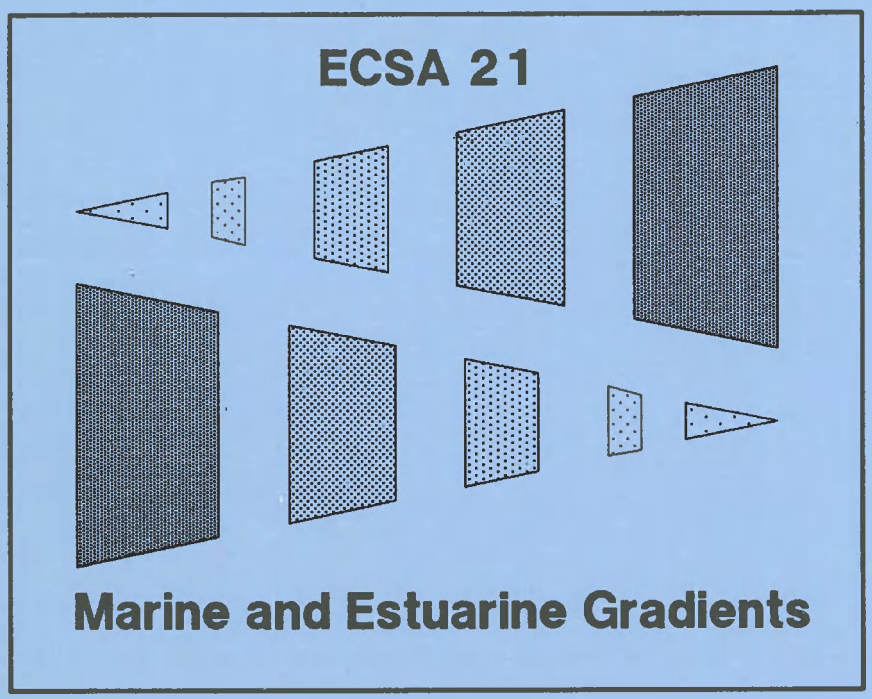
Jan Mees.

Estuarine and Coastal Science Association

ABSTRACTS

of spoken and poster papers



Symposium ECSA 21

organised jointly by

University of Gent, Insitute of Zoology,
Marine Biology Section
&
Institute of Nature Conservation
(Hasselt)

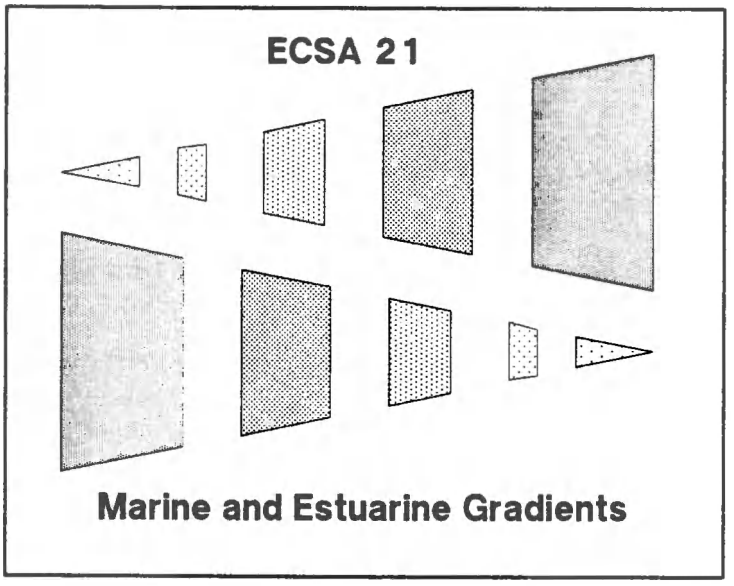
GENT September 9 to 14, 1991

BELGIUM

Estuarine and Coastal Science Association

Symposium ECSA 21
on
Marine and Estuarine Gradients

Final Programme



organised jointly by

University of Gent, Insitute of Zoology,
Marine Biology Section
&
Institute of Nature Conservation
(Hasselt)

GENT September 9 to 14, 1991

BELGIUM

ECSA 21
Marine and Estuarine gradients

Monday 9 September 1991

8h30 Registration of delegates at the University

CHAIRMAN: M. VINCX

10h30 Official opening

N. Jones on behalf of ECSA
P. Meire/M. Vincx on behalf of the organising committee
E. Derycke Minister of Science Policy

11h COFFEE

11h30 **ANDRADE F. REIS M. PEREIRA P. GOMES M.L. and VILAS-BOAS** L. (Portugal). Longitudinal and vertical gradients in the Mira estuary (V.N. Milfontes-Portugal), in relation to seasonal conditions and tide amplitude.
TACKX M. BOGAERT M. and DARO M. (Belgium). Gradients in particulate matter composition in the Westerschelde and the Belgian coastal zone.

12h20 LUNCH

CHAIRMAN: B. VAN ECK

14h **DE JONGE V.N. & ENGELKES M.E.** (The Netherlands). The role of different mineral compounds and chemical conditions in the local supply of phosphate in the Ems estuary.
QUINN N. & BREEN C. (South Africa). The application of geographic information systems to the analysis of physical and chemical gradients in a shallow coastal lake.
LANGERAK A. & VAN MALDEGEM D. (The Netherlands). A cohesive sediment balance for the Scheldt estuary.

15h15 TEA

15h45 **DARBYSHIRE E. & WEST J.** (United Kingdom). The turbidity maximum in the Tamar estuary.
MOFFAT A. & JONES M. (United Kingdom). Correlation of Mysids (Crustacea) distribution with physico-chemical gradients in a partially-mixed estuary (Tamar, England).
CYRUS D. (South Africa). Turbidity gradients in an African and Australian estuary and their effects on fish distribution.
RYBARCZYK H. DESPREZ M. OLIVESI R. and ELKAIM B. (France). Dynamique des nutriments et des germes fécaux en estuaire macrotidal: la baie de Somme (France).

ECSA 21
Marine and Estuarine gradients

Tuesday 10 September 1991

CHAIRMAN: D. CYRUS

9h **MEES J. HAMERLYNCK O. and DEWICKE A.** (Belgium). The summer and winter hyperbenthos of the Westerschelde.
TAYLOR C. (United Kingdom). The zooplankton populations of the Forth Estuary.
NEWELL S. & HOPKINSON C. (USA). Patterns of dinitrigen fixation (Acetylene reduction) on standing, decaying shoots of a marshgrass.

10h15 COFFEE

10h45 **ELLIOT M. & HULL S.** (United Kingdom). The fish populations of the freswater/brackish-water interface of estuaries: a case study of the Forth estuary.
HAMERLYNCK O. HOSTENS K. MEES J. ARELLANO R. & VAN DAMME P. (Belgium). Community analysis of the epibenthic fauna of the Dutch Delta.
MARCHAND J. (France). Influence of seasonal salinity and turbidity maximum variations on the nursery function of the Loire estuary (France).

12h LUNCH

13h30 POSTER SESSION + COFFEE

CHAIRMAN: V. DE JONGE

14h30 **FORBES A. CYRUS D. & BREEN C.** (South Africa). Salinity gradient reversals in a south-east African estuarine lake.
BODERIE P. ZWOLSMAN J. & VAN ECK G. (The Netherlands). Nutrient geochemistry in the water column and the sediments of the Scheldt estuary, S.W. Netherlands.
MALCOLM S. (United Kingdom). Benthic geochemistry and the fluxes of nutrients through the Humber and Wash.

15h45 TEA

16h15 **BAEYENS W. GILLIAN G. LEERMAKERS M. PANUTRAKUL S. MONTENY F.** (Belgium). Trace metals in the Scheldt estuary: analytical and geochemical aspects.
ZWOLSMAN J. & VAN ECK G. (The Netherlands). Behaviour of trace metals in the Scheldt estuary, S.W. Netherlands.

18h RECEPTION CITY HALL

ECSA 21
Marine and Estuarine gradients

Wednesday 11 September 1991

W. WOLF

CHAIRMAN: T. PEARSON

9h **PRESTON M.** (United Kingdom). Factors influencing the behaviour of organic chemicals in estuarine environments.
VAN ZOEST R. & VAN ECK G. (The Netherlands). Behaviour of organic micropollutants in the Scheldt estuary.
WILSON J.G. BRENNAN M. & BRENNAN B. (Ireland). Horizontal and vertical gradients in sediment nutrients on mudflats in the Shannon estuary, Ireland.

10h15 COFFEE

10h45 **DAVEY J.** (United Kingdom). Macrofaunal community bioturbation along an estuarine gradient.
WATSON P. FRICKERS P. & HOWLAND R. (United Kingdom). Estuarine sediments: chemical gradients and fluxes.
JONES K. (United Kingdom). Distribution of nitrogen-fixing bacteria in colonised and uncolonised intertidal sediments in the Lune estuary, UK.

12h LUNCH

13h30 POSTER SESSION + COFFEE

CHAIRMAN: M. ELLIOT

14h30 **SABBE K.** (Belgium). Benthic diatom assemblages in the Westerschelde-estuary: composition and distribution.
DE LEEUW J. (The Netherlands). Vascular plant species diversity along estuarine gradients.
HEMMINGA M. & VAN SOELEN J. (The Netherlands). Estuarine gradients may influence the quality of tidal marsh halophytes as host plants for endophagous insect larvae: experimental evidence.

15h45 TEA

16h15 **ESSINK K.** (The Netherlands). Distribution and life cycle of the North American Spionid Polychaete Marenzelleria viridis (Verrill, 1873) in the Ems estuary.
McGRORTY S. (United Kingdom). Population dynamics of estuarine mussels in relation to environmental gradients.
CLARKE K. (United Kingdom). Non-parametric linking of multivariate community structure with abiotic variables.

20h **MEIRE P.** Slide presentation about the Schelde estuary as an introduction to the excursion.

20h30 **Workshop** "Conservation and management of Estuaries".
Short introductions on conservation and management policy in different estuaries or countries will be given by:
DAVIDSON N. (United Kingdom); **LAFFOLEY D.** (United Kingdom); **BOLD** (United Kingdom); **WOLFF W.** (The Netherlands); **PIETERS T.** (The Netherlands)

ECSA 21
Marine and Estuarine gradients

Thursday 12 September 1991

9h **Full day excursion on the Schelde estuary.**

A boat will start in the centre of Gent, in the non-tidal part of the river Schelde, pass through the sluices into the tidal or estuarine part. We will sail through the entire freshwater tidal area of the river and make short excursions to the tidal marshes or/and to some typical small towns along the river. We will return in the evening by coach to Gent.

ECSA 21
Marine and Estuarine gradients

Friday 13 September 1991

CHAIRMAN: O. HAMERLYNCK

9h **GROENEWOLD A. VAN SCHEPPINGEN Y. & HOLTMANN S.** (The Netherlands). Zoobenthos in the Southern North Sea: the Dutch coastal area.
MAERTENS D. (Belgium). Influence of abiotic gradients on benthic invertebrates and demersal fish along the Belgian Coast and the Scheldt estuary.
MOREIRA M. QUEIROGA H. & MACHADO M. (Portugal). Environmental gradients in a southern Europe estuarine system: Ria de Aveiro, Portugal. Implications for soft bottom macrofauna colonization.

10h15 COFFEE

10h45 **RODRIGUES A. & QUINTINO V.** (Portugal). Horizontal biosedimentary gradients across the Sado estuary, Western coast of Portugal.
HULL S. ELLIOT M. & McLUSKY D. (United Kingdom). Variations in the intertidal and subtidal macrofauna and sediments along a salinity gradient in the upper Forth estuary.
YSEBAERT T. MEIRE P. SEYS J. MAES D. SAMANYAN R. BUYS J. & DEREGGE N. (Belgium). Macrobenthos of the Schelde estuary: the resultant of chemical and physical gradients.

12h LUNCH

13h30 POSTER SESSION + COFFEE

CHAIRMAN: K. ESSINK

14h **LI J. & VINCX M.** (Belgium). The temporal distribution of nematodes in the Westerschelde.
GRANT A. & MIDDLETON R. (United Kingdom). Trace metals in sediments from the tidal tributaries of the Humber estuary.
PETHICK J. (United Kingdom). Preferential transport pathways and deposition of Arsenic in the Humber estaury, UK.

15h15 TEA

15h30 **Workshop** "Conservation and management of Estuaries" (continued)

20h **SYMPOSIUM DINNER**

ECSA 21
Marine and Estuarine gradients

Saturday 14 September 1991

CHAIRMAN: N. JONES

9h **BILLEN G. DE SMEDT F. OZER J. RONDAY F. SAS M. VAN GRIEKEN R. & VERREET G.** (Belgium). An integrated modelling approach for the calculation of the mass pollutant transport within the Scheldt estuary towards the North Sea.
OUBOTER M. DE ROOIJ N. & VAN GILS J. (The Netherlands). Modelling of water and sediment quality in the Scheldt estuary.
BLUST R. & DECLEIR W. (Belgium). Speciation and biological availability of metals in salt- and freshwater mixing zones.

10h15 COFFEE

10h45 **SCHOBBEN J.** (The Netherlands). Accumulation models for the Blue Mussel (Mytilus edulis) and the Flounder (Platichthys flesus) in relation to energy-budgets and temperature.
STRONKHORST J. (The Netherlands). Effects of pollution in the Scheldt estuary.

11h35 Discussion and Closing remarks

12h Lunch/ END OF THE SYMPOSIUM

SPONSORS

The following organisations have contributed financial and/or moral sponsoring:

-the Estuarine and Coastal Science Association

-The University of Gent

-The Institute of Nature Conservation (Hasselt)

-the Belgian National Science Foundation

-the Institute for Marine Scientific Research

-The City of Gent

-Analis

ABSTRACTS OF

SPOKEN PAPERS

Longitudinal and vertical gradients in the Mira estuary (V.N. Milfontes - Portugal), in relation to seasonal conditions and tide amplitude.

F. Andrade[1], M.Reis[1], P.Pereira[1], M.L.Gomes[2] & L. Vilas-Boas[2].

1. SBMOB-Dep. Zool. Antrop. F.C.L., Laboratorio Maritimo da Guia, 2750 Cascais, Portugal.
2. Centro de Tecnologia Quimica e Biologica, estaçao Agronomica Nacional, 2870 Oeiras, Portugal.

During the year of 1990, in Spring and Fall conditions and in neap and spring tides, surveys were conducted along the estuarine section of the Mira (up to 27.5 Km from the mouth of the estuary) to investigate the longitudinal distribution of a large set of parameters.
In order to allow for the characterization of the longitudinal and vertical gradients in the Mira estuary, surveys were carried during tide slack, and equidistant sampling sites were located along the maximum depth line, with samples taken both at surface and near the bottom.
Several phenomena were made evident, namely the longitudinal and vertical gradients of salinity and turbidity and their association with the distribution of nutrients, pigments, bacteria counts and amino acids.
The differences in seasonal conditions were quite clear, mainly in terms of freshwater influence. Tide amplitude (neap vs. spring tides) was shown to be directly related to the intensity of vertical mixing - stratification vs. vertical homogeneity - and to resuspension phenomena, namely in relation to the turbidity and suspended solids (both total and organic) levels.
Tide excursions were also evaluated in terms of the differences in longitudinal profiles at low and high water. Their influence in longitudinal dispersion phenomena is also discussed.

Gradients in particulate matter composition in the Westerschelde and the Belgian coastal zone.

M.L.M. Tackx, M. Bogaert & M.H. Daro

Ecology and Systematics Laboratory, Free University of Brussels, Pleinlaan 2, B-1050 Brussel, Belgium.

Pelagic trophic studies in coastal areas are complicated by the complexity of the particulate matter, which consists of various particles of different chemical composition, size and availability to predators and nutritional value.
In front of the Belgian coast, an important contribution of particulate matter coming from the Westerschelde estuary has also to be taken into account. The study presented here aims at characterising estuarine and coastal particulate matter in order to arrive at ecologically functional distinct patterns in particulate matter.
From 1988 to 1990, particulate matter was sampled during Spring and Autumn campaigns along the brackish and the marine zone of the Westerschelde estuary and grid of stations in the Belgian coastal zone going from near coast to open sea. Analysis was carried out on chemical characteristics (chlorophyll a and b, POC, PIC) and coulter derived characteristics (particulate matter concentration and size distribution). Multivariate analysis was used distinguish specific estuarine, coastal and open sea patterns in particulate matter composition, and seasonal trends in these.

The role of different mineral compounds and chemical conditions in the local supply of phosphate in the Ems estuary

V.N. de Jonge & M.E. Engelkes

RWS, Tidal Waters Division, P.O. Box 207, 9750 AE HAREN (GN), The Netherlands.

In the Ems estuary gradients in dissolved nutrients, iron and particulates occur. The longitudinal distribution of phosphate is not a conservative one due to biological and geochemical processes. Indications are found for accumulation processes and interacting geochemical processes to be responsible for the phosphate distribution. However, the river Ems discharges also a considerable amount of iron. Also dissolved iron does not show a conservative distribution with salinity. During the water transport it disappears from the watercolumn in the low salinity region.
Phosphate can interact with different components among them organic matter, clay minerals, calcite and iron compounds. Based on previous field observation and experimental work, which indicated calcite to play a role, in the present study the role of this mineral but also organic matter and iron compounds in the interaction process was evaluated.
In laboratory experiments, in which the pH was decreased by addition of carbondioxide, the calcite bound phosphorus concentration turned out to be low. Moreover new field observations on calcite concentrations showed no clear seasonal fluctuations. The phosphate distribution, however, is clearly season dependent. Based on this it is concluded that calcite does not play an important role in governing the phosphate distribution in the Ems Estuary. Calculations show 5% of the particulate phosphorus to be calcite associated. Another important component of the suspended matter is iron. Field observations showed the concentration of particulate iron to be closely related to the concentration of particulate phosphorus. Experiments reveal that nearly 70% of the particulate inorganic phosphorus is iron-bound. Organic coatings on minerals may have an inhibiting influence on the phosphate release. However, the organic matter itself also contains a considerable amount of particulate phosphorus (ca. 20%). The remaining 5% is thought to be adsorbed to and incorporated in clay minerals. The role of the different processes om the phosphate distribution in the Ems estuary are discussed.

The application of geographic information systems to the analysis of physical and chemical gradients in a shallow coastal lake.

N.W. Quinn & C.M. Breen

Institute of Natural Resources, University of Natal, P.O.Box 375, Pietermaritzburg, 3200, Republic of South Africa.

Lake St. Lucia is a shallow coastal lake situated in the coastal plain of Zululand, South Africa; and is known internationally for its diversity and productivity as an ecosystem. The system is characterised by physical and chemical gradients which are both spatially and temporally dynamic. Salinity, for example may vary interannually between 0 gl^{-1} and 120 gl^{-1}, may drop from 120 gl^{-1} to 0 gl^{-1} within a few days, and while one part of the lake may have a salinity of 120 gl^{-1} other parts may be substantially lower (55gl^{-1}). Other gradients include turbidity, turbulence, sedimentation, resuspension and wave energy. As a consequence there is a marked spatial and temporal variability in biotic processes such as colonisation, production, grazing and predation. Understanding the rates and scales over which these chemical and physical gradients are operative is therefore of primary importance in the understanding of the structure and functioning of the system.
The availability of commercial geographic information systems (SPANS, Arc-Info) with sophisticated mapping, spatial analysis and modelling features has enabled a genre of ecological investigation hitherto precluded by unwieldy data sets, computer memory limitations and programming complexity.
In this paper, the application of such geograghic information systems (G.I.S.) to the analysis of spatio-temporal variability in ecological processes is reviewed. In particular the use of these systems in determining the significance of physical and chemical gradients in the structure and functioning of Lake St. Lucia is assessed.

A cohesive sediment balance for the Scheldt Estuary.

A. Langerak & D.C. van Maldegem

RWS - DGW, Postbus 8039, 4330 EA Middelburg, The Netherlands

The river Scheldt drains a densely populated and industrialized area in West Belgium and the south-west Netherlands. Since an important part of the industrial and domestic waste waters is discharged without prior treatment, both the river and its estuary are heavily polluted with organic wastes, nutrients, trace metals and organic micropollutants.
Five years ago Rijkswaterstaat decided to built a management oriented coupled transport, chemical/biochemical and bio-accumulation model for the Scheldt estuary. After a short introduction of the main hydrodynamical characteristics of the estuary, the model and the background studies will be presented in seven presentations. The presentations are: 1. the water- and sediment transport, 2, 3 and 4. the behaviour of nutrients, some selected trace metals and organic micropollutants, 5. the water and sediment quality part of the model, 6. the bio-accumulation part of the model and finally 7. an overview of the effects of (micro)pollutants on the biota of the Scheldt estuary.
The basis for every estuarine model is the description of the transport of water and sediment. For the water transport in the Scheldt estuary model a simple 1D approach has been adopted, although much is known about the water movement in the Scheldt estuary. This 1D approach has been chosen, because the Scheldt estuary is well-mixed and the lateral gradients are small compared to the longitudinal gradients.
Because micropollutants are preferentially bound to fluvial silt and the transport of (marine and fluvial) silt is one of the most important characteristics of estuaries, much attentions has been given in the model to the transport of silt and sedimentation and resuspension. Two different approaches have been followed: the development of a 2D horizontal silt transport model and the set-up of a silt balance for fluvial and marine silt for the 14 compartments of the Scheldt estuary model. The 2D model was not used in the final model because the model results were difficult to interpret. Some silt was set up for each of the 14 compartments of the Scheldt estuary model from dept records of dredging, the amounts of silt in bottom sediments, two decades of depth sounding, the stable isotopes of carbon to distinct fluvial from marine silt and the silt input into the upper estuary. The resulting sediment balance shows a net input of 320,000 ton of fluvial silt into the upper estuary and of 450,000 ton of marine silt from the North Sea into the lower estuary. Only 10% of the fluvial silt is transported to the North Sea. The remaining part sediments in the area around the Dutch-Belgian border. The calculated retention time of silt in the Scheldt estuary is about 30 years. The influence of the dredging operations around the Harbour of Antwerp on the sediment balance is large. Finally, the present and future silt balance of the estuary will be discussed, because

a large part of the actual silt load is anthropogenic.
Echo-soundings and side-scan sonar recordings further indicate that the bottom of the Western Scheldt typically consists of sand ripples of 1 to 25 m in length and 0.1 to 1 m in height. The displacement of the sand ripples is high. In the model, as a first estimate, it is assumed that a sediment layer of 0.5 m erodes and re-settles twice a year. This implies very high resuspension and erosion rates of typically 100 $g.m^{-2}.d^{-1}$.
The sediment transport in the Scheldt estuary (model) can be summarized as a relatively slow exchange of silt between compartments and a complete mixing of bottom and suspended sediment within a compartment.

The Turbidity Maximum in the Tamar Estuary.

E.J. Darbyshire & J.R. West.

School of Civil Engineering, University of Birmingham, U.K.

Many estuaries of medium to high tidal range exhibit an accumulation of fine cohesive material in their upper reaches in the region of the limit of saline intrusion. Much, or all, of this material is suspended each tidal cycle and the entire region undergoes a seasonal variation which appears to be dependant on fluvial input.

Two factors which are thought to influence the formation and maintenance of turdity maxima are the differing magnitudes of the bed shear stress (τ) on flood and ebb tides and the large vertical density gradient which develops on the ebb tide. Crucial to the importance of the first factor is that τ exceeds a critical value, at which erosion occurs, for a greater period on the flood than on the ebb. The effect of the density gradient is that upward propagation of bed generated eddies is inhibited and the sediment is not transported into the upper part of the flow where it will be most effectively transported. It is not clear which, if either, of these mechanisms is dominant.

Data, consisting of vertical profiles of velocity, salinity and suspended solids were collected at four stations in the Tamar estuary during a high range tidal cycle. One station, at which the depth mean salinity (S_d) varied from 0.0 to $\pm$ 12.0 *ppt*, was occupied permanently. The other stations were occupied such that data were collected as S_d varied in the range 0.0 to $\pm$ 5.0 *ppt*. In this way each station was occupied for a period of time on the ebb and flood tide.

Estimates of τ at the fixed station obtained from near logarithmic velocity profiles show values in excess of 1.0 Nm^{-2} for significant periods of both the ebb and flood phases of the tide suggesting a similar capacity for sediment transport, with higher values of solids concentration at 0.5 *m* recorded on the ebb. This occurred at S_d $\pm$*0.0 ppt* . Observations from the other station suggest that during the early ebb, when the flow is relatively deep and slow allowing stratification to persist until S_d $\pm$ *0.0 ppt* , that no significant transport occurs while the flow is saline but that there is a rapid increase after this point. During the later ebb the shallower faster flow allowed the density gradient to be eroded and significant transport was observed at S_d $\pm$ 5.0 *ppt*. On the flood tide the solids concentration decreases at 3 out of 4 stations as the flow becomes saline despite its being well-mixed throughout.

It is concluded that the major mechanism for the maintenance of the turbidity maximum during high tidal range is the density stratification where this exists. It is possible however, because of the magnitudes of during both phases of the tide, that this mechanism alone is insufficient to maintain the turbidity maximum and that a continuation of this regime will cause it to be gradually eroded and the sediment dispersed over a greater longitudinal extent of the estuary. This leads to the speculation that it is the periods of low tidal range, when the values of τ are genrally lower and the density gradients more persistent, that are also instrumental in turbidity maximum formation.

M.D

- tss 5 en 25 g/oo
- max. mei - juin

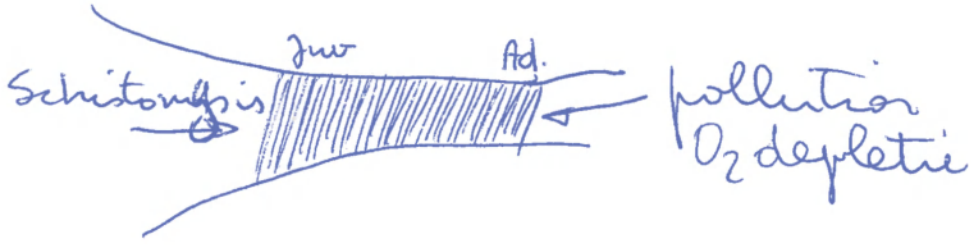
  max. 300 ind/m²⁰

  50 feb → ← 50 dec

- juv. meest abundant in hoge sal. zone.

  ad. meest in 3,5 - 3,5

  ↳ in WS competitie v. areaal ???



Correlation of Mysid (Crustacea) distribution with physico-chemical gradients in a partially-mixed estuary (Tamar, England).

A.M. Moffat & M.B. Jones.

Department of Biological Sciences, Polytechnic South West Plymouth, England.

ref. plaice & flounder!?

The physical and chemical processes operating in the Tamar Estuary (South-west England) have been comprehensively described. There are well-established gradients of salinity, suspended sediment and oxygen which vary both on short term (tidal) and long-term (seasonal) cycles. Freshwater runoff is the main factor determining salinity distribution and is also the cause of high variability in suspended sediment concentrations.

The biological processes have been less-well studied and particularly lacking is information on the link between the benthic and pelagic systems. Mysids, through their role as detritivores and as a major component in the diet of some fish, provide a significant link between the two systems. Four species of mysid are distributed horizontally along the length of the estuary. Two of these (*Mesopodopsis slabberi* and *Neomysis integer*) are abundant in the upper regions of the estuary. *M slabberi* is the more common and generally occupies a position between 5 and 25 kilometres from the head of the estuary; *N. integer* is found upstream of *M. slabberi*. Observations have shown marked seasonal changes in both abundance and distribution in the estuary. In summer and autumn, *M. slabberi* reaches relatively high densities (ca. 1800 individuals m^{-3}) at the upper part of its range. The horizontal distribution of adults becomes stable, although patchy, in salinities of 12-15% . Juveniles of this species are distributed over a wider area and occur frequently in water of higher salinity than the main adult distribution. During winter and spring, overall densities remain generally low (0-40 individuals m^{-3} for *M. slabberi)* and the population is more evenly distributed.

The above distributions are discussed in relation to the extensive published information on the physico-chemical gradients operating in the Tamar Estuary together with aspects of the biology of the dominant mysid species. It is proposed that while absolute density is determined primarily by the breeding cycle, horizontal distribution is greatly influenced by estuarine gradients.

maandelijks feb - dec
13 stations.
tss .5 en 30 ppt.
plankton net 3 repl
sal - t° - turb.

Turbidity gradients in an African and Australian Estuary and their effects on fish distribution.

D.P. Cyrus

Coastal Research Unit of Zululand, University of Zululand, Private Bag X1001, KwaDlangezwa, 3886, Natal, South Africa.

Research was undertaken in the St Lucia Estuary on the South East Coast of Africa and the Embley Estuary on the eastern side of the Gulf of Carpentaria, Queensland, Australia. Results showed that both study sites have distinct turbidity gradients present, with the turbid St Lucia system ranging from 2.0 to 568.0 Nephelometric Turbidity Units (NTU). The Embley, although also turbid, had a much more restricted turbidity range (0.6 to 55.0 NTU).

On a seasonal basis St Lucia Estuary showed little variation except when the Mfolozi, a nearby estuary, came down in flood and highly turbid water was pushed into St Lucia on incomming tides. The Embley on the otherhand showed three distinct patterns related to the three dominant seasons in the area the Wet, Early Dry and Late Dry Season. During a single year the gradient within the system, of clear at the mouth to turbid in the upper reaches, was substantially reduced, and this was followed by the gradient reversing itself before the onset of the next Wet Season.

Studies undertaken at St Lucia have shown that turbidity has a direct influence on fish distribution in the system. Distributions are determined by the extent of the gradient and levels of turbidity present along the gradient. In the Embley Estuary it was found that species groups, related to turbidity levels, exist. Due to the limited range of turbidity which occured these were somewhat restricted. Certain species and genera common to both systems showed similar patterns of distribution related to turbidity. It is concluded that dependent on the levels, turbidity gradients can have a profound effect on the distribution of fish in estuarine systems.

Dynamique des nutriments et des germes fécaux en estuaire macrotidal: la baie de Somme (France)

M. Rybarczyk (Gemel), M. Desprez (Gemel), R. Olivesi (Ifremer) & B. Elkaim (Univ. Paris VI)

C' est pour tester l'hypothèse d'une eutrophisation en Baie de Somme qu'une méthodologie originale de prélèvements d'eau sur estran a été appliquée en 1988 et 1989.
Les analyses de nutriments, de matière particulaire et de bactéries fécales ont montré la quasi-inexistence de mélange eau douce - eau salée ainsi que l'absence de stratification vertical de la colonne d'eau; les eaux douces sont repoussées en fond de baie et seules quelques lentilles présentent des caractéristiques véritablement estuariennes. Ces études préliminaires ont apporté un premier schéma explicatif sur la conservativité de la pollution.
En 1990, des prélèvements d'eau ont été réalisés simultanément sur le chenal de la Somme, sur les estrans et sur la façade maritime (point-fixe), permettant de raisonner selon un gradient continent-estuaire-mer.
Cette campagne a permis de confirmer l'importance des apports continentaux pour la pollution bactérienne d'origine fécale, pour les nitrates, les nitrites, le silicium; elle a également mis en evidence de fortes concentrations en chlorophylle continentale de bonne qualité qui, au même titre que les nitrates, sont impliquées dans l'eutrophisation de la Baie de Somme.
Au cours de ces trois campagnes, nous avons observé dans le secteur sud de la baie une recontamination par les eaux du large au cours du flot, ce qui pose le problème de la capacité épuratrice du milieu marin et celui du temps de survie des germes fécaux.
Un suivi régulier des apports continentaux et de la qualité de l'eau de mer permettrait d'évaluer comment ces deux influences, continentale et marine, gouvernent les phénomènes d'eutrophisation en baie de Somme.

The summer and winter hyperbenthos of the Westerschelde

J. Mees, O. Hamerlynck & A. Dewicke

Marine Biology Section, University Gent & Delta Institute for Hydrobiological Research, Yerseke.

The hyperbenthos of the Westerschelde estuary was sampled in August and December 1990. Fourteen stations were selected along the estuarine gradient, going from near marine conditions in the West to brackish and turbid conditions in the East.
The hyperbenthic community is dominated by several mysid species clearly segregated in space and time. Density and biomass are highest during summer near the typical estuarine maximum turbidity zone.
Community analysis shows that the Westerschelde can be roughly divided into three subareas. The different hyperbenthic communities seem to be highly correlated to salinity, turbidity and dissolved oxygen. Seasonal changes in species composition are most pronounced in the seaward part of the estuary. Samples from the brackish part are always dominated by the same few species.

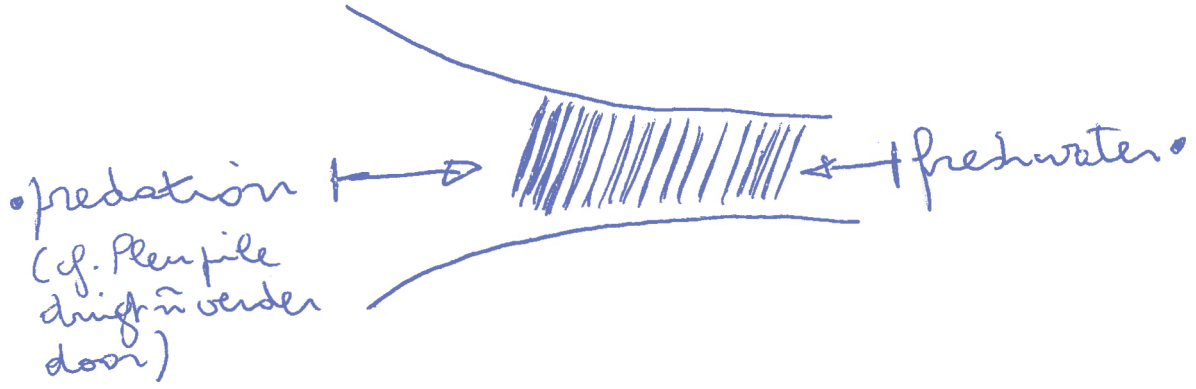
The zooplankton populations of the Forth Estuary.

C.J.L. Taylor.

Site planning and Environment Section, Nuclear Electric (location 106), Barnett Way, Barnwood, Gloucester GL4 7RS

Regular samples at nine stations ranging from fresh-water to fully marine conditions in the Forth estuary and Firth allow a description of the community structure and composition of the zooplankton. A transition gradient along the length of the estuary is clearly identified and linked to salinity and hydrographic features using both traditional and nonparametric techniques. Behavioural elements of the fauna include both resident estuarine populations and incursive marine populations, both having a strong seasonal component of variation.

check paper voor rare plots

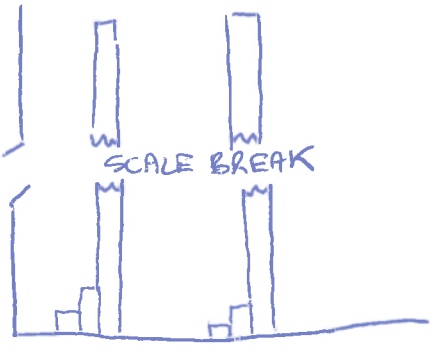


Patterns of dinitrogen fixation (Acetylene reduction) on standing decaying shoots of a Marshgrass.

S.Y. Newell[1] and C.S. Hopkinson[2]

1. Marine Institute, University of Georgia, Sapelo Island, GA 31327, U.S.A.
2. The Ecosystem Center, Marine Biological Laboratory, Woods Hole, MA 02543, U.S.A.

Dinitrogen fixation may contribute enough reduced nitrogen to saltmarsh ecosystems to supply the nitrogen demands of saltmarsh plants (such as smooth cordgrass, *Spartina alterniflora*), or it may be a minor source of nitrogen for saltmarches, depending on whether fixation rates (as acetylene reduction) have been accurately measured in several investigations yielding high rates for rhizomes, roots, and rhizospheres. Samples of standing dead cordgrass have exhibited more consistent results: high rates of nitrogenase activity (as acetylene reduction) per unit mass of sample. We measured rates of acetylene reduction over a range of situations pertaining in standing decay of cordgrass shoots. The degree to which standing, decaying leaves supported acetylene reduction was strongly correlated to the extensiveness of coverage of leaves by clay films (r^2=0.41, P<0.01). Leaves that had heaviest films (ash contents >40%) had rates of 10^2-10^4 nmol.g^{-1} organic.d^{-1}, whereas leaves decaying high on shoots with little or no clay coverage had rates < $5x10^1$ nmol.g^{-1} organic.d^{-1}. Nitrogenase activity was not limited to the clay layer on dead leaves; an equal quantity of clay on living leaves versus decaying leaves was only 7% as nitrogenase-active as on the decaying leaves. There was no detectable effect of incubation in light versus darkness on rates of acetylene reduction by decaying leaves or stems; one likely source of the high nitrogenase activity is a fungal/bacterial consortium. The highest rates of acetylene reduction by decaying cordgrass leaves were equivalent to the highest rates reported for other decomposition systems, both natural (e.g., mangrove leaves) and anthropogenic (e.g., wheat straw plus selected N_2-fixing inoculum).



* Vöökanalyses!!!

corr. matrix

Do t° sal depth Syf Abun biom. pl. biom ...

Station + ns --

DO +++

t°

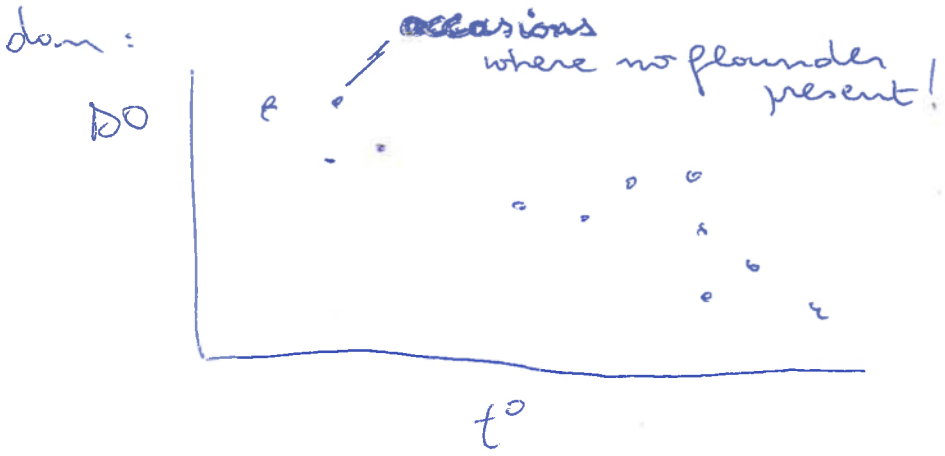
.

.

.

.

dom:



The fish populations of the freshwater/brackish-water interface of estuaries: a case-study of the Forth Estuary, Scotland.

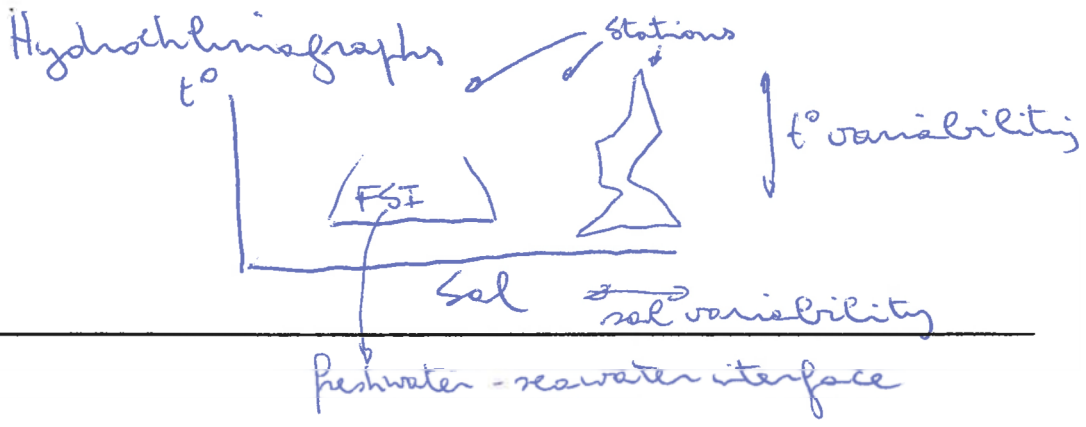
M. Elliott[1] & S.C. Hull[2]

1. Dept. of Applied Biology, Institute of Estuarine and Coastal Studies, The University, Hull, HU6 7RX, UK
2. Tidal Waters Section, Forth River Purification Board, Avenue North, Heriot-Watt Research Park, Riccarton, Edinburgh EH14 4AP, UK.

The paper describes the structure and functioning of the fish populations of the upper Forth estuary, eastern Scotland, in relation to water quality characteristics. A study from 1988 to 1991 has estimated the species composition, abundance and biomass of fish at six stations covering an area from freshwater to almost fully marine salinities. The area studied coincides with the freshwater/brackish-water interface (FBI) and the turbidity maximum of the estuary. At the FBI of the Forth, as elsewhere, the effects of natural stressors on the fish in this region are exacerbated by man's activities.

The study describes the spatial distribution and seasonal cycles of the fish community characteristics in relation to the major environmental factors of depth (and thus tidal cycle), salinity (and thus freshwater input and saline intrusion), temperature and dissolved oxygen (and thus the effects of natural and introduced organic material breakdown). In addition to showing seasonal patterns in population dynamics, the results indicate the presence of a summer water quality barrier for the indigenous fish species as well as migratory species.

Although more than 20 species have been taken in the study, the paper focuses on the resident/catadromous species flounder, *Platichthys flesus*, and the reintroduction of the smelt, *Osmerus eperlanus*. The distribution of the former in the upper Forth is contrasted with that elsewhere in this estuarine/marine system and shown to be affected by water quality. The smelt, in contrast, has recently (1989) returned to the Forth after being removed in the 1960's through commercial fishing pressures and poor water quality. The results enable water quality standards relevant to indigenous estuarine fish to be proposed and discussed. Finally, multivariate statistical techniques, including multiple regression analysis, are used to describe and interpret the patterns observed. In particular, their use in modelling the system is discussed.



Ecotopische groepen:
- marine seasonal migrant
- " juveniel "
- est. resident
- diadr. migrant
- katadr. "

Community analysis of the epibenthic fauna of the Dutch Delta

O. Hamerlynck, K. Hostens, J. Mees, R. Arellano & P. Van Damme

Marine Biology Section, University Gent & Delta Institute for Hydrobiological Research, Yerseke.

During 1989 monthly beam trawl samples were obtained from 22 stations in the shallow coastal area in front of the Dutch Delta (The Voordelta), 12 stations in an adjoining marine bay (the Oosterschelde), and 14 stations along a salinity gradient of a true estuary (the Westerschelde). These data were subjected to multivariate statistical techniques in order to define communities and to relate these communities to environmental variables.
A number of different communities can be distinguished. Sandeel species and lesser weever are characteristic for sandy stations with high wave impact and low macrobenthic biomass. Flatfish and seastars dominate in the muddy stations with high macrobenthos biomass. The stations of the inner Oosterschelde have a hard substrate component in their fish faunas. The fauna in the Westerschelde is impoverished and reflects the salinity gradient.

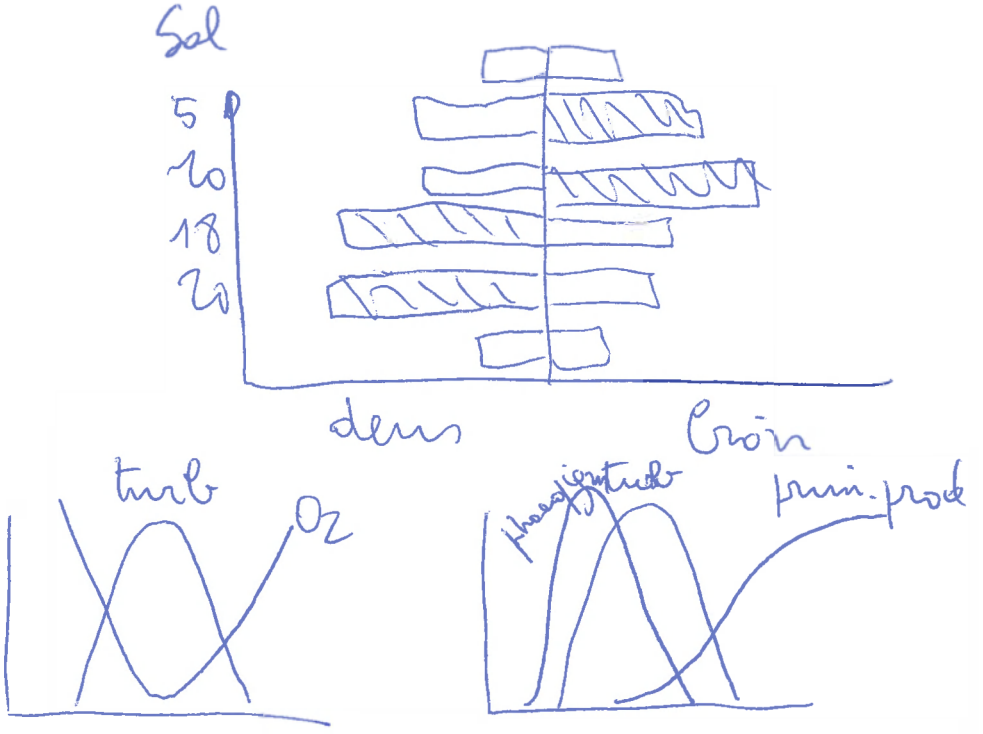
Influence of seasonal salinity and turbidity maximum variations on the nursery function of the Loire estuary (France).

J. Marchand

Laboratoire de Biologie Marine, Université de Nantes, 2 rue de la Houssinière, 44072 Nantes Cedex 03, France.

In the Loire estuary which is a macrotidal estuary, the river flow and tides induce large seasonal variations in salinity gradients and in location and density of turbidity maximum. These parameters influence colonization patterns developed by the juveniles of euryhaline fish populations (structure, distribution and density) and the dynamics of benthic communities which constitute their food resources. In some hydrological conditions, the upstream limit of the nursery function may be controlled by the turbidity maximum which induces anoxia and mortality.

MTZ



Opgebruik vooral gevaarlijk in lente wanneer veel migraties van vis

Ook breedte (of hoeveelheid) turb. zone belangrijk!

Salinity gradient reversals in a south-east African estuarine lake

A.T. Forbes[1], D.P. Cyrus[2] & C.M. Breen[3].

1. Biology Department, University of Natal, Durban, R.S.A.
2. Zoology Department, University of Zululand, P.O. Kwa Dlangezwa, R.S.A.
3. Institute of Natural Resources, University of Natal, Pietermaritzburg, R.S.A.

The St Lucia Lake system on the north coast of Natal, South Africa has an area of ca. 325 km^2 and is the largest estuarine complex in southern Africa. It is also one of the oldest nature reserves in the country. It consists of a 20 km tidal channel averaging ca. 400 m in width linking the sea with the lake. The lake is non-tidal but water movements occur as a result of relative inputs of sea or fresh water and wind induced seiche effects. The lake is roughly H-shaped with a maximum length of ca. 40 km and width of ca.25 km. Dimensions vary depending on water levels. The average depth is less than one metre.

Salinities in the lake and channel depend on evaporation, the nature of the mouth, which modifies the input of sea water, and on the input of fresh water from the four major rivers which discharge into the northern and western areas of the lake. Different combinations of the above factors allow three salinity regimes to be recognized. Under conditions of high fresh water input the lake and much of the channel are fresh; an intermediate stage characterised by a normal salinity gradient also occurs while a third stage shows a reversed salinity gradient with salinities in excess of 100 % in the upper reaches of the system.

The changing salinities, which are associated with changes in water levels, have marked effects on the biota. Cycles of appearance and disappearance depending on degrees of tolerance or the presence of dormant stages and also on powers of recolonisation and the presence of reservoir areas characterise the distribution patterns of various members of the flora and fauna. These are presently under investigation.

Catchment modifications resulting in changed patterns of fresh water input have modified cycles of salinity fluctuation. Possible adverse long term effects are of significance because the area is a designated RAMSAR site supporting major populations of crocodiles and hippopotamus as well as providing breeding sites for a number of South African Red Data bird species. It is also a major nursery area for marine fish and penaeid prawns.

Nutrient geochemistry in the water column and the sediments of the Scheldt estuary, S.W. Netherlands

P.M.A. Boderie[1], J.J.G. Zwolsman[1] & G.T.M. Van Eck2

1. Department of Geochemistry, Institute of Earth Sciences, University of Utrecht, P.O. Box 80021, 3508 TA Utrecht, The Netherlands.
2. Ministry of Transport and Public Works, Tidal Waters Division, P.O. Box 8039, 4330 EA Middelburg.

The Scheldt river drains a densely populated and industrialized area in northern France, western Belgium and the south-west Netherlands. Mineralization or the high organic load carried by the river leads to oxygen depletion in the water column and high concentrations of dissolved inorganic nitrogen and phosphorus compounds. Upon estuarine mixing dissolved oxygen concentrations are gradually restored due to reaeration and dilution with sea water. The longitudinal redox gradient present in the Scheldt estuary strongly affects the geochemistry of nutrients.
Dissolved nutrients in the water column were determined during 8 cruises in the period February 1987 - February 1988. Concentration salinity plots show conservative behaviour of dissolved Si during winter. During Spring-Summer dissolved Si may be completely removed from solution due to uptake by diatoms. The behaviour of nitrogen is controlled by denitrification in the anoxic fluvial estuary, followed by nitrification in the upper estuary (prior to oxygen regeneration). In addition, nitrogen is taken up during phytoplankton blooms in the lower estuary. The geochemistry of phosphorus is govered by inorganic and biological processes. Coprecipitation with colloidal iron may occur in the low salinity zone during summer. By contrast, phosphorus is released from suspended matter during winter, as inferred from the occurrence of phosphate "buffering" over a large salinity range. Biological uptake of phosphorus is important during phytoplankton blooms.
Nutrient poor water profiles from the upper 30 cm of the sediments where obtained from three sites of the lower estuary during March 1988 - June 1989. Dissolved Si, ammonium and nitrate concentrations are low in the upper 10 to 15 cm of the sandy and organic -poor (<1% POC) sediments. Sandwaves induced by tidal oscillations cause sediment nutrient flushing and a high spatial variability.
The pore-water profiles for silicate, ammonia and nitrate were evaluated quantitatively, using one-dimensional steady-state diagenetical models. The apparent diffusion coefficient was estimated from the response time of pore-water chloride concentrations to changing surface water chlorinities, and appeared to be 100 times the molecular diffusion coefficient. Similar results were obtained from calibration against esperimentally measured fluxes in the laboratory.
Sediment-water exchange fluxes measured in whole core incubations were: 1.2 (NH_4^+), 1.5 (NO_3^-), 1.4 (Si), 0 ± 0.1 (PO_4)mmol.m^{-2}.d^{-1}. The first-order dissolution rate of Si was calculated by the model at $7\text{-}11 * 10^{-7} s^{-1}$. The combined ammoniium-nitrate model revealed that mineralization of organic matter into nitrogen is

restricted to the upper 4 to 7 cm of the sediments. First order nitrification and denitrification rate constants were estimated ar 1.1-1.5*$10^{-3}s^{-1}$, respectively. Total nitrification ranged from 3.7-17 $mmol.^{-2}.d^{-1}$, converting nearly all ammonium produced by mineralization. The net balance between nitrification and denitrification depends on the season. Nitrate leaves the sediments during winter but is taken up from the water column during summer.

Benthic biogeochemistry and the fluxes of nutrients through the Humber and the Wash.

S.J. Malcolm

Ministry of Agriculture Fisheries and Food, Fisheries Research Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 OHT, United Kingdom.

The Joint Nutrients Study (JoNuS) is a major programme of estuarine research aimed at quantifying the input of the nutrient elements (nitrogen, phophorus and silicon) into the southern North Sea from the major estuaries of eastern England. The study is currently focussing on the Humber, as it is the major fresh-water input, and the Wash, as it is a complex, little understood area and drains a large agricultural catchment.
Benthic biogeochemistry is a major factor in determining the fluxes of nutrients through an estuary. This paper will describe the sediment process component of the JoNuS programme concentrating on processes at the sediment/water interface. Sediment samples have been collected in relation to both estuarine gradients, of salinity and nutrient concentrations, and to gradients of sediment type. Sampling emphasis in the Wash has been on the extensive intertidal area as up to half of the area dries on every tide. Data will be presented on the rate of denitrification, the sediment/water interface fluxes of nutrients and on interstitial water concentrations of nutrients to gain an understanding of the sediment processes that influence the transport of nutrients through the estuaries. The influence of these processes on the flux of nutrients along the estuarine gradients will be discussed.

Trace metals in the Scheldt estuary: analytical and geochemical aspects.

W. Baeyens[1], G. Gillain[2], M. Leermakers[1], S. Panutrakul[1] & F. Monteny[1]

1. Laboratorium voor Analytische Scheikunde en Geochemie (ANCH), VUB, B-1050 Brussel.
2. Laboratoire d'Océanologie, Université de Liège, B-4000 Sart-Tilman (Liège).

In the period 1981 - 1984 longitudinal profiles of dissolved and particulate trace metals were assessed. Thereafter, sediment cores were sampled throughout the estuary and analyzed for major and trace metals. In recent years attention was paid to the speciation of mercury in the estuary as well as to the dissolved/solid phase partitioning of trace metals in the sediments.
All steps in the analytical process were submitted to a severe assessment of occasional or permanent sources of error, whatever the type of sample considered. Estuarine water sampling was carried out with a peristaltic pump drawing the water at 6L.min^{-1} through a high density PVC tube previously soaked for several days in 6N HCL and abundantly rinsed with ultra-pure water. The unfiltered water was kept in a closed 5L glass bottle and continuously stirred for the next operation: filtration. To minimize possible external contamination, a shipboard stirred pressure system under purified nitrogen was used. Instead of filtration, on line centrifugation with a teflon coated centrifuge was also carried out. For mercury, ultra-clean sampling from a zodiac, and filtration with a teflon device is actually in use. Analyses of Cd, Cu, Pb and Zn was performed by Anodic Stripping Voltammetry allowing speciation of the labile and strongly bound fraction in the dissolved phase. The dissolved gaseous, reactive and strongly bound Hg fraction in the watercolumn was occasionally estimated. Vertical sediment cores were sampled with plexitubes by divers. Sectioning of the cores and consequently squeezing or centrifugation of the slices (both operations under nitrogen atmosphere) allowed to gain more insight about the metal partitioning between the dissolved and particulate phases.
The general pattern for all metals is fairly similar: (1) in the riverine part and the early mixing watermass (very low salinities) the dissolved metal concentrations are high except in the period of strong oxygen depletion; (2) in the area of maximum turbidity, with also a higher residence time of the watermass, the dissolved metal concentrations decrease due to adsorption; (3) downstream the turbidity maximum mobilisation processes result in an increase (stronger or weaker according to the metal) of the dissolved concentrations followed in the downstream estuary by a further decrease. The particulate metal profiles decrease in the downstream direction through mixing of riverine with marine derived suspended matter. In the bottom sediments high values are observed in the area of the turbidity maximum.

Behaviour of trace metals in the Scheldt estuary, S.W. Netherlands.

J.J.G. Zwolsman[1] & B.T.M. van Eck[2]

1. Department of Geochemistry, Institute of Earth Sciences, University of Utrecht, P.O. Box 8039, 3508 TA Utrecht, The Netherlands.
2. Tidal Waters Division (DGW), Ministry of Transport and Public Works, P.O. Box 8039, 4330 EA Middelburg, The Netherlands.

The distribution of trace metals in several abiotic compartments of the Scheldt estuary has been studied between 1987 and 1990. Data on dissolved and particulate trace metals in the water column were obtained during 8 cruises, carried out in 1987-1988. The distribution of trace metals in the sediments was assessed by evaluating a large number of existing (monitoring) data. In addition, pore water samples were taken at four locations in 1989. The results indicate that the Scheldt estuary is severely contaminated by trace metals. However, a trend towards decreasing metal pollution in the 1980's is apparent.

The behaviour of dissolved Cd, Cu and Zn depends on the season. The concentrations of these metals in the (anoxic) Scheldt river is very low during spring and summer due to precipitation of sparingly soluble metal sulphides. The dissolved metal concentrations increase rapidly along the longitudinal redox gradient in the estuary, due to oxidation of the metal sulphides and (e.g. chloro-) complexation of the release metals. Readsorption of Cd and Zn occurs in the lower estuary during phytoplankton blooms. Trace metal concentrations in the (slightly oxic) Scheldt river are relatively high during Winter. However, the metals are rapidly removed from solution in the low salinity, high turbidity zone, due to adsorption onto suspended matter. Upon further mixing desorption occurs, due to similar oxidation-complexation mechanisms as those observed during Spring and Summer. Trace metal concentrations in the suspended matter show a continuous decrease with increasing salinity. This distribution pattern is to a very large extent due to physical mixing of (contaminated) riverine particulates and marine particulates which have much lower trace metal concentrations. Desorption of Cd, Cu and Zn can also be identified but is of minor importance compared to the conservative mixing process.

Trace metal concentrations in the surficial sediments are determined by the mixing ratio of fluvial and marine silt. The only exception is Cd, which appears to be mobilized.

The distribution of dissolved trace metals in the pore waters reflects the impact of early diagenetic processes. A steep maximum is observed close to the sediment-water interface due to oxidation of labile organic matter. In the sulphate reduction zone, trace metal concentrations are much lower due to precipitation of metal sulphides. The subsurface maximum may be of great ecological importance since the metal concentrations in macrofauna species feeding on the sediments (*Nereis diversicolor*) are related more to the pore water metal concentrations than to the total metal content of the sediments.

Factors influencing the behaviour of organic chemicals in estuarine environments.

M.R. Preston

Oceanography Laboratories, Liverpool University, Liverpool, UK.

Recent studies of the distribution of organic compounds within estuaries have demonstrated that, in addition to the properties of the individual chemicals, a variety of environmental variables exert a significant influence on the partitioning of chemicals between dissolved, suspended particulate and sediment phases. These variables are clearly of considerable importance to the transport, fate and potential effects of organic chemicals within the estuarine environment. These variables include particle size, particle composition and particle buoyancy as well as more obvious parameters such as salinity.
Data will be presented to illustrate these effects using natural products such as lignins and carbohydrates, and contaminant chemicals such as PAH, phthalate esters and linear alkyl benzenes as examples. This data derives from work carried out on the Mersey, Tamar, Humber and Thames estuaries.

Behaviour of organic micropollutants in the Scheldt estuary.

R. van zoest[1] & G.T.M. van Eck[2]

1. Grondmij N.V. Postbus 203, 3730 AE De Bilt, The Netherlands.
2. RWS-DGW, Postbus 8039, 4330 EA Middelburg, The Netherlands

The behaviour of organic micropollutants in the abiotic compartments water, suspended sediment and bottom sediments of the Scheldt estuary was studied between 1986 and 1990. Special attention was given to two individual PCB congeners (PCB-52, PCB-153), two PAH compounds (Fluoranthene, Benzo(a)pyrene) and lindane, because these five compounds are part of the Scheldt estuary water quality model.

The dissolved PCBs behave conservatively in the Scheldt estuary. Of the total PCB-52 and PCB-153 concentration respectively 50% and 5% is dissolved. Most PAHs were difficult to detect in the waterphase, with fluoranthene as an exception. The few results indicate decreasing concentrations at increasing salinities. Dissolved fluoranthene behaves conservatively at salinities higher than 4.5. Fluoranthene shows a strong seasonal dependence with high concentrations in Winter and low in Summer. Of the total lindane concentration 95% is dissolved. Dissolved lindane behaves conservatively and shows a seasonal dependence with high concentrations in Spring.

Particulate PCBs and PAHs behave more or less conservatively in the Scheldt estuary as a result of the mixing of riverine particulates with high and marine particulates with low organic micropollutant contents. Fluoranthene is removed in the lower salinity range. This observation may be explained by microbial degradation at low salinities under (nearly) anoxic conditions, favoured by the long residence time of the particulates in the high turbidity zone.

For PCBs reasonable agreement is found, when observed sediment-water partition coefficents (k_{oc}) are compared to literature values.

The PCBs and PAHs contents of the bottom sediments of the Scheldt estuary are to a large extent the result of the mixing of riverine particulates with high and marine particulates with low organic micropollutants contents.

The micropollutant discharges into the estuary, necessary for the model, are difficult to determine accurately, because of the lack of data. The river Scheldt appears to be the major source for the compounds studied. Especially the organic micropollutant contents of the sediments indicate however, that important emissions along the estuary are also present.

Measurements of individual PCB congeners and PAH compound in the < 63µm fraction of two dated sediment cores from the salt marshes in the eastern part of the Scheldt estuary show that the recent input of PCBs and PAHs into the estuary is probably 2-3 times lower than the maximum input in the mid 1960s. The PCB pattern in the dated cores changes between 1965 and 1975 from less chlorinated to more heavily chlorinated PCBs. This shift coincides with the decrease of usage

of PCBs in open systems. Contrary to PCBs, the PAHs assemblage is remarkable uniform in the cores. The PAH ratios indicate that combustion of coal is the main source of PAHs in the Scheldt estuary.

Horizontal and vertical gradients in sediment nutrients on mudflats in the Shannon estuary, Ireland.

J.G. Wilson, M. Brennan & B. Brennan

Environmental Sciences Unit, Trinity College, Dublin 2, Ireland.

Spatial variability in nutrient concentrations in the intertidal sediments has been studied along downshore transects and in core profiles at three locations in the Shannon estuary on the west coast of Ireland. The parameters measured were N, as Kjeldahl N, NO_3, NO_2, and NH_3, and P as total P and PO_4 along with a range of other environmental variables such as salinity, sediment organic content, etc.
The concentrations of all nutrients varied with season, but winter values were generally low in comparison with polluted mainland european estuaries. There was a great deal of variation in nutrient concentrations along the transects, and coefficients of variability of up to 153% (NH_3), 173% (NO_3), 129% (NO_2) and 117% (PO_4) were found. Overall, there was little evidence of any trends in concentration in any of the nutrients from the top to the bottom of the transects, although it was occasionally possible to link particular instances to local conditions such as the presence of the channel or a stream.
Sediment core profiles showed the expected patterns, with NO_3 concentrations for example being highest in surface sediments, while NH_3 and PO_4 concentrations increased with depth. Rather surprisingly perhaps, NO_3 could still be detected on occasion at depths of up to 20 cm, well below the RPD and limit of oxygen penetration. This was ascribed to the activities of the macrofauna, in that the oxidised sediment which lined the burrows could clearly be seen in some cores.
This study not only shows that nutrient distributions along estuarine gradients are linked to physico-chemical factors such as oxygenation and freshwater/marine influence, but also that sediment instability, through random physical events such as storms, and macrofaunal activity play an important role and that these latter factors deserve closer attention.

Macrofaunal community bioturbation along an estuarine gradient.

J. Davey

Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, UK.

The Tamar River at Plymouth is characterised by considerable areas of fine intertidal deposits, by a tidal range of 4 or 5 metres that extends up-river for more than thirty kilometres from the open sea, by wide variation in seasonal freshwater flow, and in the extent of resuspension, redeposition and redistribution of silt-clays within the estuary. Macrofaunal communities in different parts of the river reflect the complex interplay of these parameters and studies of sediment-water chemical interactions depend critically upon an appreciation of the biological influences at work at any point.

A multidisciplinary study of the impact of bioturbation on sediment dynamics has been underway for some time at the Plymouth Marine Laboratory. The programme has been founded upon the careful selection of six sites in the Tamar, representative of important combinations of physical and biological variables, and the work is proceeding very largely via the use of undisturbed sediment cores from these sites held in a microcosm system.

The six sites include one rich and one improverished *Nereis diversicolor/Scrobicularia plana* community in the upper estuarine, low-salinity areas, an *Arenicola marina/Nephtys hombergii* community occupying an organically enriched mid-estuarine area, a largely filter-feeding as opposed to deposit feeding community on a lower-estuarine sandy mud area, together with a polluted creek community and a mid-estuarine mudflat subject to such strong physical scour as to render it periodically devoid of macrofauna.

The paper will concentrate on results to date in quantifying the bioturbation due to two species in particular, *Nereis diversicolor* and *Nephtys hombergii* whose distributions across the six sites are complementary but whose effects are mediated in quite different ways. The dominant effect of bioirrigation by *Nereis diversicolor* generally increases up the estuary and is greatest in the region of the turbidity maximum where the consequences for chemical exchange processes between sediments and the water column may be most important. The sediment mixing effects of *Nephtys hombergi* are greater towards the seaward end of the estuary but ultimately the particular sediment types and the macrofaunal communiies they support dictate the level of bioturbation in ways that do not necessarily relate to simple axial gradients along the estuary.

Estuarine sediments: chemical gradients and fluxes.

P.G. Watson, P.E. Frickers & R.J.M. Howland

Plymouth Marine Laboratory, Prospect place, West Hoe, Plymouth PL1 3DH, UK.

In estuarine and coastal waters, sedimenting material includes large amounts of organic detritus, minerals and a wide range of pollutants. Materials that are not degraded at the sediment surface are buried by physical disturbance or further sedimentation. Subsequently these undergo chemical, physical and biological alteration (diagenesis).

The vertical, and often steep, pore-water concentration gradients that result from these processes drive diffusive fluxes of soluble components across the sediment water interface which can modify the composition of the overlying water column. A combination of spatial and seasonal variations in these chemical gradients and in the processes that influence sediment-water exchange, results in fluxes throughout the course of the estuary that are also spatio-temporally variable. The assessment of the importance of estuarine sediment-water exchange to geochemical cycling and the transport of contaminants in tidal waters, is therefore critically dependent on determining these variations and understanding the processes that underlie them.

Vertical sediment pore water concentration gradients and associated fluxes of chemical components have been studied in the sediments of the Tamar Estuary SW England. Seasonal and spatial variability have been determined over the course of a year at six sites, repesentative of varying physical and bioturbational activity. Nutrients (ammonia, phosphate, silicate, nitrate & nitrite) and trace metals (iron, manganese, zinc, copper, cadmium, nickel & lead) have been determined in sediment pore waters collected with *in situ* suction samplers (Watson & Frickers, 1990, Limnol. Oceanog. 35: 1381-1389) in laboratory microcosms and at field sites. Fluxes have been determined using benthic field chambers and by laboratory incubations.

Results for measured fluxes and those calculated from pore water concentration gradients are discussed in terms of spatial and seasonal variability, the influence of macrofaunal bioturbation (particularly bioirrigation) and the overall importance of sediment-water exchange to estuarine tidal waters.

Distribution of Nitrogen-fixing bacteria in colonised and uncolonised intertidal sediments in the Lune Estuary, UK.

K. Jones

Division of Biological Sciences, Lancaster University, Lancaster LA1 4YQ, UK.

Nitrogen fixation due to heterotrophic bacteria has been demonstrated for the intertidal sediments of the river Lune. A variety of nitrogen-fixing bacteria have been isolated and this includes the aerobe, *Azotobacter chroococcum*; the facultative anaerobes, *Klebsiella, Enterobacter* and *Bacillus*; the anaerobes, *Desulfovibrio* and *Rhodopseudomonas*; and various cyanobacteria. This paper evaluates the bacteria for their capacity to contribute fixed nitrogen over the range of salinities, temperatures, and nutrient levels found in the estuary, shows their distribution and seasonal variation in both uncolonised sediments and in sediments dominated by *Spartina anglica*, confirms their capacity for nitrogen-fixation using ^{15}N-isotopic dinitrogen and discusses their point of entry into the estuarine system.

Benthic diatom assemblages in the Westerschelde-estuary (Zeeuws-Vlaanderen, the Netherlands): composition and distribution.

K. Sabbe

Laboratorium voor Morfologie, Systematiek en Ecologie van de planten - Rijksuniversiteit Gent.

At the end of October 1989, sediment samples were taken at 43 intertidal stations in the Westerschelde-estuary.
240 diatom taxa were distinguished. Some dominant species were *Navicula perminuta*, *Amphora coffaeformis, Achnanthes hauckiana, Cymatosira belgica* and *Delphineis minutissima*. Because of the small size (< 20 µm) of many taxa and the rather limited amount of literature on the systematics of estuarine benthic diatoms, 74 taxa could only be determined to genus-level. Currently, further research is done on the taxonomy and systematics of these diatoms.
The relative abundance of each diatom taxon in the different samples was determined. The results of the countings were then analysed using two multivariate techniques: a classification (TWINSPAN) and an ordination (DCA). Both the TWINSPAN and DCA analysis resulted in a clear division of the samples in two main groups; in each main group 4 subgroups were distinguished. The relation between the distribution of the diatom assemblages and two abiotic parameters (sediment composition of the samples and salinity gradient in the estuary) was investigated.
The estuary was divided into 4 salinity sectors (euhaline-polyhaline, polyhaline- -mesohaline, polyhaline-oligohaline and -mesohaline-limnetic). We could not find a clear relation between the salinity gradient and the species distribution. This could indicate that salinity is not necessary a key factor influencing the distribution of benthic diatom species in such biotopes; these estuarine diatoms could occur over wide ranges of salinity and thus seem to be euryhaline.
On the other hand, a clear relation was found between species distribution and sediment composition of the samples. The samples of the first main group mainly consisted of sand particles (>200 µm). These were characterized by communities of (often very) small (< 20 µm) diatoms that live attached to sandgrains (the so-called epipsammic diatoms). The samples of the other main group had a higher silty fraction (particles < 50 µm), which indicates a more sheltered habitat. The number of epipelic (i.e. free-living, larger (> 20 µm) diatoms) is consequently higher, although epipsammic species still dominate.
Because only a limited number of samples was taken in a single season, more detailed research is needed to confirm the results of this study. A more frequent sampling campaign is planned to investigate the (spatial and seasonal) stability and the taxonomic composition to the benthic diatom communities. In addition, further research will be extended to all benthic micro-algal groups. The influence of a few selected estuarine gradients (such as salinity and nutrients) on the distribution of the microphytobenthos will be studied.

Vascular plant species diverity along estuarine gradients

J. de Leeuw

Delta Institute for Hydrobiological Research, Vierstraat 28, 4421 EA Yerseke, The Netherlands

A reduction in vascular plant species number in relation to increasing water chlorinity has been described for North American estuarine marshes. However, the exact shape of the species versus chlorinity curve remains to be established and the factors responsible are not clear.
In this study the relation between estuarine water chlorinity and number of tidal marsh angiosperms was investigated for five outlets of the rivers Rhine, Meuse and Scheldt. More than 100 species occured in freshwater marshes, while only 24 species were recorded in salt marshes. There was a strong decrease in species number around 2 to 3%. Chlorinity, which was related to the disappearance of the freshwater species. Possible causes for the change in species number will be discussed.

Estuarine gradients may influence the quality of tidal marsh halophytes as host plants for endophagous insect larvae: experimental evidence.

M.A. Hemminga & J. van Soelen

Delta Instituut voor Hydrobiologisch Onderzoek, Vierstraat 28, 4401 EA Yerseke, The Netherlands

Phytophagous insects of estuarine tidal marshes which live inside their host plants are, in contrast to the plants, not directly exposed to estuarine gradients. Previous field studies, however, have shown that patterns of growth and development of *Agapanthia villosoviridescens* larvae, stemborers of the halophyte *Aster tripolium*, gradually change on tidal marshes along the Westerschelde estuary. In the present study we carried out a laboratory experiment in which we followed growth of *Agapanthia* larvae from two different Westerschelde tidal marshes; the larvae either were kept in *Aster* stems from their own marsh,or they were kept in stems of the other marsh. It was found that larvae from both tidal marshes showed larger weight increases in *Aster* stems from the least saline marsh. These results demonstrate a difference in host plant quality between stems of the two marshes, which will be related to specific differences in chemical or physical aspects of the stems. The results lend support to the hypothesis that growth and development of endophagous insects on estuarine tidal marshes may be indirectly influenced by estuarine gradients, via the host plant quality which changes along the estuary.

Distribution and life cycle of the North American Spionid Polychaete *Marenzelleria viridis* (Verrill, 1873) in the Ems estuary.

K. Essink

Rijkswaterstaat, Tidal Waters Division, P.O.Box 207, 9750 AE Haren, The Netherlands.

In 1983 the first specimens of the North American spionid polychaete *Marenzelleria viridis* in Europe were found in the Ems estuary. On the western side of the North Sea the species was recorded for the first time in 1984 in the Tay estuary. Since then, the species spread over several estuaries around the North Sea, and also appeared in German and Polish coastal waters of the Baltic Sea.
In the Ems Estuary *M. viridis* is present in the inner half of the estuary. A dense population is present in the brackish Dollard. Macrobenthic survey showed that juveniles are predominantly present in very muddy sediments high in the intertidal zone of the Dollard. Adult specimens are present in more sandy sediments at higher salinities.
In the centre of the Dollard numerical densities of *M. viridis* increased, whereas densities of *Nereis diversicolor* decreased. This suggest a competitive interaction between both polychaete species.
During more than a year at two locations in the Dollard, monthly measurements were carried out on density, size composition of the population, and reproductive condition of adults. The high muddy sediments proved to be a nursery for *M. viridis*. In May-June first recruits were found in very high densities (up to more than 100 000.m^{-2}). During the rest of the year numbers in the nursery decreased till in December hardly any worm was left. In the centre of the Dollard the population was fairly stable, adults being much more numerous than juveniles. The different development of densities at both locations, and data obtained from simple cage experiments indicates a significant migration of juveniles from the nursery to other parts of the estuary.
Analysis of stomach contents of juvenile *Pleuronectes platessa* and *Platichthys flesus*, foraging on the intertidal flats, showed that *M. viridis* has become a component of the food of these flatfish species.

Population dynamics of estuarine mussels in relation to environmental gradients.

S. McGrorty

Institute of Terrestrial Ecology, Furzebrook Research Station, Wareham BH20 5AS, Dorset, England.

Mussels (*Mytilus edulis* L.) living in the intertidal zone of the R. Exe estuary in Devon, England have been the subject of a long-term population study. The population dynamics have been studied on all 12 of the individual mussel beds, which toghether make up the population. Measurements of variables, such as distance from the sea, % exposure and sediment softness, on the 12 beds define the species niche along the two main axes of environmental gradients, which lie at right angles to each other within the estuary, namely 'up-estuary' and 'up-shore'. Multiple regression analyses of density, mortality and growth at different ages suggest that the most important gradient along which the population dynamics of mussels in the Exe should be viewed is the 'up-shore' gradient as measured by % exposure time.

Non-parametric linking of multivariate community structure with abiotic variables.

K.R. Clarke

Plymouth Marine Laboratory, West Hoe, Prospect Place, Plymouth PL1 3DH, UK.

The method of choice for multivariate representation of community structure is often non-metric multi-dimensional scaling (MDS). This has great flexibility in accomodating biologically relevant (i.e. non correlation-based) definitions of similarity in species composition of two samples, and in preserving the rank-order relations amongst those similarities in the proximity of samples in a (biotic) ordination. Correlation-based techniques (such as canonical variate analysis) are then inappropriate in linking the observed biotic structure to measured environmental gradients; a more natural approach is simply to compare separate sample ordinations from biotic and abiotic variables and choose that subset of environmental variables which provides a good match between the two configurations. In fact, the fundamental constructs here are not the ordination plots but the (ranked) dissimilarity matrices which underlie them: a suitable (non-parametric) measure of agreement between two such matrices is therefore proposed and used to find an optimal subset of abiotic variables which "best explains" the biotic structure, for several published data sets of macrobenthic and meiobenthic communities from UK estuaries and coastal waters.

Zoobenthos in the southern North Sea: the Dutch coastal area

A. Groenewold, Y. van Scheppingen & S. Holtmann

RWS, Tidal Water Division, P.O. Box 8039, 4330 EA Middelburg, The Netherlands.

In the framework of the MILZON (Environmental zonation)-benthos research project in 1987 a study was started of the spatial distribution of zoobenthos in front of the Dutch coast and the possible relationships to sediment characteristics. Therefore 420 bottomsamples were taken in the North Sea in the western and northern coastal zone (north of the Wadden Islands) of the Netherlands (up to 40 - 65 km from the coast) during the late spring of 1988 and 1989. The aim of this projest is the compilation of a detailed zoobenthos map, to investigate the indication of possible zonations in the area and to investigate the relationship between the zoobenthos groups (meio/macro) and (a)biotic factors (natural as well as input by human activities).

The investigated area is characterized by a sandy sediment type (mean median grain size 269 μm). West of the Dutch coast the median grain size increases from north to south, whereas north of the Wadden Islands we found the coarsest sediments in the western and extreme eastern parts. Highest mud contents were found close to the shore.

The macrobenthic densities and biomasses were found to be highest in a small near-coastal zone of circa 10 km, where bivalves played an important role. Apart from this small zone, the area along the northern coast seemed to be richer in species number, density and biomass, than the area along the western coast.

Highest meiobenthic densities, highly dominated by Nematoda, were also found in the coastal zone of about 10 km, with the exception of the area around the Wadden Islands Texel and Vlieland. The offshore area was richer than along the coast, although the densities were lower. Opposite to the macrobenthos the meiobenthos in the western area appeared to be richer than in the northern part, with the exception of the area around the Wadden Islands Texel and Vlieland.

The macro- and meiobenthos in the northern and southwestern coastal parts showed roughly the same distinction in (clustering-) areas. Although Nematoda densities agreed fairly well with macrobenthic biomass (especially Bivalvia), the richness in diversity between both groups showed the opposite in linear regression analysis. Areas rich in macrobenthos species proved to be poor in meiofauna species and vice versa.

Clusteranalysis of the zoobenthos data resulted for both macro- and meiobenthos in 4 (although different) major clusters.

The linear correlation between the zoobenthos and (a)biotic factors (median grain size, mud, chlorophyl-a, salinity and depth) proved to be rather poor. Out of all, median grain size showed the strongest linear correlation with the benthos. The distribution of the meiobenthic- and macrobenthic clusters roughly matched the distribution of coarse and fine sediments.

Macrobenthos clusters were characterized by the following:

cluster
1. Rather poor offshore zone in the southwestern part, with a few species per station, low densities and biomass. Domination by Polychaeta.
2. Transition zone in the southwestern part, somewhat richer than cluster 1. Domination by Crustacea and Polychaeta.
3. Offshore zone in the northeastern part, much richer than cluster 1 and 2, with a lot more species per station, high densities and biomasses. Closer related to cluster 2 than cluster 1. Domination by Polychaeta and Echinoidea.
4. Coastal zone, the richest part of the area. Domination by Bivalvia.

Meiobenthos cluster characterization:

cluster
1. Offshore zones in the southern, northwestern and northeastern parts. High abundances, rich in diversity. Domination by Nematoda and Copepoda.
2. Stations in the western area. Low densities, rich in diversity. Domination by Nematoda, Gastrotricha and Copepoda.
3. Found all over the area, but mostly in the northeastern and midwestern area, low diversity. Domination by Nematoda and Gastrotricha.
4. Coastal stations, not found around Texel and Vlieland. Very high densities, very poor in diversity. Domination by Nematoda.

Influence of abiotic gradients on benthic invertebrates and demersal fish along the Belgian Coast and the Scheldt Estuary

D. Maertens

Ministry of Agriculture, Fisheries Research Station, Ankerstraat 1, B-8400 Oostende, Belgium

The Western Belgian coast, influenced by south western currents caused by the incoming flow of Atlantic water through the channel, is strikingly free of muddy sediments, while the eastcoast shows a vast mud plain trapped in that area by gyratory currents. This physical difference leads to gradients in abiotic parameters associated with changes in benthic populations and demersal fish species.
Clear gradients in species diversity and composition exist from the West to the East and from the coast towards the open sea. The eastcoast is a heterogeneous collection of impoverished biotops. The westcoast is an important nursery ground for flatfishes (*Solea solea*, and *Limanda limanda*).
Results of a ten years ecological monitoring emphasize the relationship between benthic and demersal fish communities and the sediment.

Environmental gradients in a southern Europe estuarine system: Ria de Aveiro, Portugal. Implications for soft bottom macrofauna colonization.

M.H. Moreira, H. Queiroga & M.M. Machado

Department of Biology, University of Aveiro, 3800 Aveiro, Portugal

Focusing the study on the bottom macrofauna and its relation to environmental gradients in Canal de Mira (Ria de Aveiro, Portugal), four seasonal sampling surveys were carried out between December 1985 and September 1986. A total of 40 sampling stations, distributed over 13 transects, were used. Salinity, temperature, dissolved oxygen and pH of the water mass were measured at the surface and bottom of the deepest point of each transect, at high and low waters. Sediment and bottom macrofauna samples were collected at each station. The following sediment parameters were determined: granulometric composition, organic matter content, temperature, and salinity and pH of interstitial water. This paper deals mainly with the description of the environmental gradients.

With a salinity range from 35.1 % to 0.0 % , Canal de Mira behaves like a tidally and seasonally poikilohaline positive estuary. Water temperature, which varied from 8.5 to 24.7 °C, decreases along the channel towards its inner part during the cold season; an inverse and more pronounced trend is observed during the hot season. The water oxygen content is generally high during the day (50% to 240% saturation), with peaks located in areas with large amounts of rooted vegetation, throughout the growing season. pH values, largely correlated with dissolved oxygen, ranged from 6.8 to 8.9.

Four types of sediment are represented in Canal de Mira, the dominant ones being medium sands and muddy sands. Sampling sites were classified through UPGMA, using sediment parameters plus tidal amplitude and depth as variables. Three major clusters were identified, one corresponding to the large intertidal mudflats up to the middle reaches of canal de Mira, another to the subtidal stations in the same area, and a third one including all stations from the middle to the far reaches of the channel. A principal components analysis, employing sampling sites as operational taxonomic units in the space defined by the same variables used in the classification technique, permitted the description of the relationship between the variables and also the position of the groups of stations relative to environmental gradients. The biological significance of the three groups of stations is discussed with regard to the colonization patterns exhibited by the soft bottom macrofauna.

Horizontal biosedimentary gradients across the Sado estuary, western coast of Portugal.

A.M. J. Rodrigues & V.M.S. Quintino

Laboratorio Nacional de Engenharia e Tecnologia Industrial Azinhage des Lameiros, 22, 1699 Lisboa Codex, Portugal.

The Sado estuary is located 40 km South of Lisbon, on the western coast of Portugal. It is the second largest portuguese estuary and it compreends, on a topography basis, the outer bassin, inwards of the entrance channel, and the inner bassin, inwards of which begin the tidal mudflats.
Along its longitudinal axis, the outer bassin presents a series of intertidal sand-banks allowing the distinction between a northern and a southern channel. The city of Setubal and a major industrial complex, comprising, among others, electric power generation, shipyards, pulp mill industry, chemical industry and the municipal abbatoir, all use the northern channel to dispose their effluents.
In June-July 1986, a major subtidal benthic survey was held en the outer bassin, during which a total of 133 sampling stations were visitid. The superficial sediments granulometry and the organic matter content were analysed together with the basic primary macrofauna biological variables, namely species richness, abundance and biomass, on a wet, dry and ash-free dry weight basis. During 1987, a series of physical and chemical descriptors were also measured in the water column, also covering the outer bassin area.
This paper presents the major results and horizontal gradients across the estuary in both the biological and environmental variables.

Variations in the intertidal and subtidal macrofauna and sediments along a salinity gradient in the upper Forth estuary.

S.C. Hull[1], M. Elliott[1,2] & D.S. McLusky[3]

1. Tidal Waters Section, Forth River Purification Board, Heriot-Watt Research Park, Riccarton, Edinburgh, EH14 4AP, UK
2. Department of Applied Biology, The University, Hull, HU6 7RX, UK
3. Department of Biological & Molecular Science, The University, Stirling, FK6 4LA, UK

The intertidal and subtidal soft-sediment macrofauna of the upper Forth estuary, eastern Scotland, UK has been examined. The intertidal fauna was sampled in 1977, and again in 1988/89, at up to twelve stations along the salinity gradient. The subtidal fauna sas sampled in 1982 and in 1988/89 at up to fifteen stations. Large spatial and temporal variations in macrofaunal abundance and species composition were observed. Sites at the head of the estuary with low salinity were dominated by oligochaetes, but more saline areas were characterised by a depauparate estuarine fauna. The area has historically received large quantities of organic waste both from sewage and industrial discharges which supported very high abundances of oligochaetes of up to 500,000 m^{-2} in the upper reaches of the estuary. Reductions in the organic inflow to the area since the mid-1980's have begun to cause reductions in oligochaete populations and also allowed the further penetration intertidally of non-oligochaete species into the upper and middle reaches of the estuary. No comparable upstream penetration by the non-oligochaete subtidal fauna has been observed, possible on account of the greater sediment instability in the estuary's main channel.

The macrozoobenthos of the Schelde estuary: the resultant of chemical and physical gradients

T. Ysebaert, P. Meire[1], J. Seys, D. Maes, R. Samanya, J. Buys & N. Deregge

Univeristy of Gent, Laboratory of Animal Ecology, Ledeganckstraat 35, B9000 Gent
1 Institute of Nature Conservation, Kiewitdreef 3, B3500 Hasselt.

It is generally accepted that the distribution and abundance of the benthic fauna of estuaries is controlled by both physical and chemical gradients, either natural or from anthropogenic origin. The influence of these gradients on macrozoobenthos was studied in the Schelde estuary.

On a large scale, the distribution pattern of the benthic fauna is controlled by a gradient in salinity and pollution. Along the estuary both gradients occur in opposite direction. Based on multivariate analysis three main faunal groupings are distinguished: a fresh water tidal zone characterised by an impoverished benthic fauna dominated by *Oligochaeta*, a brackish part with only a few, typically estuarine and deposit feeding species (e.g. *Nereis diversicolor* and *Corophium volutator*), and a marine part characterised by a relatively high diversity and biomass. Filter feeders (*Cerastoderma edule*) are here relatively more important.

Within a section of the estuary, the distribution pattern of the benthic fauna is related to sediment characteristics (e.g. grain size, mud content), which are function of hydrodynamic features (e.g. current speed), and to depth. In general, the sublittoral zone is characterised by a greater species diversity as compared to the littoral zone. However, abundance and biomass of the benthic fauna is much higher in the littoral zone.

Within the brackish part not only sediment characteristics but also the degree of pollution seems to determine the distribution of the benthic fauna.

The temporal distribution of Nematodes in the Westerschelde

J. Li & M. Vincx

Marine Biological Section, Zoology Institute, University of Gent, Belgium.

Biannual meiobenthic sampling (Spring and Autumn) have been carried out over the period 1983-1989 at two fine sandy intertidal stations, which are exposed daily for more than one hour, and are situated at different salinity zones (Terneuzen as polyhalinicum over 15 km from the mouth and Valkenisse as mesohalinicum over 35 km from the mouth) along the Westerscheldt Estuary.
Higher nematode densities are found in the polyhaline station (3240 ind./10 cm^2) in comparison with the mesohaline station (2268 ind./10 cm^2); the higher densities originate from higher nonselective deposit-feeders and predators densities in the first station. A similar trend in density evolution is found in both stations (Kendall's $t>0$, slope $\pm$ 100 ind./10 cm^2/year from multiplicative and additive model). Feeding type distribution by average density data show: non-selective deposit-feeders > predators > epigrowth-feeders > selective deposit-feeders for both stations. Density peaks are present in Autumn for non-selective deposit-feeders and in both seasons for epigrowth-feeders and predators. However, obvious heterogeneous temporal distribution is found for non-selective deposit-feeders and predators in both stations and epigrowth-feeders in the mesohaline station, in which one or two peaks are present over seven years rather than each year.

Trace metals in sediments from the tidal tributaries of the Humber Estuary.

A. Grant[1] & R. Middleton[2]

1. School of Environmental Sciences, University of East Anglia, Nowich, NR4 7TJ, UK
2. School of Earth Resources, Hull University, Hull, HU6 7RX, UK

Concentrations of industrial metals have been measured in sedi
ments from sites on the tidal sections of the rivers flowing into the Humber estuary. At the majority of sites, metal concentrations are rather uniform after the influence of sediment grain size has been adjusted for. This uniformity of sediment chemistry extends well beyond the limit of significant salt penetration. The presence in the rivers of niobium and arsenic, which are both discharged to the lower half of the estuary, indicate that there must be substantial upstream transport of sediment from the Humber into the tidal rivers. In those parts of the rivers which are beyond the limit of salt penetration this transport cannot be a consequence of density driven residual circulation and is presumably driven by asymmetric tidal currents resulting from deformation of the tidal wave, as it progresses upstream.
Sections of several of the tributaries close to the limit of tidal influence show very severe metal contamination. Even when a single anomalous metal rich sediment is excluded, concentrations reach 1000 $\mu g.g^{-1}$ Zn; 1050 $\mu g.g^{-1}$ Pb; 440 $\mu g.g^{-1}$ Cr and 270 $\mu g.g^{-1}$ Cu. Two patterns of contamination can be distinquished. On two rivers, only Pb and Zn are enriched, suggesting the influence of river-borne material from the North Pennine orefield, an area of lead-zinc mineralization. On three others, concentrations of Cu, Cr and Ni are also elevated suggesting more general industrial contamination. On one river, metal concentrations in water are locally elevated in the section in which contaminated sediments occur.

Inter-relationships between contaminants and the spatial pattern of contamination will be examined using multivariate statistical analysis.

Preferential transport pathways and deposition of Arsenic in the Humber estuary, U.K.

J. Pethick

Institute of Estuarine and Coastal studies, University of Hull.

This paper reports the findings of a detailed study of the relationships between, and spatial distribution of, arsenic and inter-tidal sediment characteristics in the 70km long inter-tidal zone of the Humber estuary. Input of arsenic from point source effluent outfalls in the Humber has resulted in its incorporation in inter-tidal sediment troughout the estuary. The longitudinal gradients of arsenic levels are not, however, a simple function of distance from the outfalls but are related to estuarine flow patterns, mainly horizontal residual currents themselves induced by salinity gradients. A secondary feature of the arsenic gradients is its observed differential concentration in the inter-tidal embayments which occur along the estuary.
Normalisation of arsenic levels against sediment grain size, indicates that such differential sedimentation patterns are not merely the result of enhanced deposition of fine grained sediments in the shelter of the embayment. Instead they must represent the increased residence time of dissolved and suspended material in these embayments which allows more efficient scavenging of heavy metals so increasing their concentration in the deposited sediment. The importance of these findings to investigations which seek to link inter-tidal contaminants to sources is stressed.

An Integrated modelling approach for the calculation of the mass pollutant transport within the Scheldt Estuary towards the North Sea.

G. Billen[1], F. De Smedt[2], J. Ozer[3], F. Ronday[4], M. Sas[5], R. Van Grieken[6] & G. Verreet[3]

1. University Libre de Bruxelles, Groupe de Microbiologie des Milieux aquatiques, Campus de la Plaine CP 221, Boulevard du Triomphe, B-1050 Bruxelles.
2. Vrije Universiteit Brussel, Faculty of Applied Sciences, Hydrology section, Pleinlaan 2, B-1050 Brussels
3. Management Unit North Sea & Scheldt Estuary Mathematical Models, Gulledelle 100, B-1200 Brussels, to whom correspondence should be addressed.
4. Université de Liège, Hydrodynamique des Fluides Géophysiques, Institut de Physique B5, Sart-Tilman, B-4000 Liège.
5. International Marine & Dredging Consultants nv (IMDC), Wilrijkstraat 37-45 bus 4, B-2140 Borgerhout.
6. University of Antwerp (UIA), Chemistry Department, Universiteitsplein 1, B-2610 Antwerpen-Wilrijk

As a support for the management of the pollutant load reduction strategies internationally agreed, a framework is being developed aiming at the calculation of mass pollutant transport in the Scheldt Estuary towards the North Sea.
The framework will consist of a system analysis and a intergrated software package. The crux of the package will be a pollutant transport model, which will incorporate:

*physico-chemical characteristics (Eh, pH, T, sal) and (micro)biological activity (organic matter, phytoplankton) in the water column;
*physical (solid/solute) state of a selection of pollutants (Cd, Hg, Pb, Zn, Cu; PCB, lindane, nutrients N, P);
*residual transport of water and suspended material.

The model will be used to compute annual within th estuary, with the aim of estimating the yearly pollutant transport towards the sea, and its evolution with changing conditions. The information required by the model (daily value of water flux, salinity, suspended matter) will be provided by hydrodynamical and advection/diffusion mathematical models which will work at the tidal time scale
The modelling developments and some preliminary results will be discussed.

Modelling of water and sediment quality in the Scheldt estuary

M.R.L. Ouboter, N.M. de Rooij, J.A.G. van Gils

This paper describes a water and sediment quality model for the Scheldt estuary. The variables under investigation are dissolved oxygen, nitrogen (NH_4^+, NO_3^-, organic nitrogen), acidity (pH, alkalinity and CO_2-concentration), trace metals (Cd, Cu, Zn and Cr) and organic micropollutants (PGB-52, PCB-153, Benzo-a-pyrene, fluoranthene and lindane). The developed model is a 1D dynamical model, which runs on a PC. Transport of dissolved and solid matter is modelled on a tidally averaged basis. The tidal mixing is represented by dispersion coefficients, which are calibrated on measured chloride concentrations. The developed model is a box model. The Scheldt estuary, from Rupelmonde to Vlissingen about 100 km, is divided into 14 compartments. Based on waste loads to the estuary, the transport of water, the transport of suspended solids and processes, the model calculates concentrations and fluxes of the modelled compounds. The waste loads to the estuary, the transport of suspended solids and the hydrodynamics are derived from other SAWES projects.

The processes in a compartment are divided into processes which attain equilibrium instantaneously, examples are the pH-CO_2-alkalinity system and trace metal speciation, and kinetically controlled processes, which are described as zero, first or second order differential equations. Examples are the decay of organic matter, nitrification, denitrification, reaeration and primary production. Special attention is paid to the modelling of trace metals, because the water of the upper Scheldt estuary, which has low oxygen concentrations, contains metal sulfides. In the model the trace metals are divided over three phases. The metal sulfides oxidize due to the increasing concentrations of dissolved oxygen downstream; the metals divide over the water phase and the suspended solids following the concepts of partitioning. The partitioning, determined by the laws of Thermodynamics, depend on macrochemical variables, such as pH (acidity), alkalinity and salinity. It is modelled, using an equilibrium chemistry sub-model. The sulfide minerals do not participate in this system. Their concentration is determined by a first order decay, dependent on dissolved oxygen concentration and temperature.

The model was calibrated on 1987 data and validated with 1980-1988 data. The calibration procedure is described, again with attention to trace metals. The equilibrium chemistry system and the decay of metal sulfides are calibrated in relation to each other: The equilibrium chemistry system definition is calibrated by means of a method of autocalibration. Next it is extrapolated to the sulfidic part of the estuary; the amount of particulate metals in equilibrium with the dissolved metal concentration, is calculated. This fraction was subtracted from the total particulate amount to yield the sulfide mineral concentrations. The calculated sulfide concentration were used to calibrate the parameters concerning sulfide oxidation.

The model results give an understanding of the fate of the modelled compounds

(storage in bottom sediments, removal by processes, outflow out of the system, eg. to the sea). For the main compounds in the model mass balances containing transport fluxes and process fluxes were derived, which form an aid in the evaluation of the model system.
In the model, generally waste disposals and transport are determining factors in model results. However, processes are essential to reproduce measured concentrations of the main model compounds. The most important process determining low oxygen concentrations in the upper part of the estuary is nitrification. Decay of wasted BOD in the upper part of the estuary is of minor importance. BOD is imported into the estuary from the North Sea; the decay of BOD is compensated for by reaeration. All the wasted ammonium is transposed in nitrate, which partially (± 25-35%) is removed from the system by denitrification. In the largest (especially the upstream) part of the estuary more than 90% of the metals are found in particulate phases; total metal concentrations therefore show a conservative behaviour. Concentrations of dissolved metals, however, do not. Where sulfide minerals exist they tend to be low. For cadmium and copper this can be seen at salinities lower than 0.005% in winter and 0.01% in summer. Sulfides of zinc show a significant influence only in summer at salinities of 0.007% at the maximum. Concentrations in the non-sulfidic zone are determined by the macrochemistry. Metals in the Scheldt estuary adsorb stronger to the solid phase than in other systems. This can be explained by the presence of freshly precipitated iron hydroxyde in the redox gradient zone of the estuary. Dissolved concentrations are modelled in an appropriate way, even during production of algae at high pH.

Speciation and biological availability of metals in salt- and freshwater mixing zones.

R. Blust* & W. Decleir

Laboratory of Biochemistry and Zoology, University of Antwerp. Groenenborgerlaan 171, Antwerp

* R .B. is a Senior Research Assistant of the N.F.S.R.

The availability of metals to aquatic organisms is determined by: 1) the physical and chemical processes which determine the speciation of the metals in the environment and 2) the nature of the transport systems which are involved in the translocation of the metals across the solution-body interface.
The effect of chemical speciation on the biological availability of metals in changing environments is exemplified by the effect of salinity and alkalinity gradients on the availability of cadmium, cobalt and copper to the brine shrimp, *Artemia*.
Experiments concerning the uptake of the metals in the brine shrimp were performed in chemically defined solutions. The equilibrium speciation of the metals in the solutions was calculated using an ion-association model.
The result of this work is a mechanistic description of the effects of changes in the salinity and alkalinity of the water on the biological availability of metals to the brine shrimp. Metal complexation decreases metal uptake and this effect appears independent of the stability of the complexes being formed. Changes in salinity and alkalinity cause changes in the osmolarity and hydrogen activity of the solution. These effects directly affect the flux of the metals across the solution-body interface. Metal uptake increases with decreases in the osmolarity and hydrogen activity of the solution.

Accumulation models for the blue Mussel (*Mytilus edulis*) and the flounder (*Platichthys flesus*) in relation to energy-budgets and temperature.

J.H.M. Schobben

RWS-DGW, Postbus 20907, 2500 EX 's-Gravenhage

To predict the effects of micropollutants on birds and mammals, the toxicant concentration in their food must be known. In the SAWES-project (System Analysis of the Western Scheldt) the Oystercatcher (*Haematopus ostralegus*) and the Seal (*Phoca vittulina*) are selected as toppredators. Using accumulation models it is possible to calculate toxicant concentrations in their food: the blue mussel (*Mytilus edulis*) or the flounder (*Platichthys flesus*).
The Western Scheldt is a dynamic estuary with many (environmental) gradients. In such a system, a simple one-compartment model is not accurate enough to describe the concentration fluctuations in the mussel and the flounder. The fat content (for lipophilic compounds) or the amount of protein (for heavy metals) in an organism are keyfactors for the accumulation of such micropollutants. The amount of fat and protein is determined by foodconsumption. Therefore first an energy-budget model is developed to describe the growth, storage (of fat and protein) and reproduction of both species.
Subsequently an accumulation model is developed. In this model the uptake is via food and water and correlates with the surface of the organism. The partitioning to non-aqueous structural biomass and to stored materials (i.e. lipids, carbohydrates and proteins) is assumed to be instantaneously. The result is a simple first order kinetic model with variable coefficients. The watertemperature (another keyfactor to explain variation in pollutant concentrations in organisms) influences all process rates in the model.
The models are validated with laboratorium experiments and field measurements. An experiment with the mussel, kept under three different algae concentrations, shows that the elimination of PCBs, PAHs and heavy metals is highly determined by the amount of foodintake. Monthly micropollutant measurements in mussels and three-monthly measurements in the flounder were carried out in the Western Scheldt and correlated with watertemperature, reproduction and size of the two species. With the accumulation models we were able to explain the fluctuations in micropollutant concentration on the basis of these latter three factors.

Effects of pollution in the Scheldt estuary

J. Stronkhorst.

Ministry of Transport and Public Works, Tidal Waters Division, Grenadierweg 31, 4338 PG Middelburg, Netherlands.

The first step in the judgement of the pollution of the Scheldt and Western Scheldt ecosystem is an evaluation of the oxygen situation. The oxygen content in the river Scheldt is zero in summer and very low in winter. This, in combination with the high suspended matter input and the high concentration of hydrogen sulfide means that nearly every form of aquatic life is missing.
The high input of nutrients does not result in noxious phytoplankton blooms in the estuary itself; the primary production is low due to the high amount of suspended matter in the water, causing light limitation.
For an ecotoxicological risk assessment, data from the compartments water, sediment and organisms have been used.
The measured water concentrations of heavy metals and organic micropollutants in the river Scheldt have been compared with Dutch ecotoxicologically based standards for fresh water. The standards are exceeded for many contaminants. The concentrations in the estuary have been compared with effect levels for estuarine and marine organisms from literature. Most of these levels originate from the AQUIRE database of the US-EPA. The results of the comparison will be presented.
Informations of sediment toxicity from bioassays with oyster larvae and a crustacean is available and shows decreasing mortality from upper to lower estuary.
Concentrations of toxicants in various organisms from the Western Scheldt have been determined. Compared to other Dutch coastal waters the highest concentrations of PAHs, PCBs and cadmium are found in the Scheldt estuary. The cadmium content of mussels suggests that growth is impaired and the PCB concentration in fish is so high that the reproduction of seals probably is effected. The PCB concentration in eggs of the Common Terns from a colony in Saeftinghe is at a level by which reproduction in probably impaired.

ABSTRACTS OF

POSTER PAPERS

The Cesiumisotope-activity within the Weser ecosystem three years after the incident in Chernobyl.

B. Claus, E. Peters, M. Schirmer, I. Schmitz-Feuerhake & E. Rieger.

University Bremen, Department of Biology.

This study is concerned with the Cs contamination of the Weser estuary (FRG) three years after the incident in Chernobyl. In 1989 (24.7.89 - 17.11.89) water, sediments, suspended solids, algae (*Enteromorpha* spec., *Cladophora* spec.) and crustacean (*Gammarus* spec.) were studied in five sections of the Weser estuary covering the tidal freshwater region up to the mixomesohaline region. The samples were analysed for Cs-137 and Cs-134 by gamma spectrometry. In addition the sediment samples were analysed for organic matter content and grainsize; the algal samples for species and the crustacean samples for species and population structure (age, sex). The water parameters, pH, temperature; conductivity, K^+, O_2 and the concentration of suspended solids were analysed in each section. The resulting accumulation factors AF (sample activity * kg^{-1}/activity water * 1^{-1}) were tested for correlation with these parameters.

The Cs activity of the water ranged from 4.3 to 15.9 mBq/1. The Cs activity per dryweight of suspended solids and sediments varied from 36.2 to 132.7 Bq/kg and 3.0 to 124.7 Bq/kg respectively, that of algae from 9.0 to 37.2 Bq/kg and of crustaceans from 2.3 to 10.3 Bq/kg.

An effect of the Chernobyl explosion is clearly detectable in suspended solids and sediments. In 1989 an average of 54,2 - 87,4% of the activity is derived from Chernobyl, with typical differences between the results from the brackish and freshwater areas. However, there is no significant effect detectable in water, algae and crustacaens (the Cs-activity is not significant higher than it was in the years before the incident.)

Linear regression analysis demonstrated negative correlations between the AF of each sample and the water parameters K^+-content and conductivity. The AF of suspended solids was positively correlated with the pH and inversely with the suspended solid concentration. Sediment activity was positively correlated with the particle size distribution. No correlation was found between the AF and organic matter content in the sediments. A positive correlation was found between the AF of suspended solids and AF of algae.

For the algae, the influence of the suspended solid concentration in water was probably less then that of K+-content and conductivity. No difference was found in the Cs accumulation in different algal species, but different species of crustaceans seem to have specific accumulation features.

The use of multivariate methods and rank-frequency diagrams in time series analyses of benthic communities.

D. Davoult, J.M. Dewarumez, A. Migne & Frontier.

Station Marine, URA 1363 du CNRS, B.P. 80, 62930 Wimereux, France.

Time series of macrobenthic data are analysed by simultaneously using two methods: factor correspondence analyses (FCA) and rank-frequency diagrams (RFD).
Sampling of macrobenthos has been realised every year in the eastern Channel between 1979 and 1986, then every two years in 1988 and 1990 in three different communities: the "heterogeneous sandy coastal community" (*Ophelia borealis community), a coastal mussel bed (Mytilus edulis*) and the "pebbles with sessile epifauna open sea community".
RFD allow the analysis of the global structure and the diversity of these communities and give more information than a diversity index (e.g. the Shannon index), which is too synthetic. They allow to visualize both the number of sampled species, the distribution of relative abundances and the identification of main species and to make clear rare species, temporal variations of the community structure and permutations between main species. These variations may then be discussed at the biological level by taking into account some characteristics of species such as their relation with the sediment (moving or sessile epifauna, endofauna), their trophic behaviour (suspension-feeders, deposit-feeders, carnivores...) and their reproduction (period, duration of the larval stage...).
Factor analyses allow to recognize what species or groups of species greatly contribute to the variations of global structure. In some cases, pluriannual cycles can be seen. Both discontinuities (groups of species....) and trends (gradients) can be shown by this method.
The three communities are stable in space: their location is related to the sedimentary conditions which are governed by strong tidal currents. This dynamical stability depends on the more or less great variability of recruitment of main species and on the heterogeneity of the sediment.
The mussel bed is naturally strongly dominated by *Mytilus edulis* but its seasonal fluctuations of abundance and its variability of recruitment are very important: some years, another species with very close characteristics (the ascidian *Molgula manhattensis*, a suspension-feeder with a gregarious recruitment) can sometimes become dominant. Despite of these variations, RFD keep quite the same shape because the global structure of the community is unchanged.
The "pebbles with sessile epifauna community" is also varying with the variability of recruitment of species but main ones are always the ophiurid *Ophiothrix fragilis*, the crustacean *Pisidia longicornis*, the annelids *Thelepus setosus* and *Lepidonotus squamatus* and the sea urchin *Psammechinus miliaris*. The abundance of *Pisida longicornis* is minimum in Spring, but its rank is about the same every year even if

its recruitment is fluctuating.
As most of sandy communities, the specific richness and the biomass of the "heterogeneous sandy community" is low. Low abundances of main species allow numerous permutations between them. Recruitments induce great temporary changes in the community structure, but these fluctuations appear to be oscillations around a mean structure.
So, RFD and FCA allow to show different properties of these communities. The use of both methods is favourable to a better interpretation of the evolution of benthic communities: heavy variations of the diversity or of the abundance of some species do not always induce a complete modification of the community structure.

Abundance and quality of the suspended particulate matter in five small estuaries: a comparative view.

Franco, J., Gonzalez, L., Martinez, R., Orive, E., Ruiz, A., Villate, F.

Universidad del Pais Vasco, Facultad de Ciencias, Departemento de Biologia Vegetal y Ecologia, Apartado 644, 48080 Bilbao, Spain

The abundance and quality of the size-fractionated SPM was studied in five small estuaries of the Basque Country (Gulf of Biscay) in relation to their hydrological properties, in July 1989. Sampling was performed by two longitudinal surveys, made at low and high tide, in each estuary during successive days. Water samples for the determination of SPM amount, particulate C and N contents, and chlorophyll were obtained in surface and near the bottom at three sampling sites. Considerated fractions were > 200 μm, 20-200 μm and <20 μm.

In general, the highest C/N ratios were found in the > 200 μm fraction, denoting the dominance of detritical materials in this fraction. By contrast, in the smaller fractions the values of the C/N ratio were found to be more closely related to those obtained for the living plankton. In rela-tion to the salinity, the highest values of the C/N ratio were observed in the euhaline region, in the 30-35%. range. Among estuaries, the lowest values of the C/N ratio were found in estuaries which receives a smaller river discharge.

N/chlorophyll ratios were also calculated in order to determine the contribution of the phytoplankton biomass to the amount of total N in the SPM.

Behaviour of organic matter in the Deltaic areas of the Gulf of Lions (Mediterranean Sea).

F. Gadel[1], B. Charriere[2] & L. Serve[2]

1 Laboratoire de Sédimentologie et Géochimie Marines-Université de Perpignan-France.
2 Laboratoire de Biologie Végétale-Université de Perpignan-France.

The behaviour of organic matter in the microtidal deltaic areas is tackled thanks to the elemental analysis, the PY-GC-MS analysis, the phenol HPLC analysis applied to the sediment, humic and fulvic acids and to the molecular weight classes of humic compounds.
At the mouth of the Rhône river, associated to the deposition by load excess, flocculation processes are observed that are emphasized by the settling of high molecular weight humic compounds rich in phenols and carbohydrates from the ligno-cellulosic complex.
Off the river mouth, a multilayer water system is observed, characterized by surficial layers rich in fresh organic matter and a benthic nepheload carrying a more degraded organic material rich in phenols and aromatic hydrocarbons. In the deeper water layers, some gradients are observed for the suspended load, particulate organic carbon and organic compounds with a higher concentration at 0,5 m near the sea bottom.
The terrestrial input of the river characterized by high phenols and some aromatic hydrocarbons is more distant off-shore during the high river flow in the Rhône delta, but more reduced for the local rivers. Off the mouth, the content of nitrogen containing compounds progressively increases, resulting from the increasing of the marine character.
The bottom nepheloid allows, thanks to advective currents, the transport of the organo-mineral material from the continental shelf to the deep areas through the canyons as shown by the similarity of the nature of organic compounds in the bottom layers of the prodelta and those of the deep areas.
In the prodelta and the open sea, the terrestrial material is associated with the marine organic matter produced by the plankton activity that enriches the deposits in nitrogen containing compounds.

Heterogeneity in pattern and gradient of biota distribution in a small tidal estuary.

G. Houvenaghel, P. Aelbrecht & A. De Cock

Laboratoire d'Océanographie Biologique, Université libre de Bruxelles.

In small estuaries with high tidal range like the Guillec (Brittany, France), different geomorphological and hydrological parameters including the sea- and freshwater advections, mixing and circulation patterns, combine their effects to provide an heterogeneous distribution pattern for the marine and brackish organisms. The case of typical macrobenthic invertebrates colonising both sediments and hard bottoms, as well as macrophytes are discussed, leading to the difficulty to establish, for such environment, a definite and stable estuarine gradient.

The circulation of fresh and seawater in the estuary of the riviere de Morlaix (Brittany, France) and its influence for the distribution of contaminants in the Oyster farming areas.

G. Houvenaghel & E. Hannon

Laboratoire d'Océanographie Biologique, Université libre de Bruxelles

The estuary of the Rivière de Morlaix belongs to the Ria type. A large volume of tidal seawater is influenced by rather small and irregular continental runoffs. However, the intensity of land use in the surroundings, including heavy farming, stresses the entire coastal area.
Much of the effects that can be deleterious for the oyster farming in the estuary are lowered due to the high tidal activity driving the estuarine water downstream above rich and productive (macroalgae) beds in the coastal area. Due to the spatial distribution of the water flows and the tidal gradient, the oyster beds are provided with a sheltering from direct and heavy pollution.

Influences tidales sur le comportement des aquifères karstiques ou continus: estuaires endokarstiques et biseaux salés sur le littoral français de la Manche Orientale.

T. Leboulanger[1,2&3], P. Beaudeau[4], J.P. Dupont[1&2], R. Lafite[1&2], C. Lorin[3], S. Violette[1&3] & R. Meyer[2]

1. Groupe d'Etude des Milieux Estuariens et Littoraux, Faculté des Sciences, B.P. 118, F-76134 Mont Saint Aignan cedex
2. Laboratoire de Géologie, Université de Rouen, B.P. 118, F-76134 Mont Saint Aignan cedex
3. Commission Scientifique de la Fédération Française de Spéléologie, 130 rue Saint Maur, F-75011 Paris
4. Bureau Municipal Hygiène-Santé, 83 Rue de Tourneville, F-76600 Le Havre.

Les résultats présentés ici ont été acquis à l'occasion d'études menées depuis 1984 par le G.E.M.E.L. et le laboratoire de Géologie de l'Université de Rouen, les explorateurs de la fédération Française de Spéléologie, et la Ville du Havre.
Les aquifères littoraux, tant en milieu continu qu'en milieu kartifié, sont exploités pour l'Alimentation en Eau Potable, surtout en Basse-Normandie. Il s'ensuit des problèmes, chroniques, sporadiques ou saisonniers, de contaminations de la ressource par intrusion marine.
Le gradient de chlorinité susceptible d'accompagner la marée dynamique peut ne pas être la seule nuisance, ou n'être qu'indirectement responsable des difficultés rencontrées dans la gestion de la ressource.
L'existence d'une forte intrusion marine permanente dans l'aquifère (biseau salé), peut à l'inverse devenir un atout économique (aquaculture et toutes autres activités nécessitant une stabilité de qualité du profil physicochimique), bien que ce type de ressource soit encore méconnu par les gestionnaires et aménageurs.
La discontinuité structurelle qui caractérise les aquifères karstiques, induit une discontinuité latérale et verticale des gradients. Le suivi de cycles tidaux en points fixes permet l'interprétation des gradients longitudinaux dans ces systèmes seulement partiellement accessibles.
Si leur exutoire est soumis à l'influence du régime mégatidal semidiurne (amplitude de 6 à 9m environ), les systèmes karstiques développés peuvent ainsi montrer un comportement de type estuarien (estuaires endokarstiques). Celui-ci se manifeste par une dynamique fortement dépendante du cycle tidal, se traduisant par un important marnage qui peut être ressenti jusqu'à plusieurs kilomètres du rivage, mais aussi par des cycles de turbidité, dont l'intensité et la forme sont susceptibles de varier de manière reproductible avec le coefficient de la marée. Les émergences, en général de type vauclusien, ont des débits, des températures et des salinités faisant apparaître des cycles semi-diurnes : les intrusions marines se diluent dans les apports continentaux.
Pour une bonne gestion de la ressource, les épisodes de turbidité, de

biocontaminations d'origine fécale et d'altérations du profil physicochimique doivent être pris en compte en termes prévisionnels. Ces épisodes, qui accompagnent les crues, ont une origine essentiellement continentale, même si leur expression est modulée par le cycle tidal. La caractérisation des matières en suspension responsables de la turbidité, par microgranulométrie et observation en microscopie électronique à balayage, permet d'étudier les modifications apportées par le régime tidal au faciès du matériel en suspension.

Geochemistry of Mercury in the Sediments of the intertidal flat "Groot Buitenschoor" of the Scheldt Estuary.

M. Leermakers, M. Elskens, S. Panatrakul & W. Baeyens

Laboratorium voor Analytische Scheikunde en Geochemie, Vrije Universiteit Brussel, B-1050 Brussel.

The "Groot Buitenschoor" is an intertidal flat located at about 60 km from the river mouth. Trace metal geochemistry has extensively been studied in the last few years (Panatrakul and Baeyens, 1991 in press; Baeyens et al, submitted ; Elskens et al, submitted). The mud flat is separated in two parts by a dike which influences the sedimentation pattern and hence the sediment characteristics resulting in the formation of a sandy part upstream and muddy part downstream of the dike.
Surface sediments (0-1 cm) as well as depth sediments (10-11 cm) were sampled at 10 stations showing varying sediment structure. Hg concentrations ranged from 20 to 2000ng/g; the concentrations were strongly correlated with fine grain fraction, organic matter content and sulfide concentrations.
Vertical profiles at a characteristic sandy station (station A) and a muddy station (station B) were performed. Station B was sampled at various occasions. In addition to sedimentation, the temporal variability is influenced by sediment movements due to tidal currents. At station B porewater profiles were made as well as methylmercury profiles.
The transformation of inorganic mercury into methylmercury is an important factor controlling bioavailability and mobility of mercury from sediments. Incubation experiments were thus performed in order to determine the potential methylation rates as well as biotic and abiotic factors influencing this transformation.
About 1 to 2 % of the added Hg is converted into methylmercury. This is about the same equilibrium ratio as was observed in the natural sediments, indicating an equilibrium between methylation and demethylation reactions in the sediments.
Incubation of a sterilised sediment significantly decreased the methylation rate, but the methylmercury concentrations observed are still ten times higher than the natural (unspiked) sediment. This could be the result of either a chemical (non-enzymatic) methylation of mercury by celextracts such as methylcobalamine, reactions with humic acids, or transalkylation reactions with alkyllead and alkyltin compounds.
Sulfate reducing bacteria are the main species responsible for the methylation of mercury at this site. Addition of Na_2MoO_4, a specific inhibitor of sulfate reducing bacteria, decreased the methylation rate to the abiotic level (sterilised sediment). Sulfate reducing bacteria have also been shown to account for more than 80% of the total organic matter degradation in these sediments (Elskens et al., in press). Increasing the sulfate concentrations in the incubations increases the sulfate reduction rate but decreases the methylation rate. Increased formation of sulfides due to microbial sulfate reduction leads to enhanced HgS formation, this reaction

being in competition with the methylation process. HgS is in fact the major product formed by the reaction of sulfate reducing bacteria with Hg species. About 50% of Hg spiked to the sediments is transformed into HgS during the incubation experiments. HgS is practically unavailable as substrate for methylation in contrast to other bound Hg forms.

references
- W. Baeyens, S. Panatrakul, M. Elskens, M. Leermakers, J. Navez, F. Monteny. Geochemical processes in mud and sandy sediments, submitted.
- M. Elskens, M. Leermakers, S. Panatrakul, F. Monteny, W. Baeyens. Microbial activity in sandy and muddy sediments, submitted.
- S. Panatrakul, W. Baeyens. (1991). Behaviour of heavy metals in a mud flat of the Scheldt Estuary, Belgium. Marine Pollution Bulletin, (1991), in press.

The influence of density gradients on the transport of solutes in a deep estuary.

P. Lindsay[1], E.J. Darbyshire[1], N.M. Lynn[2], J.R. West[1] & R.W. Horsington[1].

1. School of Civil Engineering, University of Birmingham, Birmingham B15 2TT, UK.
2. Dept. of Nuclear Science and Technology, Royal Naval College, London SE10 9NN, UK.

The transport of solutes and momentum in estuaries is influenced by the production and propagation of turbulence. Turbulent eddies may be produced near to the bed or internally within the flow, particularly if internal wave activity or fronts are present. In shallow estuaries bed generated turbulence often dominates the turbulence field, particularly if the currents are strong. In deep estuaries the influence of the bed is less pronounced and vertical density gradients due to temperature or salinity differences may be generated during some parts of the tidal cycle. Although these density gradients may be small (< 0.1 kgm^{-4}) compared with those found near to the fresh/saltwater interface in the upper reaches of estuaries, the small velocity gradients often found in deeper water (< 0.05 s^{-1}) result in stable conditions ($Ri \geq 0.4$). The stable conditions lead to a tendency for steeper vertical velocity and density gradients to develop, but internal mixing processes tend to couteract this trend. the temporal change in the balance between these two effects causes the longitudinal dispersion to be spatially and temporally dependent.

Transverse gradient effects may be caused by the shallow water of the inter-tidal zones at the channel margins, channel curvature and sand banks within the main channel. Transverse density gradients may become steepened to the extent that longitudinal fronts are produced for parts of the tidal cycle, particularly in the lower reaches of estuaries near to low water, when bed effects and longitudinal salinity gradients are able to interact most effectively.

In order to improve the predictive capability of mathemathical models of estuarine solute transport processes there is a need to develop a better understanding of the underlying influence of the turbulence field.

The proposed paper reports on an investigation into the lower Forth estuary where a combination of hydrodynamic measurement techniques has been employed to quantify the effects of temporally varying vertical and transverse density gradients on the diffusion and dispersion processes that influence estuarine solute transport.

The results show that for summer conditions and a tidal range $\pm$ 4m the vertical density gradients increase during the ebb tide and the early flood tide due to the interaction of bed shear, longitudinal density gradient and inertia. The latter part of the flood tide becomes well mixed, probably due to the effects of gravitational instability and deceleration. Even though for much of the tidal cycle the flow is stable with respect to vertical mixing, the results of dye tracing experiments suggest that turbulent transverse mixing is still possible. However the formation of fronts,

possible by sand banks, leads to the inhibition of transverse mixing processes. Values of the transverse diffusion coefficient are generally in the range of 100-400 cm^2s^{-1}.

Light absorption in the turbid waters of the Gernika estuary.

Iosu de Madariaga

Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth PL1 3DH, U.K.

Daily measurements of the depth-mean P.A.R. (photosynthetically active radiation) extinction coefficient, K, and Secchi disc depth, Z_s, were taken along the Gernika estuary during three weeklong periods over an annual cycle. Strong turbidity gradients were found within the estuary (K = 4.84 - 0.53) when intense rain pulses substantially altered river inflow rates. Short-term variations in turbidity and salinity showed a significant correlation and occurred in response to both tidal and river inflow changes. The diffuse optical depth of the Secchi depth, J_s, was then calculated from K and Z_s and gave a value of j_s = 1.47. This result supports the recent correlation to the original Poole & Atkins calculation.

Mercury accumulation in Eelpout, *Zoarces viviparus*, along a mercury concentration gradient in the Forth estuary, Scotland.

S. Mathieson

Department of Biological and Molecular Sciences, University of Stirling, Stirling FK9 4LA, Scotland

The results of studies on mercury accumulation by the eelpout, a resident estuarine fish species, at sites along a water and sediment mercury concentration gradient in the Forth estuary, are presented.
A general trend is demonstrated in muscle and liver mercury concentrations with distance from an industrial mercury discharge. Relationships between fish length and muscle mercury levels are presented for a 12 month period, showing considerable seasonal fluctuation and overlap between sites.
The eelpout has a viviparous mode of reproduction, with brood size demonstrated as being proportional to maternal length. The relationship between maternal and brood mercury content is presented for fish from three Forth estuary sites.

Fauna of the upper Forth estuary

D.S. Mclusky

Department of Biological & Molecular Sciences, University of Stirling, Stirling FK9 4LA, UK.

A description of the distribution of the fauna of the upper Forth estuary, eastern Scotland. The upper estuary is dominated by the inflow from the River Teith, plus the Allan and the Forth. It has also received waste from domestic sewage plants at Stirling and Alloa, although this has been reduced in recent years.
The fauna is dominated by abundant populations of oligochaete worms, supplemented by a few freshwater species at the river end, and a few estuarine invertebrates at the middle estuary. Reductions of organic inflow into the area have begun to cause changes to the abundance and biomass of the oligochaetes, which will be described.

Biological monitoring of heavy metals in the tidal freshwater reaches (TFR) of the Weser estuary.

M. Müller, M. Schirmer & J. Kettler.

University of Bremen (FRG), Fb2 (Biology)

Transport and fate of contaminants in estuaries are strongly influenced by physical and chemical processes. Biological availability of heavy metals for example is affected by salinity and suspended matter concentration, and can not yet be calculated satisfactorily.

Therefore the suitability of the algae *Enteromorpha intestinalis* for an active biomonitoring of heavy metals in the Weser estuary was investigated. Enteromorpha is the most common green macroalga in estuaries and of cosmopolitan distribution. E. *Intestinalis* was cultured in an artificial seawater medium at 15 $\%_0$ salinity. For the active monitoring cultured thalli were exposed in the TFR of the Weser estuary for 14 days. Expositions were carried out in 1987 and 1988 from May until September at 3 stations between the uppermost border of the estuary, a tidal weir, and 32 km downstream. Another sampling station was located directly upstream the weir. Simultaneously *Enteromorpha sp.* was collected from the bands (passive monitoring).

In all experiments the exposed algae showed an accumulation of Cd, Zn, Cu, Pb, Cr and Ni. The metal content of exposed algae was higher than the contents of the collected samples. The amounts of accumulated metals varied significantly over space and time.

A significant decrease of Pb, Zn and Cd in the algae occured with increasing distance from the weir, while Cu and Cr contents increased. Cd was less bioavailable in 1988, whereas the other heavy metals behaved variably.

The results of linear regression analysis and the bioconcentration factors indicate that the biological availability of Zn, Cu and Ni for the algae vary between the stations. At the seaward station significant correlations between heavy metals in water and in exposed algae were found throughout the whole period.

Manganese in Seine estuary: speciation by chemical analysis and ESR spectroscopy.

Ouddane B., Boughriet A., Fisher J.C., Wartel M.

Université des Sciences et Techniques de Lille I.
Laboratoire de Chimie Analytique et Marine Bât. C8
59655 Villeneuve d'Ascq Cedex

In marine environment, manganese occurs in different chemical forms. Indeed, Mn is predominantly at oxidation state II in dissolved phases, whereas its oxidation state is II, III and/or IV in suspended matter and sediment. In this work, we have studied more paricularly the chemical characteristics of manganese in particularly the chemical characteristics of manganese in particules obtained from samples collected in Seine river where the variation of salinity is known to be very high. Speciation has allowed us to appraise partly the chemical partitioning and the oxidation states of Mn. In order to get more information about the chemical aspect of Mn present in Seine river, we have then undertaken a detailed study of suspended matter by means of the ESR spectroscopy. The results have been compared with those found for several Mn oxydes and hydroxydes able to be present in natural media. Thus, particulate manganese has been found to be both at oxidation states II (when it is associated to calcite), and III (in the form of manganite). In order to sustain these results, we have also carried out acidic or thermal treatments on particules. The main steps of the chemical speciation have been followed by ESR technique in order to ascertain the validity of chemical treatments commonly used. Thus, we have shown that if the step corresponding to the determination of Mn associated to carbonates occurs rightly, chemical phenomena are more complicated during the step involving Mn oxydes. Despite this, the use of the ESR spectroscopy has been found to be of great interest to obtain chemical information relative to manganese present at low contents in solid phases in natural media.

Porewater chemistry of estuarine Rhine/Meuse sediments; (re)mobilization of trace metals.

M.A.A. Paalman, G.C. Van de Meent-Olieman & C.H. Van der Weijden.

Department of Geochemistry, Institute of Earth Sciences, University of Utrecht, P.O. Box 80.021, 3508 TA Utrecht, The Netherlands.

Sediment cores from the Rhine/Meuse estuary were sampled in a fresh, brackish and marine environment. Pore water data show a decrease in redoxpotential with depth, indicating the transition from an oxygenated condition near the surface to a more reduced environment deeper in the sediments. Due to the mineralisation of organic matter, alkalinity and ammonium increase with depth. Moreover, nitrate and sulphate, as well as iron and manganese oxides are reduced.
In fresh and brackish sediment cores, the porewater profiles show that sulphate is depleted within 2 cm beneath the sediment-water interface. Beneath this depth methanogenesis is the dominant process in the decomposition of organic matter.
In the marine core, sulphate reduction is the dominant process down to a depth of 21 cm. Deposition of iron sulphides is limited by the presence of sulphide in the upper 7 cm.
Deeper in the sediments, reduced iron becomes the limiting factor and sulphide concentrations increase up to a maximum concentration of 1.4 mM at a depth of 15 cm.
In all sediment cores, the trace metals Cu, Zn and Ni are (re)mobilized directly beneath the sediment-water interface (0 - 1.4 cm). This is the result of the reductive dissolution of iron and manganese oxides and decomposition of organic matter (POC). Mineralization of POC is reflected by the increase of dissolved organic matter with depth, which favours the organic complexation of trace metals as Cu and Zn. Deeper in the sediments, trace metal concentrations decrease due to precipitation with sulphides. Using electron microprobe analysis, discrete Zn and Cu sulphide precipitates were found in the sediments

Photosynthesis characteristics and Salt tolerance of *Actinocyclus normanii* (Hustedt) (Bacillariophyceae) from the tidal freshwater reaches of the Weser estuary.

R. Rehbehn, B. Schuchardt, M. Schirmer & G.O. Kirst.

Universität Bremen, FB 2, D 2800 Bremen.

During late Summer and Autumn the autochtonous species *Actinocyclus normanii* (Hustedt), a large (55µm) centric diatom, dominates the phytoplanton community in the Elbe and Weser estuary. Peak abundance occurs clearly upstream of the turbidity maximum in the tidal freshwater reaches (TFR). Due to its long residence time within the TFR, the species may occur with high cell numbers although suspended matter concentrations within the TFR are relatively high.
Laboratory photosynthesis experiments were performed to describe the effect of light limitation and hyperosmotic stress. These factors may control spatial distribution and downstream extension of the population. Natural populations of *A. normanii* were collected, concentrated by filtration and tested under various light intensities (5, 12, 25, 200, 400, 600, 1000, 1400 and 2000 µE m^{-2} s^{-1}) and increasing salinities (2 ‰ up to 16,5‰), in accordance to the ambient salinity ranges in the lower Weser estuary.
The shape of the photosynthesis vs irradiance curves revealed, that *A. normanii* does not have any preferences for a special light climate. The species can obviously utilize a great amplitude of irradiances very effectively: The values of light saturated photosynthesis capacity (Pmax) and light saturation (I_k) as well as the light limited photosynthesis efficiency (a) were high and the species does not show any photoinhibition under high irradiance. The compensation light intensity was relatively high, but this does not seem to be ecologically disadvantageous because of the high energy balance (Photosynthesis/respiration-ratio under light saturation) of the algae. The salt stress experiments revealed, that *A. normanii* tolerates a broad range of salinities. A rapid increase in salinity from ca. 2 up to 16,5‰ (5 up-shocks within 45 minutes) only caused little inhibition of the photosynthesis capacity (Pmax). The same was notable after 5-6 hours adaptation to this hyperosmotic stress. Since *A. normanii* obviously tolerated higher salinities than have been encountered in its habitat within the TFR, we conclude that the downstream of the population in the lower Weser estuary is not restricted by salinity but primarily due to light limitation in the area of the turbidity maximum.

Phytoplankton biomass maxima along the salinity gradient in a tidal estaurine system

A. Ruiz, J. Franco, E. Orive and F. Villate

Universidad del Pais Vasco, Facultad de Ciencias, Departemento de Biologia Vegetal y Ecologia, Apartado 644, 48080 Bilbao, Spain

In July and August 1990 two types of sampling were carried out in the estuary of Mundaka : longitudinal gradients of salinity, temperature, pH, turbidity, nutrients and chloro-phyll were obtained on 12 permanent stations, while the oxygen content, the amount of size-fractionated seston and the plankton abundance and composition were analysed on 3 representative stations. Sampling was performed by 8 surveys, made at three daily intervals, in each month. Troughout the study period the river discharge was very low (between 28 and 46 $l.sec^{-1}$) in relation to the basin volume (mean volume = $32.105m^3$), and the estuary appeared relatively well-mixed and sea-water dominated. At high tide, waters of more than 30%. filled most of the estuarine basin, and noticeable salinity gradients were only found in the innermost part. Chlorophyll maxima were located in this region, in waters of less than 20%., but secondary peaks were usually found seaward, in the 32 to 34%. salinity region. pH decreased toward the upper estuary in relation to the oxygen content, and nutrients showed, in general, non-conservative patterns. The zonation of plankton populations was related to hydrological properties of water masses. The aim of this study is to analyse the short-term variability in the longitudinal structure of the Mundaka estuary during the period of greatest biological activity. Because of the tidal exchange is important in the longitudinal dispersion processes, the effect of tides inducing hydrological and biological variability within the estuary will be specifically discussed.

Crassostrea cucullata (Ostreidae): variations of form as related to environmental parameters

J.F. Tack[1], E. Vanden Berghe[2] & P. Polk[1]

1. Laboratorium voor Ecologie en Systematiek, Vrije Universiteit Brussel, Pleinlaan 2, B 1050 Brussels, Belgium
2. Department of Zoology, University of Nairobi, P.O. Box 30197, Nairobi, Kenya.

Fourier analysis was used to describe the circumference of oysters of the species *Crassostrea cucullata* growing in the mangrove swamps of Gazi Creek. The result of the Fourier analysis is a set of coefficients, that can describe the form with any degree of precision, depending on the number of coefficients calculated. These coefficients were compared for the different specimens, using cluster analysis. The different groups of oysters resulting from the cluster analysis were then compared with environmental parameters. The dataset was collected by taking photographs of 85 oysters, all growing in a limited area of 10 x 10 meter. Only oysters were taken that did not touch any other oyster, so that alteration of form caused by competition for space is not influencing the results.

The environmental parameters considered were (1) the species of mangrove tree on which the oyster was growing (*Avicennia marine, Rhizophora mucronata, Bruguiera gymnorrhiza* and *Sonneratia alba*), (2) orientation with respect to tidal currents (parallel or perpendicular), (3) diameter of the mangrove branch serving as substrate (diameter less than 30 mm or more than 100 mm) and (4) height above datum (continuous measurement).

The classification of the 85 mangrove oysters by cluster analysis is highly correlated with both height above datum, and diameter of the substrate. The correspondence of the clusters with substrate diameter is virtually perfect (only one misclassification out of 85). For the clusters based on the height measures, 9 oysters, for intermediate levels for this parameter (between 3.05 and 3.13 m above datum), were distributed over the two groups, but all the others were correctly classified.

The correspondence between the groups obtained by cluster analysis and the other environmental parameters was less outspoken. Mangrove species did not seem to have an influence on the form (although there is a clear influence on the density). For the orientation with respect to tidal current, there were eleven misclassifications.

Size gradient of the mangrove oyster *Crassostrea cucullata* (*Ostreidae*) in a mangrove creek (Gazi, Kenya).

J.F. Tack[1], E. Vanden Berghe[2] & P.Polk[1]

1. Laboratorium voor Ecologie en Systematiek, Vrije Universiteit Brussel, Pleinlaan 2, B 1050 Brussels, Belgium.
2. Department of Zoology, University of Nairobi, P.O. Box 30197, Nairobi, Kenya.

In a study of the influence of environmental factors on the size of *Crassostrea cucullata*, the length of 956 oysters, growing along two transects in the mangrove creek in Gazi were measured. Length is defined as the distance from the centre of the hinge to the farthest point of the opposite end. Measurements were made with calipers, to the nearest 0.1 mm. Both transects were located near the entrance of the creek, on opposite sides of the main channel. For each of the measurements, a number of parameters were recorded; species of the mangrove tree and diameter of the branch serving as a substrate, approximate density of the oyster growth, height above the bottom, height above datum, and orientation with respect to the main current. A regression analysis was performed to try to correlate length with each of these parameters separately. The species of mangrove tree, diameter of the branch substrate and the orientation with respect to the main current appeared not to be of importance. For the density, the length was not influenced up to a cover of 70%. For densities higher than 70%, there was a fairly strong negative correlation (r^2 = 0.674).
Length seemed not to be correlated with height above bottom for heights higher than 20 cm. The oyster length at lower levels is smaller than the lengths at higher levels.
The correlation with height above datum was negative but very low (r = 0.060). However, if all measurements of oysters closer than 20 cm to the bottom, and all from a density of more than 70% are deleted from the data set, the correlation increased dramatically, the slope still being negative (r^2 = 0.850; n = 544).
So height above datum, and thus percentage of time immersed, seems to be the primary factor determining the length of the oyster. This relationship is obscured by the influence of crowding, and proximity of the bottom.

Relationships between organic matter and suspended particles across the macrotidal, hydrodynamical gradient of the Seine-estuary.

H. Texier[1], R. Lafite[2], J.P. Dupont[2], V. Firmin[1 et 2], F. Gadel[3] & L. Serve[4]

1 Laboratoire de Géologie marine (chimie marine), Université de Caen
2 Laboratoire de Géologie, Université de Rouen
3 Laboratoire de Sédimentologie et Géochimie marine, Université de Perpignan
4 Laboratoire de Biologie Végétale, Université de Perpignan

The macrotidal Seine estuary receives particulate and organic fluxes from a strongly industrialized basin.
Analysis of P.O.C., total Nitrogen, carbohydrates and phenolics components in particulate fraction and D.O.C. were measured accross the upstream-downstream estuarine gradient.
At the same time, particles were characterized and particulate markers quantified using grain size analysis and S.E.M. techniques. These sedimentary data define :
- the ratio of marine particulate flux to continental particulate flux,
- the mechanisms controlling suspended particulate matter loading within the estuarine mixing zone. These include resuspension, frontal enrichment and turbulent mixing processes.
Organics parameters confirm particulate matter data and are used to distinguish between marine and continental components, defined by the upstream and downstream samples.
Between the two end members, variations in organic parameters are mainly controlled by the hydrodynamics of the estuarine mixing zone rather than by salinity changes.

Salinity gradients in some Southern African estuarine systems: the role of river inflow, tidal prism, mouth dynamics and mixing processes

A.K. WITHFIELD

J.L.B. Smith Institute of Ichthyology, Private Bag 1015, Grahamstown 6140, South Africa

Salinity is a major factor determining the distribution of aquatic flora and fauna in estuarine systems. It is also central to the definition of a southern African estuary, i.e. a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of seawater with freshwater derived from land drainage. Altogether, five types of estuarine systems are recognised on the sub-continent, viz. permanently open estuaries, temporarily open estuaries, estuarine lakes, estuarine bays and river mouths. In this paper I review the role of river input, tidal prism, mouth dynamics and mixing processes in determining the salinity regime of the various types of estuaries. In addition, the influence of reduced freshwater inflow on selected estuarine systems is examined and attention is drawn to the increasing swings in the salinity pendulum.

A summary of some of the generalised physical characteristics of southern African estuarine systems is given below :

System	Tidal prism	Mixing process	Salinity
Estuarine bay	Large	Tidal	30-35 x 10^{-3}
Open estuary	Moderate	Tidal/riverine	20->35 x 10^{-3}
River mouth	Negligible	Riverine	<5 x 10^{-3}
Temporarily closed estuary	Absent	Wind	1->35 x 10^{-3}
Estuarine lake	Negligible	Wind	1->35 x 10^{-3}

Estuarine copepod response to salinity and temperature gradients in a semi-arid region.

T. Wooldridge

Department of Zoology and Institute for Coastal Research, Box 1600, University of Port Elizabeth, Port Elizabeth, South Africa.

The copepod component of estuarine zooplankton along the south coast of southern Africa is dominated by three species, *Pseudodiaptomus hessei, Acartia longipatella* and *A. natalensis*. Characteristically, estuaries in the region exhibit wide fluctuations in salinity, which on occasions, exceed 40 % . Water temperatures range between 14 and 28°C. *P. nessei* demonstrates opportunism, attaining high population densities (>100.000 m^{-3}) following pulses of freshwater inflow into estuaries. These events may occur during any season, but response is rapid (days to weeks), and most marked during the warmer months. Spatially, peak production occurs in middle and upper estuarine regions, with values greater than 4.0 g dry mass $m^{-3}y^{-1}$ having been calculated. Annual P/B ratios for this species range between 78 and 100. Population densities of *A. longipatella* and *A. natalensis* may each exceed 150.000 m^{-3}. These congeneric species exhibit temporal and spatial succession, the latter attaining peak abundance in late Winter - Spring and in regions of relatively high salinity. *A. natalensis* occurs more abundantly during mid to late summer in upper estuarine areas. During prolonged periods of drought, population densities of *A. natalensis* decrease progressively through successive Summers, and may result in the species disappearing from the plankton if volumes of freshwater inflow remain persistantly low. A regression of the average summer (October to March) copepod standing stock (dry mass m^{-3}) on mean axial salinity range for six estuaries showed a significant and positive correlation between these parameters.

Dynamics of gut pigment in the estuarine copepods *Eurytemora affinis* and *Acartia sp.*

X. Zhang[1], C. Soetaert[2] & M. Tackx[2]

1. Delta Institute for Hydrobiological Research, Vierstraat 28, 4401 EA Yerseke, The Netherlands.
2. Labo voor Ekologie, Vrije Universiteit Brussel, Pleinlaan 2 1050 Brussel, Belgium.

Dynamics of gut pigment in the estuarine copepods *Eurytemora affinis* and *Acartia sp.* in the Westerschelde have been studied in different seasons in 1990 and 1991. The dynamics of gut pigment was investigated in the laboratory by monitoring the increase in gut fluorescence of the animals (Dagg 1983) during feeding. Comparison of the dynamics of gut pigment were made between species and between sex. Potential zooplankton grazing pressure on pigment containing particulate matter is calculated using standing stock data of the dominant zooplankton species.

Reference

Dagg, M.J. 1983. A method for the determination of copepod feeding rates during short time intervals. Mar. Biol. 75:63-67.

Abdulkerin Z. VUB FAME Pleinlaan 2 Brussel 1050 (B)
Andrade F. Lab. Maritimo de Guia Estrado do Guincho Cascais 2750 (P)
Arellano R. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Baeyens W. VUB Dienst Analytische Scheikunde Pleinlaan 2 Brussel 1050 (B)
Belgrano A. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Bessineton C. Cellule Suivi Littoral H.Norm. Rue colonel Fabien 4 Le Havre 76600 (F)
Billen G. ULB Groupe Microbiol. Mil. Aquat. Campus de la Plaine CP221 Brussel 1050 (B)
Blackstock J. Seas LTD c/o DML Oban, Argyll PA344AD (U.K.)
Blust R. Lab. Biochemistry & Zoology University of Antwerp Groeneborgerlaan 171 Antwerpen 2020 (B)
Boderie P.M.A. Boedapestlaan 4 Utrecht 3508 TA (NL)
Bogaert M. VUB Ecologie Pleinlaan 2 Brussel 1050 (B)
Bolt S. Joint Nature Conservation Com. Monkstone House City Road Peterborough PE1 1JY (U.K.)
Boorman L.A. Institute of Terrestrial Ecol. Monks Wood Experim. Station Huntingdon Cambs PE172LS (U.K.)
Buijs J.A. Delta Inst. Hydrobiol. Onderz. Vierstraat 28 Yerseke 4401 EA (NL)
Cattrijsse A. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Clarke K.R. Plymouth Marine Laboratory Prospect Place/W.Hoe Plymouth PL1 3DH (U.K.)
Claus B. Universität Bremen AG. Limnische Ökologie Lebener Str./NW2 Bremen 33 D2800 (D)
Codling I.D. WRC Medmenham P.O. Box 16 Marlow Bucks SL7 2HD (U.K.)
Coomans A. RUG Lab. Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Coosen J. Rijkswaterstaat Tidal Waters Division P.O. BOX 8039 Middelburg 4330 EA (NL)
Cunningham E. Analyt.&Environm. Services LTD Biology Lab.,Gregsons Building Howdon, Wallsend Tyne and Wear NE280QD (U.K.)
Cyrus D. Coast Res. Unit of Zululand Department of Zoology Private Bag X1001 Kwa Dlawgezwa 3886 (R.S.A.)
Daemen E. Rijkswaterstaat Directie Zeeland P.O. BOX 5014 Middelburg 4330 KA (NL)
Darbyshire E. School of Civil Engineering University of Birmingham Edgbaston Birmingham B15 2TT (U.K.)
Daro M. VUB Ecologie Pleinlaan 2 Brussel 1050 (B)
Davey J.T. Plymouth Marine Laboratory Prospect place Plymouth PL1 3DH (U.K.)
Davidson N. Science Directorate Nature Concervancy Council Eng Northmunster House Peterborough PE1 1UA (U.K.)
Davies G. National Rivers Authority Welsh region-Rivers House St Mellons Business St Mellows Card CF3 0EG (U.K.)
Davoult D. Station de Biol. Mar. Wimereux B.P. 80 Wimereux 62930 (F)
De Graeve S. KBIN Vautierstraat 29 Brussel 1040 (B)
De Jonge V. Rijkswaterstaat Tidal Waters Division P.O. BOX 207 Haren (Gn) 9750 AE (NL)
de Leeuw J. Delta Instituut Hydrobiol.Ond. Vierstraat 28 Yerseke 4401 EA (NL)
De Madariaga I. Plymouth Marine Laboratory Prospect Place Plymouth,Devon PL1 3DH (U.K.)
De Regge N. RUG Labo voor Ecologie der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
De Smet G. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Demetriades N. University of Natal Biology Department King george V Avenue Durban (RSA)
Dupont J.P. Université de Rouen Dept. de Geologie B.P. 118 Mont-St.Aignan 76134 (F)
Edwards A. Dunstaffnage Marine Laboratory P.O. BOX 3 Oban,Argyll PA344AD (U.K.)
Elkaïm B. Université P. et M. Curie Hydrobiologie Rue Cuvier 12 Paris 75005 (F)
Elliot M. University of Hull Dept. Applied Biology Hull HU6 7RX (U.K.)
Elskens M. VUB Analytische Scheikunde Pleinlaan 2 Brussel 1050 (B)
Essink K. Rijkswaterstaat Tidal Waters Division P.O. BOX 207 Haren 9750 AE (NL)
Fockedey N. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Forbes A.T. University of Natal Biology Department King George V Avenue Durban (RSA)
Francis C. Calton Walk 11 Bath (Avon) BA2 4QQ (U.K.)
Gadel F. Université de Perpignan Labo Sédimentologie et Géochim Avenue de Villeneuve Perpignan 66000 (F)
Galvin P. Research Institute Zoology Department U.C.D./Belfield Dublin 4 (IRL)
Gijselinck W. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Grant A. University of East Anglia School Environmental Sciences Norwich NR4 7TJ (U.K.)
Groenewold A. Rijkswaterstaat Tidal Water Division Grenadierweg 31 Middelburg 4338 PG (NL)
Haesloop U. Universität Bremen AG. Limnische Ökologie Lebener Str./NW2 Bremen 33 D2800 (D)
Hamerlynck O. RUG Labo Morf.& Syst.der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Hegeman W. Universiteit van Utrecht Boedapestlaan 4 Utrecht (NL)
Hemminga M. Delta Institute Hydrobiol.Ond. Vierstraat 28 Yerseke 4401 EA (NL)
Hiscock K. Joint Nature Conservation Comm Monkstone House Peterborough PE1 1UA (U.K.)
Hostens K. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Houvenaghel G.T. ULB/Fac. Sc.& Section d'Agron. Laboratoire d'Ocean.Biologique AV. Roosevelt 50 Brussel 1050 (B)
Hull S.C. Forth River Purification Board Heriot-Watt Research Park Av. North,Riccarton Edinburgh EH144AP (U.K.)
Huys R. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Iedema C.W. Rijkswaterstaat Directie Zeeland P.O. BOX 5014 Middelburg 4330 KA (NL)
Jager Z. Dienst Getijdewateren Haren Haren - Gr. (NL)
Jaspers E. IZWO Victorialaan 3 Oostende 8400 (B)
Jian L. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Jonas P. National Rivers Authority SWR Tidal Waters Manley House/Kestrel Way Exeter EX2 7LQ (U.K.)
Jones K. Lancaster University Division Biological Sciences Lancaster LA1 4YQ (U.K.)
Jones R.E. Countryside Council for Wales Plas Penrhos Fford Penrhos Bangor,Gwynedd LL572LQ (U.K.)
Jones N.V. University of Hull Inst.Estuarine&Coastal Science Hull HU6 7RX (U.K.)
Knoester M. Rijkswaterstaat Dienst Getijdewateren Postbus 20907 's Gravenhage 2500 EX (NL)
Kuycken E. Instituut voor Natuurbehoud Kiewitdreef 3 Hasselt 3500 (B)
Laffoley D. Marine science English Nature Peterborough PE1 1UA (U.K.)
Lafite R. Université de Rouen Dept. de Géologie B.P. 118 Mont-St. Aignan 76134 (F)
Langerak A. Rijkswaterstaat Tidal Waters Division P.O. BOX 8039 Middelburg 4330 EA (NL)
Leboulanger T. Université de Rouen GEMEL-Laboratiore de Géologie B.P. 118 Mt St Aignan Ce F 76134 (F)
Leermakers M. VUB Dienst Analytische Scheikunde Pleinlaan 2 Brussel 1050 (B)
Lindsay P. University of Birmingham School of Civil Engineering Birmingham B15 2TT (U.K.)
Maas D. RUG Labo voor Ecologie der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Maertens D. Ministry of Agriculture Fisheries Research Station Ankerstraat 1 Oostende 8400 (B)

Malcolm S.J. MAFF Directorate Fisheries Res Fisheries Research Laboratory Pakefld Rd Lowestoft Suffolk NR330HT (U.K.)
Marchand J. Laboratoire de Biologie Marine Maitre de Conférences Rue d/l Haussinière 2 NANTES Cedex 03 44072 (F)
Martin T. University of Zululand Department of Zoology Private Bag X1001 Kwadlangezwa 3886 (RSA)
Mathieson S. University of Sterling Dept.Biological&Molecular Scie Stirling FK9 4LA (U.K.)
McGrorty S. Inst. of Terrestrial Ecology Furzebrook Research Station Furzebrook Wareham/Dorset BH2 05A (U.K.)
McLusky D.S. University of Stirling Dept. Biol.& Molecular Science Stirling (U.K.)
Meakin D. Inst.Estuarine Coast Studies University of Hull Cottingham Rd Hull HU6 7RX (U.K.)
Mees J. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Meire P. Institute Nature Conservation Kiewitdreef 3 Hasselt B3500 (B)
Mitchell R. Joint Nature Conservation Com. Monkstone House City Road Peterborough PE1 1JY (U.K.)
Moens M. Min. Public Health&Environment BMM Gulledelle 100 Brussel 1200 (B)
Moffat A. Polytechnic South West Dept. of Biological Sciences Drake Circus Plymouth PL4 8AA (U.K.)
Monteny F. VUB Analytische Scheikunde Pleinlaan 2 Brussel 1050 (B)
Moreira M.H. University of Aveiro Department of Biology Campus Universitario Aveiro 3800 (P)
Muhando C. VUB FAME Pleinlaan 2 Brussel 1050 (B)
Muirhead S.J. ETSU Harwell Laboratory Oxfordshire OX110RA (U.K.)
Mulder H. Rijkswaterstaat Dienst Getijdewateren Grenadierweg 31 Middelburg 4338 PG (NL)
Müller M. Universität Bremen AG. Limnische Ökologie Lebener Str. Bremen 33 D2800 (D)
Newell S.Y. University of Georgia Marine Institute Sapelo Island GA31327 (USA)
Ouboter M.R.L. Delft Hydraulics P.O. BOX Delft 2600 MH (NL)
Ouddane B. USTL Lab. Chimie Analytique&Marine Bâtiment C8 Villeneuve Ascq 59655 (F)
Paalman M.A.A. University of Utrecht Inst.of Sciences/Dept. Geochem P.O. BOX 80021 Utrecht 3508 TA (NL)
Parada Encisa J.M. Universidad de Santiago Dep. Biologia Animal Santiago d.Comp 15706 (E)
Pearson T.H. Dunstaffnage Marine Laboratory P.O. BOX 3 Oban,Argyll (U.K.)
Pearson J.R. Dunstaffnage Marine Laboratory P.O. BOX 3 Oban,Argyll (U.K.)
Pethick J.S. Inst. Est.Coastal Studies University of Hull Cottingham Rd Hull HU67RX (U.K.)
Pieters P.O. BOX 8039 Middelburg 4330 (NL)
Pollentier A. Ministry Publ. Health& Environ BMM 3°-23° Linieregiment Oostende 8400 (B)
Pomfret J. Analyt.&Environm. Services LTD Biology Lab.,Gregsons Building Howdon, Wallsend Tyne and Wear NE280QD (U.K.)
Preston M.R. Liverpool University Earth Sciences Department P.O. BOX 147 Liverpool LG9 3BX (U.K.)
Quinn N. University of Natal Institute of Natural Resources P.O. BOX 375 Pietermaritzbur 3200 (RSA)
Quintino dos Santos V.M. Laboratorio Nacional de Engen- haria e Tecnologia Industrial Azinhaga d. Lameiros 22 Lisboa Codex 1699 (P)
Rehbehn R. Universität Bremen AG. Limnische Ökologie Lebener Str./NW2 Bremen 33 D2800 (D)
Rieger E.M. Universität Bremen AG. Limnische Ökologie Lebener Str./NW2 Bremen 33 D2800 (D)
Rodrigues A.M.J. Laboratorio Nacional de Engen- haria e Tecnologia Industrial Azinhaga d. Lameiros 22 Lisboa Codex 1699 (P)
Rybarczyk H. G.E.M.E.L. Picardie S.E.B.S. Quai Jeanne d'Arc 115 St.-Val.s/Somme 80230 (F)
Saad M.A.H. Alexandria University Faculty of Science/Science Fac Moharem Bay Alexandria (EGYPT)
Sabbe K. RUG Labo Morf. Syst. Ecol. Planten K.L. Ledeganckstraat 35 Gent 9000 (B)
Samaya R. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
San Sebastian J.F. Universidad del Pais Vasco Depto Biol. Vegetal y Ecologia Aptdo 644 Bilbao 48080 (E)
Sanchez Mata A. Universidad de Santiago Dep. Biologia Animal Santiago d.Comp 15706 (E)
Schobben J.H.M. Rijkswaterstaat Dienst Getijdewateren P.O. BOX 20907 Den Haag 2500 EX (NL)
Schram D. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Serve L. Université de Perpignan Avenue de Villeneuve Perpignan 66860 (F)
Seys J. RUG Labo Ecologie der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Shillabeer N. ICI Group Environm. Laboratory Freshwater Quarry Brixham, Devon TQ5 8BA (U.K.)
Smith A. Binnie and Partners Grosvenor House London Road 69 Redhill(Surrey) RH1 1LQ (U.K.)
Smol N. RUG Labo Morf.& Syst. der Dieren K.L. Ledegankcstraat 35 Gent 9000 (B)
Stronkhorst J. Rijkswaterstaat Tidal Waters Division P.O. BOX 8039 Middelburg 4330 EA (NL)
Tack J. VUB Ecologie Pleinlaan 2 Brussel 1050 (B)
Tackx M. VUB Ecologie Pleinlaan 2 Brussel 1050 (B)
Taylor C.J.L. Nuclear Electric plc Barnett Way Barnwood Gloucester GL4 7RS (U.K.)
Tulkens M. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Turner A. Institute of Marine Studies Polytechnic South West Drake Circus Plymouth PL4 8AA (U.K.)
Tyler A. BMT St. John's Street Southampton SO4 6YS (U.K.)
Van Damme P. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Van Eck G.T.M. Rijkswaterstaat Dienst Getijdewateren P.O. BOX 8039 Middelburg 4330 EA (NL)
Van Gansbeke D. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Van Hove S. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
van Zoest R. Grontmij n.v. P.O. BOX 203 De Bilt 3730 AE (NL)
Vanreusel A. RUG Labo Morf.& Syst. der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Verreet G. Ministry Public Health&Environ BMM Gulledelle 100 Brussel 1200 (B)
Vijverman W. RUG Labo Morf.,Syst.& Ecol.Planten K.L. Ledeganckstraat 35 Gent 9000 (B)
Villate F. Facultad de Ciencias Laboratorio de Ecologia UPV/EHU Apdo 644 Bilbao 48080 (E)
Vincx M. University of Gent Marine Biology Section Ledeganckstraat 35 Gent B9000 (B)
Watson P. Plymouth Marine Laboratory Prospect Place Plymouth PL1 3DH (U.K.)
West J. University of Birmingham School of Civil Engineering Birmingham B15 2TT (U.K.)
White S. National Rivers Authority Wessex Region-Rivers House EastQuay Bridgewater Sommerset TA6 4YS (U.K.)
Whitfield A.K. J.L.B. Smith Inst. of Ichtyol. Private Bag 1015 Grahamstown 6140 (RSA)
Wilckins H. Koning Boudewijnstr. 27 Gent 9000 (B)
Wilson J. Trinity College Environmental Science Unit Trinity College Dublin 2 (IRL)
Wolf W. RIN (NL)
Wooldridge T. University Port Elisabeth Dept. of Zoology P.O. BOX 1600 Port Elisabeth 6000 (RSA)
Ysebaert T. RUG Labo Ecologie der Dieren K.L. Ledeganckstraat 35 Gent 9000 (B)
Zwolsman J.J.G. Hondsrug 869 Utrecht 3524 BZ (NL)