

Shipboard Report

RESIN project (Restoration of Estuarine Systems in the Netherlands) HV-B cruise to the Haringvliet with R.V. Navicula

17-21 September, 2002 (HV-B)



prepared by:

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Abstract

The research cruise HV-B in the Haringvliet from September 17-21, 2002, was the second cruise of the RESIN project. RESIN is a joint project of RIZA and Utrecht University to examine the response of trace metal and nutrient (N, P) cycling in freshwater sediments to progressive salinization (RESIN; Restoration of estuarine systems in the Netherlands: response of biogeochemical processes). The RESIN project runs from 2001-2005 and includes field studies in the Haringvliet (the first cruise HV-A was conducted from November 12-16, 2001), laboratory experiments and modeling studies. Prior to the construction of the Haringvliet dam, which was built as part of the Delta Works, the Haringvliet was one of the estuarine outlets of the Meuse-Rhine River. Since 1970, the Haringvliet has been isolated from the North Sea and has become a freshwater lake. Estuarine conditions will be restored, beginning in 2005 by partial opening of the Haringvliet dam. The goal of the cruises is to obtain information about existing conditions of trace metal and nutrient cycling in the sediments and collect material for experimentation. Three study sites were sampled during the first cruise; these sites were sampled again during this cruise. Initial results are consistent with results from HV-A. They also show the influence of the warmer site temperatures during HV-B.

1 Introduction

This report will describe the work conducted on board the R.V. Navicula during the HV-B cruise to the Haringvliet. Information about the project and the study site is presented to demonstrate the relevance of the work. This report includes text from the HV-A shipboard report prepared by Caroline Slomp. Descriptions of methods and preliminary results have been provided by the participating scientists. All data presented in the report are preliminary and subject to revision.

1.1 Project Background

The HV-B cruise to the Haringvliet, is part of a joint project of the Institute for Inland Water Management and Wastewater Treatment (RIZA) and Utrecht University (UU) on trace metal and nutrient cycles in freshwater sediments and their response to progressive salinization (RESIN; Restoration of estuarine systems in the Netherlands: response of biogeochemical processes). This research runs from 2001-2005 and includes field studies, laboratory experiments and modeling studies. The first research cruise, HV-A, took place from November 12-16, 2001.

1.2 Site History & Existing Conditions

As part of the implementation of the Dutch Delta Project, the Haringvliet estuary (Fig. 1), a major outlet of the Meuse and Rhine Rivers, was closed by sluices in 1970. Consequently, the Haringvliet changed from a tidal estuary to a semi-stagnant freshwater lake. The estuarine ecosystem consisted of a brackish and freshwater tidal system with characteristic gradients in flora and fauna. Both marine and fluvial material accumulated in the intertidal areas (Smit et al., 1997). Closure of the Haringvliet resulted in physical and chemical changes to the waterbody including: decreased tidal amplitude, decreased water velocity, decreased salinity, and increased sedimentation. The changes in physical-chemical conditions brought about by closure, in-turn brought about ecological changes as flora and fauna responded to the new environment (Ferguson and Wolf, 1984).

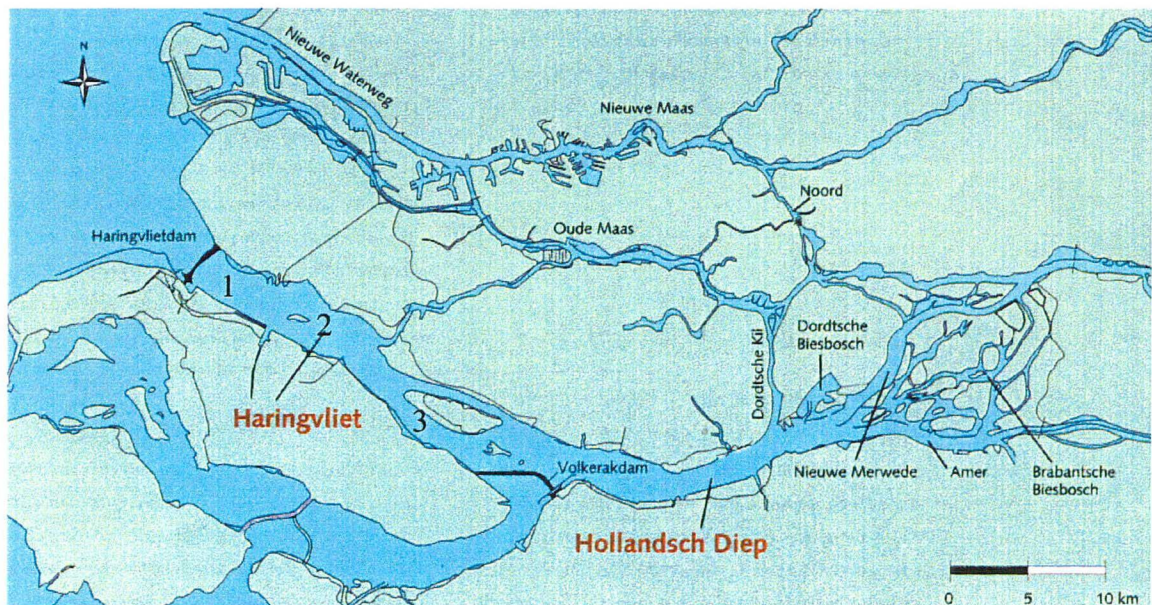


Figure 1. Site locus map, the numbers indicate the locations of the study sites

The ecological changes which have occurred after the closure of the Haringvliet have reduced the system's ecological value. Current Dutch environmental policy aims at the development of a broad range of tidal systems with a high ecological diversity. Within the framework of this policy, restoration of estuarine conditions is now planned for three coastal areas: the Haringvliet, the Eastern Scheldt and Lake IJssel (Environmental Impact Assessment (EIA) on the Management of the Haringvliet Sluices, 1998).

The Haringvliet sediments now contain high concentrations of nutrients and trace metals, such as Zn, Cu, Cr, Pb, Cd and Ni (Ferguson and Wolf, 1984; Smit et al., 1997; Wijdeveld, 1999, HV-A Cruise Report, 2001). The average thickness of this contaminated, fine-grained surface layer increases from ca. 10 cm in the western part of the Haringvliet to more than 2 m in the eastern part of the Hollandsch Diep (Venema et al., 2000).

1.3 Restoration

Estuarine conditions in the Haringvliet will be restored by implementation of an alternative management of the Haringvliet sluices (shown on the cover photo), which will start in 2005. Between 2005 and 2010, the sluices will be opened slightly to allow for an initial assessment of hydrologic and ecological responses to salinity. From 2010 onwards, the sluices will be opened more frequently to result in a salinity gradient which extends up to 30 km inland from the dam. The increased salinity is expected to have a profound impact on biogeochemical processes in the sediments and water column.

1.4 Research

We hypothesize that progressive salinization in the Haringvliet may cause an initial enhanced release of nutrients and trace metals from the sediments and suspended matter. Release of trace metals has been observed in mesocosm incubations of Haringvliet sediment with water of increasing salinity, likely as the result of ion exchange reactions (Wijdeveld, 1999). If this release occurs in the field, it could have detrimental effects on the water quality in the Haringvliet and the adjacent coastal zone. The initial, salinity-driven, remobilization of metals and nutrients may be counteracted by additional biogeochemical processes. These may include microbial processes such as nitrification, or chemical reactions, such as iron sulfide precipitation.

The restoration will change the physical and chemical conditions in the sediments. It is difficult to predict the magnitude of possible metal or nutrient release because many interrelated chemical and biological processes control the mobility of the elements. To determine the impact of estuary restoration on microbiological and abiotic processes in sediments, this research includes:

- a detailed biogeochemical field study to determine the existing conditions of metal and nutrient cycling in fine grained sediments in the Haringvliet,
- experiments to study the chemical and biological responses to increase salinity,
- reactive transport modeling to help determine which parameters are the most important in controlling sediment-water column exchanges of metals and nutrients.

1.5 Goals

The major objectives of the research proposed for 2001-2005 are to:

- Characterize the present-day cycles of nutrients and trace metals in the sediments of the Haringvliet.
- Identify and quantify the expected effects of progressive salinization and changes in redox conditions on the cycles of phosphorus, nitrogen and trace metals in Haringvliet sediments and their release to the water column.
- Identify the key biogeochemical processes and parameters, in order to create the scientific basis for monitoring plans of the Haringvliet dam after 2005.

2 Research Cruise

This section will describe what occurred during the cruise, including who participated (Table 1), a schedule of events (Table 2), and a summary of the coring (Table 3).

2.1 Participants

Table 1. Participants, dates on-board R.V. Navicula, and main tasks

Name	Dates	Main tasks
Richard Canavan	17-21	Co-chief scientist, DGT-DET
Helen de Waard	17-21	Co-chief scientist, directing coring procedures
Anniët Laverman	18-21	denitrification: reactors, profiling, MPNs
Ralf Haese	17-20	microelectrodes: metal profiles & trace metals
Yvonne van Lith	17-19	sulfate reduction
Christelle Hyacinthe	17-20	anoxic core sectioning, alkalinity
Celine Pallud	17-20	reactor collection
Jacqueline Claessens	17-20	Chl-a extractions
Debby Los	18, 19, 20	carbon mineralization
Pieter Kleingeld	17, 18	technical assistance, sediment temperature
Gerard v/d Berg (RIZA)	19	assistance with anoxic sediment sampling
Ronald Struyk (RIZA)	19	assistance with coring

Additionally the following people provided assistance for this research cruise.

- The Captain of R.V. Navicula, Kees van der Star, and his crew Tony van der Vis and Johan Tuntelder, provided excellent conditions and collected the boxcores. Congratulations to Johan on his retirement.
- Caroline Slomp, chief scientist for the first (HV-A) cruise, helped with the planning and organization of this cruise including contacts with NIOZ.
- Ron Baarends and Christof Miele helped with the transfer of materials and staff between Utrecht University and R.V. Navicula.
- Philippe Van Cappellen (UU) and Gertjan Zwolsman (RIZA) provided useful feedback on the proposed sampling scheme.
- Dineke van de Meent changed her schedule to allow for the rapid analysis of samples after our return to Utrecht.



Figure 2. Participants and crew at Dordrecht on Friday afternoon

2.2 Schedule

Table 2. Schedule of events, September 16-21

Date	Location, Activity
Monday 16	Navicula travels from Texel to Amsterdam. Supplies and equipment packed for transport at Utrecht
Tuesday 17	Materials and staff brought to R.V. Navicula at zuidersluice Utrecht. Laboratory set up, evening in Dordrecht
Wednesday 18	Site 3, South of Tiengemetten, evening in Middelharnis
Thursday 19	Site 1, near the Haringvlietsluizen, evening in Middelharnis
Friday 20	Site 2, Slijkplaat, evening in Dordrecht
Saturday 21	Transit from Dordrecht to Beatrixsluizen, return of material and equipment to Utrecht

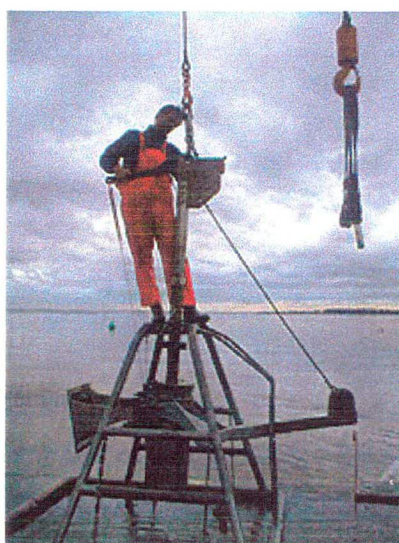


Figure 3 Tony prepares the box corer

2.3 Boxcore summary

Table 3. Summary of box cores: Haringvliet cruise September 17 – 21, 2002, RV Navicula (HV-B)

Core code	Site	Date	Time	Latitude (N)	Longitude (E)	water depth (m)	Measurements/subcores	Main responsible
BW1	3	18/09/02	10:50	51.53.428	04.17.469	8.8	Bottomwater collection	Rick
BC2	3	18/09/02	11:10	51.53.427	04.17.508	8.6	Sediment & Porewater collection, O ₂ -Winkler, O ₂ -profile	Helen, Anniet
BC3	3	18/09/02	11:59	51.53.425	04.17.503	7.7	Trace-metal-porewater, O ₂ -Winkler, Br-core incubations,	Ralf, Helen, Debby
BC4	3	18/09/02	12:07	51.53.424	04.17.500	7.7	Denitrification, Sulfate reduction	Annet, Yvonne
BC5	3	18/09/02	13:15	51.53.429	04.17.504	8.1	Porosity, MPN	Annet
BC6	3	18/09/02	13:23	51.53.430	04.17.505	7.8	DET/DGT	Rick
BC7	3	18/09/02	12:32	51.53.428	04.17.506	7.4	Chlorophyll-a, Vial Incubations, Storage	Rick, Debby
BC8	3	18/09/02	12:40	51.53.426	04.17.510	7.6	Shuttlecore storage	Celine
BC9	3	18/09/02	12:49	51.53.424	04.17.504	7.7	Shuttlecore storage	Celine
BC10	3	18/09/02	13:00	51.53.426	04.17.502	7.7	Spare boxcore (not used)	Helen
BW1	1	19/09/02	9:08	51.50.091	04.04.339	7.4	Bottomwater collection	Rick
BC2	1	19/09/02	9:12	51.50.089	04.04.347	7.3	Sediment & Porewater collection, O ₂ -Winkler, O ₂ -profile	Helen, Anniet
BC3	1	19/09/02	9:21	51.50.091	04.04.343	7.4	Trace-metal-porewater, Br-core incubations	Ralf, Jacqueline
BC4	1	19/09/02	9:27	51.50.088	04.04.342	7.4	Denitrification, Sulfate reduction	Annet, Yvonne
BC5	1	19/09/02	9:36	51.50.085	04.04.339	7.3	Porosity	Annet
BC6	1	19/09/02	9:45	51.50.088	04.04.340	7.3	DET/DGT, O ₂ -Winkler	Rick, Helen
BC7	1	19/09/02	9:53	51.50.086	04.04.333	7.2	MPN	Annet
BC8	1	19/09/02	10:01	51.50.090	04.04.342	7.3	Chlorophyll-a, Vial Incubations, Storage	Rick, Yvonne
BC9	1	19/09/02	10:08	51.50.087	04.04.338	7.2	Shuttle core storage	Celine
BC10	1	19/09/02	10:15	51.50.087	04.04.341	7.2	Shuttle core MPN	Annet
BW1	2	20/09/02	8:35	51.48.242	04.097.780	6.4	Bottomwater collection	Helen
BC2	2	20/09/02	8:40	Not noted			O ₂ Winkler	Helen

Table 3. Summary of box cores: Haringvliet cruise September 17 – 21, 2002, RV Navicula (HV-B)

Core code	Site	Date	Time	Latitude (N)	Longitude (E)	water depth (m)	Measurements/subcores	Main responsible
BC3	2	20/09/02	8:44	51.48.236	04.097.782	6.4	Sediment & Porewater collection, O ₂ -profile, Trace Metals	Helen, Anniet, Ralf
BC4	2	20/09/02	8:50	51.48.238	04.097.779	6:4	Storage	Helen
BC5	2	20/09/02	8:55	51.48.237	04.097.784	6.4	Br-core incubation, Denitrification	Jacqueline, Celine
BC6	2	20/09/02	9:03	51.48.241	04.097.777	6.4	Porosity, MPN, Sulfate reduction	Celine
BC7	2	20/09/02	9:11	51.48.239	04.097.778	6.4	DET/DGT	Rick
BC8	2	20/09/02	9:20	51.48.238	04.097.780	6.4	Chlorophyll-a, Vial Incubations, Storage	Rick, Jacqueline
BC9	2	20/09/02	9:28	51.48.237	04.097.782	6.4	Shuttle core storage	Celine
BC10	2	20/09/02	9:35	Not noted		6.4	Spare boxcore: additional shuttle core, vial incubation	Annet, Rick

Note: Additional details about the box coring and subcoring are provided in the appendix.

3 Methods & Preliminary Results

This section will provide descriptions of the shipboard methods conducted for sample collection, analysis, and experimentation. In some cases further description of methods conducted at Utrecht University are provided. Preliminary results are provided where available, again these results are preliminary and are provided to give a general idea of site conditions and not a complete discussion. In some cases additional results are included in the appendix. Experimental work was conducted on subcores taken from the box cores. A complete list of subcores taken is provided in the appendix.

Methods selected for this cruise are designed to obtain information about one of the four following topics:

- current site conditions (3.1-3.6)
- physical effects of biota on sediment (3.7 & 3.8)
- bacterial rate measurements (3.9-3.11)
- trace metal concentration and availability (3.12 & 3.13)

3.1 Porewater collection

(Christelle Hyacinthe-sectioning in glovebox, Gerard van den Berg, Jacqueline Claessens- assisting with glovebox & centrifugation, Helen de Waard, Yvonne van Lith, Celine Pallud, Christelle Hyacinthe, -porewater subsampling)

One sediment core (10 cm diameter) was processed for porewater collection at each site. The sediment core was sliced in a glovebox under nitrogen in the temperature-controlled lab container (17 °C). Twenty depth intervals were sampled per core, see the core notes in the appendix for details. Sediment was collected in centrifuge tubes, sluiced out of the glove box, and centrifuged at 3500 rpm for 30 minutes. The centrifuge tubes were then brought into another glovebox where the supernatant was poured into a 20 ml syringe and filtered through a 0.2 µm pore size membrane into a 30 ml Nalgene vial. The pH and conductivity of a drop and 0.5 ml of porewater, respectively, were measured in the glove box. The remaining porewater was then sub-sampled in the glovebox following the scheme given in Table 4. Alkalinity was determined on-board using 0.5 ml of porewater, which was removed from the major element vials outside the glove box (see Alkalinity section 3.6). The remaining major element sample was acidified after this procedure.

Table 4. Porewater sub-sampling procedure

Analysis	Vol. (ml)	Vial	Treatment (per ml)	Method	Storage
pH, conductivity	0.5		Run on-board	electrodes	
Trace metals	5	Nalgene 8 ml	10 µl suprapur HNO ₃	ICP-MS	4°C
NO ₃ , NO ₂	1.5	AA-cup + cap	-	AA	-20°C
NH ₄	1.5	AA-cup + cap	-	AA	-20°C
SO ₄ , Br, Cl	1	IC-vial, 2 ml	-	IC	-20°C
HS ⁻	1	Supelco 4ml glass vial	10 µl 1 M NaOH	AA	4°C
PO ₄ , Si	2	AA-cup + cap	10 µl 1 M HCl	AA	4°C
Major element	1	Nalgene 8 ml	10 µl suprapur HNO ₃	ICP-OES	4°C
Alkalinity	0.5		Run on-board	Spectrophotometric	
DOC	1	DOC vials		Shimadzu	4°C

Figure 4 Porewater profiles of pH, Conductivity, Cl⁻, NO₃⁻, and SO₄⁻² at Site 2. More porewater profiles are available in the appendix.

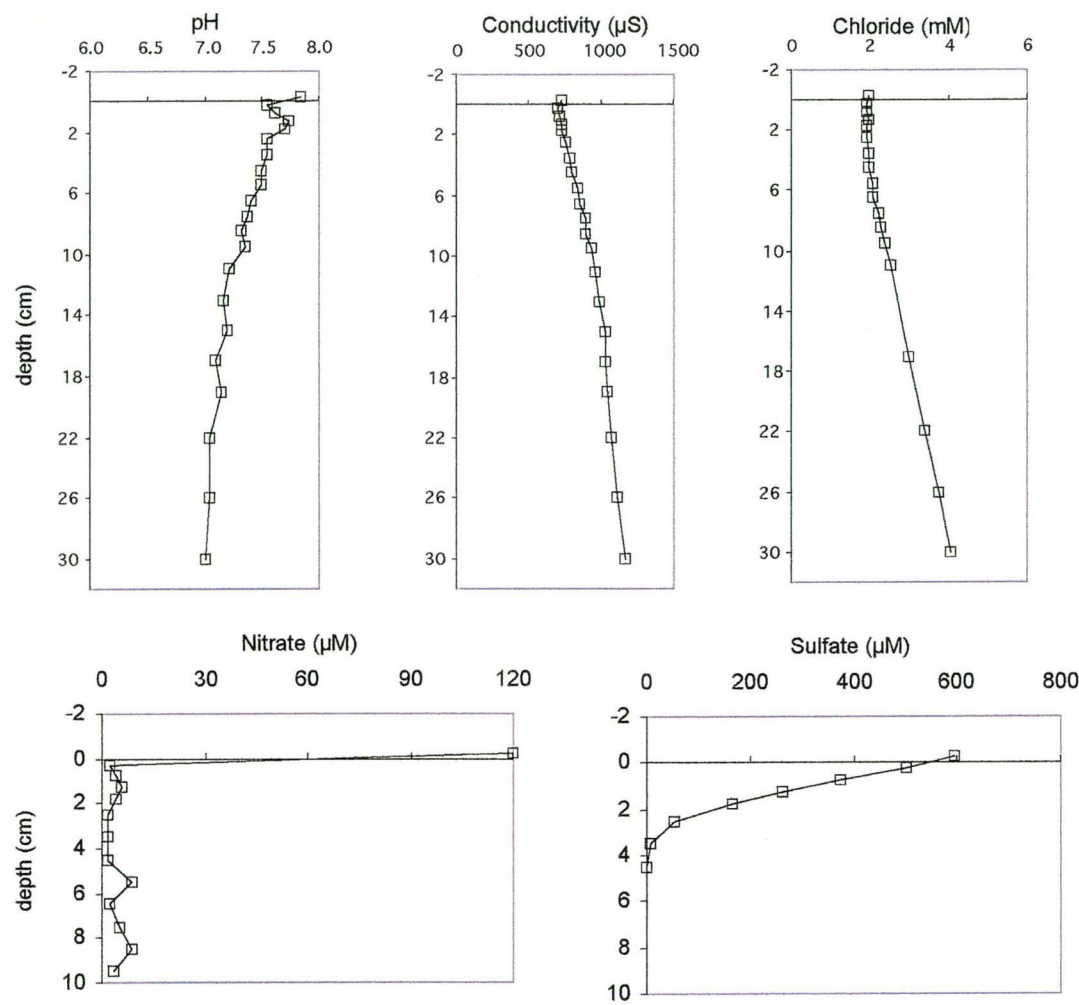


Figure 5 Christelle and Gerard slice a sediment core using the anoxic glove box

3.2 Solid phase sample collection

(Christelle Hyacinthe-anoxic sediment collection, Jacqueline Claessens, Rick Canavan-oxic sediment collection, Celine Pallud-reactor collection, porosity samples)

At each site a second sediment core was sliced under nitrogen in the glove box. This sediment was collected in centrifuge tubes stored at 4°C (AVS analysis), in plastic bags at -20°C (extractions and experimental work), and pre-weighed 15 ml glass vials (water content).

Sediment was collected from a core sliced oxically (for Chlorophyll-a extraction 3.7) and stored in plastic bags at -20°C. Sediments to use in future reactor experiments were also collected in reactor rings with a shuttle corer. In addition a shuttle core was taken with 1 cm intervals and collected in pre-weighed centrifuge tubes for the determination of sediment porosity.

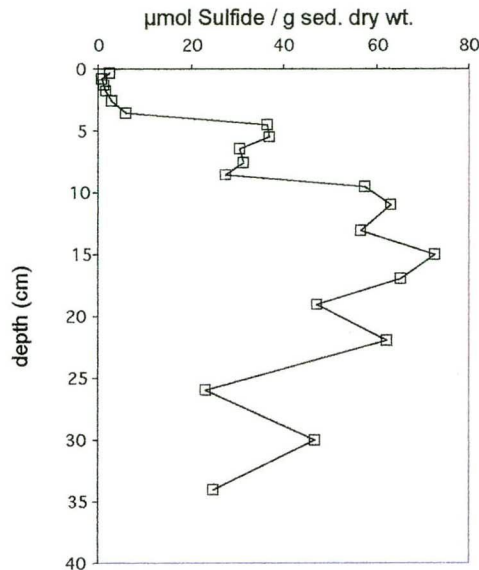


Figure 6 Acid Volatile Sulfide (AVS) profile from Site 3, presented as an example of solid phase analysis.

3.3 Bottom water sampling

(Pieter Kleingeld, Yvonne van Lith, Rick Canavan, Helen de Waard, Tony van der Vis, and Johan Tuntelder)

Bottom water was sampled with a Niskin bottle that was provided by the RIZA for the cruise. The bottle was attached to a cable, lowered with a winch to a depth of 1 m above the sediment, and triggered with a messenger. Collected water was used in experiments (e.g. bioirrigation, carbon mineralization) and filtered and prepared for analysis in the same manner as the porewater samples (see section 3.1).



Figure 7 Pieter and Johan prepare the Niskin bottle for bottom water sampling

3.4 Temperature (Pieter Kleingeld, Helen de Waard)

A temperature probe (chrome-nickel thermocouple with a 0.1 °C accuracy) was used to measure air, surface water, bottom water, and sediment temperature in the box cores. Measured temperatures ranged from 16 to 18°C with no observed temperature gradients in the sediments (see appendix for results).

3.5 Dissolved oxygen (Helen de Waard)

The oxygen content of bottom water was measured using the Winkler titration method, results are presented below.

Table 5. Bottom water dissolved oxygen concentration

Site	Number of samples	Mean [O ₂] (μmol L ⁻¹)	σ (μmol L ⁻¹)
1	5	253	6.7
2	6	336	3.0
3	5	214	7.2

3.6 Alkalinity (Christelle Hyacinthe, Helen de Waard, Rick Canavan)

Porewater alkalinity was determined on-board using the colorimetric method of Sarazin et al. (1999). A 0.5 ml porewater sample was added to the method reagents and its absorbance at 590 nm was determined with a spectrophotometer.

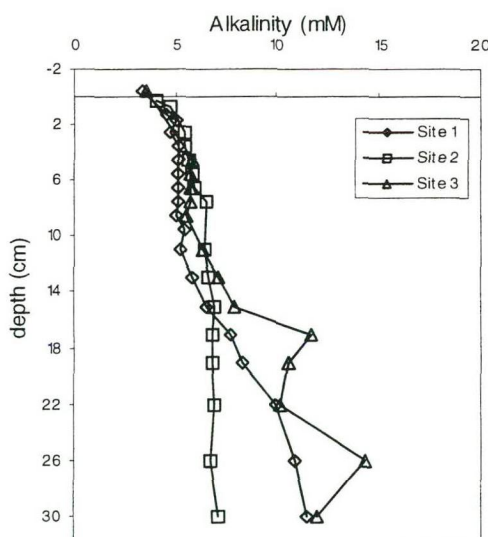


Figure 8 Porewater alkalinity profiles

3.7 Chlorophyll-a profiles (Jacqueline Claessens, Rick Canavan, Celine Pallud)

At each site, a core was sliced to obtain a profile of the pigment Chlorophyll-a (Chl-a). As the Chl-a analysis requires only a small amount of sediment most of sediment collected was stored for future experimentation (3.2). Chl-a profiles in the sediment can be used to constrain bioturbation intensity estimates (Sung et al., 1991, 1994). Between 2-3 ml of sediment was placed in a pre-weighed 15 ml Greiner tube. Samples were then reweighed and acetone was added to each tube for a final total weight of 20 g. The acetone and sediment were mixed using a vortex and then placed into an ultrasonic bath for 20 minutes. Following the ultrasonic bath samples were centrifuged at 3500 rpm for 10 minutes. The supernatant was collected in a new 15 ml Greiner tube and stored in a freezer until final analysis at the university by spectrophotometer or fluorescence.

3.8 Bioirrigation – Whole core Br⁻ incubation

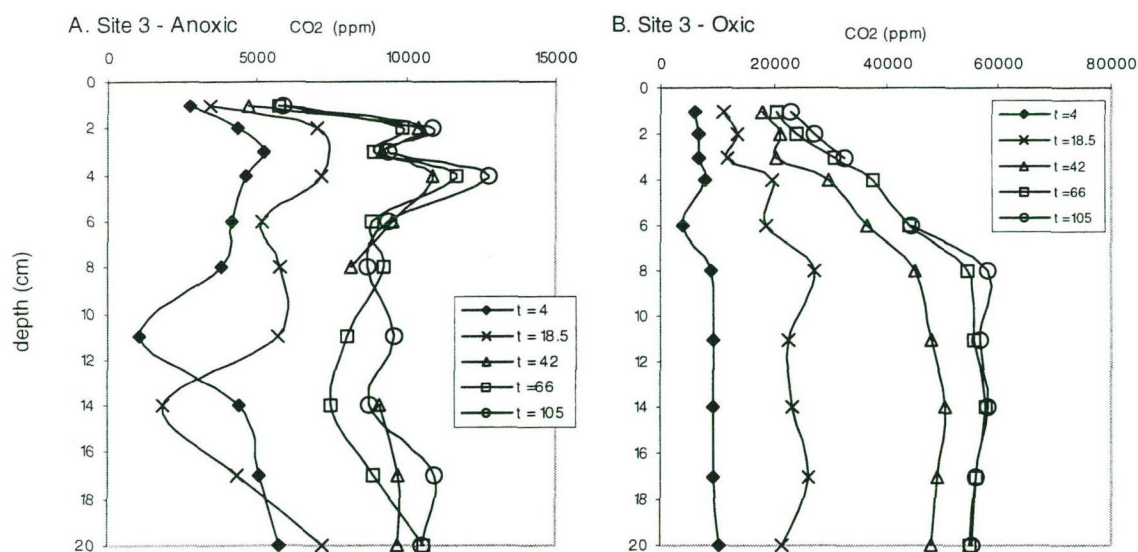
(Rick Canavan, Jacqueline Claessens, Debby Los, Celine Pallud, Annet Laverman)

Two 7 cm diameter cores were taken at each site and incubated with Br⁻ spiked surface water to measure bioirrigation rates. The surface water of the cores was spiked with 1M NaBr to increase the Br⁻ concentration from approximately 2 μ M to 10 mM. The cores were fitted with covers containing a stir bar and an air source to keep the overlying water oxic. Surface water was sub-sampled to determine the Br⁻ concentration at the beginning and end of the incubation. Cores were incubated between 50 to 75 hours (this required the transfer of the site 2 cores from R.V. Navicula to Utrecht). After incubation, cores were sliced in 1 cm intervals from 0 to 10 cm. This sediment was centrifuged to obtain the porewater and filtered through a 0.2 μ m pore size membrane. Bromide concentrations of the porewater were determined by ion chromatography. The expected concentrations of Br⁻ that would result from diffusion can be calculated, concentrations that are higher than expected can occur as the result of bioirrigation. This method is based on Martin and Banta, (1992).

3.9 Carbon mineralization

(Debby Los-sampled, picked up samples daily and returned them to Utrecht, conducted the gas analysis, Yvonne van Lith, Rick Canavan, Jacqueline Claessens- sample preparation, Annet Laverman- guidance with method and GC)

Carbon mineralization rate profiles are estimated from CO₂ and CH₄ production in slurry incubations of discrete sediment intervals using a method adapted from Dauwe et al., (2001). This method provides an estimate of maximum C-mineralization rates with sediment depth rather than *in-situ* rates, as the slurry alters the sediment structure. The upper 20 cm of a core were sliced into 10 sections (with greater resolution near the surface). Incubations were conducted in 100 ml vials that were prepared with 20 ml sediment and 10 ml de-oxygenated Haringvliet water (bottom water purged with N₂). After the vials were capped the headspace was flushed. At each depth two samples were incubated one oxically and the other anoxically. This was achieved by flushing the oxic samples with air and the anoxic samples with N₂ (flushing was conducted for 3x 10 minutes). The samples were brought to Utrecht the same day for analysis by GC for CO₂ and CH₄ production. The samples were incubated on a shaker at 20°C.



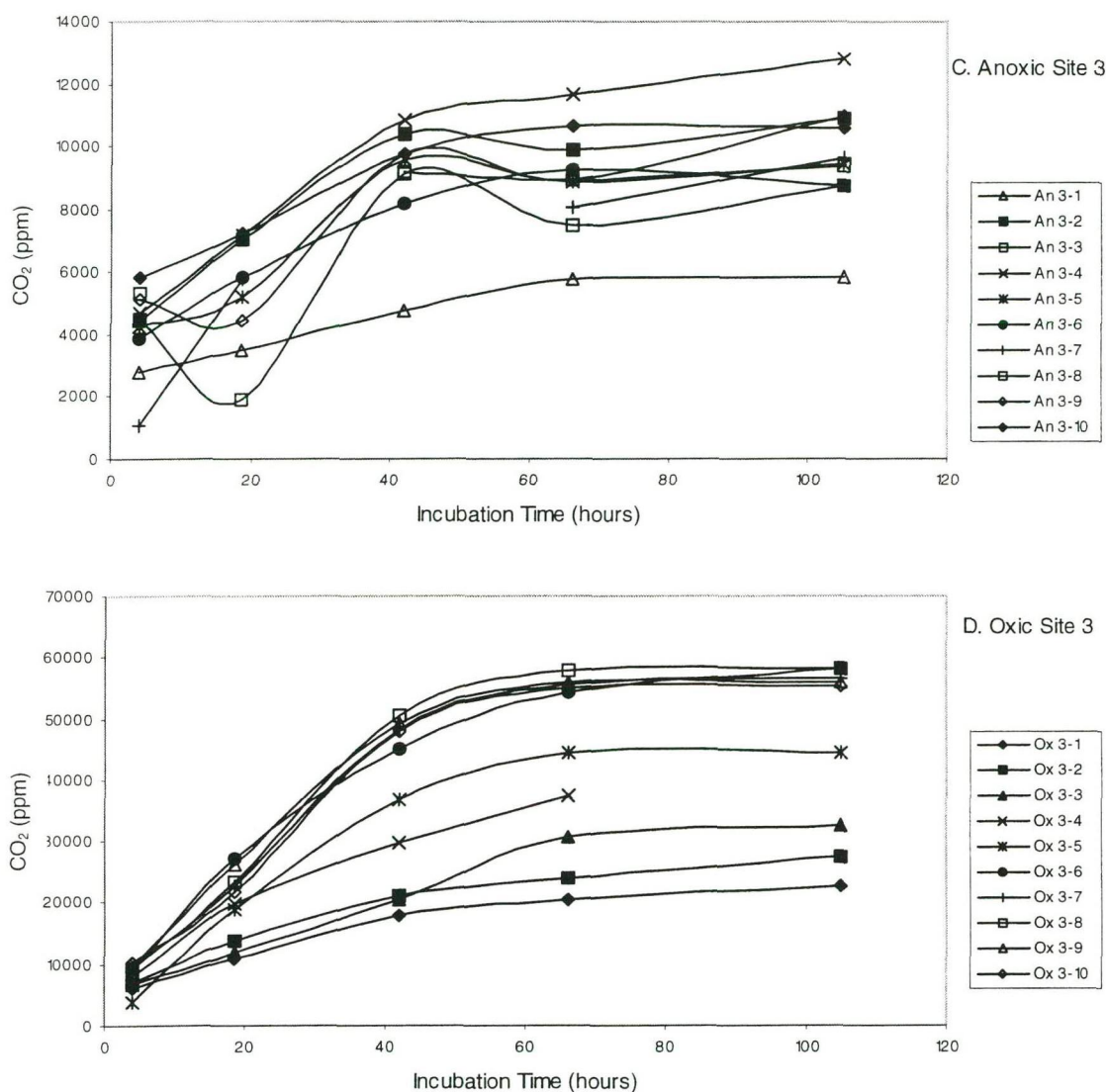


Figure 9 The CO₂ concentrations in incubation vial headspace for the oxic and anoxic incubations plotted versus depth (A, B) and versus incubation time (C, D) at Site 3. Note the larger scale on the oxic incubation figures (B,D).

3.10 Denitrification

(Anniel Laverman-plug flow through reactors, microprofiling, MPNs Celine Pallud-MPNs)

Denitrification refers to the respiration pathway whereby bacteria break down organic carbon using nitrate as their electron acceptor. This process can be important in anoxic sediments and plays an important role in the N-cycle.

3.10.1 Core incubation and profiling

Sediment incubations for microprofiling were done in small cores (diameter 42 mm, height 150 mm) at 18°C. Approximately 8 cm sediment was collected in the cores and 50 ml of overlying water was added. The overlying water was continuously mixed, without disturbing the sediment-water interface, by carefully pumping air at the surface of the water. Acetylene was added to overlying water and sediment (through silicone filled holes along the side of the core) to block the N₂O reductase. At regular intervals

N₂O and O₂ profiles were measured. Samples were taken from the overlying water to measure NO₃ and NO₂ at the same times as the profile measurements.

3.10.2 Denitrifier MPN

The shuttle corer was used to obtain samples from depths of 0-1, 1-2, 2-3, and 3-4 cm. Slurries were made from 2 ml sediment samples and 20 ml saline solution in a 30 ml bottle. Serial dilutions are made in 9 ml denitrifier medium (modified from Widdle and Bak, 1992) in hungate tubes with inverted Durham tubes.

3.10.3 Plug flow through reactors

The shuttle corer was used to collect sediment in four 1 cm reactor cells with the same intervals used for the MPNs. The reactors were run for approximately 20 hours. The input solution contained both NO₃ (reactive tracer) and Br (non reactive tracer). Samples were collected at regular time intervals using a fraction collector. The breakthrough curves of Br will be used to determine hydrodynamic properties, the nitrate break through curves will be used to determine nitrate reduction rates at the 4 different depths.

3.11 Sulfate reduction rates (Yvonne van Lith)

Three cores at each site (with cm-spaced, silica-filled holes or a silica-filled strip) were collected for on-land sulfate reduction rate measurements. The core is transported at approximately 4 °C. Radioactive-labeled ³⁵SO₄ is injected into the sediment through the silicone-filled holes. During an incubation period at *in situ* temperature of the sediment, the radioactive-labeled sulfate is reduced to radioactive-labeled sulfide (H₂³⁵S) and other reduced sulfur species (³⁵S₀, ³⁵S_n²⁻, Fe³⁵S and Fe³⁵S₂). After 6-8 hr incubation, the core is sliced and the reduced sulfide is fixed in zinc-acetate. The sediment slices are centrifuged to extract the pore water, decanted, and the liquid is kept for counting on a beta scintillation counter (Fossing, 1995). To separate all the sulfate from the sulfides and to release all the reduced sulfide species, a cold distillation of the centrifuged sediment is performed (T. Ferdelmann and J. Kallmeyer, pers com.) after addition of acid, demethylformamide (DMF), and Cr²⁺-solution. The acid releases the acid volatile sulfides, the Cr²⁺-solution the pyritic sulfides, and the DMF releases the S⁰ and accelerates the reaction. The sulfide gasses are washed by flowing through a citrate solution and are fixed in zinc-acetate to be analyzed by the beta scintillation counter. The sulfate reduction rate can be calculated according to the following equation:

$$SRR = {}^{35}\text{S}_{\text{red}} / ({}^{35}\text{SO}_4^{2-} + {}^{35}\text{S}_{\text{red}}) * [\text{SO}_4^{2-}] * 24/t * 1.06 \text{ nmol SO}_4^{2-} \text{ cm}^{-3} \text{ day}^{-1}$$

where ³⁵S_{red} is the radioactivity of the reduced sulfur (per unit volume), ³⁵SO₄²⁻ is the radioactivity of the sulfate after incubation (per unit volume), [SO₄²⁻] is the sulfate concentration (nmol cm⁻³), t is the incubation time (hours), and 1.06 is the isotopic fractionation factor. Generally ³⁵SO₄²⁻ + ³⁵S_{red} equals ³⁵SO₄²⁻. A duplicate measurement is carried out on a second core, and third core is injected with label and sliced immediately (t₀) to determine a background signal (blank) (Jorgensen, 1978).

3.12 Analysis of redox-sensitive species (O_2 , Fe^{2+} , Mn^{2+} , ΣS^{2-}) and trace metals (Cu, Cd, Pb, Zn) by voltammetric solid-state electrodes (Ralf Haese)

Voltammetry is an electrochemical method to analyze solute concentrations as a function of changes in current at characteristic potentials during a scan of potentials. The controlling instrument, the potentiostat, applies changing potentials over time between a reference and a working electrode and records the resultant current between the counter and working electrodes. Redox-sensitive species in solution are reduced or oxidized at species-specific potentials. As a result of the redox reaction, an electron transfer occurs, which is measured as a change in current and its amplitude correlates with the concentration of the analyzed species in solution.

During this fieldwork, two different kinds of working electrodes were used. The Hg/Au amalgam needle electrode is used for in situ measurements of O_2 , Fe^{2+} , Mn^{2+} , and ΣS^{2-} (Brendel et al. 1995) and is fabricated in-house. The Disposable Thick Film Modified Graphite Electrode (DTFMGE) is used for the analysis of trace metals (Cu, Cd, Pb, Zn) in extracted pore water volumes of 2 – 3 ml (Brainina et al. 1997).

Technical details of the applied methods:

Hg/Au amalgam needle electrode:

O_2 is measured in Linear Sweep Mode (LSV), whereas species undergoing a reversible electrode reaction (Mn^{2+} , Fe^{2+} , ΣS^{2-}) are measured in Square Wave Mode (SWV). The following parameters are used: Scan rate 200 mV sec^{-1} , pulse height 15 mV, step increment 2 mV, frequency 100 Hz. The potential scan typically starts at -0.05 V and ends at -1.6 V . To guarantee an electrode surface free of ions aimed to be analyzed before each measurement in a series of measurements, the electrode is 'cleaned' by applying a certain potential, whereby residual ions on the electrode surface are oxidized or reduced and are released into ambient solution (conditioning). In the presence of Mn^{2+} , Fe^{2+} , or ΣS^{2-} conditioning (see below) of the electrode was accomplished at -1.0 V during 60 sec.

DTFMGE

Cu, Cd, and Pb can be measured during one run using Anodic Stripping-Square Wave Voltammetry (AS-SWV). Trace metals are preconcentrated at the electrode surface (deposition) under reducing conditions, followed by a potential scan towards more positive potentials (anodic stripping, AS) in the SWV mode. The following parameters are used for the analysis of Cd, Cu, and Pb. Prior to AS:

$E_{\text{cond}} -0.05\text{ V}$ (60 sec), $E_{\text{dep}} -1.2\text{ V}$ (120 sec), $E_{\text{eq}} -1.2\text{ V}$ (15 sec).

AS is accomplished as follows: SWV with $E_{\text{start}} -0.9$ and $E_{\text{end}} -0.05\text{ V}$, $E_{\text{step}} 0.005\text{ V}$, $E_{\text{ampl}} 0.025\text{ V}$, frequency 25 Hz. The analysis of Zn requires a special procedure, which has not been tested yet.

Preliminary results:

Hg/Au amalgam needle electrode:

The oxygen penetration depth was approximately 2 mm at all three sites (data not shown). Dissolved iron was not detected at all. Dissolved manganese increased with depth at site 3 and 1. This is reflected in the increase in the resultant current at a potential of -1.53 V (Fig. 10), which is the characteristic potential for the electrode

reaction $\text{Mn}^{2+} + 2\text{e}^- \rightarrow \text{Mn}^0$ with the formation of an HgMn complex at the electrode surface.

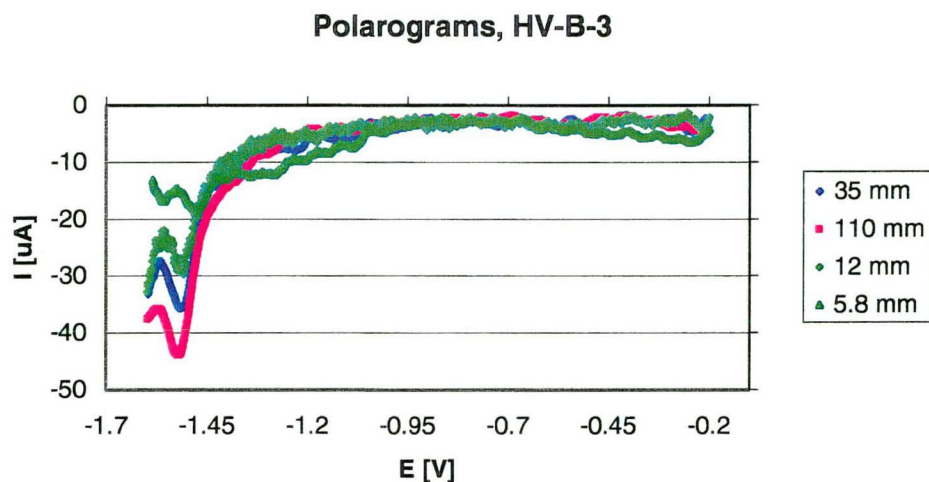


Figure 10 Polarograms, Site 3

At site 2 the detection of very low sulfide concentrations was a major goal next to the oxygen profile. By using a particularly low sensitivity range (10 nA), evidence for sulfide in the concentration range of $0 - 3\text{ }\mu\text{mol/l}$ was found at depths below the oxic zone down to at least 8 cm. This is reflected in the broad peak at $\sim 0.6\text{ V}$ (Fig. 11). This implies that the sulfide profile is not shaped by production and diffusion, but rather by chemical equilibrium, possibly with $\text{Fe}^{2+}_{\text{aq}}$. This would also explain, why no dissolved iron was detected.

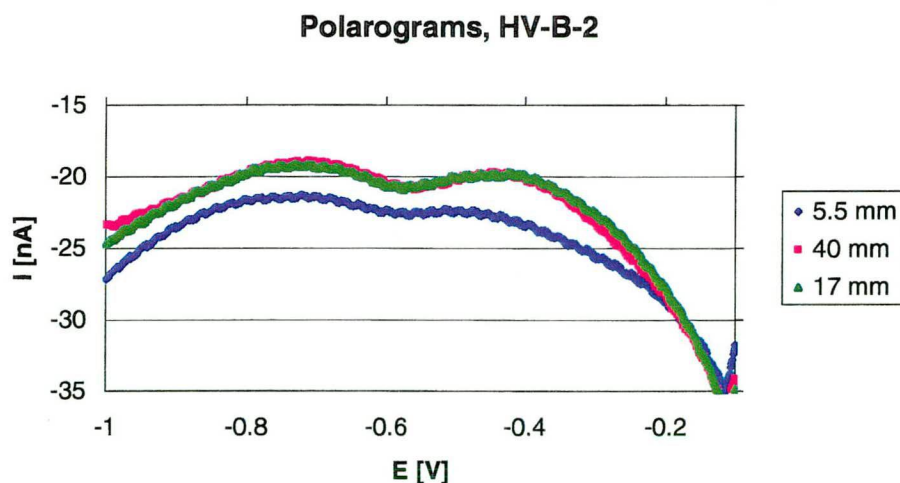


Figure 11. Polarograms, Site 2

DTFMGE

Pore water was extracted from sediment of site 2 and 3 for trace metal analysis by DTFMGE. Because only free ions are measured by this method, pore waters were analyzed prior and after UV irradiation to distinguish the fraction of free and chelated trace metal ions. UV irradiation leads to the decomposition of dissolved organic

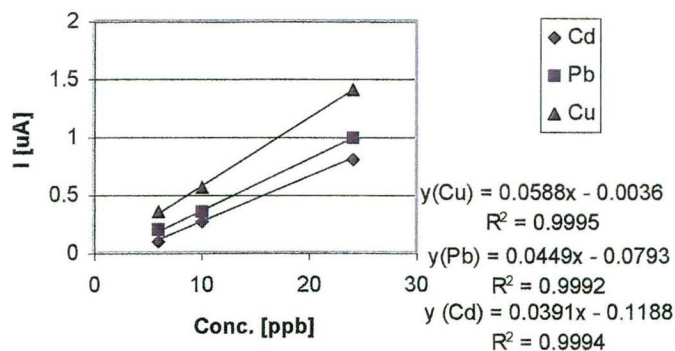


Figure 12 Calibration results



Figure 13 Ralf running the electrodes with a PDA

molecules and thereby releases bound metal ions. On board, samples from site 3 were analyzed. Samples from site 2 were acidified and stored until analysis at UU.

The electrode was calibrated for the range of 20 – 100 ppb with a Ag/AgCl reference electrode and for a range of 5 – 25 ppb with a solid state reference electrode (Fig. 12).

Cd was below detection limit in all samples except for the one shown in Figure 14. The samples of site 3 were contaminated by variable degrees from the saturated Ag/AgCl solution in the reference electrode. This was only recognized after measuring the series and therefore true concentrations cannot be recalculated.

For the series of site 2 a solid state reference electrode will be used which excludes this source of contamination. Figure 14 shows a polarogram measured on porewater from 0 – 0.5 cm at Site 3. Characteristic maximum peak currents are found at -0.65 , -0.45 and -0.22 (all ± 0.7) V for Cd, Pb and Cu, respectively. The peak with a maximum current at -0.75 V remains unidentified.

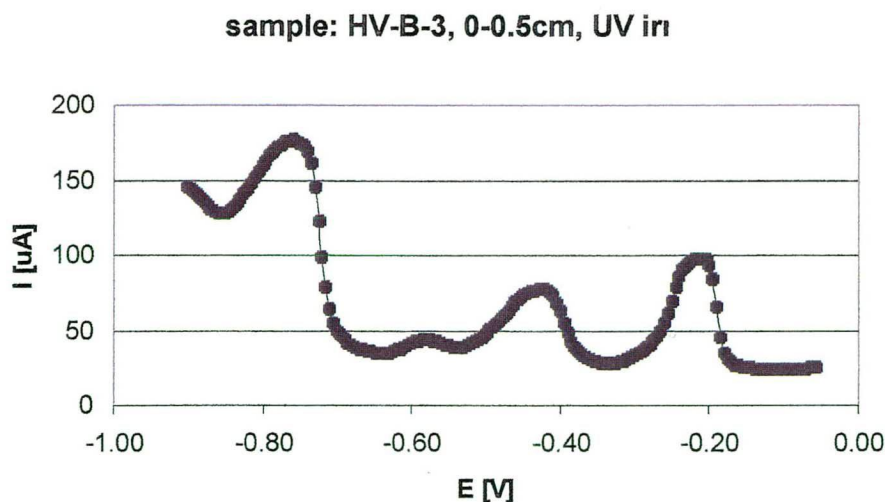
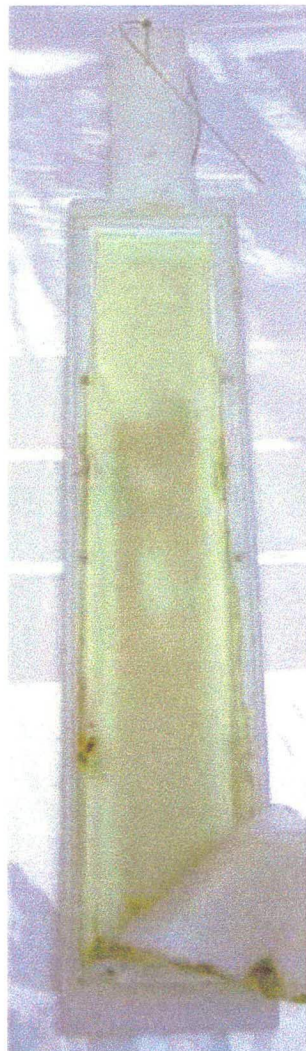


Figure 14 DTFMGE polarogram at Site 3

3.13 DGT and DET (Rick Canavan)

These techniques involve gel probes inserted in the sediment to determine porewater concentrations and trace metal fluxes (DGT-Davidson and Zhang, 1994 DET-Davidson et al., 1991).



3.13.1 Diffusive Equilibria in Thin-films (DET)

The DET technique is used to determine the porewater concentration of Fe and Mn. One core was examined at each site using a constrained sediment probe. The probe has small chambers (1 mm x 1 mm x 1.8 cm) that are filled with an agarose gel. The probes were kept anoxic until insertion into the sediment cores. When inserted in the sediment the water within the agarose gel quickly comes to equilibrium with the adjacent porewater because of the small gel volume. After incubation (24 hours), gel slices were removed from the probe and placed in pre-labeled microcentrifuge tubes. The gel slices were eluted and analyzed by ICP-MS.

3.13.2 Diffusive Gradients in Thin-films (DGT)

The DGT technique is used to determine 'available' trace metal concentrations and sulfide concentrations in sediments. The trace metals are bound to a cation exchange resin imbedded in gel and sulfide is bound by an AgI containing gel. Two probes at each site were used; one with a trace metal probe, and one with a combination metal-sulfide probe. Both the metal and combination probes were deployed for approximately 24 hours. The AgI probes showed evidence of sulfide with darkening at depth in the probe (see photo). Further calibration of the AgI gel system is needed to allow for quantitative analysis by a desktop computer scanner using the method of Teasdale et al. (1999).

Figure 15 Sulfide sediment probe

4 Acknowledgements

Support for this cruise and its staff is provided both by UU and RIZA. The scientific staff who participated in the cruise are UU staff members (unless otherwise noted see section 2.1). Costs of materials and sample analysis are covered by UU. RIZA paid for the use of R.V. Navicula. Gerard van den Berg and Gertjan Zwolsman are RIZA staff members directly involved in the RESIN project, and Richard Canavan is supported by a Ph.D fellowship from RIZA.

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6 Appendix

- Temperature data
- Porewater profiles
- Boxcoring log
- Core descriptions

Temperature data:

Site HVB-3 September 18, 2002:

Temperature Air:	18°C
Temperature Bottomwater:	18°C
Temperature Haringvliet surface:	18°C
Temperature Sediment Top layer:	18°C
Temperature Sediment 20 cm depth:	17°C
Bottom water sampler from RIZA	

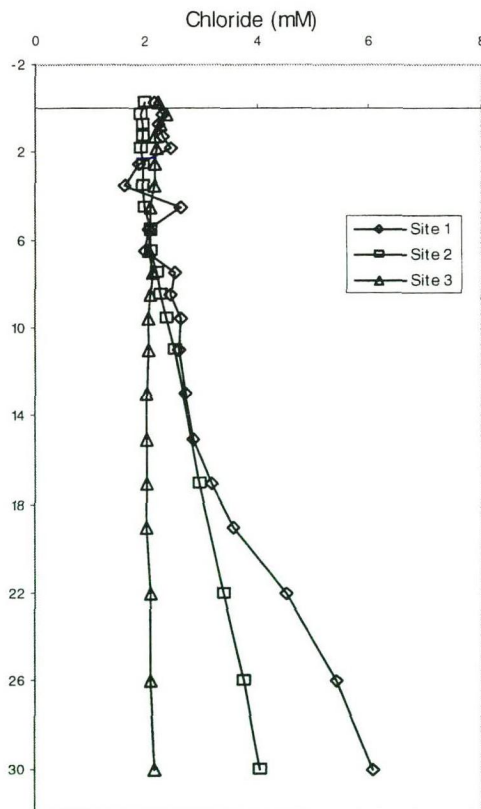
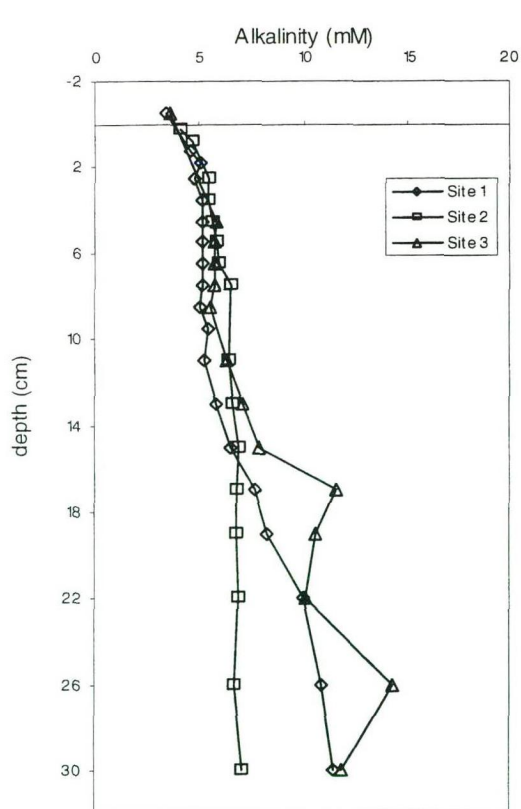
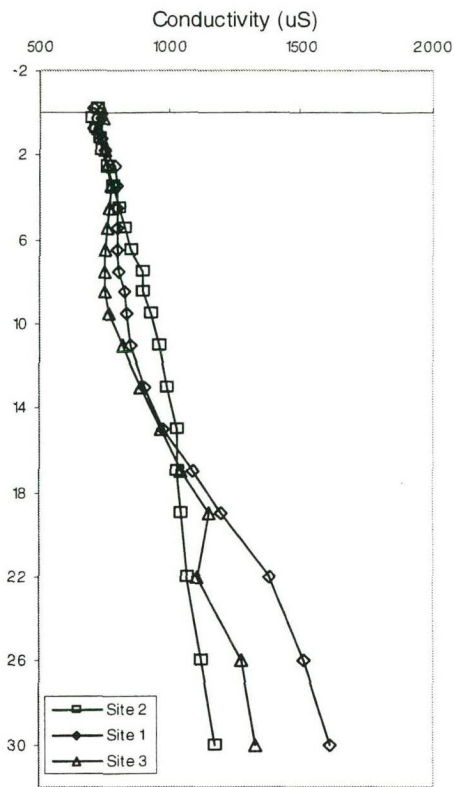
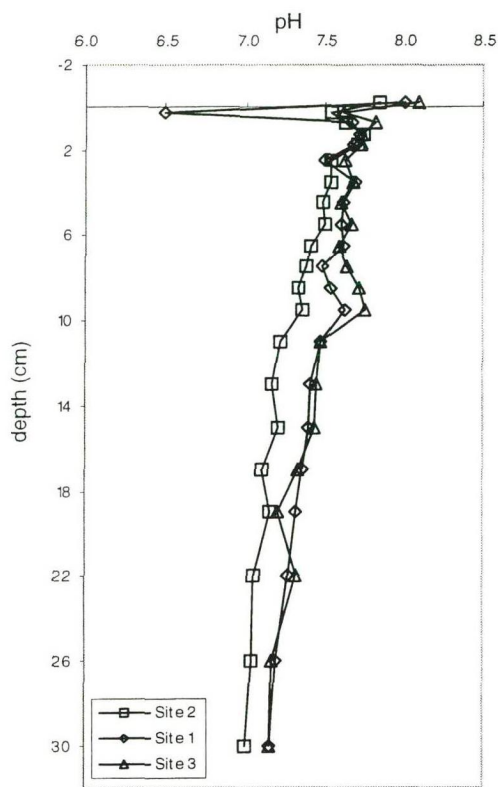
Site HVB-1 September 19, 2002

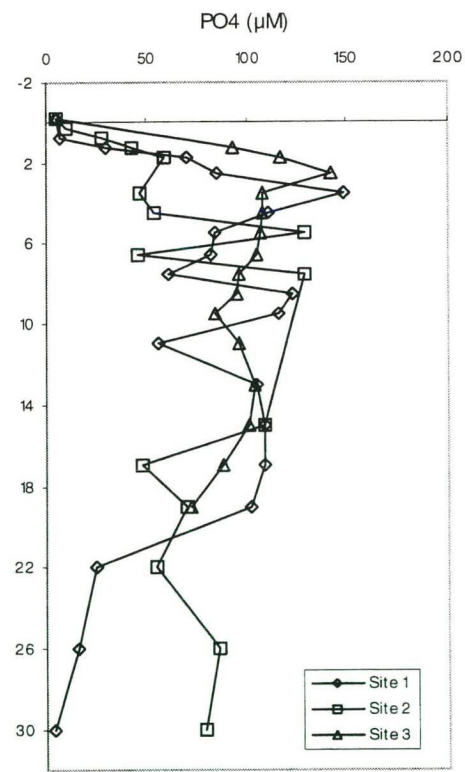
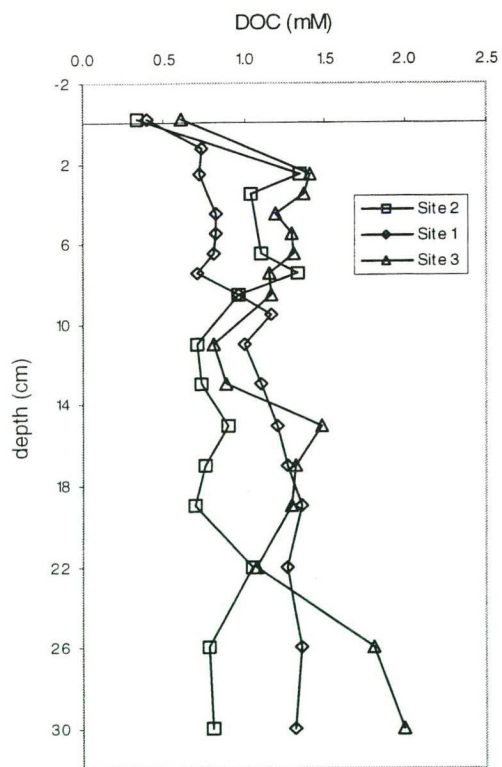
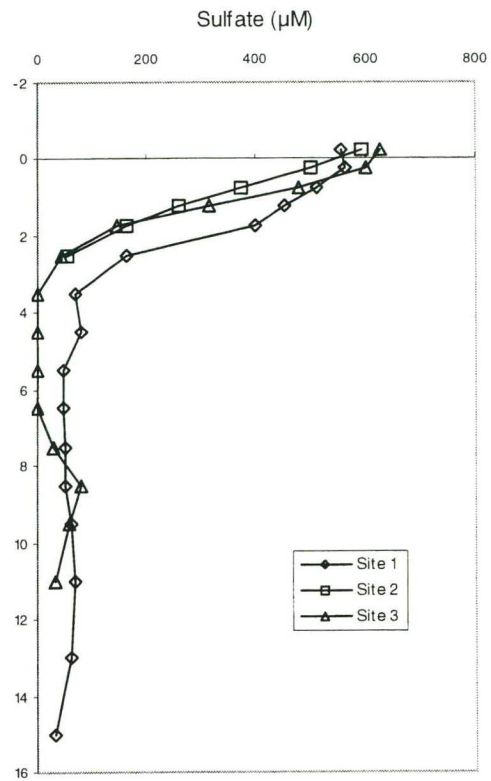
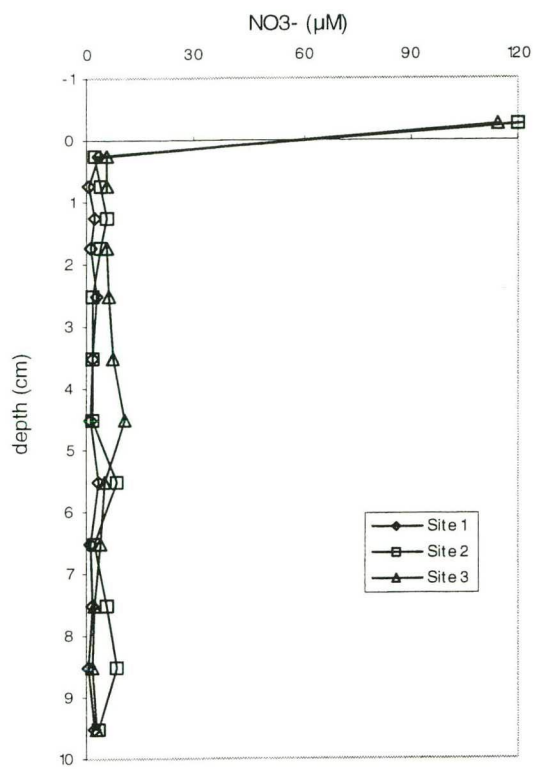
Temperature Air:	17°C
Temperature Bottomwater:	17°C
Temperature Haringvliet surface:	17°C
Temperature Sediment Top layer:	17°C
Temperature Sediment 20 cm depth:	17°C
Bottom water sampler from RIZA	

Site HVB-1 September 19, 2002

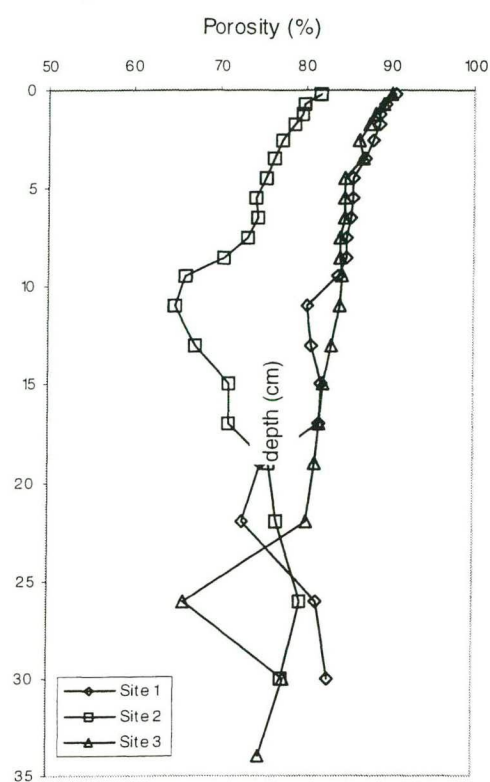
Temperature Air:	16°C
Temperature Bottomwater:	16°C
Temperature Haringvliet surface:	16°C
Temperature Sediment Top layer:	16°C
Temperature Sediment 20 cm depth:	16°C
Bottom water sampler from RIZA	

Porewater profiles





Porosity Profiles



Boxcoring Log

Total number of cores taken:

Ship nr.	Nr.	Sample	Name	Subcore	Remarks
18/09/2002					
0	1	Sample bottle	HVB3-1	1	Bottom water sampler, took samples for spare bottom-water, could not fill O ₂ bottles (when upper lid was opened water came through bottom-lid)
	2	Box core			Too heavy, next: 1 lead weight less (box core K6)
	3	Box core			Too heavy, next: 3 lead weight less
	4	Box core			Too heavy, next: repaired trip-arm (2 lead-rings left)
	5	Box core			Still too heavy, next: slower speed when reaching the bottom
1	6	Box core	HVB3-2	1	Small tube: O ₂ -profiling (Annet)
				2	10 cm tube: Anoxic porewater sampling (Christelle, Jacqueline, Yvonne, Helen)
				3	10 cm tube: Anoxic sampling for storage (Christelle, Jacqueline)
					(O ₂ -Winckler (Helen), and 2 liter bottomwater (spare))
	7	Box core			Too little overlaying water
2	8	Boxcore	HVB3-3	1	7 cm core: Br- core incubations (Debby)
				2	7 cm core: Br- core incubations (Debby)
				3	10 cm core: Trace metal porewater profiles and oxygen (Ralf)
					(O ₂ -Winckler (Helen) and 2 liter bottomwater (spare))
3	9	Boxcore	HVB3-4	1	Small core: Denitrification (Celine, Annet)
				2	Small core: Denitrification (Celine, Annet)
				3	Small core: Denitrification (Celine, Annet)
				4	Small core: Sulfate reduction (Yvonne)
				5	Small core: Sulfate reduction (Yvonne)
				6	Small core: Sulfate reduction (Yvonne)
4	10	Box core	HVB3-5	1	Shuttle core: Porosity (Celine, Yvonne)
				2	Shuttle core: MPN (Celine, Yvonne)
5	11	Box core	HVB3-6	1	10 cm core: DET/DGT (Rick, Debby)
				2	10 cm core: DET/DGT (Rick, Debby)
				3	10 cm core: DET/DGT (Rick, Debby)
6	12	Box core	HVB3-7	1	10 cm core: Chlorophyll-a and storage (Debby, Pieter)
				2	10 cm core: Vial incubations (Rick, Debby)
				3	10 cm core: Spare (..)
7	13	Box core	HVB3-8	1	Shuttle core: Spare 10 x 2 cm reactors (Celine)
8	14	Box core	HVB3-9	1	Shuttle core: Spare 4 x 1 cm reactors (Celine)

Ship nr.	Nr.	Sample	Name	Subcore	Remarks
9	15	Box core			Spare (not used)
19/09/2002					
0	1	Sample bottle	HVB1-1	1	Bottom water sampler, took samples for spare bottomwater
1	2	Box core	HVB1-2	1	Small tube: O ₂ -profiling (Annet)
				2	10 cm tube: Anoxic porewater sampling (Christelle, Gerard, Yvonne, Helen)
				3	10 cm tube: Anoxic sampling for storage (Christelle, Gerard)
					O ₂ -Winckler (Helen)
2	3	Box core	HVB1-3	1	7 cm core: Br- core incubations (Jacqueline)
				2	7 cm core: Br- core incubations (Jacqueline)
				3	10 cm core: Trace metal porewater profiles and oxygen (Ralf)
3	4	Box core	HVB3-4	1	Small core: Denitrification (Celine, Annet)
				2	Small core: Denitrification (Celine, Annet)
				3	Small core: Denitrification (Celine, Annet)
				4	Small core: Sulfate reduction (Yvonne)
				5	Small core: Sulfate reduction (Yvonne)
				6	Small core: Sulfate reduction (Yvonne)
4	5	Box core	HVB1-5	1	Shuttle core: Porosity (Celine, Ronald)
				2	Shuttle core: MPN (Celine, Ronald), core fell down and was replaced (see 1-7)
5	6	Box core	HVB1-6	1	10 cm core: DET/DGT (Rick)
				2	10 cm core: DET/DGT (Rick)
				3	10 cm core: DET/DGT (Rick)
					O ₂ -Winckler (Helen)
6	7	Box core	HVB1-7	2	Shuttle core: MPN (Celine, Ronald)
7	8	Box core	HVB1-8	1	10 cm core: Chlorophyll-a and storage (Yvonne, Jacqueline, Ronald)
				2	10 cm core: Vial incubations (Jacqueline, Yvonne, Ronald, Debby)
				3	10 cm core: Spare (..)
8	9	Box core	HVB1-9	1	Shuttle core: Spare 10 x 2 cm reactors (Celine,)
				2	Shuttle core: Spare 4 x 1 cm reactors (Celine)
9	10	Box core	HVB1-10	1	Shuttle core: MPN (Annet)
20/09/2002					
0	1	Sample bottle	HVB2-1	1	Bottom water sampler, took samples for spare bottomwater
-	2	Box core	HVB2-2	-	O ₂ -Winckler (Helen), no sediment taken, too little sediment in core. Next time more speed when reaching the bottom
1	3	Box core	HVB2-3	1	10 cm tube: Anoxic porewater sampling (Christelle, Jacqueline, Rick, Helen)

Ship nr.	Nr.	Sample	Name	Subcore	Remarks
				2	10 cm tube: Anoxic sampling for storage (Christelle, Jacqueline)
				3	10 cm tube: Trace metal porewater profiles and oxygen (Ralf)
				4	Small tube: O ₂ -profiling (Anniet)
2	4	Box core	HVB2-4	1	7 cm core: Br- core incubations (Jacqueline) too little overlaying water, not used
				2	7 cm core: Br- core incubations (Jacqueline) too little overlaying water, not used
3	5	Box core	HVB2-5	3	10 cm core: Trace metal porewater profiles and oxygen (Ralf)
				1	7 cm core: Br- core incubations (Jacqueline, Helen)
				2	7 cm core: Br- core incubations (Jacqueline, Helen)
				3	Small core: Denitrification (Celine, Anniet)
				4	Small core: Denitrification (Celine, Anniet)
				5	Small core: Denitrification (Celine, Anniet)
4	6	Box core	HVB2-6	1	Shuttle core: Porosity (Celine)
				2	Shuttle core: MPN (Celine)
				3	Small core: Sulfate reduction (Celine, Rick)
				4	Small core: Sulfate reduction (Celine, Rick)
				5	Small core: Sulfate reduction (Celine, Helen)
5	7	Box core	HVB2-7	1	10 cm core: DET/DGT (Rick, Helen)
				2	10 cm core: DET/DGT (Rick, Helen)
				3	10 cm core: DET/DGT (Rick, Helen)
6	8	Box core	HVB2-8	1	10 cm core: Chlorophyll-a and storage (Rick, Helen, Jacqueline)
				2	10 cm core: Vial incubations (Rick, Helen, Jacqueline)
7	9	Box core	HVB2-9	1	Shuttle core: Spare 10 x 2 cm reactors (Celine)
				2	Shuttle core: Spare 4 x 1 cm reactors (Celine)
9	10	Box core		2	Spare – shuttle core (Anniet), 10 cm core : Vial incubations (Rick, Debby)

Core descriptions
Sediment description site 3 (Anoxic storage).

Date: 18/09/02
 Site: 3, Tiengemeenten
 Coordinates: 51.24.427N, 04.17.508E
 Watertemperature: 18° Celsius
 Core code: HV-B-3-BC2 subcore 3
 Total length of core (cm):
 Processed by: Christelle Hyancinthe & Jacqueline Claessens
 Ship: RV Navicula

sample no.	average depth (cm)	depth interval (cm)	sediment description
1	0.25	12.7 - 13.2	Soupy, brown
2	0.75	13.2 – 13.7	Idem
3	1.25	13.7 – 14.2	Idem
4	1.75	14.2 – 14.7	idem
5	2.5	14.7 – 15.7	A little less soupy
6	3.5	15.7 – 16.7	Idem, 1 burrow
7	4.5	16.7 – 17.7	Black spots, less soupy, 3 burrows
8	5.5	17.7 – 18.7	Idem
9	6.5	18.7 – 19.7	Idem
10	7.5	19.7 – 20.7	Compact, 2 worms (alive), black spots
11	8.5	20.7 – 21.7	More than 10 burrows, black spots
12	9.5	21.7 – 22.7	More black, many burrows
13	11	22.7 – 24.7	Idem
14	13	24.7 – 26.7	Idem
15	15	26.7 – 28.7	Idem
16	17	28.7 – 30.7	idem
17	19	30.7 – 32.7	More burrows
18	22	32.7 – 36.7	shell
19	26	36.7 – 40.7	Wood layer
20	30	40.7 – 44.7	Very sandy sediment
21	34	44.7 – 48.7	idem

Sediment description site 3 (porewater core).

Date: 18/09/02
Site: 3, Tiengemeenten
Coordinates: 51.24.427N, 04.17.508E
Watertemperature: 18° Celsius
Core code: HV-B-3-BC2 subcore 2
Total length of core (cm):
Processed by: Christelle Hyancinthe & Jacqueline Claessens
Ship: RV Navicula

sample no.	average depth (cm)	depth interval (cm)	sediment description
1	0.25	15.5 – 16.5	Soupy, brown
2	0.75	16.0 – 16.5	Idem
3	1.25	16.5 – 17.0	Idem
4	1.75	17.0 – 17.5	idem
5	2.5	17.5 – 18.5	Idem
6	3.5	18.5 – 19.5	Brown color is more clear, 2 holes, soupy
7	4.5	19.5 – 20.5	Blackish spots
8	5.5	20.5 – 21.5	More compact, 7 burrows
9	6.5	21.5 – 22.5	Worm (dead), 2 big burows, 2 small burrows
10	7.5	22.5 – 23.5	Many burrows, black sediment
11	8.5	23.5 – 24.5	3 worms (alive),net or burrows, black sediment
12	9.5	24.5 – 25.5	Idem
13	11	25.5 – 27.5	Idem
14	13	27.5 – 29.5	Idem
15	15	29.5 – 31.5	Less brown spots, sediment more blackish, many burrows
16	17	31.5 – 33.5	Idem
17	19	33.5 – 35.5	Very black sediment
18	22	35.5 – 39.5	Wood like material at 24 cm (layer), sandy (under wood layer)
19	26	39.5 – 43.5	Very stick, brown material
20	30	43.5 – 47.5	idem

Sediment description site 1 (porewater core).

Date: 19/09/02
 Site: 1, Haringvliet Sluis
 Coordinates: 51.50.091N, 04.04.339E
 Watertemperature: 17° Celsius
 Core code: HV-B-1-BC2 subcore 3
 Total length of core (cm): 32
 Processed by: Christelle Hyancinthe & Gerard v/d Berg
 Ship: RV Navicula

sample no.	average depth (cm)	depth interval (cm)	sediment description
1	0.25	15.5 – 16.5	Fine-grained, very unconsolidated, brown-green
2	0.75	16.0 – 16.5	Fine-grained, unconsolidated, brown-greenish
3	1.25	16.5 – 17.0	Fine-grained, unconsolidated, greenish
4	1.75	17.0 – 17.5	Idem
5	2.5	17.5 – 18.5	Fine-grained, slightly consolidated, greenish, grey spots
6	3.5	18.5 – 19.5	Fine grained, slightly consolidated, greenish, burrows
7	4.5	19.5 – 20.5	Fine grained, slightly consolidated, darker green, burrows
8	5.5	20.5 – 21.5	Fine grained, slightly consolidated, dark green, 10 burrows
9	6.5	21.5 – 22.5	Fine grained, slightly consolidated, dark green, oxygenated burrows
10	7.5	22.5 – 23.5	Fine grained, slightly consolidated, dark green, gray spots, burrows
11	8.5	23.5 – 24.5	Fine grained, slightly consolidated, dark green → gray, burrows
12	9.5	24.5 – 25.5	Fine grained, slightly consolidated, dark green → gray, burrows / tubes
13	11	25.5 – 27.5	Fine grained, slightly consolidated, dark green → gray, nice tubes
14	13	27.5 – 29.5	Fine grained, more consolidated, gray with green spots, many burrows
15	15	29.5 – 31.5	Fine grained, consolidated, gray, many burrows
16	17	31.5 – 33.5	idem
17	19	33.5 – 35.5	Fine grained, consolidated, gray → dark green, borrows
18	22	35.5 – 39.5	Idem
19	26	39.5 – 43.5	Idem
20	30	43.5 – 47.5	Fine grained, consolidated, dark green

Sediment description site 1 (anoxic storage core).

Date: 19/09/02
 Site: 1, Haringvliet Sluis
 Coordinates: 51.50.091N, 04.04.339E
 Watertemperature: 17° Celsius
 Core code: HV-B-1-BC2 subcore 2
 Total length of core (cm): 32
 Processed by: Christelle Hyancinthe & Gerard v/d Berg
 Ship: RV Navicula

sample no.	average depth (cm)	depth interval (cm)	sediment description
1	0.25	16.2 – 16.7	Fine-grained, very unconsolidated, brown-green
2	0.75	16.7 – 17.2	Fine-grained, unconsolidated, brown-green
3	1.25	17.2 – 17.7	Fine-grained, unconsolidated, greenish
4	1.75	17.7 - 18.2	Idem
5	2.5	18.2 – 19.2	Fine-grained, slightly consolidated, green
6	3.5	19.2 – 20.2	idem
7	4.5	20.2 – 21.2	Fine grained, slightly consolidated, dark green, burrows
8	5.5	21.2 – 22.2	Fine grained, slightly consolidated, dark green, gray spots, burrows
9	6.5	22.2 – 23.2	Fine grained, slightly consolidated, dark green, many burrows
10	7.5	23.2 – 24.2	Fine grained, slightly consolidated, dark green, burrows
11	8.5	24.2 – 25.2	Fine grained, slightly consolidated, dark green → gray, burrows
12	9.5	25.2 – 26.2	Idem
13	11	26.2 28.2	Idem
14	13	28.2 - 30.2	Fine grained, consolidated, gray→ dark green, many burrows
15	15	30.2 – 32.2	Fine grained, consolidated, gray, burrows
16	17	32.2 – 34.2	Fine grained, consolidated, gray, many burrows
17	19	34.2 – 36.2	Fine grained, consolidated, gray → dark green, many borrows
18	22	36.2 – 40.2	Fine grained, consolidated, gray → dark green, foraminafera / borrows
19	26	40.2 - 44.2	Idem
20	30	44.2 – 48.2	Fine grained, consolidated, dark green → gray, burrows

Sediment description site 2 (porewater core).

Date: 20/09/02
Site: 2, Slijkplaat
Coordinates: 51.53.428N, 04.17.469E
Watertemperature: 16° Celsius
Core code: HV-B-2-BC2 subcore 2
Total length of core (cm):
Processed by: Christelle Hyancinthe & Jacqueline Claessens
Ship: RV Navicula

sample no.	average depth (cm)	depth interval (cm)	sediment description
1	0.25	17.1 – 17.6	Surface not flat
2	0.75	17.6 – 18.1	Brown soup surface sediment
3	1.25	18.1 – 18.6	Borrows begin, less soupy
4	1.75	18.6 – 19.1	Some grey color
5	2.5	19.1 – 20.1	Idem
6	3.5	20.1 – 21.1	Big burrow
7	4.5	21.1 – 22.1	Much more black
8	5.5	22.1 – 23.1	Idem
9	6.5	23.1 – 24.1	Idem
10	7.5	24.1 – 25.1	Idem
11	8.5	25.1 – 26.1	Idem
12	9.5	26.1 – 27.1	Idem
13	11	27.1 – 29.1	A crack in the middle of layer small white shells
14	13	29.1 – 31.1	More and more sticky, more burrows
15	15	31.1 – 33.1	Idem
16	17	33.1 – 35.1	Idem
17	19	35.1 – 37.1	Idem
18	22	37.1 – 41.1	Idem
19	26	41.1 – 45.1	Very, very black
20	30	45.1 – 48.1	Idem

Sediment description site 2 (anoxic storage core).

Date: 20/09/02
Site: 2, Slijkplaat
Coordinates: 51.53.428N, 04.17.469E
Watertemperature: 16° Celsius
Core code: HV-B-2-BC2 subcore 1
Total length of core (cm):
Processed by: Christelle Hyancinthe & Jacqueline Claessens
Ship: RV Navicula

sample no.	average depth (cm)	depth interval (cm)	sediment description
1	0.25	16.0 – 16.5	Surface not flat
2	0.75	16.5 – 17.0	Brown soup surface sediment
3	1.25	17.0 – 17.5	Borrows begin, less soupy
4	1.75	17.5 – 18.0	Some grey color
5	2.5	18 – 19	Idem
6	3.5	19 – 20	Big burrow
7	4.5	20 – 21	Much more black
8	5.5	21 – 22	Idem
9	6.5	22 – 23	Idem
10	7.5	23 – 24	Idem
11	8.5	24 – 25	Idem
12	9.5	25 – 26	Idem
13	11	26 – 28	A crack in the middle of layer small white shells
14	13	28 – 30	More and more sticky, more burrows
15	15	30 – 32	Idem
16	17	32 – 34	Idem
17	19	34 – 36	Idem
18	22	36 – 40	Idem
19	26	40 – 44	Very, very black
20	30	44 - 48	Idem

