

For bestemmelse av BTEXN og C5-C10 alifater analyseres med "head space" teknikk der prøven tilføres vann og varmes opp slik at flyktige forbindelser drives over i gassfasen over prøven.

Metaller i blåskjell

Analysene av biologisk materiale er utført av SGAB Analytica etter pakke M-4 +B. V og Mo

Oppslutning er utført i mikrobølgeovn i lukket teflonbeholder med konsentrert ultraren salpetersyre og hydrogenperoksyd.

Metode for sluttbestemmelse av metallinnholdet ses i tabellen under. Analyseprøvene for bestemmelse av metall er tørket ved 50^{o}C.

Parameter	**Metode**
As, Cd, Co, Cr, Cu, Hg, Ni, Pb, V, Mo	Plasma-massespektrometri (Sektor)
Zn, B	Plasma-emissjonspektrometri
Tørrstoff	Svensk standard (SS028113).

PAH i blåskjell

Analysene er foretatt av GBa lab i Tysklang Laboratoriet er akkreditert for PAH analyser av Deutche Akkrediterungs Rat (DAR) reg. Nr. DAC-P-0040-97-01. Fettbestemmelsen er ikke akkreditert.

Metode:10 – 20 g frisk prøve tørkes med natriumsulfat i en mikser og lagres i 24 timer i en Soxhlet-timble i en eksikator. Prøven Soxhlet ekstraheres (105 °C) med 70 ml n-heksan i en time . 10 % av ekstraktet veies inn og fordampes for å finne fettinnholdet. Fra dette beregnes mengde ekstrakt som må til for at det totale fettinnholdet i ekstraktet som analyseres ikke overstiger 250 mg. Denne mengden ekstrakt fordampes forsiktig ned til ca. 5 ml og renses deretter på 15 g aluminiumoksid aktivert med 6% H_2O og n-heksan. Kolonnen elueres med 200 ml n-heksan og eluatet inndampes forsiktig til 1 ml og analyseres på GC-MS.

Fettbestemmelsen utføres på en delprøve fra ekstraktet (10 %) som dampes inn slik at fettinnholdet kan bestemmes gravimetrisk.

Hydrokarboner i SPMD

SPMD membranene ekstraheres med n-Heksan. Ekstraktet membran-filtreres og renses på GPC med Cykloheksan/Etylacetat som mobil fase. Ekstraktet dampes så inn og overføres til n-Hexan. PAH og alifater bestemmes deretter på GC-MS.

Appendix C. Results from hydrocarbon analysis of sediments

From: SGAB Analytica, Hoffsveien 1, 0275 Oslo. Tlf. +47 22 52 51 75. Faks. +47 22 52 51 77. Email: sgab@sgab.no
To: Noteby as Ref: O. Bruskeland
[john.berge@niva.no]
Program: OJ-1
Ordernumber: N00096

Forbindelse	Måleenhet	Stasjon				
		20A	Naut S	Naut V	Naut N	BRVIKA i + y
tørrstoff (TS)	%	49,5	76,5	77,8	71,9	77,9
acenaften	mg/kgTS	<0,050	<0,050	<0,050	<0,050	<0,050
acenaftylen	mg/kgTS	<0,050	<0,050	<0,050	<0,050	<0,050
alifater >C5-C8	mg/kgTS	<10	<10	<10	<10	<10
alifater >C8-C10	mg/kgTS	<10	<10	<10	<10	<10
antracen	mg/kgTS	<0,010	<0,010	<0,010	<0,010	<0,010
bens(a)antracen	mg/kgTS	0,065	<0,010	<0,010	<0,010	<0,010
bens(a)pyren	mg/kgTS	0,057	<0,010	<0,010	<0,010	<0,010
bens(b)fluoranten	mg/kgTS	0,075	<0,010	<0,010	<0,010	<0,010
bens(k)fluoranten	mg/kgTS	<0,050	<0,010	<0,010	<0,010	<0,010
bensen	mg/kgTS	<0,025	<0,025	<0,025	<0,025	<0,25
benso(ghi)perylen	mg/kgTS	0,089	<0,010	<0,030	<0,030	<0,030
dibens(ah)antracen	mg/kgTS	<0,030	<0,010	<0,030	<0,030	<0,030
etylbensen	mg/kgTS	<0,025	<0,025	<0,025	<0,025	<0,25
fenantren	mg/kgTS	<0,050	<0,050	0,095	0,095	<0,050
fluoranten	mg/kgTS	0,15	<0,010	<0,010	0,12	<0,010
fluoren	mg/kgTS	<0,050	<0,050	<0,050	<0,050	<0,050
fraktion C10-C12	mg/kgTS	<20	<20	<20	<20	<20
fraktion C12-C16	mg/kgTS	<20	<20	<20	<20	<20
fraktion C16-C35	mg/kgTS	283	<50	<50	<50	<50
indeno(123cd)pyren	mg/kgTS	0,081	<0,010	<0,030	<0,030	<0,030
krysen	mg/kgTS	0,075	<0,010	<0,010	<0,010	<0,010
naftalen	mg/kgTS	<0,050	<0,050	<0,050	<0,050	<0,050
pyren	mg/kgTS	0,13	<0,010	<0,010	0,099	<0,010
Sum 16 EPA-PAH	mg/kgTS	0,72	<0,21	<0,21	0,314	<0,21
toluen	mg/kgTS	<0,025	<0,025	<0,025	<0,025	<0,25
xylen	mg/kgTS	<0,025	<0,025	<0,025	<0,025	<0,25

Appendix D. Results from PAH analysis of mussels

From: SGAB Analytica, Hoffsveien 1, 0275 Oslo. Tlf. +47 22 52 51 75. Faks. +47 22 52 51 77.
Email: sgab@sgab.no
To: Noteby Ålesund Ref: Arne Fagerhaug
[john.berge@niva.no]
Program: OB1-FV
Ordernumber: N00124
Report created: 2000-10-03 by
TORGEIR

		Stasjon						
Forbindelse	**Måleenhet**	Naut S	Naut N	Risa 1	Ref,	Risa 3	Risa 4	Rott (start)
fettinnhold	%	2,93	1,86	2,52	2,79	2,50	1,99	1,52
acenaftylen	mg/kg w.w.	<0,001	<0,001	0,0012	0,0019	0,0015	<0,001	<0,001
acenanften	mg/kg w.w.	<0,001	<0,001	0,0014	0,0011	0,001	<0,001	<0,001
antracen	mg/kg w.w.	<0,001	<0,001	<0,001	0,0027	<0,001	0,0013	<0,001
bens(a)antracen	mg/kg w.w.	0,0012	0,0034	0,0071	0,0018	0,0066	0,0036	<0,001
bens(b)fluoranten	mg/kg w.w.	0,0035	0,0015	<0,003	<0,003	<0,003	<0,003	0,0018
bens(k)fluoranten	mg/kg w.w.	<0,001	<0,001	<0,003	<0,003	<0,003	<0,003	<0,001
benso(a)pyren	mg/kg w.w.	0,0032	0,0012	0,0044	0,0024	0,0052	0,0022	0,0016
benso(ghi)perylen	mg/kg w.w.	<0,001	<0,001	<0,003	<0,003	<0,003	<0,003	<0,001
dibenso(ah)antrasen	mg/kg w.w.	<0,001	<0,001	<0,003	<0,003	<0,003	<0,003	<0,001
fenantren	mg/kg w.w.	0,022	0,011	0,027	0,029	0,023	0,016	0,022
fluoranten	mg/kg w.w.	0,013	0,0074	0,025	0,025	0,023	0,013	0,014
fluoren	mg/kg w.w.	0,0025	0,0013	0,0057	0,0062	0,0041	0,0025	0,0018
Indeno(123,cd)pyren	mg/kg w.w.	<0,001	<0,001	<0,003	<0,003	<0,003	<0,003	<0,001
krysen	mg/kg w.w.	0,0031	0,0023	0,020	0,0066	0,020	0,010	0,0037
naftalen	mg/kg w.w.	0,0045	0,0025	0,0029	0,0034	0,0055	0,0034	0,0031
pyren	mg/kg w.w.	0,0064	0,0041	0,027	0,017	0,025	0,013	0,0074
Sum 16 PAH	mg/kg w.w.	0,0594	0,0347	0,1217	0,0971	0,1149	0,065	0,0554

Appendix E. Results from analysis of SPMDs

.
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To: Noteby Ålesund Ref: Arne Fagerhaug [john.berge@niva.no]
Program: OB-1TS
Ordernumber: N00125
Report created: 2000-10-24 by TORGEIR

Please note that results are given in ng or µg per SPMD device

		Stasjon				
Forbindelse	**Måleenhet**	Naut S	Naut N	Risav 1	Ref	Luftkontroll (1/8-00)
Acenaften	ng	<40	<30	46	<30	<30
Acenaftylen	ng.	<40	<30	41	47	<30
Antracen	ng.	<40	<30	70	100	<30
Benzo(a)antracen	ng.	<40	<30	82	53	<30
Benzo(a)pyren	ng.	<40	<30	<30	<30	<30
Benzo(b)fluoranten	ng.	<40	<30	<30	<30	<30
Benzo(ghi)perylen	ng.	<40	<30	<30	<30	<30
Benzo(k)fluoranten	ng.	<40	<30	<30	<30	<30
Dibenzo(ah)antracen	ng.	<40	<30	<30	<30	<30
Fenantren	ng.	<60	110	310	810	<30
Fluoranten	ng.	<60	170	400	580	<30
Fluoren	ng.	<40	31	300	380	1100
Indeno(123,cd)pyren	ng.	<40	<30	<30	<30	<30
Krysen	ng.	<40	<30	86	110	<30
Naftalen	ng.	<40	<30	120	85	53
Pyren	ng.	<40	37	170	290	<30
Sum PAH 16	ng.	<680	348	1625	2455	1153
Olje >C11 - C20	µg	<100	47	180	190	490

Appendix F. Identified species of soft bottom macrofauna

Species/taxa and number of individuals in grab samples in Risavika and Brunnvika, 2. August 2000

GROUP	FAMILY	SPECIES/TAXON	20G1	20G2	20G3	20G4	20G5	20AG1	20AG2	20AG3	20AG4	20AG5	22G1	22G2	22G3	22G4	22G5	BVYG1	BVYG2	BVYG3	BVIG1
ANTHOZOA		Anthozoa indet			1		1		2	9		1									
ANTHOZOA	Cerianthidae	Cerianthus lloydi	2		2		2		1	3		1									
ANTHOZOA	Edwardsiidae	Edwardsiidae indet	11	5	2	4	5	5	16	13	3	12					1				
PLATYHELMINTHES		Platyhelminthes indet	3	2		5	2	1	2	3	4	2									
NEMERTINEA		Nemertinea indet	56	52	55	73	105	28	39	30	53	31	3	1	2			5		1	
POLYCHAETA	Amphinomidae	Paramphinome jeffreysii	2	1		3		3	4	6	20	7									
POLYCHAETA	Polynoidae	Harmothoe sp	1	1					1					1			3				
POLYCHAETA	Sigalionidae	Pholoe minuta	1	1			2	2	4	1	4	6									
POLYCHAETA	Phyllodocidae	Eteone lactea						1													
POLYCHAETA	Phyllodocidae	Eteone sp				1	1				3		1	2	1		9	5	3	6	
POLYCHAETA	Phyllodocidae	Phyllodoce groenlandica						1	1		1	1			3	1	5	79	53	81	1
POLYCHAETA	Phyllodocidae	Phyllodoce sp							1												
POLYCHAETA	Phyllodocidae	Phyllodocidae indet							1					1			1			1	
POLYCHAETA	Hesionidae	Kefersteinia cirrata													4						
POLYCHAETA	Hesionidae	Nereimyra punctata													2						
POLYCHAETA	Hesionidae	Ophiodromus flexuosus	1		1		2		3	1		1									
POLYCHAETA	Syllidae	Exogone sp	5	3	3		13	9	8	4	15	9							2		
POLYCHAETA	Syllidae	Typosyllis cornuta			3	1		3	4	7	28	7									
POLYCHAETA	Nereidae	Nereis sp															2	1		3	
POLYCHAETA	Nephtyidae	Nephtys hombergii																	1		
POLYCHAETA	Nephtyidae	Nephtys pente															1				
POLYCHAETA	Sphaerodoridae	Sphaerodoridium fauchaldi	1						3	1	2	2									
POLYCHAETA	Sphaerodoridae	Sphaerodorum flavum								1		1									
POLYCHAETA	Glyceridae	Glycera alba		1			2	6	6	6		11					2				
POLYCHAETA	Glyceridae	Glycera sp									1										
POLYCHAETA	Goniadidae	Goniada maculata	1	1	2		1	6	5	6	3	7									
POLYCHAETA	Lumbrineridae	Lumbrineris sp	3	1			3						1								
POLYCHAETA	Dorvilleidae	Dorvilleidae indet									1										

(Appendix F continued)

GROUP	FAMILY	SPECIES/TAXON	20G1	20G2	20G3	20G4	20G5	20AG1	20AG2	20AG3	20AG4	20AG5	22G1	22G2	22G3	22G4	22G5	BVYG1	BVYG2	BVYG3	BVIG1
POLYCHAETA	Orbiniidae	Scoloplos armiger	188	208	164	169	269	276	234	103	362	175	2				10	156	208	134	29
POLYCHAETA	Apistobranchidae	Apistobranchus tullbergi	11	6	6	14	15		2	6	15	2									
POLYCHAETA	Paraonidae	Paradoneis lyra	416	316	330	385	333	97	243	235	719	236									
POLYCHAETA	Paraonidae	Paraonis gracilis	1	7	8	2	1		1	9	22										
POLYCHAETA	Spionidae	Malacoceros fuliginosus											4	14	1	21	7				
POLYCHAETA	Spionidae	Polydora cf.caulleryi	1																		
POLYCHAETA	Spionidae	Polydora sp															34			1	
POLYCHAETA	Spionidae	Prionospio cirrifera	1					5	2	3	3										
POLYCHAETA	Spionidae	Prionospio fallax	55	69	66	54	52	36	93	47	79	108	1	1			1				1
POLYCHAETA	Spionidae	Prionospio ockelmanni	2						1		2										
POLYCHAETA	Spionidae	Pseudopolydora pulchra												2							
POLYCHAETA	Spionidae	Pseudopolydora sp						2													
POLYCHAETA	Spionidae	Scolelepis sp							1	5	2	3									1
POLYCHAETA	Spionidae	Spio filicornis																	6		1
POLYCHAETA	Spionidae	Spio sp																2		3	
POLYCHAETA	Spionidae	Spiophanes bombyx																8	1	3	
POLYCHAETA	Spionidae	Spiophanes kroeyeri							1												
POLYCHAETA	Magelonidae	Magelona mirabilis	1		2	1	3				1							4	6	4	1
POLYCHAETA	Cirratulidae	Caulleriella sp	365	5	63	155	25	99	32	16	7	15	1								
POLYCHAETA	Cirratulidae	Chaetozone setosa	168	81	121	238	93	20	4	5	5	8					7			2	
POLYCHAETA	Cirratulidae	Chaetozone sp												1							
POLYCHAETA	Cirratulidae	Cirratulus cirratus	23	26	31	40	24														
POLYCHAETA	Cirratulidae	Cirriformia tentaculata													20		16				
POLYCHAETA	Cirratulidae	Macrochaeta sp											1								
POLYCHAETA	Cirratulidae	Tharyx sp											1								
POLYCHAETA	Cirratulidae	Tharyx/Caulleriella sp		120	426	456	354														
POLYCHAETA	Flabelligeridae	Brada sp										1									
POLYCHAETA	Flabelligeridae	Brada villosa							1												
POLYCHAETA	Flabelligeridae	Diplocirrus glaucus					1														

(Appendix F continued)

GROUP	FAMILY	SPECIES/TAXON	20G1	20G2	20G3	20G4	20G5	20AG1	20AG2	20AG3	20AG4	20AG5	22G1	22G2	22G3	22G4	22G5	BVYG1	BVYG2	BVYG3	BVIG1
POLYCHAETA	Scalibregmidae	Scalibregma inflatum	9	11	31	25	20	22	17	3	24	9									
POLYCHAETA	Capitellidae	Capitella capitata	1										316	247	14	338	62	935	226	512	40
POLYCHAETA	Capitellidae	Heteromastus filiformis															13				
POLYCHAETA	Capitellidae	Mediomastus sp	1	2	1	3	2				5	3									
POLYCHAETA	Capitellidae	Notomastus latericeus	3	1	5	2	5				3						1				
POLYCHAETA	Maldanidae	Maldane sarsi							1			1									
POLYCHAETA	Maldanidae	Rhodine gracilior							1												
POLYCHAETA	Oweniidae	Myriochele oculata				1		2		3		2					5	1			
POLYCHAETA	Oweniidae	Owenia fusiformis						1												1	
POLYCHAETA	Pectinariidae	Pectinaria koreni												3			1				
POLYCHAETA	Pectinariidae	Pectinaria sp										1									
POLYCHAETA	Ampharetidae	Ampharete sp		2	1	1	1		1	5	2	3									
POLYCHAETA	Ampharetidae	Anobothrus gracilis						3	1	2											
POLYCHAETA	Ampharetidae	Mugga wahrbergi									2										
POLYCHAETA	Ampharetidae	Sabellides octocirrata		3	3	1	4		1	10	11	2	1								
POLYCHAETA	Ampharetidae	Sosane sulcata								1											
POLYCHAETA	Terebellidae	Polycirrus plumosus						1	1	1											
POLYCHAETA	Trichobranchidae	Terebellides stroemi								1											
POLYCHAETA	Sabellidae	Sabellidae indet	10	7	2	7	12	8	5	4	14	11					2				
OLIGOCHAETA		Oligochaeta indet	10	1	45	53	47	45	16	5		30	2	2500	500	2500	1500	1	2	2	
PROSOBRANCHIA		Prosobranchia indet								1										1	
PROSOBRANCHIA	Lacunidae	Lacuna vincta																		10	1
PROSOBRANCHIA	Naticidae	Lunatia alderi									2				1			2	2	1	
PROSOBRANCHIA	Epitoniidae	Clathrus clathrus										1									
OPISTOBRANCHIA		Tectibranchia indet	1						1												
OPISTOBRANCHIA	Diaphanidae	Diaphana minuta								2											
OPISTOBRANCHIA	Retusidae	Retusa obtusa															1				
OPISTOBRANCHIA	Philinidae	Philine quadrata	8	6	9	2	5	3	1	4	6										
OPISTOBRANCHIA	Philinidae	Philine scabra	1	1		5	2	7	4	2	1	1									

(Appendix F continued)

GROUP	FAMILY	SPECIES/TAXON	20G1	20G2	20G3	20G4	20G5	20AG1	20AG2	20AG3	20AG4	20AG5	22G1	22G2	22G3	22G4	22G5	BVYG1	BVYG2	BVYG3	BVIG1
OPISTOBRANCHIA	Scaphandridae	Cylichna alba	4				2			1											
CAUDOFOVEATA		Caudofoveata indet						1													
BIVALVIA		Bivalvia indet											1							1	
BIVALVIA	Mytilidae	Modiolus modiolus															2				
BIVALVIA	Mytilidae	Modiolus sp				1						1	2	1	13	1					4
BIVALVIA	Mytilidae	Mytilus edulis												1				95	5	500	7
BIVALVIA	Lucinidae	Lucinoma borealis							2		1										
BIVALVIA	Thyasiridae	Thyasira cf.sarsi				4															
BIVALVIA	Thyasiridae	Thyasira flexuosa	42	37	43	75	41	21	43	32	45	39									
BIVALVIA	Thyasiridae	Thyasira sarsi						4			6						19				
BIVALVIA	Lasaeidae	Montacuta ferruginosa																	64		
BIVALVIA	Lasaeidae	Mysella bidentata		1					1		2	1	402	767	109	38	214	7	3	7	11
BIVALVIA	Cardiidae	Acanthocardia echinata							1	1		2									
BIVALVIA	Cardiidae	Cerastoderma edule																	2		37
BIVALVIA	Mactridae	Spisula elliptica					1			1								60	303	68	57
BIVALVIA	Solenidae	Cultellus pellucidus															8				2
BIVALVIA	Tellinidae	Macoma sp											4	14			5	1	5		1
BIVALVIA	Tellinidae	Tellina tenuis																14	18	4	
BIVALVIA	Scrobiculariidae	Abra alba											5	10	17	4					
BIVALVIA	Scrobiculariidae	Abra longicallus															1				
BIVALVIA	Scrobiculariidae	Abra nitida	2	5	4	1	4	1		1	3	5									
BIVALVIA	Arcticidae	Arctica islandica								1								1			
BIVALVIA	Veneridae	Dosinia lupinus	3	2	5		5	2	5	1	9	6									
BIVALVIA	Veneridae	Venerupis pullastra															1				
BIVALVIA	Veneridae	Venus striatula	5	8	11	1	6	1	2	6	16	1					7	2			1
BIVALVIA	Petricolidae	Mysia undata	1	1	2		1		1	2	2	3									
BIVALVIA	Myidae	Mya arenaria								1		1	1	8			4	3	3	4	2
BIVALVIA	Corbulidae	Corbula gibba	9	7	6	7	13	4	2	12	12	4	2	8	1		38	1			
BIVALVIA	Hiatellidae	Hiatella arctica										1	1		5		1				

(Appendix F continued)

GROUP	FAMILY	SPECIES/TAXON	20G1	20G2	20G3	20G4	20G5	20AG1	20AG2	20AG3	20AG4	20AG5	22G1	22G2	22G3	22G4	22G5	BVYG1	BVYG2	BVYG3	BVIG1
BIVALVIA	Thraciidae	Thracia sp							1												
CIRRIPEDIA		Balanus sp												2							
CUMACEA	Bodotriidae	Cuma edwardsii					1			1											
CUMACEA	Bodotriidae	Iphinoe trispinosa																1	1	1	
CUMACEA	Nannastacidae	Campylaspis rubicunda				1															
CUMACEA	Diastylidae	Diastylis echinata															2				
CUMACEA	Diastylidae	Diastylis rostrata		2	1	5	5	4			1										
CUMACEA	Diastylidae	Diastylis sp	6						1	2		1									
TANAIDACEA		Tanaidacea indet				1															
ISOPODA	Idoteidae	Idotea baltica																1		1	
ISOPODA	Idoteidae	Idotea emarginata																1			
ISOPODA	Idoteidae	Idothea sp						1													
AMPHIPODA	Lysianassidae	Acidostoma obesum				1															
AMPHIPODA	Lysianassidae	Tryphosites longipes				3		1													
AMPHIPODA	Ampeliscidae	Ampelisca brevicornis																2	13	9	2
AMPHIPODA	Gammaridae	Gammarus locusta																1		1	
AMPHIPODA	Haustoriidae	Bathyporeia sp																	1		1
AMPHIPODA	Oedicerotidae	Perioculodes longimanus																5	6	17	2
AMPHIPODA	Oedicerotidae	Westwoodilla caecula				1		1													
AMPHIPODA	Calliopiidae	Apherusa bispinosa																		1	
AMPHIPODA	Atylidae	Atylus swammerdami																		3	
AMPHIPODA	Dexaminiidae	Dexamine spinosa					1								2					2	
AMPHIPODA	Isaeidae	Microprotopus maculatus																		4	1
AMPHIPODA	Corophiidae	Corophium sp															1				
AMPHIPODA	Ischyroceridae	Ericthonius sp																		1	
DECAPODA		Decapoda indet					1			1								2		3	
DECAPODA	Crangonidae	Philocheras bispinosus	1																		
DECAPODA	Paguridae	Pagurus bernhardus				1															2
DECAPODA	Paguridae	Pagurus sp						1													

(Appendix F continued)

GROUP	FAMILY	SPECIES/TAXON	20G1	20G2	20G3	20G4	20G5	20AG1	20AG2	20AG3	20AG4	20AG5	22G1	22G2	22G3	22G4	22G5	BVYG1	BVYG2	BVYG3	BVIG1
DECAPODA	Portunidae	Macropipus pusillus	1			1														1	
CHIRONOMIDAE		Chironomidae indet													1						
SIPUNCULIDA		Phascolion strombi		2				1	1												
PRIAPULIDA		Priapulus caudatus	10	4	7	3	9	4	1	4	7	1			1						
ASTEROIDEA		Asteroidea indet	2	2	2	5	3	1	1	3	2			1			2				
ASTEROIDEA	Astropectinidae	Astropecten irregularis	1																		
OPHIUROIDEA	Amphiuridae	Amphiura chiajei										1									
OPHIUROIDEA	Amphiuridae	Amphiura filiformis	10	20	13	69	23	23	26	59	10	43					1				
OPHIUROIDEA	Ophiuridae	Ophiura sp			1			1												1	
ECHINOIDEA	Loveniidae	Echinocardium cordatum										3						1	21		
ECHINOIDEA	Loveniidae	Echinocardium flavescens						1	3	6		2									
ECHINOIDEA	Loveniidae	Echinocardium sp	3	2		38		41	19	31	2	15					25	28		54	7
HOLOTHUROIDEA	Synaptidae	Labidoplax buski		4		10	3	5	4	4	1	12									
ASCIDIACEA		Ascidiacea indet													2						
VARIA		Ubestemt indet									1	2						1			1
VARIA		Vermiformis indet		5	6	1	1	4	2	10	1	1									
		Artstall	48	43	38	46	49	48	59	58	51	55	20	20	19	7	38	31	24	37	24
		Individtall	1463	1042	1484	1930	1527	815	882	744	1546	856	752	3585	699	2903	2015	1426	955	1449	213